Ensaios e Ciência
ISSN 1415-6938 e ISSN 2178-695X

DOI: https://doi.org/10.17921/1415-6938.2025v29n1p66-79

Intercrop between Corn and *Urochloa ruziziensis* Managed or not with Glyphosate for Silage

Consórcio entre Milho e *Urochloa ruziziensis* Manejado ou não com Glifosato Visando à Produção de Silagem

Recebido em: 25/10/2024
Aceito em: 27/11/2024

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Abstract
Integrated cropping is a viable option when seeking sustainability in agricultural systems, but competition between consort species may occur. The objective of this study was to evaluate the interaction between corn and intercropped *Urochloa ruziziensis*, managed or not with subdoses of glyphosate, in no-tillage (NT) and conventional (CTS) systems, in addition to the effects of treatments on weeds. Two trials were conducted, one NT and the other in CTS, in a randomized block design, in a split-plot scheme (3x4), with four replications. In both trials, the main treatments consisted of three cropping systems: corn monoculture, intercropping without the use of glyphosate and intercropping treated with subdoses of glyphosate. Secondary treatments were established at four times: on the day of treatment application, 15 days after treatment application, at corn flowering and at the harvest stage for silage. During these periods, the dry weights of corn and forage plants were evaluated, as well as the density and dry weight of weeds. Weed control occurred in the corn monoculture by adopting the highest dose of glyphosate. It was observed in both NT and CTS that the cultivation of *U. ruziziensis* in consortium with corn, with and without the application of a subdose of glyphosate, did not interfere with the production of corn for silage. Glyphosate at the dose tested suppressed the growth of *U. ruziziensis*.

Keywords: Weeds. No-tillage. Conventional Systems. Herbicide.

Resumo
O cultivo integrado se mostra como uma opção viável, quando se busca a sustentabilidade dos sistemas agrícolas, porém pode ocorrer competição entre as espécies consortes. O objetivo do trabalho foi avaliar a interação entre milho e *Urochloa ruziziensis* consorciada, manejadas ou não com subdoses de glifosato, em sistemas de plantio direto (SPD) e convencional (SPC), além dos efeitos dos tratamentos sobre as plantas daninhas. Foram conduzidos dois ensaios, sendo um SPD e o outro em SPC, em delineamento de blocos ao acaso, em esquema de parcelas subdivididas (3x4), com quatro repetições. Nos dois ensaios, os tratamentos principais foram formados por três sistemas de cultivo: monocultivo do milho, consórcio sem uso de glifosato e consórcio tratado com subdose de glifosato. Os tratamentos secundários foram estabelecidos por quatro épocas: dia da aplicação dos tratamentos, aos 15 dias após aplicação dos tratamentos, no florescimento do milho e na fase de colheita para silagem. Nestes períodos foram avaliadas as massas secas das plantas de milho e da forrageira, além da densidade e massa seca de plantas daninhas. O controle de plantas daninhas ocorreu no monocultivo de milho pela adoção da maior dose de glifosato. Foi observado tanto em SPD quanto SPC, que o cultivo de *U. ruziziensis* em consórcio com o milho, com e sem a aplicação de subdose de glifosato, não interferiu na produção de milho para silagem. O glifosato na dose testada suprimiu o crescimento de *U. ruziziensis*.

Palavras-chave: Plantas Daninhas. Sistema Plantio Direto. Sistema Convencional. Herbicida.

1 Introduction

In the Cerrado region, there is a scarcity of bulky feed for animal nutrition during the off-season, and storing feed as silage is an alternative for obtaining feed with improved nutritional value (Ponciano *et al.*, 2022). Maize is the most commonly used crop for this purpose due to its high energy value, low fiber content, good fermentation characteristics, high dry matter yield, ease of harvest (García-Chávez *et al.*, 2022), and adaptability to intercropping systems (Sarto *et al.*, 2021).

When opting for intercropping, in addition to the yield from the annual crop, there is the production of pasture for the dry season and/or straw formation for the subsequent crop, which can serve as an additional source of income while contributing to the sustainability of the agricultural system. Species of the genus *Urochloa* are more tolerant to adverse conditions and are among the most promising for inclusion in intercropping systems (Almeida *et al.*, 2017; De Carvalho *et al.*, 2017).

