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Physiologic and morphologic characters of soybean and *Urochloa* sp. intercropped under reduced rates of glyphosate

Caracteres fisiológicos e morfológicos da soja e da *Urochloa* sp. consorciados sob doses reduzidas de glifosato

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Abstract

The intercropping between soybean and *Urochloa* spp. is an alternative for the use of the area, straw formation, and pasture. In coexistence, the use of herbicide underdoses for forage suppression is required to reduce its interference with soybean plants. The aim of this study was to assess the effects of densities of *Urochloa* spp. in coexistence with soybean plants and treated or not with glyphosate underdoses. Two experiments with *U. brizantha* and *U. ruziziensis* under coexistence with RR (Roundup Ready®) soybean plants were assessed in a randomized block design with four replications. The absence and application of glyphosate underdoses (120 g a.e. ha^{-1}) and five densities of each forage (0, 1, 2, 4, and 6 plants per pot) in coexistence with soybean plants were tested in a 2 × 5 factorial scheme. The action of glyphosate on forages promoted a reduction in their competitive capacity with soybean plants. Glyphosate decreased the size, tillering, and dry matter accumulation of forages. When glyphosate was not applied, forages interfered negatively in soybean development, especially when in coexistence with *U. ruziziensis*. The increased forage density raises the degree of interference on soybean plants when forages are not treated with glyphosate.

Additional keywords: competition; *Glycine max* (L.); *Urochloa brizantha; Urochloa ruziziensis.*

Resumo

O consórcio entre a cultura da soja e *Urochloa* spp. é uma alternativa para o aproveitamento de área, formação de palhada e de pastagens. Em convivência, o uso de subdose de herbicidas para supressão da forrageira é requerida para reduzir a competitividade destas sobre as plantas de soja. Objetivou-se avaliar os efeitos de densidades de *Urochloa* spp. em convivência com plantas de soja, tratada ou não, com subdose de glifosato. Foram avaliados dois ensaios com as forrageiras *U. brizantha* e *U. ruziziensis*, convivendo com plantas de soja RR (Roundup Ready®), delineados em blocos casualizados com quatro repetições. Testaram-se, em fatorial 2x5, a ausência e a aplicação de subdose de glifosato (120 g e.a ha^{-1}) e cinco densidades de cada forrageira (0, 1, 2, 4 e 6 plantas vaso^{-1}) convivendo com plantas de soja. A ação do glifosato sobre as forrageiras promoveu a redução da capacidade competitiva destas com as plantas de soja. O glifosato diminuiu o porte, o perfilhamento e o acúmulo de massa seca das forrageiras. Quando o glifosato não foi aplicado, as forrageiras interferiram negativamente no desenvolvimento da soja, principalmente quando em convivência com *U. ruzizizensis*. O aumento da densidade das forrageiras eleva o grau de interferência sobre as plantas de soja, quando as forrageiras não são tratadas com glifosato.

Palavras-chave adicionais: competição; *Glycine max* (L.); *Urochloa brizantha*; *Urochloa ruziziensis.*

Introduction

Brazil is one of the world's largest soybean producers, mainly due to extensive areas available for its cultivation. The area cultivated with soybean in the 2018/19 agricultural season was approximately 35.874 million hectares, with an average productivity of 3,206.00 kg ha^{-1}. Soybean is the main agricultural crop produced in Brazil in terms of quantity and sown area (CONAB, 2019). Soybean productivity can be compromised by several factors, especially the interference with weeds (Lamego et al., 2013; Mata et al., 2014).

The intercropping between soybean and forages has not been used mainly because the forage becomes the main competing with the legume (Machado et al., 2017). Considering that most of the forage species used in intercropping with grain crops are perennial and of C_4 photosynthetic metabolism, their coexistence with soybean may become unfavorable to it due to the higher competitive capacity of forages. However, the forage suppressed with soybean-selective herbicides may contribute to the maintenance of its productivity by reducing forage interference (Dan et al., 2011; Tironi et al., 2012). The use of herbicide underdoses in forages of the genus *Urochloa* may make feasible the intercropping between soybean and forage (Silva et al., 2004; Silva et al., 2005).

