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Use of glyphosate in the management of *Panicum maximum* cv. BRS Zuri intercropped with maize[1]

Uso de glyphosate no manejo de *Panicum maximum* cv. BRS Zuri consorciado com milho

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HIGHLIGHTS:
Maize grain yield was not affected by the presence of forage.
Forage biomass production provided a reduction in the weed community.
Different doses of glyphosate influenced forage yield.

ABSTRACT: The intercropping between maize and forage species is an alternative commonly used within farming systems. Competition among crops may be a limiting factor in intercropping, compromising maize and forage yield. Although necessary, the literature does not provide satisfactory answers on the interaction of forage crops launched in the market recently, such as BRS Zuri, intercropped with maize. Therefore, techniques such as the use of herbicide subdoses come in as an option to suppress forage growth, making simultaneous cultivation feasible. Thus, the present study aimed to evaluate the effects of glyphosate herbicide subdoses on the development of *Panicum maximum* cv. BRS Zuri intercropped with Roundup Ready® (RR) maize and how this interaction reflects on the weed population, forage yield, and biometric and yield variables of maize. The experimental design was randomized blocks with treatments consisting of six subdoses of glyphosate herbicide (0, 48, 96, 240, 480, and 960 g acid equivalent [a.e.] ha^{-1}) and maize in monoculture with four replications. For the conditions of this study, the dose of 480 g a.e. ha^{-1} of glyphosate may be an alternative since there was weed suppression and adequate forage development. Maize yield was not affected by the presence of forage.

Key words: phytosociology, crop-livestock integration, weeds, suppression, *Zea mays* L.

RESUMO: O consórcio entre milho e espécies forrageiras é uma alternativa comumente utilizada dentro dos sistemas agropecuários. A competição entre as culturas pode ser um fator limitante no consórcio, comprometendo a produção do milho e forragem. Embora necessário, a interação de forrageiras lançadas no mercado nos últimos anos, como a BRS Zuri consorciada com a cultura do milho, não fornece respostas satisfatórias na literatura. Por isso, técnicas como a utilização de subdoses de herbicida entra com uma opção a fim de suprimir o crescimento da forrageira, viabilizando o cultivo simultâneo. Assim, objetivou-se no presente estudo avaliar os efeitos de subdoses do herbicida glyphosate sobre o desenvolvimento de *Panicum maximum* cv. BRS Zuri consorciado com milho RR (Roundup Ready®) e como essa interação reflete na população de plantas daninhas, no rendimento da forrageira e nas variáveis biométricas e produtivas do milho. O delineamento foi em blocos casualizados, cujos tratamentos consistiram em seis subdoses do herbicida glyphosate (0, 48, 96, 240, 480 e 960 g equivalente ácido [e.a.] ha^{-1}), além do milho em monocultivo com quatro repetições. Para as condições do presente estudo, a dose de 480 g e.a. ha^{-1} de glyphosate pode ser uma alternativa, visto que houve a supressão de plantas daninhas e um adequado desenvolvimento da forragem. Já o rendimento do milho não foi afetado pela presença da forrageira.

Palavras-chave: fitossociologia, integração lavoura-pecuária, plantas daninhas, supressão, *Zea mays* L.

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Introduction

The Integrated Crop-Livestock Systems (ICLS) consists of a sustainable alternative of cultivation that provides synergism between agricultural and livestock production in the same area, promoting benefits to the producer and the environment (Costa Jr. et al., 2019). In the Brazilian Cerrado, areas cultivated with ICLS have increased significantly through intercropping, crop rotation, and/or succession (Zolin et al., 2021).

Intercropping can be defined as cultivation that simultaneously integrates two or more species of interest (Martins et al., 2019). Among the benefits, they include the production of grains, silage, forage, cultural control of weeds, and the formation of quality straw (Laroca et al., 2018).

Perennial species, such as forage plants of the genus *Panicum* spp., are considered interesting options to be inserted in intercropping with crops such as maize and sorghum (Silva et al., 2020a). However, simultaneous cultivation between two or more species can become unfeasible due to competition between the crops, especially in the early stage of development (Pezzopane et al., 2019).

Some agronomic techniques can be used to minimize the effect of competition between the cultivated species; among them is the application of subdoses of selective herbicides for the maize crop (Freitas et al., 2018) just for suppresses the initial growth of the forage crop (Oliveira et al., 2018), without the expectation that such doses will manage the weeds that may eventually be present which is controlled by the remaining straw (Schuster et al., 2019).

The present study aimed to evaluate the effects of glyphosate herbicide subdoses on the development of *Panicum maximum* cv. BRS Zuri intercropped with Roundup Ready® maize, which exhibits tolerance to the herbicide, and how this interaction reflects on the weed population, forage yield, and biometric and yield variables of maize.

