ISSN: 1984-5529

Científica

Jaboticabal

v.47, n.1, p.36–45, 2019

http://dx.doi.org/10.15361/1984-5529.2019v47n1p36-45

Coexistence of soybean plants and *Urochloa* spp. under glyphosate and water deficit effects

Convivência entre plantas de soja e *Urochloa* spp. sob efeitos de glifosato e déficit hídrico

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Recebido em: 21-07-2018; Aceito em: 13-12-2018

Abstract

In the insertion of forage plants of the genus *Urochloa* P. Beauv. (Poaceae) coexisting with annual crops, proper management of the intercropping becomes necessary to avoid economic losses. Among management measures, the chemical inhibition of forage plants with herbicide subdoses is highlighted. Therefore, this study evaluates the morphophysiological responses of soybean (*Glycine max* (L.) Merr.) genetically modified to tolerate glyphosate (RR soybean), in coexistence with *Urochloa* spp., treated or not with glyphosate subdoses and subjected to water deficit. Two tests were carried out in pots with forage species *Urochloa ruziziensis* (R.Germ & Evrard) Crins and *Urochloa brizantha* (Hochst. Ex A. Rich.) R. D. Webster cv. Marandu coexisting with soybean, in randomized blocks with five replicates. The tests were arranged in a 2x2x2 factorial arrangement: the first factor was represented by the absence and presence of forage; the second by the absence and use of glyphosate subdoses; and the third factor by 50% and 100% field capacity in the pots. The use of glyphosate suppressed the competitive capacity of forages, benefiting the soybean in coexistence. In the absence of suppression from glyphosate, the competition exerted by the forage promoted lower values for the physiological and morphological variables of soybean plants. Among the forages,*U. ruziziensis* was the most competitive with soybean plants. The root system of forages was not affected by water deficit, only the physiological and morphological characteristics of soybean, mainly rootdry mass. Glyphosate affected forage growth.

Additional keywords: *Glycine max* (L.) Merr.; herbicide; interference; intercropping.

Resumo

Na inserção de plantas forrageiras do gênero *Urochloa* P. Beauv. (Poaceae), em convivência com culturas anuais, torna-se necessário o manejo adequado do consórcio, evitando-se prejuízos econômicos sobre as culturas. Dentre as medidas de manejo, destaca-se a inibição química da forrageira com subdoses de herbicidas. Com isso, objetivou-se avaliar as respostas morfofisiológicas da soja (*Glycine max* (L.) Merr.) geneticamente modificada para tolerância ao glifosato (RR), em convivência com *Urochloa* spp., tratada ou não com subdose de glifosato e submetida ao déficit hídrico. Foram conduzidos dois ensaios em vasos com as forrageiras *Urochloa ruziziensis* (R.Germ. & Evrard) Crins e *Urochloa brizantha* (Hochst. ex A. Rich.) R. D. Webster cv. Marandu, em convivência com a soja, em blocos ao acaso, com cinco repetições. Os ensaios foram dispostos em arranjo fatorial 2x2x2: o primeiro fator, representado pela presença e ausência da forrageira; o segundo fator, pela ausência e uso de subdose de glifosato; e o terceiro fator, representado por 50% e 100% da capacidade de campo nos vasos. O uso de glifosato suprimiu a capacidade competitiva das forrageiras, beneficiando a soja em convivência. Na ausência da supressão com o glifosato, a competição exercida pela forrageira promoveu menores valores para as variáveis fisiológicas e morfológicas das plantas de soja. Dentre as forrageiras, a *U. ruziziensis* foi a mais competitiva com as plantas de soja. O sistema radicular das forrageiras não foi afetado pelo déficit hídrico, apenas as características fisiológicas e morfológicas da soja, principalmente a massa seca das raízes. O glifosato afetou o crescimento das forrageiras.

Palavras-chave adicionais: consórcio; *Glycine max* (L.) Merr.; herbicida; interferência.

Introduction

The climatic instability in recent years has significantly affected the production of several crops in Brazil, including soybean (CONAB, 2018). According to Hirakuri (2016), the survey of the last six soybean harvests in almost all Brazilian states showed losses above 10%, caused by drought periods during the crop cycle.