The simultaneous growth of species in intercropping systems can lead to competition and, consequently, yield reduction, primarily due to resource limitations. However, when resource demands occur at different times, competition is mitigated, making the maize-*Urochloa* intercropping system viable (Martins *et al.*, 2018; Sarto *et al.*, 2021). Additionally, intercropping *Urochloa* species with annual crops can contribute to weed control (Martins *et al.*, 2018; Souza *et al.*, 2024).

One alternative to delay the initial growth of forage species is the application of herbicides at sublethal doses (Martins *et al.*, 2019; Mello *et al.*, 2023; Silva *et al.*, 2023; Oliveira *et al.*, 2024). With the use of genetically modified crops tolerant to glyphosate, this herbicide becomes an option for managing forage crops intercropped with genetically modified glyphosate-tolerant maize (Roundup Ready® – RR), aiming to suppress the initial growth of forage species.

In addition to competition among intercropped species, weed interference may also occur. The weed flora present in the area is influenced by soil management systems-either no-tillage or conventional tillage with plowing and harrowing. The adoption of the no-tillage system (NTS), which is based on the principle of minimal soil disturbance, alters weed population dynamics and reduces weed density (Gomes Jr.; Christoffoleti, 2008; Cunha *et al*., 2014).

This study aimed to evaluate the intercropping system of maize and *Urochloa ruziziensis* under NTS and conventional tillage (CTS), both managed with sublethal doses of glyphosate, as well as the effects of these management practices on weed population dynamics.

2 Material and Methods

The study was conducted during the 2018/2019 agricultural year at the Instituto Federal Goiano, Rio Verde Campus (17° 48' 67" S, 50° 54' 18" W, and an altitude of 754 m), located in the southwest of Goiás State, Brazil. The experimental area soil is classified as a Dystrophic Red Latosol with a clayey texture (Embrapa, 2013). According to the Köppen climate classification, the region has an Aw-type climate, characterized by two well-defined seasons: a rainy summer and a dry winter.

Prior to the experiment setup, soil analysis at a depth of 0–20 cm revealed the following characteristics: pH 5.4 (SMP method), Ca 2.30, Mg 0.87, Al^{3+} 0.15, H+Al 6.01, CEC 9.55 cmolc dm^{-3}, P (Mehlich) 6.12 mg dm^{-3}, K 145.0 mg dm^{-3}, organic matter 36.24 g kg^{-1}, base saturation 3.54%, clay content 67.4%, silt 11.1%, and sand 21.5%.

The forage species *Urochloa ruziziensis* was intercropped with the genetically modified maize hybrid AG8088 PRO2 (Agroceres), which is tolerant to glyphosate. Two experiments were conducted: one under a no-tillage system (NTS) and the other under a conventional tillage system (CTS), involving one plowing operation and two harrowings.

Fifteen days before sowing, chemical desiccation of the area was carried out using glyphosate at a dose of 1,200 g a.e. ha^{-1}. On November 23, 2018, maize was sown first in rows spaced 0.50 m apart, with a plant density of 60,000 plants ha^{-1}. Subsequently, *U. ruziziensis* seeds were manually distributed along the maize sowing rows and manually covered, with a cultural value index (CVI) of 400 per hectare.

The experimental design was a randomized block design in a split-plot arrangement, with three treatments and four evaluation periods, replicated four times. In both trials, the main treatments, arranged in the plots, consisted of three cropping systems: (i) maize monoculture, (ii) maize intercropped with *U. ruziziensis* without glyphosate application, and (iii) maize intercropped with *U.*

ruziziensis treated with a subdose of glyphosate (50 g a.e. ha^{-1}).

The secondary treatments, arranged in the subplots, corresponded to four evaluation periods: (i) the day of glyphosate application, (ii) 15 days after application, (iii) maize flowering stage, and (iv) the hard dough stage of the maize grain, which represents the silage harvest point. Each experimental plot consisted of 12 maize rows, spaced 0.45 m apart and 6 m in length, covering a total area of 32.4 m^2. The outer rows (first and last) and 1.0 m from the ends of the rows were considered border areas.