Material and Methods

The study was conducted under field conditions in the experimental area of the Instituto Federal Goiano, Campus Rio Verde, GO, located in the city of Rio Verde, southwest of the state of Goiás, under the coordinates 17° 81’ 03” S and 50° 90’ 51” W and altitude of 754 m.

The soil of the area is classified as Dystrophic Red Latosol (EMBRAPA, 2018) corresponding to an Oxisol (United States, 2014), with the following physical-chemical characteristics in 0-20 cm soil layer: pH ($CaCl_2$) 5; P = 23.8 mg dm^{-3}; K = 133 mg dm^{-3}, Ca = 1.57 cmol$_c$ dm^{-3}; Mg = 0.90 cmol$_c$ dm^{-3}; Al = 0.06 cmol$_c$ dm^{-3}; base saturation = 55.9%; OM = 36.1 g dm^{-3}, and particle size 48, 8, and 44 dag kg^{-1} of clay, silt, and sand, respectively.

The climate of the region is characterized as humid tropical, Aw-type, with rain in summer and dry in winter, according to the Köppen classification. The climate data during the experiment is presented in Figure 1 and was collected from the Instituto Nacional de Meteorologia (INMET, 2022).

Before sowing, the experimental area was desiccated with glyphosate (Shadow®) herbicide at 1.680 g a.e. ha^{-1} to eliminate the plant biomass present. After 15 days, soil tillage was performed with plowing and light disc harrowing. Maize hybrid B2360PW (Brevant) was sown at a depth of 4 cm on 19/12/2020 using a four-row multiple seed drill with 0.45 m between rows, totaling a population of approximately 66.666 plants ha^{-1}. This hybrid has a super-early cycle with tolerance to glyphosate and glufosinate-ammonium herbicides. The fertilization in the sowing furrow consisted of 300 kg ha^{-1} of the 5-25-15 formulation of N-P_20_5-K_20. On the same date, the BRS Zuri grass was sown manually and broadcast, using 10 kg ha^{-1} of seeds with 79% of Cultural Value (CV).

The treatments consisted of six doses of glyphosate (Shadow®) (0, 48, 96, 240, 480, and 960 g a.e. ha^{-1}) and maize in monoculture, with four replications totaling 28 experimental plots. The doses were determined according to the product package insert, where a concentration of 960 g a.e. ha^{-1} is recommended for weed control. From the reference dose, the concentrations were fractionated into subdoses. The plots had an area of 18 m^2, with eight rows 5 m long. The area of evaluations (observation area) consisted of the four central rows.

The treatments were applied 20 days after maize emergence (DAE), when the forage had three tillers. A CO_2 pressurized

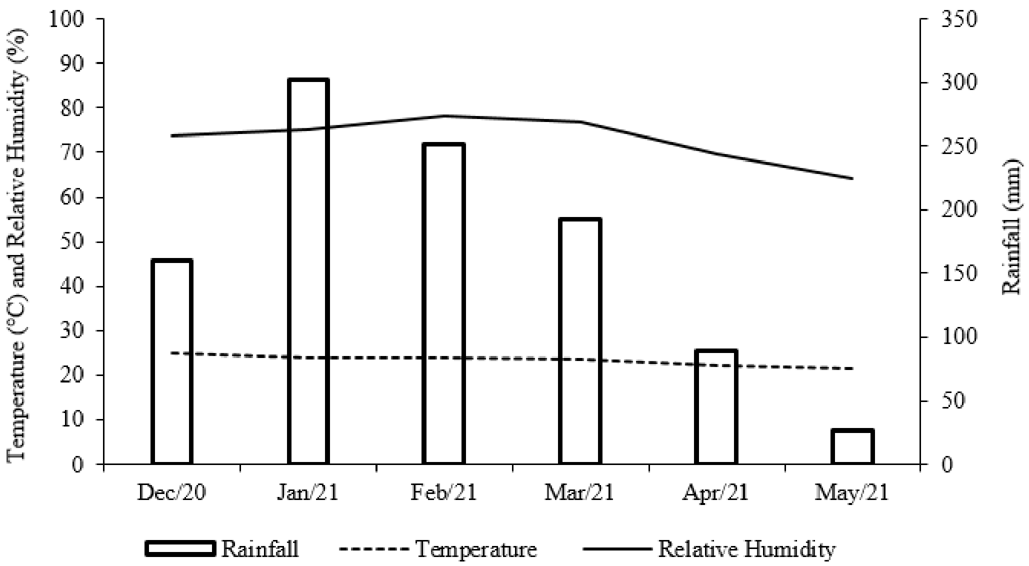


Figure 1. Average values of rainfall, temperature, and relative air humidity during the experimental period

knapsack sprayer was used for the application, composed of an aluminum bar containing four spray tips spaced 0.5 m apart. The equipment pressure at the time of application was 2.0 bars with an application rate of 200 L ha^{-1}.