Water use efficiency must increase in the coming years to ensure food security for the human population. Large areas in the world have limited arable land, while other areas must overcome the production shortage to feed the world population. For this to happen, it is necessary to increase the yield of crops, including soybean (Abeboye et al., 2017).

Various environmental factors may affect soybean crop performance, such as impacts caused by water stress, which can reduce soybean yield by up to 50% (Gava et al., 2018). Under these conditions, plants under any type of stress present changes in their morphology and physiology, negatively affecting yield (Lisar et al., 2012). Water deficit is an abnormal condition for crops, where there is a lack of water to meet the normal plant needs, which impairs crop development (Freitas et al., 2017).

According to Rodrigues et al. (2017), early soybean cultivars have their yield affected when subjected to water deficit, mainly in the flowering and grain-filling stages. Dry matter accumulation, yield, and production are generally reduced with greater intensity by stresses occurring between the reproductive stage R1 and the physiological maturity of the plant. The authors state that water deficiency in this period may accentuate flower abortion and the abscission of leaves, shortening the culture cycle.

The use of soybean intercropped with forage plants has been advocated regarding the challenge of straw formation for no-tillage system, pasture renewal, and phytosanitary control, including weed control. Among the main species tested in intercropping with soybean are *Urochloa ruziziensis* (R. Germ. & Evrard) Crin and *Urochloa brizantha* (Hochst. Ex A. Rich.) R. D. Webster cv. Marandu (Silva et al., 2005; Mariani et al., 2012; Machado et al., 2017). However, soybean and brachiaria intercropping has been one of the challenges, as the forage becomes the main plant competing with soybean (Machado et al., 2017). Due to C_4 photosynthetic metabolism, intercropped forages present a greater competitive capacity, being necessary their suppression with subdoses of some herbicides to reduce yield losses (Dan et al., 2012; Tironi et al., 2012).

Glyphosate is one of the main herbicides used in weed management in Roundup Ready® soybean (RR soybean) because it presents low purchase cost and high efficiency in controlling weeds (Gusmão et al., 2011). In addition,it shows potential use in the suppression of intercropped forage species when used at low doses.

Understanding the physiological processes of plants underconditions of water deficit, forage competition, and the effects of herbicide subdoses becomes essential to predict the impacts on soybean plants intercropped with forage species. Thus, this study evaluates the morphophysiological responses of RR soybean to *Urochloa ruziziensis* (R. Germ. & Evrard) Crin and *Urochloa brizantha* (Hochst. Ex A. Rich.) R. D. Webster cv. Marandu, treated with glyphosate subdoses and under water deficit conditions.

Materials and methods

Two experiments were carried out in a greenhouse in the municipality of Rio Verde, Goiás State, from September 24 to November 28, 2017. The experimental units consisted of perforated plastic pots with 6 dm^3, containing dystroferric Red Latosol, of medium texture, at a 2:1 ratio of soil and sand, and fertilized according to chemical analysis. Fertilization consisted of the application of dolomitic limestone (360 mg dm^{-3}) with 92.5% of relative power of total neutralization, thermophosphate (228 mg dm^{-3}), and potassium chloride (66.6 mg dm^{-3}).

In both experiments, the experimental design was a randomized block design with four replicates. The first experiment consisted of the coexistence of *Urochloa ruziziensis* with soybean plants, and the second consisted of the coexistence of *Urochloa brizantha* cv. Marandu with soybean. The treatments were arranged in a 2x2x2 factorial scheme: the first factor was represented by the absence and presence of the forage *Urochloa ruziziensis* or *Urochloa brizantha* cv. Marandu, coexisting with soybean; the second factor comprised the use or non-use of glyphosate subdoses; and the third factor referred to the water deficit condition represented by 50% and 100% field capacity in the pots.

On September 24, 2017, the early cultivar Guaiá 7487 RR (7.5) was treated with 62.5 g of chlorantraniliprole (Dermacor®) for 100 kg^{-1} of seeds and inoculated with 80 g of *Bradyrhizobium japonicum* (Kirchner) Jordan for 50 kg^{-1} of seeds. Four soybean and six forage seeds were sown in the pots.Nine days after emergence (DAE) of the plants, thinning was performed leaving two soybean plants in the center of the pot and three forage plants per pot.