In both experiments, atrazine was applied at 1,000 g ha^{-1} 28 days after sowing (DAS) for broadleaf weed control. In maize monoculture plots, glyphosate was applied at 480 g a.e. ha^{-1}. On December 21, 2018, at 28 DAS, the glyphosate subdose treatments were applied using a CO_2-pressurized sprayer fitted with a 2-m spray boom containing four TT11002 nozzles spaced 0.50 m apart and positioned 0.50 m above the plant surface. The spray solution volume was 170 L ha^{-1}. The application was carried out in the morning, between 10:40 AM and 11:20 AM, under the following environmental conditions: air temperature of 32.5°C, soil temperature of 28.2°C, relative humidity of 52.7%, cloud cover of 4%, and wind speed of 1.0 m s^{-1}. At the time of application, the maize was at the V5–V6 growth stage.

For maize and *U. ruziziensis* growth analysis, samplings were conducted at four time points: (i) the day of treatment application (22 days after emergence – DAE), (ii) 15 days after application (37 DAE), (iii) maize flowering (65 DAE), and (iv) the hard dough stage (100 DAE). At each evaluation period, two maize plants per plot were collected, while *U. ruziziensis* plants were sampled from a 0.60 m row section. After collection, *U. ruziziensis* plants were separated into stems + sheaths and leaf blades, whereas maize plants were separated into stems + sheaths, leaf blades, tassels, and ears. The plant fractions were dried in a forced-air oven at 60°C until reaching a constant weight to determine dry mass.

For leaf area measurements, a sample of 20 *U. ruziziensis* leaves was collected, and both length and width were measured. For maize, 20 leaf blade samples were taken using a cylindrical cutter with a known area, from which the total leaf area of the sub-sample was calculated. The sub-samples were then dried, and the total leaf area was determined by multiplying the dry matter of the sub-samples with the total dry matter of the leaf samples for both maize and *U. ruziziensis*.

During the same plant growth evaluation periods, weed population assessments were also conducted. In each plot, a 0.5 m^2 sampling area was selected, where weed species were identified, counted, cut at the soil surface, separated, and placed in paper bags for subsequent drying in a forced-air oven at 60 °C until a constant weight was reached. The dry mass was then measured.

The obtained data were subjected to analysis of variance (ANOVA) using a split-plot design, with main treatments (cropping systems) and secondary treatments (evaluation periods) compared using an F-test ($p < 0.05$). When significant differences were detected, means were compared using Tukey's test ($p < 0.05$) for main treatments, while regression analysis was conducted for evaluation periods.

3 Results and Discussion

In both trials (NTS and CTS), significant interactions were observed between cropping systems and evaluation periods for weed density and dry mass, as well as for the leaf area index of the intercropped plants (Table 1).

Table 1 - F-values and coefficients of variation (CV, %) applied to the mean weed density and dry mass, as well as the leaf area index of maize and *Urochloa ruziziensis*, in the no-tillage and conventional tillage system trials

Treatments	Weed Plants		Leaf Area Index	
	Dry Mass (g m^{-2})	Density (plants m^{-2})	Maize	*Urochloa*
Intercropping of maize and *Urochloa ruziziensis* in a no-tillage system				
Cropping Systems (CS) (SC)	2.97*	13.4*	2.26ns	339.1*
Evaluation Periods (Ep)	9.7*	10.8*	339.1*	2.97*
CS × Ep Interaction	10.5*	5.8*	2.97*	9.7*
CV (SC) (%)	2.26	62.2	9.7	10.5
CV (Ep) (%)	39.1	39.5	10.5	2.26
Intercropping of maize and *Urochloa ruziziensis* in a conventional tillage system				
Cropping Systems (CS) (SC)	153.5*	47.5*	0.14ns	22.5*
Evaluation Periods (Ep)	45.2*	13.6*	345.06*	39.20*
CS × Ep Interaction	27.0*	7.6*	3.36*	11.50*
CV (SC) (%)	31.9	31.2	13.9	15.2
CV (Ep) (%)	37.1	26.1	9.8	29.5

*Significant at $p < 0.05$, ns = not significant.
Source: research data.