Glyphosate is one of the main molecules used in weed management in Roundup Ready (RR) soybean because it presents a low acquisition cost and high efficiency in controlling several weeds (Gusmão et al. 2011). The reduction in forage growth may be related to the site of action of glyphosate, as it interferes with the shikimic acid route, which significantly modifies the transport of carbon for this route, which should be directed to plant growth (Nascentes et al., 2015). Therefore, studies on the competition of forage species in relation to RR soybean are necessary, aiming at developing management strategies and guaranteeing proportions that confer a higher competitive ability to the crop (Agostinetto et al., 2013).

Thus, this study aimed to assess the competitive ability among soybean plants genetically modified to tolerate the glyphosate herbicide in coexistence with five densities of *Urochloa ruziziensis* and *Urochloa brizantha* cv. Marandu treated or not with glyphosate.

Material and methods

The experiment was conducted in a climatized greenhouse located in Rio Verde, GO, Brazil, from September 24 to November 28, 2017. The experimental units consisted of 6 dm^{-3} plastic drilled pots containing a medium textured Oxisol in a 2:1 ratio (soil:sand), and fertilized following the chemical analysis. Fertilization consisted of the application of a dolomitic limestone with a TRNP of 92.5% (360 mg dm^{-3}), thermophosphate (228 mg dm^{-3}), and potassium chloride (66.6 mg dm^{-3}).

Two experiments were conducted on the coexistence of forages with soybean, one of them with *U. ruziziensis* and the other with *U. brizantha* cv. Marandu. The experimental design was a randomized block design with four replications. Treatments were arranged in a 2×5 factorial scheme. The first factor consisted of the absence and application of glyphosate underdose on the forage and the second factor consisted of different densities of forage plants (0, 1, 2, 4, and 6 plants per pot). On September 24, 2017, the soybean cultivar Guaiá 7487 RR (7.5) was treated with 62.5 g chlorantraniliprole 100 kg^{-1} seeds and inoculated with 80 g *Bradyrhizobium japonicum* 50 kg^{-1} seeds.

Four soybean seeds and eight forage seeds were sown at each experimental unit. Thinning was carried out 9 days after emergence (DAE), leaving two soybean plants in the center of the pot and a variable number of forage plants according to the treatment (0, 1, 2, 4, and 6 plants per pot).

The insecticide pyriproxyfen was applied at 9 DAE at a dose of 25 g ha^{-1} for controlling *Bemisia tabaci* race B. At 24 DAE, 120 g ha^{-1} glyphosate (Lima et al., 2019) was applied by means of a CO_2 sprayer equipped with a 2.0 m boom, nozzles AXI 110 02, and a volume of spray solution of 160 L ha^{-1}. A wind speed of 1 m s^{-1}, relative humidity of 54.7%, and air temperature of 28.3 °C were registered at application time.

Topdressing fertilization was carried out at 30 DAE with potassium chloride (50 mg dm^{-3}). At the beginning of flowering (36 DAE), micronutrients were applied. Two applications of fungicide were performed. The first application was carried out on October 25 with 70 g trifloxystrobin + 60 g prothioconazole and the second application on November 10 with 58.45 g fluxapiroxade + 116.55 g pyraclostrobin for controlling *Septoria glycines*.

Gas exchanges of soybean plants were assessed for registering the photosynthetic (A, µmol m^{-2} s^{-1}) and transpiration (E, mmol mm^{-2} s^{-1}) rates, stomatal conductance (gs, mol H_2O m^{-2} s^{-1}), and the internal to external CO_2 concentration ratio (Ci/Ca). These assessments were performed using an automated photosynthesis analyzer model LI-6400XTR (Licor®, Nebraska, USA) with a block temperature of 24 °C and photon flux density of 1000 µmol m^{-2} s^{-1}. The assessments were performed on the sixth branching of the soybean plant, in the fully expanded leaf at 60 days after the beginning of the coexistence of soybean and forage plants, specifically between 8:30 and 10:30 h.

Plant height, stem dry matter, leaf dry matter, average number of lateral branches and leaves, average stem diameter, leaf area, and root dry matter were determined at 60 DAE of soybean (at harvest time). Plant height was obtained by the average of the two plants of each pot, measured with a ruler graduated in centimeters. The aerial part was cut close to the soil, the number of branches and leaves of each plant was counted, and the length and width of ten leaflets were measured (Richter et al., 2014). The stem diameter of both plants was measured with an automatic caliper. Soybean roots were separated from forage roots, taken to dry in an oven at 65 °C for 72 hours, and weighed.