At the time of application of the treatments, 1.500 g a.i. ha^{-1} of the herbicide atrazine (Aclamado BR®) was also added to help control broad-leafed weeds. For maize in monoculture, in addition to the herbicide atrazine (Aclamado BR®), glyphosate (Shadow®) was also applied at a dose of 1.440 g acid equivalent (a.e.) ha^{-1} to help control weeds. The climatic conditions at application time were determined with a thermo-hygrometer, with a relative air humidity of 45.7%, air temperature of 28 °C, and wind speed of 2.2 m s^{-1}.

At the V4 stage, around 20 DAE of the maize, topdressing fertilization of 150 kg of N was performed. The application of insecticides occurred at 7, 12, 27 DAE, with the insecticides teflubenzuron (Nomolt®150) at a dose of 0.15 L of commercial product per hectare; chlorpyrifos (Capataz®) + teflubenzuron (Nomolt®150) at a dose of 1 L of commercial product per hectare and 0.15 L of commercial product per hectare and thiamethoxam (Engeo Pleno™ S) at a dose of 0.25 L of commercial product per hectare, respectively, with a spray volume of 170 L ha^{-1}.

For maize, at 63 DAA, during flowering, the following variables were measured: plant height (PH), from the ground up to the flag leaf, ear insertion height (EH), and stem diameter (SD), at a height of 3 cm from the ground. For these evaluations, five plants per plot were randomly selected. A ruler, graduated in centimeters, was used to measure plant height and ear insertion height. The diameter of the stem was measured with the aid of a digital pachymeter.

At 128 DAE of the maize, the crop was harvested manually in the observation area (four central rows, 3 m long) to assess the grain yield (GY). After the harvest, the grains and cobs were separated with the help of a thresher, and then the grains were weighed. Five ears from each plot were used to determine ear length (SL), ear diameter (ED), number of grain rows per ear (NRE), 1000-grain mass (MTG), and the total number of grains (TNG). Grain yield per hectare and 1000-grain mass were corrected to 13% humidity.

After the maize harvest, around 135 DAE, the evaluation of forage height and cutting was performed. For height, a ruler graduated in centimeters was used, taking as a basis the height of the plant canopy at two points per plot. To measure biomass, the forage was cut with the help of a cleaver at a height of 30 cm from the ground. The observation area consisted of 2 m².

Then, the plant material was weighed, and an aliquot of approximately 500 g was removed and placed in paper bags. Later, the leaves and stems were separated in the laboratory to measure the leaf-stem ratio of the forage. Then the material was placed in an oven with air-forced circulation for drying for 72 hours at 65 °C. After drying, the material was weighed, and the values were converted to t ha^{-1}.

The phytosociological evaluations of weeds were performed at 43 and 108 days after application (DAA) of the treatments, which consisted in the reproductive phase and at the time of maize harvest, being represented by the relative importance (RI) of the species in the weed community, according to the methodology proposed (Mueller-Dombois & Ellenberg, 1974). Three random samples were collected per plot, using a square with an area of 0.25 m². The weeds present in the squares were identified, quantified, and separated to species level. Then, they were placed in paper bags and dried in an oven with air-forced circulation at 65 °C for 72 hours for later weighing.

The results obtained for the maize crop, forage, weed density, and dry mass variables were submitted to regression analysis. The models were adjusted according to simplicity, biological significance, and determination coefficient. The normality of the data was previously verified using the Shapiro-Wilk test ($p \leq 0.05$). The behavior of the weed community was obtained through the relative importance of the species, calculated by the phytosociological indexes of weed frequency, density, and dominance (Mueller-Dombois & Ellenberg, 1974; Pitelli, 2000). Weeds listed according to their RI were named based on the code (EPPO, 2022).

Results and Discussion

In the weed evaluations conducted at 43 DAA (Table 1) and 108 DAA of the treatments (Table 2), obtained by the plant community's phytosociological analysis, we observed the presence of a total of 16 species distributed in nine families. The species found in the two periods of evaluation were: hairy beggarticks (*Bidens pilosa* - BIDPI), bristly starbur (*Acanthospermum hispidum* - ACAHI), tropic ageratum (*Ageratum conyzoides* - AGECO), hairy fleabane (*Conyza bonariensis* - CONBO), cupid's-shaving-brush (*Emilia fosbergii* - EMIFO), all belonging to the Asteraceae family; Jamaican crabgrass (*Digitaria horizontalis* - DIGHO), mission grass (*Pennisetum setosum* - PENSE), goosegrass (*Eleusine indica* - ELEIN), all belonging to the Poaceae family.