The main weed species found in both trials were Benghal dayflower (*Commelina benghalensis*), slender amaranth (*Alternanthera tenella*), and sourgrass (*Digitaria insularis*), which are considered difficult to control with glyphosate. These species exhibited lower density and dry mass accumulation values in maize monoculture compared to intercropping, particularly in the evaluations conducted at 65 and 100 days after emergence (DAE) (Table 2). For the aforementioned weed species, chemical control through the application of a higher glyphosate dose (480 g a.e. ha^{-1}) in maize monoculture was crucial in reducing infestation compared to the subdose used in intercropping, which did not contribute to effective weed control.

Table 2 - Breakdown of the significant interaction of weed density and dry mass in intercropping with *Urochloa ruziziensis*, regression equations, and determination coefficients (R^2) from trials in the no-tillage system and conventional tillage system in maize monoculture (MM), intercropping (C) without glyphosate application (0 g), and intercropping treated with a glyphosate subdose of 50 g a.e. ha^{-1}, as a function of evaluation periods

Treatments	Evaluation Periods (DAE)				Regression Equations	R^2
	22	37	65	100		
Maize and *Urochloa ruziziensis* intercropping in no-tillage system						
	Weed density (plants m^{-2})					
MM	26 a	10 a	3 a	5 a	$\hat{Y}=24.1047-0.2340x$	77.05*
C0g	18 a	28 b	27 b	17 b	$\hat{Y}=4.3715+0.8355x-0.0071x^2$	94.72*
C50g	63 b	27 b	41 b	20 b	$\hat{Y}=60.0296-0.3978x$	72.01*
	Dry biomass of weeds (g m^{-2})					
MM	0.21 a	0.26 a	0.28 a	0.58 a	$\hat{Y}=0.0796+0.0045x$	92.48*
C0g	0.18 a	0.94 a	7.25 b	6.44 b	$\hat{Y}=6.8453/(1+\exp(-(x-41.6575)/2.5360))$	99.55*
C50g	0.24 a	1.61 a	6.63 b	5.50 b	$\hat{Y}=6.0672/(1+\exp(-(x-40.5895)/3.5503))$	98.76*
Intercropping of maize and *Urochloa ruziziensis* under conventional tillage system						
	Weed density (plants m^{-2})					
MM	64 a	10 a	4 a	4 a	$\hat{Y}=54.6324-0.6095x$	71.80*
C0g	84 a	46 b	57 b	50 b	S.A.	--
C50g	65 a	71 c	88 c	68 b	$\hat{Y}=32.8522+1.6279x-0.0127x^2$	93.91*
	Dry biomass of weeds (g m^{-2})					
MM	0.58 a	0.62 a	0.62 a	0.08 a	$\hat{Y}=0.6067/(1+\exp(-(x-97.4101)/-1.3743))$	99.74*
C0g	1.04 a	5.89 b	7.13 b	5.99 b	$\hat{Y}=-5.2475+0.3675x-0.0026x^2$	95.62*
C50g	0.69 a	5.44 b	21.6 c	19.3 c	$\hat{Y}=20.4648/(1+\exp(-(x-40.8391)/3.8070))$	99.52*

*Significant at 5% probability by the F test for R^2. Means followed by the same letter in the same column do not differ from each other according to Tukey's test at 5% probability. N.A.: no adjustment. DAE: days after emergence.
Source: Research data.

In maize monoculture, the highest initial weed density was observed in the conventional tillage system (CTS). In both CTS and no-tillage system (NTS), values decreased linearly due to chemical control applied at different evaluation times, up to the hard-dough grain stage, which corresponded to maize harvesting for silage (Table 2). In intercropping, regardless of glyphosate subdose application, weed density results were heterogeneous, sometimes following quadratic models (absence of glyphosate in NTS and 50 g glyphosate in CTS), linear models (50 g glyphosate in NTS), or showing no fit in the untreated intercropping system in NTS. However, in general, higher weed densities in intercropping were confirmed in CTS compared to NTS.