Plant height, shoot dry matter, average number of tillers, and root dry matter of forage plants were also measured. Plant height was obtained by the average of the proportion of plants at each pot, measured with a ruler graduated in centimeters. At harvest time, plant shoot was cut close to the ground and the average number of tillers was counted. Forage roots were separated from soybean roots, taken to an oven at 65 °C for 72 hours, and weighed.

The statistical analyses were performed by using the statistical software SISVAR (version 5.6) (Ferreira, 2014). The data were submitted to analysis of variance ($p<0.05$) and adjusted to regression models when significant. These models were selected according to the significance, coefficient of determination, simplicity, and biological significance.

Results and discussion

No significant interactions were observed for the physiological variables (*A*, *gs*, *E*, and *Ci/Ca*) measured in soybean plants as a function of the glyphosate underdose application and forage densities (Table 1). An effect of glyphosate was observed on the variables *A*, *gs*, and *E* assessed in soybean plants in coexistence with *U. ruziziensis*, confirming a reduction of forage interference capacity (Table 1). On the other hand, a higher forage interference was observed on soybean plants when forage was not treated with glyphosate, with lower values of *A*, *gs*, and *E*, except for *Ci/Ca* ratio, which did not present statistical difference. Soybean plants in coexistence with *U. ruziziensis* were more affected by the interference in relation to the coexistence with *U. brizantha* cv. Marandu (Table 1).

Table 1 - Photosynthetic rate (*A*), stomatal conductance (*gs*), transpiration rate (*E*) and the internal to external CO_2 concentration ratio (*Ci/Ca*) of RR soybean plants cultivated in coexistence with *Urochloa ruziziensis* and *Urochloa brizantha* cv. Marandu treated (TG) or not (NTG) with glyphosate.

Experiment 1 – Coexistence of RR soybean × *Urochloa ruziziensis*				
Herbicide	*A* (μmol m^{-2} s^{-1})	g_s (mol m^{-2} s^{-1})	*E* (mmol m^{-2} s^{-1})	*Ci/Ca*
NTG	10.02 b	0.19 b	3.61 b	0.75 a
TG	13.15 a	0.27 a	4.76 a	0.77 a
Density (plants per pot)				
0	13.97	0.28	5.00	0.76
1	13.65	0.28	4.88	0.76
2	9.74	0.18	3.49	0.76
4	10.55	0.21	3.94	0.76
6	10.01	0.20	3.62	0.77
Regression	$\hat{Y}=\bar{Y}=11.58$	$\hat{Y}=\bar{Y}=0.23$	$\hat{Y}=\bar{Y}=4.19$	$\hat{Y}=\bar{Y}=0.76$
CV (%)	36.35	41.42	34.12	4.60
Experiment 2 – Coexistence of RR soybean × *Urochloa brizantha* cv. Marandu				
Herbicide	*A* (μmol m^{-2} s^{-1})	g_s (mol m^{-2} s^{-1})	*E* (mmol m^{-2} s^{-1})	*Ci/Ca*
NTG	10.56 a	0.23 a	4.21 a	0.77 a
TG	10.77 a	0.23 a	4.36 a	0.77 a
Density (plants per pot)				
0	11.29	0.24	4.43	0.78
1	10.84	0.22	4.14	0.75
2	11.04	0.25	4.46	0.77
4	9.34	0.20	3.92	0.77
6	10.82	0.23	4.49	0.78
Regression	$\hat{Y}=\bar{Y}=10.67$	$\hat{Y}=\bar{Y}=0.23$	$\hat{Y}=\bar{Y}=4.29$	$\hat{Y}=\bar{Y}=0.77$
CV (%)	40.99	52.18	39.58	5.36

* Means followed by the same letter in the rows do not differ statistically by the F-test ($p<0.05$).