Table 1. Relative importance of weed species evaluated at 43 days after application (DAA) of glyphosate herbicide

Species	MM	Doses (g a.e. ha^{-1})						Average (%)
		0	48	96	240	480	960	
ACAHI	13.33	15.51	42.16	33.99	24.90	13.93	24.26	24.01
ALTTE	30.22	27.08	14.26	9.29	20.07	18.30	23.13	20.34
ARGME	0.00	0.00	0.00	0.00	0.00	13.50	0.00	1.93
BIDPI	3.18	20.86	1.69	13.09	23.05	13.90	7.42	11.88
COMBE	28.75	21.31	9.21	8.51	4.78	15.99	16.06	14.94
DIGHO	8.76	15.23	0.00	18.83	0.00	0.00	0.00	6.12
ELEIN	3.71	0.00	0.00	0.00	17.71	5.95	6.98	4.91
IPOMO	0.00	0.00	8.96	9.78	0.00	0.00	0.00	2.68
NICPH	6.13	0.00	0.00	6.51	0.00	0.00	0.00	1.80
RINCO	5.92	0.00	23.72	0.00	9.50	18.45	22.15	11.39

*ACAHI - *Acanthospermum hispidum*; ALTTE - *Alternanthera tenella*; ARGME - *Argemone mexicana*; BIDPI - *Bidens pilosa*; COMBE - *Commelina benghalensis*; DIGHO - *Digitaria horizontalis*; ELEIN - *Eleusine indica*; IPOMO - *Ipomoea* spp.; NICPH - *Nicandra physaloides*; RINCO - *Ricinus communis*; MM - Maize monoculture

Table 2. Relative importance of weed species evaluated at 108 days after application (DAA) of glyphosate herbicide

Species	MM	Doses (g a.e. ha^{-1})						Average (%)
		0	48	96	240	480	960	
ACAHI	7.06	0.0	0	0.00	0.00	0.00	0.00	1.01
AGECO	2.49	0.0	0	0.00	1.14	9.36	2.59	2.23
ALTTE	13.06	49.4	0	31.84	36.23	23.47	15.51	24.22
ARGME	0.00	0.0	0	0.00	2.13	10.28	0.00	1.77
BIDPI	4.15	0.0	0	0.00	10.47	5.96	5.73	3.76
COMBE	4.95	19.8	100	33.57	35.02	7.19	8.76	29.90
CONBO	18.16	0.0	0	0.00	9.56	32.92	19.97	11.51
DIGHO	0.29	30.9	0	0.00	0.00	0.63	9.16	5.85
ELEIN	13.70	0.0	0	0.00	0.00	8.45	14.55	5.24
EMIFO	7.07	0.0	0	0.00	0.00	0.00	0.00	1.01
NICPH	0.00	0.0	0	0.00	0.00	0.00	7.96	1.14
PENSE	16.70	0.0	0	0.00	0.00	0.00	8.53	3.60
PHYNI	3.77	0.0	0	34.60	2.35	1.74	0.00	6.07
RICBR	7.12	0.0	0	0.00	0.00	0.00	0.00	1.02
RINCO	1.47	0.0	0	0.00	3.10	0.00	7.24	1.69

*ACAHI - *Acanthospermum hispidum*; AGECO - *Ageratum conyzoides*; ALTTE - *Alternanthera tenella*; ARGME - *Argemone mexicana*; BIDPI - *Bidens pilosa*; COMBE - *Commelina benghalensis*; CONBO - *Conyza bonariensis*; DIGHO - *Digitaria horizontalis*; ELEIN - *Eleusine indica*; EMIFO - *Emilia fosbergii*; NICPH - *Nicandra physaloides*; PENSE - *Pennisetum setosum*; PHYNI - *Phyllanthus niruri*; RICBR - *Richardia brasiliensis*; RINCO - *Ricinus communis*; MM - Maize monoculture

It was also evidenced the appearance of niruri (*Phyllanthus niruri* - PHYNI) and castor bean (*Ricinus communis* - RINCO) belonging to the Euphorbiaceae family; calico plant (*Alternanthera tenella* - ALTTE) belonging to the Amaranthaceae family; Bengal dayflower (*Commelina benghalensis* - COMBE) of the Commelinaceae family; apple of Peru (*Nicandra physaloides* - NICPH) belonging to the Solanaceae family; brazil pusley (*Richardia brasiliensis* - RICBR) of the Rubiaceae family; morning-glory (*Ipomoea* spp. - IPOMO), belonging to the Convolvulaceae family and Mexican prickly poppy (*Argemone mexicana* - ARGME), from the Papaveraceae family.