In both NTS and CTS, dry mass accumulation of the weed community increased over evaluation periods, following logistic models, except in CTS under the no-glyphosate treatment, where it was best explained by a quadratic model (Table 2).

The accumulation of weed dry mass in NT and CT was considered low due to the treatments (Table 2), with emphasis, in the intercropping system, on the treatment managed with glyphosate in CT, which presented higher values compared to the other treatments. The logistic model that defined dry mass accumulation for some treatments was the three-parameter nonlinear equation, as follows:Y^=1+exp(−b(x−x0))a, where $\hat{Y}$ is the response variable, x is the herbicide dose, and a, x_0, and b are the equation parameters: a represents the difference between the maximum and minimum points of the curve, x_0 is the dose that provides 50% of the response variable, and b is the slope of the curve.

In the logistic models of dry mass accumulation in NT, the highest estimates of coefficient a ranged between 6.06 and 6.84 g m^{-2}, with 50% of this response variable occurring between 40 and 41 DAE (Table 2). In CT, for the treatment with glyphosate application, the estimate of coefficient a related to dry mass accumulation was 20.46 g m^{-2}. Similar results were observed by Jakelaitis et al. (2004) in their evaluation of maize intercropped with *Urochloa decumbens* in CT and NT, where they reported higher estimates of dry mass accumulation of vegetatively propagating and hard-to-control weeds in CT compared to NT.

The evolution of the leaf area index (LAI) of maize in monoculture and intercropped with *U. ruziziensis* in NT and CT was explained by quadratic models (Table 3). For monoculture maize, the maximum estimated LAI in NT was 5.03 at 76 DAE and in CT was 5.38 at 73 DAE; for intercropped maize managed without glyphosate, it was 5.24 in NT and 5.38 in CT, both at 75 DAE; and for intercropped maize managed with a subdose of 50 g ha⁻¹ of glyphosate, it was 4.95 at 75 DAE in NT and 5.46 at 78 DAE in CT (Table 3).

Table 3 - Breakdown of the significant interaction of maize leaf area index, regression equations, and determination coefficients (R^2) from trials in no-tillage (NT) and conventional tillage (CT) systems in maize monoculture (MM) and intercropping systems without glyphosate (C 0g) and with glyphosate applied at a subdose of 50 g a.e. ha⁻¹ (C 50g), as a function of evaluation periods

Treatments	Evaluation Periods (DAE)				Regression Equations	R^2
	22	37	65	100		
Maize and *Urochloa ruziziensis* intercropping in no-tillage system						
	Leaf area index					
MM	1.19 a	2.75 b	5.27 a	2.38 a	$\hat{Y}$=-5.4769+0.2827x-0.0019x²	96.36*
C0g	1.22 a	3.23 ab	5.07 ab	2.42 a	$\hat{Y}$=-4.9859+0.2714x-0.0018x²	99.87*
C50g	1.17 a	3.29 a	4.63 b	2.01 a	$\hat{Y}$=-4.5152+0.2537x-0.0017x²	99.74*
Intercropping of maize and *Urochloa ruziziensis* under conventional tillage system						
MM	1.05 a	4.68 a	4.76 a	2.48 a	$\hat{Y}$=-4.7271+0.2772x-0.0019x²	83.84*
C0g	1.19 a	4.02 b	4.98 a	2.74 a	$\hat{Y}$=-4.6967+0.2693x-0.0018x²	95.67*
C50g	0.92 a	4.21 ab	4.53 a	3.00 a	$\hat{Y}$=-4.3910+0.2511x-0.0016x²	85.39*

*Significant at a 5% probability level by the F test for R^2. Means followed by the same letter in the same column do not differ from each other according to Tukey's test at a 5% probability level. DAE: days after emergence. **Source:** research data.

The main changes in the evolution of the leaf area index (LAI) during the maize cycle, whether intercropped or in monoculture, in both NT and CT systems, were observed between 37 and 65 DAE, with statistical differences between treatments. In intercropped systems, the evolution of maize LAI is crucial for competition with the forage crop, as the latter, when subjected to shading, exhibits slower growth due to its C4 photosynthetic carbon fixation metabolism (Portes *et al*., 2000). As maize LAI values decrease over the cycle and leaf senescence occurs, the forage crop establishes itself, benefiting from increased radiation penetration into the crop canopy, which promotes tillering and pasture formation (Lima *et al*., 2020).