Competitive capacity is determined by aggressiveness characteristics of each competing species in the environment of the main crop (Jakelaitis et al., 2010). Thus, soybean plants in coexistence with *U. ruziziensis* suppressed by glyphosate were favored with a higher photosynthetic efficiency (Bastini et al., 2016). Regardless of density and use of glyphosate in *U. brizantha* cv. Marandu, gas exchanges of soybean plants in coexistence with forage species were not affected (Table 1). However, a correct management of forage can minimize the competitive potential with soybean (Machado et al., 2017) since, in other environmental conditions, *U. brizantha* in coexistence reduced soybean productive capacity (Mata et al., 2014; Saraiva et al., 2014).

For plant height (PH), stem diameter (SD), average number of leaves (ANL), average number of lateral branches (ANLB), leaf dry matter (LDM), stem dry matter (SDM), and leaf area (LA), interactions were observed between the density of *U. ruziziensis* and glyphosate (Table 2). The suppression of *U. ruziziensis* by glyphosate benefited PH, SD, LDM, SDM, and LA in soybean plants in coexistence at densities of 4 and 6 forage plants per pot, as well as ANL and ANLB at densities of 2, 4, and 6 plants per pot, when compared to plots not treated with glyphosate (Table 2).

Table 2 - Plant height (PH), stem diameter (SD), average number of leaves (ANL), average number of lateral branches (ANLB), leaf dry matter (LDM), stem dry matter (SDM), root dry matter (RDM), and leaf area (LA) of RR soybean plants cultivated in coexistence with densities of *Urochloa ruziziensis* treated (TG) or not (NTG) with glyphosate.

Experiment 1 – Coexistence of RR soybean × *Urochloa ruziziensis*								
Herbicide	Density (plants per pot)					Mean	Regression	R^2
	0	1	2	4	6			
PH (cm)								
NTG	32.06 a[1]	28.33 a	26.60 a	23.95 b	22.04 b	26.59	$\hat{Y}=30.6502-1.5597x$	93.05*
TG	30.55 a	26.94 a	26.84 a	28.39 a	30.25 a	28.59	$\hat{Y}=\bar{Y}=26.60$	--
CV (%)	10.17							
SD (mm)								
NTG	6.55 a	5.11 a	4.71 a	4.26 b	3.89 b	4.91	$\hat{Y}=5.897-0.381x$	80.00*
TG	5.64 a	5.30 a	5.14 a	5.55 a	5.65 a	5.46	$\hat{Y}=\bar{Y}=5.46$	--
CV (%)	12.44							
ANL								
NTG	48.38 a	27.13 a	24.88 b	16.25 b	18.38 b	27.00	$\hat{Y}=48.3787/(1+(x/1.7207)^{0.5086})$	97.95*
TG	41.88 a	29.75 a	38.75 a	34.38 a	39.50 a	36.85	$\hat{Y}=\bar{Y}=36.85$	--
CV (%)	24.61							
ANLB								
NTG	10.88 a	8.38 a	7.13 b	5.88 b	5.25 b	7.50	$\hat{Y}=9.72-0.856x$	85.13*
TG	11.00 a	9.25 a	9.50 a	10.00 a	9.88 a	9.93	$\hat{Y}=\bar{Y}=9.93$	--
CV (%)	16.95							
LDM (g per pot)								
NTG	3.58 a	1.76 a	1.52 a	0.82 b	0.80 b	1.70	$\hat{Y}=3.5798/(1+(x/1.0496)^{0.7516})$	99.04*
TG	3.16 a	1.97 a	2.25 a	2.53 a	2.86 a	2.55	$\hat{Y}=\bar{Y}=2.55$	--
CV (%)	31.48							
SDM (g per pot)								
NTG	6.57 a	3.73 a	3.20 a	2.01 b	1.91 b	3.48	$\hat{Y}=6.5637/(1+(x/1.5691)^{0.7157})$	99.31*
TG	4.98 a	3.96 a	3.82 a	4.65 a	5.18 a	4.52	$\hat{Y}=\bar{Y}=4.52$	--
CV (%)	28.62							
RDM (g per pot)								
NTG	4.05	2.91	3.20	4.43	4.02	3.71	$\hat{Y}=\bar{Y}=3.70$	--
TG	5.10	3.06	3.01	3.33	3.87	3.67		
CV (%)	31.76							
LA (cm^2)								
NTG	1681.43 a	854.20 a	688.32 a	395.81 b	336.60 b	791.27	$\hat{Y}=1680.31/(1+(x/1.1105)^{0.8303})$	99.64*
TG	1488.56 a	896.22 a	1039.91 a	1018.77 a	1174.67 a	1123.63	$\hat{Y}=\bar{Y}=1023.63$	--
CV (%)	33.16							

[1] Means followed by the same letter in the rows do not differ statistically by the F-test ($p<0.05$). *Significant by the F-test ($p<0.05$).