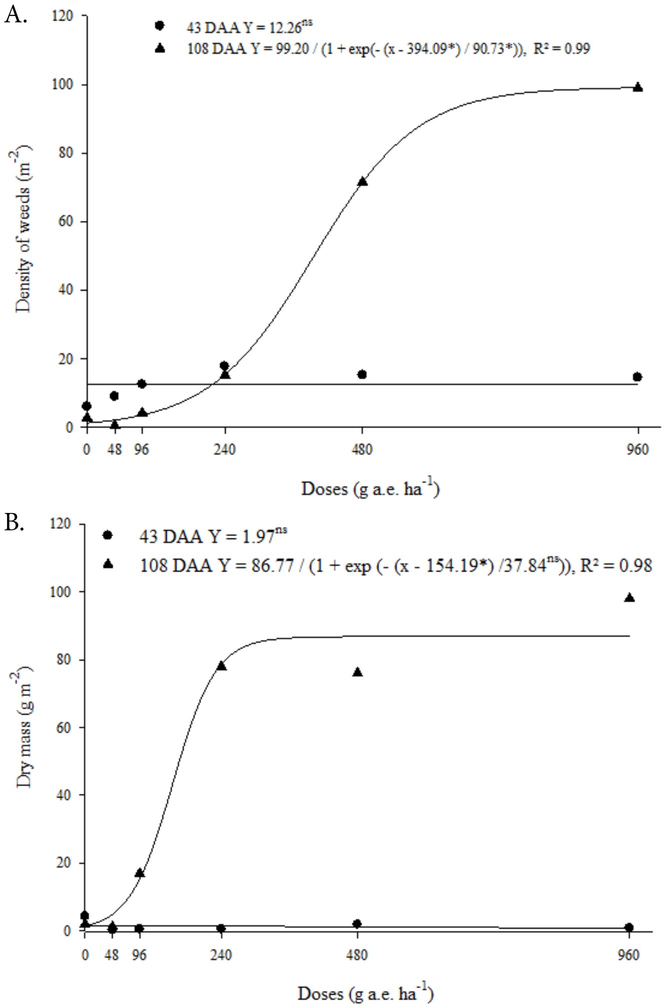
The highest RI values were observed for ACAHI, ALTTE, BIDPI, COMBE, and RINCO at 43 DAA (Table 1) with values of 24.01, 20.34, 11.88, 14.94, and 11.39, respectively. RI is the ratio that shows the importance of each species within the weed community. Such weeds were the most important in terms of infestation (Pitelli, 2000), considering the distribution of species, number of individuals, and concentration in the sampled area. The other species present in the area showed low mean RI values, except for DIGHO, at doses of 0 and 96 g a.e. ha^{-1}, and for ELEIN at the dose of 240 g a.e. ha^{-1}, which can be justified by the presence of the biomass produced by BRS Zuri forage.

At 108 DAA of the treatments, it is observed that the species COMBE and ALTTE, similar to the first evaluation, showed high values of RI with 29.90 and 24.22, respectively, followed by CONBO, with 11.51. Such species present a high RI value in Brazilian agriculture, which is difficult to control and has high dissemination (Ribeiro Neto et al., 2019; Miranda et al., 2020). Biological characteristics such as propagation, life cycle, high seed production, and easy adaptation, among others, can justify the importance of these species in the study area.

Another species with a high RI value at 108 DAA is CONBO, with 11.51. CONBO is a weed species that presents biotypes resistant to the glyphosate herbicide distributed throughout the country. Like other weeds, this species presents characteristics that confer its establishment and ability to germinate even in unfavorable weather conditions (Bruno et al., 2021).

At 43 and 108 DAA, there was the highest number of weed species in maize in monoculture, which can be explained by the fact that there was no coverage of the plots imposed by the presence of forage, so there was no barrier to the development of weeds.

The variables of density (Figure 2A) and dry mass (Figure 2B), the effects on the population of invasive species are



Values maize in monocrop: (A) 43DAA: 25,5 plants m^{-2}, 108 DAA: 95,25 plants m^{-2}; (B): 43DAA: 1,17g m^{-2}, 108DAA: 83 g m^{-2}. ns - Not significant; * - Significant at 0.05 probability by the F test

Figure 2. Density (A) and dry mass (B) of weeds at 43 and 108 days after application (DAA) of glyphosate herbicide

related to the evaluation periods and the competitiveness characteristics of the weeds. Higher values of weed density and dry mass were observed in the second evaluation (108 DAA of the treatments).