The results of the evolution of the LAI of U. ruziziensis forage in response to the treatments in NT and CT systems are presented in Table 4 and are considered low. In all treatments in NT and CT, LAI evolution was explained by logistic models, with LAI estimates ranging between 0.14 and 0.28.

Under shading, the leaf area of U. ruziziensis was suppressed, and this effect was further restricted when treated with a subdose of glyphosate. LAI values were lower compared to plots that did not receive herbicide application, especially in evaluations conducted after 37 DAE in CT and at 65 DAE in NT.

Table 4 - Breakdown of the significant interaction of the leaf area index of *Urochloa ruziziensis*, regression equations, and determination coefficients (R^2) from the trials in the no-till system (NT) and conventional tillage system (CT), in maize monoculture (MM), and intercropping systems without glyphosate (C0g) and with glyphosate applied at a subdose of 50 g a.e. ha^{-1} (C50g), as a function of evaluation periods

Treatments	**Evaluation Periods (DAE)**				**Regression Equations**	**R^2**
	22	**37**	**65**	**100**		
Leaf area index *of Urochloa ruziziensis*						
Maize and *Urochloa ruziziensis* intercropping in no-tillage system						
C0g	0.01 a	0.21 a	0.37 a	0.20 a	$\hat{Y}$=0.2799/(1+exp(-(x-39.0224)/3.5277))	76.77*
C50g	0.02 a	0.21 a	0.12 b	0.11 b	$\hat{Y}$=0.1467/(1+exp(-(x-28.9841)/0.5850))	65.41*
Intercropping of maize and *Urochloa ruziziensis* under conventional tillage system						
C0g	0.01 a	0.19 a	0.35 a	0.25 a	$\hat{Y}$=0.2649/(1+exp(-(x-39.7936)/3.2328))	73.58*
C50g	0.02 a	0.13 b	0.16 b	0.18 b	$\hat{Y}$=0.2593/(1+exp(-(x-53.0474)/18.1095))	92.82*

*Significant at a 5% probability level by the F-test for R^2. Means followed by the same letter in the same column do not differ from each other by the F-test at a 5% probability level. DAE: days after emergence.
Source: research data.

For the production of dry mass of leaves, stems, and the total maize plants evaluated in SPD and SPC, no significant interactions were observed between the main treatments and evaluation periods, only an effect of periods, indicating uniformity in the accumulation of dry mass in maize plants (Table 5). Conversely, *U. ruziziensis* was more affected by the treatments compared to maize, showing a significant interaction for the dry mass of leaves, stems, and total between cropping systems and periods in SPD, and for the dry mass of leaves and total dry mass in SPC (Table 5).

Table 5 - F values and coefficients of variation (CV%) applied to the mean dry mass of leaves (DML), stems (DMS), and total (DMT) of maize and Urochloa ruziziensis in the no-till system and conventional tillage system

Treatments	Maize			*Urochloa*		
	MSF[1]	MSC[2]	MST[3]	MSF	MSC	MST
	g plants^{-1}			g m^{-2}		
Maize and *Urochloa ruziziensis* intercropping in no-tillage system						
Cropping Systems (CS) (SC)	0.27^{ns}	1.07^{ns}	1.12^{ns}	32.05*	8.67^{ns}	21.80*
Evaluation Periods (Ep)	186.2*	647.2*	778.8*	38.40*	28.26*	34.42*
CS × Ep Interaction	0.22^{ns}	1.30^{ns}	0.92^{ns}	17.51*	8.24*	13.83*
CV (SC) (%)	14.2	15.1	14.3	28.2	36.3	29.2
CV (Ep) (%)	14.6	11.9	13.0	30.9	35.2	31.4
Intercropping of maize and *Urochloa ruziziensis* under conventional tillage system						
Cropping Systems (CS) (SC)	1.88^{ns}	0.86^{ns}	3.47^{ns}	10.14*	5.42^{ns}	7.45^{ns}
Evaluation Periods (Ep)	151.9*	89.2*	317.1*	76.62*	69.53*	71.04*
CS × Ep Interaction	0.99^{ns}	0.79^{ns}	0.68^{ns}	5.17*	3.01^{ns}	3.98*
CV (SC) (%)	13.7	29.4	8.8	19.9	29.7	24.2
CV (Ep) (%)	15.8	29.5	19.9	18.8	23.9	20.9

*Significant at $p < 0.05$, ns = not significant.
Source: research data.