At nine DAE, the insecticide pyriproxyfen (Tiger 100 EC®) was applied at a dose of 25 g ha^{-1} for control of *Bemisia tabaci*, race B. In the treatments with glyphosate, application was performed at 24 DAE, at a dose of 120 g a.i.ha^{-1} (Roundup Ready®) (Lima, 2018). Glyphosate was sprayed using a CO_2-pressurized sprayer equipped with a 2.0 m bar, AXI 110 02 flat-fan nozzles, and 160 L ha^{-1} syrup volume.

Cover fertilization was performed with potassium chloride (50 mg dm^{-3}) at 30 DAE. Two fungicide applications were made, the first using 70 g ha^{-1} trifloxystrobin + 60 g ha^{-1} prothioconazole from the commercial product (FOX®), on October 25; and the second applying 58.45 g ha^{-1} fluxapyroxad + 116.55 g ha^{-1} pyraclostrobin from the commercial product (Orkestra® SC) for control of *Septoria glycines* Hemmi, on November 10, 2017.

Field capacity was determined by weighing the perforated pot with 6 kg dry soil. At the end of the day, the soil was saturated with water until a water depth was formed above the soil. Then, weighing was performed again and the pot was covered with PVC film. After 12 hours, that is, on the following day, the pot was weighed once more. The amount of water accumulated in the tray was weighed and subtracted from the quantity supplied, thus determining the sufficient amount of water to saturate the substrate (Buske et al., 2013).

Irrigation was suspended at the reproductive stage R3, critical period of the plant. The weight of the pots was monitored for four days until constant weight (50% field capacity. The other pots were always kept moist with 100% field capacity. After this period, plants were kept for ten days under such conditions.

At 60 DAE, gas exchange was evaluated on the sixth branching of the soybean plant, in the fully expanded leaf, to estimate photosynthetic rate variables (*A*, μmol CO_2 m^{-2} s^{-1}), stomatal conductance (*g*s, mol H_2O m^{-2} s^{-1}), transpiration rate (*E*, mmol H_2O m^{-2} s^{-1}), and the ratio between internal and external CO_2 concentration (*Ci*/*Ca*). Measures were taken with an infrared gas analyzer (LI-6400XTR, Licor®, Lincoln, Nebraska, USA) between 8 and 12 h, using constant photosynthetically active radiation (PAR) of 1000 μmol photons m^{-2} s^{-1}, atmospheric CO_2 concentration (Ca) of ~409 μmol mol^{-1}, temperature of ~25 ºC, and humidity between 46 and 67%.

After the physiological evaluations, the following were determined: plant height, dry mass of stems, leaf dry mass, number of tillers and leaves, stem diameter, leaf area, and root dry mass of soybean plants. Plant height was obtained by the average heightof plants of each pot. After measuring the shoots, the plants were cut close to the ground, counting the number of tillers and leaves and measuring the length and width of ten leaflets to determine leaf area (Richter et al., 2014). Soybean roots were separated from the roots of forage plants (*Urochloa* spp.) and all plant material was taken for drying in a forced-air circulation oven at 65 ºC for 72 hours, being subsequently weighed. The following variables were also measured on forage plants: plant height, shoot dry mass, number of tillers per plant, and root dry mass.

Statistical analyses were performed using the statistical program SISVAR (version 5.6), by submitting the results to analysis of variance. When significant, the results were compared by the F test at 5% probability (Ferreira, 2014).

Results and discussion

The photosynthetic variables of soybean plants, in both tests, are presented in Table 1. In the coexistence of soybean with *U. ruziziensis*, there was interaction of the factors glyphosate and forage plant for photosynthetic rate (*A*), stomatal conductance (*gs*), transpiration rate (*E*) and *Ci*/*Ca* ratio in soybean plants.

Table 1 - Photosynthetic rate (A), stomatal conductance (gs), transpiration rate (E), Ci/Ca ratio of soybean plants, cultivated with and without water deficit, in the absence and presence of *Urochloa ruziziensis* (Experiment 1) and *Urochloa brizantha* cv. Marandu (Experiment 2) without and with glyphosate subdose.