The presence of soil cover has physical, chemical, and biological effects on weed suppression in several crops. Tropical perennial species, such as BRS Zuri grass, may have a greater suppressive effect when compared with the grain crop in monoculture (Schuster et al., 2020). Although depending on factors such as competitive ability, soil cover, proper management, and weed pressure, the presence of forage can even eliminate the need for herbicide application over time (Dominschek et al., 2021).

For weed density (Figure 2A), it is evident from the regression equation that there was an increase in the variable from the dose of 394.09 g. a.e. ha^{-1}, where 99% of the effect found is related to the treatments applied. The increase in weed density due to the increase in the dose of glyphosate herbicide may be associated with the suppressive effect caused by the forage. Another factor that may be linked to the increase in density refers to the non-suppression promoted by the forage, considering that with the increase in doses, the established biomass of the forage was lower.

For Lima et al. (2019), the occupation of the soil surface by forages reduces the density and development of weeds, highlighting the importance of using these species as options in integrated management. According to Summers et al. (2021), the soil coverage promoted by plants that present high biomass production, for example, forage plants of the genus *Panicum* spp. reduces the density of invasive species and, consequently, the application of herbicides in pre and post-emergence in succession crops.

In the study by Ferreira et al. (2018), which aimed to evaluate the amount of dry mass of different coverage plants and their effect on weed suppression in three years of conduction in the Cerrado region, the authors evidenced that the average dry mass of 10,857 kg ha^{-1} of *P. maximum*, prevented the infestation of weeds such as *A. tenella*, *C. benghalensis*, *S. rhombifolia*, *B. pilosa*, *E. indica*, among others, resulting in the total control of them, being an important component to be used within the management of weeds in integrated systems.

The dry mass of the weed community did not show a significant difference in the first evaluation (43 DAA), being inexpressive (Figure 2B). This result may be related to the size of the weeds and the low competition among species in this period. However, in the second evaluation, there was an accumulation of dry mass with increasing doses, reinforcing the claims of the potential of forage in occupying the area and, consequently, reducing weed biomass. According to the model (Figure 2B), from a dose of 154.19 g. a.e. $ha^{-1,}$ there was an increase in weed dry mass, with 99% of the observed effect related to the application of the treatments.

At lower doses (0, 48, and 96 g a.e. ha^{-1}), lower weed dry mass was observed than in the higher doses. At the three lowest doses, the weeds that stood out were: ALTTE, COMBE, and DIGHO, being that at the dose of 48 g a.e. ha^{-1}, only COMBE was present (Table 2). The dry mass increased with increasing doses (240, 480, and 960 g a.e. ha^{-1}). Such results demonstrate the contribution of forage in cultural weed control, corroborating with other studies (Lima et al., 2018; Martins et al., 2019).

Table 3 shows that 75% of the height of maize plants is a biological response to the application of treatments, so that for each 1 g a.e., there was a reduction of 0.0001 m in plant height. As for the yield components of the crop according to the herbicide doses, there was no significant difference (Table 3). These results indicate that intercropping with the forage BRS Zuri did not affect maize yield. Furthermore, the results may be associated with water availability during crop development (Figure 1).

As in the present assay, other studies show that using herbicide subdoses is a viable alternative for maize production in integration systems (Martins et al., 2019; Sanches et al., 2020). The inhibition of forage growth caused by the action of the herbicide, combined with the shading imposed by the grain crop, can mitigate the competitive effect between the crops and maximize the benefit of the intercrop.