The accumulation of dry mass in leaves, stems, and the total dry mass of maize plants was not affected by the treatments and showed similar behavior in both trials (Table 6), being explained by a logistic model based on the evaluation periods. Until 22 DAE, at the time of glyphosate application, there was little dry mass accumulation in maize, and no significant differences were observed between treatments, indicating uniform plant growth. After this period, there was an intense increase in dry mass until 100 DAE.

Table 1 - Breakdown of the significant interaction for dry mass of leaves (DML), stems (DMS), and total dry mass (TDM) of maize, regression equations, and determination coefficients (R^2) from trials in the no-till system and conventional tillage system in maize monoculture (MM), in intercropping without glyphosate (C 0g), and with glyphosate applied at a subdose of 50 g a.e. ha^{-1} (C 50g), based on evaluation periods

Treatments	Evaluation Periods (DAE)				Regression Equations	R^2
	22	37	65	100		
Maize and *Urochloa ruziziensis* intercropping in no-tillage system						
Maize leaf dry mass						
MM	7.0	26.0	42.4	41.1	$\hat{Y}$=41.3456/(1+exp(-(x-39.6825)/6.7219))	98.98*
C0g	6.7	25.0	43.6	37.8		
C50g	6.1	24.8	42.2	39.5		
Maize stem dry mass						
MM	2.9	19.0	77.5	72.1	$\hat{Y}$=71.6005/(1+exp(-(x-46.5220)/3.4213))	99.53*
C0g	2.6	18.9	73.7	63.7		
C50g	2.3	18.3	70.6	71.4		
Total maize dry mass						
MM	9.9	45.1	162.5	314.4	$\hat{Y}$=316.9943/(1+exp(-(x-68.1710)/13.1666))	99.93*
C0g	9.3	43.9	148.6	291.9		
C50g	8.5	43.1	141.5	314.3		
Intercropping of maize and *Urochloa ruziziensis* under conventional tillage system						
Maize leaf dry mass						
MM	5.6	38.6	44.4	43.3	$\hat{Y}$=42.0928/(1+exp(-(x-35.8175)/4.0965))	99.28*
C0g	5.9	33.0	45.4	35.8		
C50g	4.9	36.0	41.9	41.8		
Maize stem dry mass						
MM	2.1	30.1	60.0	70.3	$\hat{Y}$=74.0139/(1+exp(-(x-45.8335)/5.3427))	99.98*
C0g	2.3	25.8	77.5	79.4		
C50g	1.8	26.7	78.7	73.9		
Total maize dry mass						
MM	7.7	68.7	140.9	340.9	$\hat{Y}$=356.8950/(1+exp(-(x-70.9529)/15.8080))	99.43*
C0g	8.1	58.8	156.8	312.3		
C50g	6.7	62.7	163.8	348.4		

*Significant at $p < 0.05$, ns = not significant.
Source: research data.

The estimated accumulation of maize leaf dry mass was 41.34 and 42.09 grams per plant in the no-till system (NT) and conventional tillage system (CT), respectively. The stem dry mass was 71.60 and 74.01 grams per plant in NT and CT, respectively, while the total dry mass was 316.99 and 356.89 grams per plant in NT and CT, respectively (Table 6), highlighting the competitive ability of maize in relation to the forage crop.

From 65 DAE onwards, the highest contribution to total dry mass is linked to ear formation, which progressively increases its share in total dry mass from its emergence until the silage harvest point. On the other hand, the dry mass production of *U. ruziziensis* was low at all evaluation periods during the maize crop, especially when treated with a subdose of glyphosate in both trials (Table 7). The data fit the logistic model, showing through the estimated dry mass of leaves, stems, and total dry mass that there were no significant increases in dry mass accumulation and that forage growth was suppressed by maize.