Glyphosate	Forage: Without	Forage: With	Mean	Field capacity – soil moisture: 50%	Field capacity – soil moisture: 100%	Mean
Experiment 1 – Soybean RR x *Urochloa ruziziensis*						
A (μmol m^{-2} s^{-1})						
Without	18.02 aA*	15.30 bA	16.65	17.78	15.53	16.65 b
With	17.40 aA	19.56 aA	18.48	18.45	18.51	18.48 a
Means	17.71	17.43		18.11	17.02	
CV (%)			17.82			
g_s (mol m^{-2} s^{-1})						
Without	0.33 aA	0.26 bA	0.30	0.35	0.24	0.30 b
With	0.32 aA	0.40 aA	0.36	0.38	0.34	0.36 a
Means	0.32	0.33		0.36 A	0.30 B	
CV (%)			27.31			
E (mmol m^{-2} s^{-1})						
Without	3.64 aA	3.04 bA	3.34	3.80	2.88	3.34 b
With	3.51 aB	4.33 aA	3.92	4.09	3.75	3.92 a
Means	7.15	3.68		3.94	3.31	
CV (%)			21.85			
Ci/Ca						
Without	0.75 aA	0.72 bA	0.73	0.76	0.71	0.73 b
With	0.74 aB	0.77 aA	0.76	0.77	0.74	0.76 a
Means	0.74	0.74		0.76	0.72	
CV (%)			4.17			
Experiment 2 – Soybean RR x *Urochloa brizantha* cv. Marandu						
A (μmol m^{-2} s^{-1})						
Without	16.14	12.93	14.53	15.41 aA	13.66 bA	14.53
With	16.42	16.14	16.28	14.81 aA	17.75 aA	16.28
Means	16.28	14.53		15.11	15.70	
CV (%)			21.12			

Table 1 - Continuity

Experiment 1 – Soybean RR x *Urochloa ruziziensis*						
Glyphosate	Forage		Mean	Field capacity – soil moisture		Mean
	Without	With		50%	100%	
			g_s (mol m^{-2} s^{-1})			
Without	0.31	0.21	0.26	0.27 aA	0.24 bA	0.26
With	0.28	0.27	0.27	0.33 aA	0.22 aB	0.27
Means	0.29 A	0.24 B		0.30	0.23	
CV (%)			28.56			
			E (mmol m^{-2} s^{-1})			
Without	3.42	2.59	3.01	3.18 aA	2.83 bA	3.01
With	3.31	3.31	3.31	2.77 aB	3.85 aA	3.31
Means	3.36	2.95		2.97	3.34	
CV (%)			24.78			

* Means followed by the same lowercase letters in the columns and upper case in the rows are statistically the same by the F test ($p < 0.05$).

The application of glyphosate subdoses suppressed the interference of the forage *U. ruziziensis*. Furthermore, soybean plants under this interference had higher values for physiological variables compared to those that coexisted with forage plants not treated with glyphosate (Table 1). The herbicide action on the forage favored the use of growth resources such as water, light, and nutrients by soybean plants (Vivian et al., 2013). According to Ferreira et al. (2015), the physiological behavior of soybean under interference is related to the population density of the crop and competing plant, the period of coexistence, and the competitive potential of the infesting species.

There was no interaction between the factors soil moisture, glyphosate, and forage plant for physiological variables. For the isolated factors, there were effects for *gs* as a function of field capacity and for *A*, *gs*, *E*, and *Ci*/*Ca* ratio as a function of glyphosate subdose (Table 1). The competition of the forage plant with soybean was restricted by the use of the herbicide, thus avoiding the occurrence of deleterious effects of water deficit on the crop. The higher water extraction capacity of some weed species increases their chances of establishment in crop areas (Craine & Dybzinski, 2013) and may limit the water availability to the crop, affecting its growth and development by inhibiting photosynthesis (Lima et al., 2016).

Lower *gs* values for field capacity compared to water deficit condition may be associated to the competition with soybean by the forage nonsuppressed with glyphosate. The water deficit could also have affected the forage's competitive capacity regarding this variable (Table 1). Thus, it can be considered that the competitiveness of the forage plant with soybean varies with the soilwater availability. In contrast, some species may cause more damage to the crop under water deficit than under adequate water conditions (Machado et al., 2017).