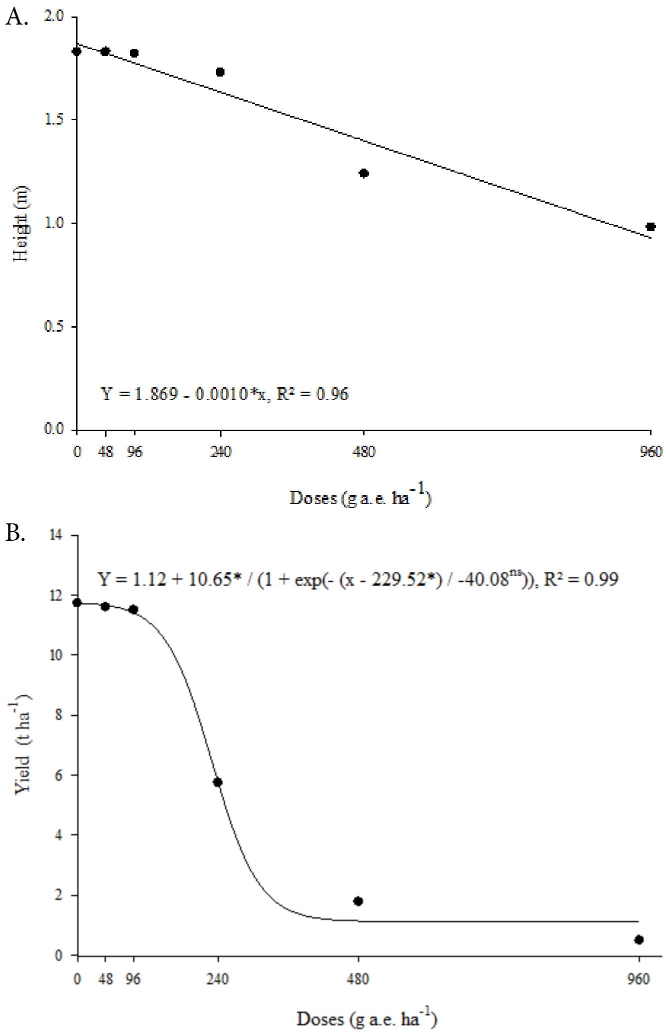
The forage height (Figure 3A) and yield (Figure 3B) showed significant differences in response to the treatments studied. There was a reduction in forage height according to the increase in herbicide dose, 96% of the effect on height was influenced by herbicide application, and a decrease of 0.0010 m was observed with the increase of 1 g of a.e. ha^{-1}.

The growth of forage at lower doses of the herbicide may have been induced by intra-specific competition for light and space within the fields and, consequently, greater elongation of the stem. Lower height values, on the other hand, may be related to less stem elongation due to delayed forage growth

Table 3. Plant height (PH), ear insertion height (EH), stem diameter (SD), ear length (SL), ear diameter (ED), number of rows per ear (NRE), 1000-grain mass (MTG), total number of grains in five ears (TNG), and grain yield (GY) of maize intercropped with *Panicum maximum* cv. BRS Zuri, according to the application of different doses of glyphosate herbicide

Variables	Doses (g a.e. ha^{-1})						Regression	MM	$F_{0.05}$	CV%
	0	48	96	240	480	960				
PH (m)	1.98	2.07	2.06	2.11	2.15	2.17	$\hat{Y} = 2.04 + 0.0001x$. $R^2 = 0.75$	2.17	5.37*	6.0
EH (m)	1.07	1.09	1.09	1.10	1.09	1.12	$\hat{Y} = \bar{Y} = 1.09$	1.14	1.5^{ns}	3.1
SD (mm)	26.54	25.2	25.4	25.8	24.9	24.2	$\hat{Y} = \hat{Y} = 26.00$	25.3	1.47^{ns}	5.8
SL (cm)	17.69	17.26	17.52	17.46	17.42	17.24	$\hat{Y} = \hat{Y} = 17.53$	17.54	1.35^{ns}	6.0
ED (mm)	49.89	47.81	49.45	50.07	49.01	47.83	$\hat{Y} = \hat{Y} = 49.08$	47.54	0.88^{ns}	5.9
NRE	17.4	16.8	17.4	17.3	17.4	16.8	$\hat{Y} = \hat{Y} = 17.35$	17.1	0.55^{ns}	5.76
MTG (g)	238.7	245.5	240.1	242.7	241.2	238.7	$\hat{Y} = \hat{Y} = 241.9$	242.5	0.67^{ns}	5.8
TNG	3.186	3.104	3.162	3.120	3.099	3.173	$\hat{Y} = \hat{Y} = 3.163$	3.148	1.70^{ns}	6.33
YG (t ha^{-1})	10.06	10.06	9.74	9.94	9.96	9.84	$\hat{Y} = \hat{Y} = 10.03$	10.04	0.54^{ns}	6.0

MM - Maize in monocrop; ns - Not significant; * - Significant at 0.05 probability by the F test



ns - Not significant; * - Significant at 0.05 probability by the F test

Figure 3. Height (A) and yield (B) of BRS Zuri forage as a function of glyphosate subdoses

after application. Cruz et al. (2021) reported that shading could directly interfere with the morphogenetic characteristics of forage, showing that the higher the shade imposed, the greater the stem elongation rate. These results resemble the study of Lima et al. (2019), where the authors evidenced the reduction in the height of two species of the genus *Urochloa* intercropped with maize according to increasing subdoses of glyphosate.