Soybean plants of the cultivar Guaiá 7487 RR (7.5) have a low size, which makes easier the growth of competing plants, especially *Brachiaria* (Syn. *Urochloa*), which has a fast growth (Portes et al., 2017), justifying the use of glyphosate as a forage growth inhibitor. No interaction was observed between the tested factors for root dry matter (RDM) of soybean (Table 2).

When *U. ruziziensis* was treated with glyphosate, no effect of plant density was observed on the variables assessed in soybean plants (Table 2). Untreated, the increased density of *U. ruziziensis* led to linear reductions of 1.55 cm, 0.38 mm, and 0.85 in PH, SD, and ANLB, respectively, with the addition of a forage plant in coexistence with soybean (Table 2). For ANL, LDM, SDM, and LA, the reductions were explained by the three-parameter sigmoidal model, in which densities that provided a 50% reduction in response variables were 1.72, 1.05, 1.57, and 1.11 plants of *U. ruziziensis* in coexistence with soybean, respectively, demonstrating that soybean plants were susceptible to the interference imposed by the forage plants (Table 2).

These results are supported by Brighenti et al. (2011), who verified variability in the tolerance of *Urochloa* species to glyphosate and observed that *U. ruziziensis* was more sensitive in relation to *U. decumbens* and *U. brizantha*. Galon et al. (2011) reported that might occur damage to crop and weed growth when competing in a given community, with a peculiar competitive effect on each species. Morphological and physiological differences and resource extraction capacity by *U. ruziziensis* may have contributed to its interference on soybean. As an example, the fasciculate root system of *U. ruziziensis* allows the plant to more easily explore soil volume when compared to plants with a pivoting root system such as soybean (Machado et al., 2017). In addition, studies conducted with *U. ruziziensis* have shown allelopathic inhibitory activity in soybean (Nepomuceno et al., 2019), mainly due the protodioscin that is compound that has a significant phytotoxic effect (Nepomuceno et al., 2017). Thus, the suppression of *U. ruziziensis* by the glyphosate underdose also contributed to the reduction of allelopathic capacity on soybean plants.

In coexistence with *U. brizantha* cv. Marandu, significant interactions were observed between the use of herbicide and forage densities for SD, ANL, ANLB, LDM, SDM, RDM, and LA, except for PH of soybean plants (Table 3). Within the tested densities, the use of glyphosate was necessary to increment the variables SD, LDM, SDM, and RDM of soybean at densities of 4 and 6 plants of *U. brizantha* per pot in coexistence with soybean, and ANL and ANLB at a density of 6 plants per pot (Table 3). In these treatments, the absence of suppression of forage growth affected soybean growth.

Considering the coexistence of soybean with forage plants without the suppression promoted by the herbicide, linear reductions 0.18 mm, 3.76, 0.25, and 0.34 g were observed for SD, ANL, LDM, and RDM, respectively (Table 3). Thus, by contrasting forage competition with soybean plants in both experiments and considering the number of soybean variables affected by competition, the models that explain the biological phenomenon (sigmoidal and linear), and the regression models, we can conclude that *U. ruziziensis* interfered more with soybean than *U. brizantha* cv. Marandu (Tables 2 and 3).

Table 3 - Plant height (PH), stem diameter (SD), average number of leaves (ANL), average number of lateral branches (ANLB), leaf dry matter (LDM), stem dry matter (SDM), root dry matter (RDM), and leaf area (LA) of RR soybean plants cultivated in coexistence with densities of *Urochloa brizantha* cv. Marandu treated (TG) or not (NTG) with glyphosate.