There was interaction between the use of glyphosate and soil water levels for the variables *A*, *gs*, and *E*, evaluated in the soybean coexisting with *U. brizantha* cv. Marandu (Table 1). For the field capacity condition, lower values of *A*, *gs*, and *E* were found in soybean plants coexisting with nonsuppressed compared to suppressed forage plants. Under stress conditions, this behavior was not verified, showing that the lower soil water level also affected the competitive capacity of the forage, due to water limitation. In addition, soybean plants coexisting with forage species presented lower *gs* compared to growth free of competition (Table 1).

The intensity of water deficit effects depends on the species and the adaptation mechanisms. More sensitive species compete less for water than more tolerant ones, which have a greater capacity to compete with the crop (Lima et al., 2016). Therefore, the adaptation capacity of the species to water deficit is determinant for the maintenance of the photosynthetic activity (Vivian et al., 2013). In competitive conditions, plants with an efficient stomatal control are more competitive under water deficit situations (Ferreira et al., 2015).

In the case of soybean plants coexisting with *Urochloa brizantha* cv. Marandu, there was interaction between the factors glyphosate, forage plant, and field capacity for the *Ci*/*Ca* ratio (Table 2). Moreover, the herbicide dose used suppressed the forage interference on the crop regarding the *Ci*/*Ca* ratio (Table 2). This ratio was higher when soybean plants were not competing with *U. brizantha* and when they did not receive glyphosate application. In turn, plants under the presence of forage plants not treated with glyphosate, and with 100% field capacity, presented lower values (Table 2).

The increase of the *Ci*/*Ca* ratio when soybean plants were submitted to competition with forage species shows the attempt of plants to escape the alteration of environmental resources. The change in physiological components indicates that the photosynthetic apparatus is fully functioning. Furthermore, the reduction of the photosynthetic rate is a consequence of decreased CO_2 concentration in the substomatal chamber. To avoid stress, the plants promoted greater stomatal closure (Ferreira et al., 2015).

In the coexistence of *U. ruziziensis* with soybean, there was interaction between the factors herbicide and forage plant for number of leaves (NL), number of *lateral branches* per plant (NLB), and leaf area

(LA) (Table 3). On the other hand, significant effects of dry mass of stems (DMS) and total leaf dry mass (TLDM) of soybean were observed when the forage was suppressed by herbicide action. Moreover, root dry mass (RDM) and LA were influenced by soil water levels, regardless of the action of other factors (Table 4).

Table 2 - Interaction between herbicide x forage *Urochloa brizantha* cv. Marandu, herbicide x field and forage capacity *U. brizantha* cv. Marandu x field capacity for the variable Ci / Ca ratio of soybean plants.

Glyphosate	Forage	Field capacity – Soil moisture 50%	100%	Mean
Without	Without	α 0.74 aA*	α 0.77 aA	0.75
	With	α 0.73 aA	α 0.68 bB	0.71
	Mean	0.73	0.73	0.73
With	Without	β 0.69 aB	α 0.75 aA	0.72
	With	α 0.70 aA	β 0.76 aA	0.73
	Mean	0.69	0.75	0.72

* Means followed by the same letter, lowercase in the column and upper case in the row, do not differ statistically from each other by the F test ($p > 0.05$). Means followed by the same Greek letters (α or β) do not differ statistically from each other by the F test ($p > 0.05$) when comparing the means of absence and the presence of herbicide within the factors forage x field capacity.

Table 3 - Plant height (PH), stem diameter (SD), mean number of leaves (NL), mean number of lateral branches (NLB), total leaf dry mass (TLDM), stem dry mass (SDM),root dry matter (RDM) and leaf area (AF) of RR soybean plants, cultivated with and without water stress, in the presence and absence of *Urochloa ruziziensis*, with and without glyphosate subdose