Table 7 - Breakdown of the significant interaction for dry mass of leaves (MSF), stems (MSC), and total (MST) of Urochloa ruziziensis, regression equations, and determination coefficients (R^2) from trials in the no-tillage system and conventional tillage system in intercropping without (C 0g) and with glyphosate applied at the subdose of 50 g a.e. ha^{-1} (C 50g), according to the evaluation periods

Treatments	Evaluation Periods (DAE)				Regression Equations	R^2
	22	37	65	100		
Maize and *Urochloa ruziziensis* intercropping in no-tillage system						
	Leaf dry mass of *Urochloa ruziziensis*					
C0g	0.37 a	3.11 a	6.29 a	1.95 a	Ŷ=4.1115/(1+exp(-(x-38.1516)/4.1360))	49.90*
C50g	0.52 a	2.50 a	1.90 b	1.64 a	Ŷ=2.0100/(1+exp(-(x-39.6825)/0.6266))	81.44*
	Stem dry mass of *Urochloa ruziziensis*					
C0g	0.11 a	2.00 a	4.32 a	2.30 a	Ŷ=3.3092/(1+exp(-(x-41.4919)/3.3965))	77.03*
C50g	0.17 a	1.78 a	1.66 b	2.34 a	Ŷ=2.0005/(1+exp(-(x-35.9849)/3.3662))	91.04*
	Total dry mass of *Urochloa ruziziensis*					
C0g	0.48 a	5.12 a	10.61 a	4.25 a	Ŷ=7.4208/(1+exp(-(x-39.7463)/3.9710))	78.29*
C50g	0.69 a	4.27 a	3.56 b	3.98 a	Ŷ=3.9367/(1+exp(-(x-28.9571)/0.6180))	96.88*
Intercropping of maize and *Urochloa ruziziensis* under conventional tillage system						
	Leaf dry of *Urochloa ruziziensis*					
C0g	0.23 a	2.72 a	3.01 a	3.12 a	Ŷ=3.0622/(1+exp(-(x-36.2327)/3.2858))	99.89*
C50g	0.49 a	1.78 b	2.85 a	2.12 b	Ŷ=2.4814/(1+exp(-(x-36.9021)/6.0655))	90.12*
	Stem dry of *Urochloa ruziziensis*					
C0g	0.05 a	3.06 a	4.34 a	3.02 a	Ŷ=2.9424/(1+exp(-(x-41.8895)/4.5784))	98.99*
C50g	0.13 a	1.39 a	4.14 a	1.61 a		
	Total dry of *Urochloa ruziziensis*					
C0g	0.30 a	4.79 a	5.80 a	6.75 a	Ŷ=6.2789/(1+exp(-(x-38.7752)/3.6343))	98.15*
C50g	0.64 a	3.02 b	5.59 a	4.69 b	Ŷ=5.1544/(1+exp(-(x-40.6347)/5.9338))	96.70*

*Significant at a 5% probability level by the F test for R^2. Means followed by the same letter in the same column do not differ from each other according to the F test at a 5% probability level. DAE: days after emergence. **Source:** research data.

In no-tillage system (SPD), *Urochloa ruziziensis* showed higher dry mass production in the absence of glyphosate application in evaluations conducted at 65 DAE, while in the conventional tillage system (SPC), this effect was more evident at 100 DAE for leaves and total dry mass (Table 7). *Urochloa ruziziensis* intercropped with maize has limited growth during its coexistence with the crop and experiences a phase of rapid dry mass accumulation during the physiological senescence of maize leaves, which typically occurs during the grain-filling stage (Lima et al., 2014).

4 Conclusion

The intercropping of *Urochloa ruziziensis* with maize, with or without the application of a glyphosate subdose, does not interfere with maize production for silage.

Glyphosate suppresses the initial growth of *Urochloa ruziziensis* intercropped with maize at a dose of 50 g a.e. ha^{-1}.

Acknowledgments
To the Instituto Federal Goiano and CNPq for financial support.

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