Experiment 2 – Coexistence of RR soybean × *Urochloa brizantha* cv. Marandu								
Herbicide	Density (plants per pot)					Mean	Regression	R^2
	0	1	2	4	6			
PH (cm)								
NTG	30.13	30.96	29.82	29.51	29.74	29.74 a[1]	$\hat{Y}=\bar{Y}=29.23$	--
TG	27.27	27.45	28.90	30.98	28.70	28.70 a		
CV (%)	8.04							
SD (mm)								
NTG	5.27 a	5.48 a	5.25 a	4.53 b	4.43 b	4.99	$\hat{Y}=5.4687-0.1812x$	84.12*
TG	5.47 a	5.36 a	5.35 a	5.97 a	6.28 a	5.68	$\hat{Y}=\bar{Y}=5.68$	--
CV (%)	10.71							
ANL								
NTG	39.12 a	45.50 a	38.62 a	27.50 a	21.12 b	34.37	$\hat{Y}=44.1670-3.7662x$	84.98*
TG	44.12 a	44.87 a	32.37 a	39.87 a	45.25 a	41.30	$\hat{Y}=\bar{Y}=41.30$	--
CV (%)	24.45							
ANLB								
NTG	9.25 a	10.00 a	9.87 a	8.50 a	7.37 b	9.00	$\hat{Y}=\bar{Y}=9.00$	--
TG	10.12 a	9.62 a	9.00 a	9.75 a	10.50 a	9.80	$\hat{Y}=\bar{Y}=9.80$	--
CV (%)	14.07							
LDM (g per pot)								
NTG	2.59 a	2.91 a	2.69 a	1.78 b	1.41 b	2.28	$\hat{Y}=2.9242-0.2464x$	84.51*
TG	3.17 a	2.80 a	2.30 a	3.02 a	3.96 a	3.05	$\hat{Y}=\bar{Y}=3.05$	--
CV (%)	27.67							
SDM (g per pot)								
NTG	4.66 a	5.15 a	5.00 a	3.77 b	3.62 b	4.44	$\hat{Y}=\bar{Y}=4.44$	--
TG	5.05 a	4.15 a	4.51 a	5.06 a	6.04 a	4.96	$\hat{Y}=\bar{Y}=4.96$	--
CV (%)	18.53							
RDM (g per pot)								
NTG	3.28 a	2.40 a	2.36 a	1.43 b	1.17 b	2.13	$\hat{Y}=3.0101-0.3363x$	91.81*
TG	4.36 a	3.20 a	2.70 a	3.91 a	4.08 a	3.65	$\hat{Y}=\bar{Y}=2.13$	--
CV (%)	29.57							
LA (cm^2)								
NTG	1237.69 a	1200.99 a	1229.88 a	780.18 a	633.37 b	1016.42	$\hat{Y}=\bar{Y}=1016.42$	--
TG	1337.83 a	1164.99 a	999.89 a	1269.49 a	1773.27 a	1309.09	$\hat{Y}=\bar{Y}=1309.09$	--
CV (%)	32.42							

[1] Means followed by the same letter in the rows do not differ statistically by the F-test (p<0.05). *Significant by the F-test (p<0.05).

Soybean plants also have a competitive capacity as some weeds, as observed by Forte et al. (2017) for the varieties BMX Alvo RR and Fundacep 55RR, which showed a higher competitive capacity when compared to *Bidens pilosa* and *Euphorbia heterophylla*. However, the competitive capacity of *Urochloa plantaginea* was lower and that of *Commelina benghalensis* was similar to soybean (Dias et al., 2010).

In coexistence with soybean, significant interactions were observed for PH, SDM, and RDM of plants of *U. ruziziensis* (Table 4).

Table 4 - Plant height (PH), number of tillers per plant (NTP). shoot dry matter (SDM). and root dry matter (RDM) of different plant densities of *Urochloa ruziziensis* and *Urochloa brizantha* cv. Marandu competing with RR soybean treated (TG) or not (NTG) with glyphosate.