Regarding the forage biomass produced, it can be seen that the phytotoxic effect of the herbicide concerning yield, since with increasing doses, the yield was reduced. The regression model shows that the dose 229 g a.e. ha^{-1} was sufficient to reduce 50% of the maximum value found for the variable. At lower doses, it is observed that the forage recovered from the effect caused by the herbicide. These results show that maize did not exert a competitive effect on the forage. Moreover, this behavior may be linked to the morphological characteristics of BRS Zuri grass and, as with maize sowing in the harvest period, where precipitation helped the forage development, even after the application.

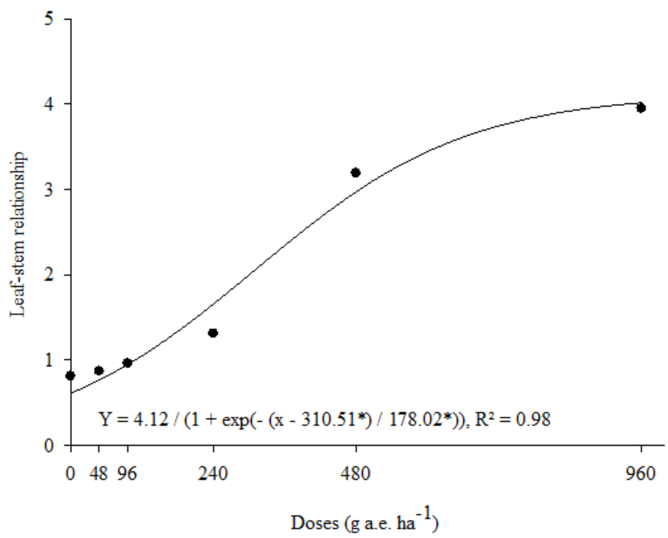
Silva et al. (2020b) state that the BRS Zuri cultivar presents characteristics of high biomass quantity, vigorous regrowth, and fast growth and recovery to adverse conditions. This fact contributes to corroborating these results. Cruvinel et al. (2021) showed that BRS Zuri forage presented higher values of height and yield when compared to other forages such as *U. ruziziensis* and *P. maximum* cv. BRS Tamani and Quênia, after application of subdoses of the herbicides tembotrione (42 and 84 g a.e. ha^{-1}), mesotrione (48 and 96 g a.e. ha^{-1}), glyphosate (100 and 200 g a.e. ha^{-1}), and nicosulfuron (7.8 and 15.6 g a.e. ha^{-1}) for suppression.

For the leaf-stem relationship variable, it is evident that the action of the herbicide interfered directly since, with increasing doses, the value for this variable increased (Figure 4). According to the model, doses from 310.51 g. a.e. ha^{-1} increased this variable, and the action of glyphosate explains 98% of the effect on the variable. The leaf-stem ratio is a variable of great importance for grazing and animal nutrition and the formation of successive straws.

The increase in the leaf-stem ratio may be associated with lower forage growth and less competition of the species in the area. Under conditions of competition for light and space, the forage species tends to elongate the stem, inducing leaf projection and light capture to conduct photosynthetic processes. According to Echeverria et al. (2016), the higher stem production is stimulated by the competition for light between plants, leading to the lower accumulation of leaf area and, consequently, the reduction of protein contents, digestibility, and the lower consumption by the animal.

The higher values of the leaf-stem ratio at higher doses may also be related to the absence of the flowering stage of forage at harvest since the suppression caused by the herbicide delayed growth. Forage species tend to emit more stems in the flowering stage, reducing the leaf area. Results similar to the present study were observed by Lima et al. (2019), where the authors evidenced that increasing subdoses of the glyphosate herbicide in suppression of the forage plants *U. brizantha* cv. Marandu and *U. ruziziensis* showed an increase in the leaf-stem ratio.

According to the results obtained in the present study, broad-spectrum herbicides on transgenic tolerant maize hybrids may be an interesting alternative in the production of grains, the inhibition and production of forage, and the suppression of weeds within integrated systems. It is important to emphasize that for the greatest success of the method, factors



* - Significant at 0.05 probability by the F test

Figure 4. Leaf-stem relationship of BRS Zuri forage according to glyphosate subdoses

such as the stage of development of the plant, correct moment of application, the dose used, morphogenetic characteristics of the forage, and climatic conditions, among others, must be taken into consideration.

Conclusions

1. The forage BRS Zuri is efficient in the suppression of weeds within the production system.

2. The maize yield was not affected by the presence of the forage, regardless of the subdoses of herbicide applied.

3. The increase in herbicide subdoses reduced the height of the forage and increased the leaf-stem ratio.

4. Starting at 229 g a.e. ha^{-1} of glyphosate, BRS Zuri had reduced 50% of its forage yield concerning the absence of the herbicide.

5. The dose starting at 480 g a.e. ha^{-1} can be considered the most viable since the variables of height and biomass of forage presented better management conditions within the system.

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