Herbicide	Density (plants per pot) 1	2	4	6	Mean	Regression	R^2
Experiment 1 – Coexistence of RR soybean × *Urochloa ruziziensis*							
					PH (cm)		
NTG	42.20 a[1]	33.75 a	31.58 a	31.26 a	34.70	$\hat{Y}=31.3528+48.7584^{exp-1.5032x}$	99.97*
TG	13.30 b	19.64 b	17.83 b	17.34 b	17.03	$\hat{Y}=\bar{Y}=17.03$	--
CV (%)					15,07		
					NTP		
NTG	4.25	3.13	3.13	2.79	3.32 a	$\hat{Y}=\bar{Y}=2.49$	--
TG	1.75	1.63	1.50	1.79	1.67 b		
CV (%)					25.13		
					SDM (g per pot)		
NTG	2.30 a	2.39 a	3.91 a	4.86 a	3.36	$\hat{Y}=1.5749+0.5509x$	97.11*
TG	0.06 b	0.15 b	0.36 b	0.81 b	0.34	$\hat{Y}=\bar{Y}=0.34$	--
CV (%)					28.03		
					RDM (g per pot)		
NTG	1.04 a	1.71 a	2.77 a	3.69 a	2.30	$\hat{Y}=0.5993+0.5245x$	99.53*
TG	0.02 b	0.10 b	0.24 b	0.52 b	0.22	$\hat{Y}=\bar{Y}=0.22$	--
CV (%)					46.21		
Experiment 2 – Coexistence of RR soybean × *Urochloa brizantha* cv. Marandu							
					PH (cm)		
NTG	48.30	40.68	39.41	37.91	41.57 a	$\hat{Y}=39.5772+2.1041x$	76.75*
TG	31.88	23.64	20.68	18.07	23.46 b		
CV (%)					21.98		
					NTP		
NTG	4.00	4.25	3.56	3.37	3.80 a	$\hat{Y}=3.4205+0.1727x$	76.72*
TG	2.75	1.87	1.31	1.75	1.92 b		
CV (%)					20.45		
					SDM (g per pot)		
NTG	2.51 a	3.17 a	5.34 a	6.00 a	4.26	$\hat{Y}=1.859+0.7383x$	95.29*
TG	0.47 b	0.77 b	0.65 b	0.79 b	0.67	$\hat{Y}=\bar{Y}=0.67$	--
CV (%)					24.03		
					RDM (g per pot)		
NTG	3.12 a	4.09 a	6.21 a	7.52 a	5.24	$\hat{Y}=2.3292+0.8954x$	98.89*
TG	0.27 b	1.24 b	0.52 b	0.62 b	0.67	$\hat{Y}=\bar{Y}=0.66$	--
CV (%)					35.48		

[1] Means followed by the same letter in the rows do not differ statistically by the F-test (p<0.05). *Significant by the F-test (p<0.05).

For the number of tillers per plant (NTP), only the effects of glyphosate suppression reduced the value of this variable in the treated plants (Table 4). Glyphosate at a dose of 120 g ha^{-1} affected PH, SDM, and RDM of the forage, reducing its competitive capacity with soybean. These results are in accordance with Concenço et al. (2014), who stated that doses above 96 g ha^{-1} of glyphosate are sufficient to reduce fresh and dry matter and cause tiller mortality in *Panicum maximum*. In general, without suppression by glyphosate, a linear increase was observed in the dry matter accumulation of *U. ruziziensis* from the higher acquisition of environmental resources as density increased, resulting in a reduction of growth variables observed in soybean (Tables 2 and 4).

For *U. brizantha* cv. Marandu, significant interactions were observed between the use of glyphosate and plant density for SDM and RDM, with no interactions for PH and NTP (Table 4). For PH and NTP, only isolated effects were observed. In this case, glyphosate reduced the values of both variables, with reductions of 2.1 cm and of 0.17 tiller per plant in the pots. Considering the effects within each forage density, glyphosate was effective in suppressing SDM and RDM of forages in relation to the absence of application (Table 4). In the absence of glyphosate, linear increases were observed in the accumulation of SDM and RDM of the order of 0.73 and 0.89 g per pot, resulting in a higher forage competitive capacity in relation to soybean as density increased (Table 3).

Conclusions

Glyphosate at a dose of 120 g ha^{-1} suppresses growth of grasses and reduces its competitive capacity with soybeans, even with increasing plants density.

When not suppressed with glyphosate, forages at the highest densities (4 and 6 plants per pot) affect the growth of soybean plants in coexistence, being this effect more pronounced with *U. ruziziensis*.

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