Experiment 1 – Soybean RR x *Urochloa ruziziensis*						
Glyphosate	Forage: Without	With	Mean	Forage: Without	With	Mean
	PH (cm)			SD (mm)		
Without	29.01*	26.89	27.95	5.33	4.90	5.12
With	29.29	28.03	28.66	5.33	5.48	5.41
Médias	29.15	27.46		5.33	5.19	
CV (%)	10.52			13.09		
	NL per pot			NLB per pot		
Without	43.90 aA	28.40 bB	36.15	12.00 aA	8.90 aB	10.45
With	45.60 aA	47.05 aA	46.32	10.30 aA	10.05 aA	10.18
Médias	44.75	37.72		11.15	9.47	
CV (%)	26.50			19.98		
	TLDM (g per pot)			SDM (g per pot)		
Without	2.80	1.77	2.28	4.30	3.32	3.80
With	2.90	2.95	2.92	4.49	4.61	4.54
Médias	2.85	2.36		4.39	3.96	
CV (%)	34.94			25.51		
	RDM (g per pot)			LA (cm^2 per pot)		
Without	2.72	3.11	2.92	1674.70 aA	763.80 bB	1219.30
With	2.83	2.89	2.86	1401.20 aA	1440.10 aA	1420.60
Mean	2.77	3.00		1537.95	1101.95	1319.95
CV (%)	33.05			37.27		

* Means followed by the same lowercase letter between upper and lower case columns are statistically the same as the F test ($p > 0.05$).

Table 4 - Plant height (HP), stem diameter (SD), mean number of leaves (NL), mean number of lateral branches (NLB), total leaf dry mass (TLDM), stem dry mass (SDM) and leaf area (LA) of soybean plants, cultivated with and without water stress, in the presence and absence of *Urochloa ruziziensis*, with and without glyphosate subdose.

Experiment 1 – Soybean RR x *Urochloa ruziziensis*						
Glyphosate	Without Forage, Field capacity 50%	100%	Mean	With Forage, Field capacity 50%	100%	Mean
			PH (cm)			
Without	28.34*	29.69	29.01	25.58	28.20	26.89
With	29.16	29.42	29.29	26.74	29.33	28.03
Mean	28.75	29.55		26.16	28.76	
CV(%)			10.52			

Table 4 - Continuity

Experiment 1 – Soybean RR x *Urochloa ruziziensis*						
Glyphosate	Without Forage Field capacity 50%	100%	Mean	With Forage Field capacity 50%	100%	Mean
			SD (mm)			
Without	5.22	5.44	5.33	4.69	5.12	4.90
With	5.26	5.40	5.33	5.35	5.61	5.48
Mean	5.24	5.42		5.02	5.36	
CV(%)			13.09			
			NL per pot			
Without	44.10	43.70	43.90a	23.30	33.50	28.40 b
With	42.90	48.30	45.60a	39.00	55.10	47.05 a
Mean	43.50	46.00		31.15	44.30	
CV(%)			26.50			
			NLB per pot			
Without	11.90	12.10	12.00	7.90	9.90	8.90
With	9.90	10.70	10.30	9.30	10.80	10.05
Mean	10.90	12.40		8.60	10.35	
CV(%)			19.98			
			TLDM (g per pot)			
Without	2.74	2.86	2.80	1.24	2.30	1.77 b
With	2.79	3.01	2.90	2.23	3.68	2.95 a
Mean	2.76	2.9		1.73 B	2.99 A	
CV(%)			34.94			
			SDM (g per pot)			
Without	4.27	4.32	4.29	2.81	3.83	3.32 b
With	4.32	4.65	4.48	3.87	5.36	4.61 a
Mean	4.29	4.48		3.34 B	4.59 A	
CV(%)			25.51			
			RDM (g per pot)			
Without	2.53	2.92	2.72a	2.31	3.91	3.11a
With	2.64	3.02	2.83a	2.25	3.53	2.89a
Mean	2.58	2.97		2.28 B	3.72 A	
CV(%)			33.05			
			LA (cm^2 per pot)			
Without	1581.70	1767.74	1674.72	524.08	1003.48	763.78
With	1345.39	1456.95	1401.17	1076.62	1803.51	1440.06
Mean	1463.54	1612.34		800.35 B	1403.49 A	
CV(%)			37.27			

* Means followed by the same lowercase letter between upper and lower case columns are statistically the same as the F test ($p > 0.05$).

The coexistence between nonsuppressed *U. ruziziensis* (three plants per pot) and soybean decreased NL and NTP vaues, consequently decreasing LA. This led to a reduced photosynthetic capacity of soybean plants. *U. ruziziensis* is a C_4 species, which requires more energy than soybean in the carboxylation process. Since all energy comes from light, the reduction of soybean access to light favors the forage. Plant height (PH) and stem diameter (SD) were not influenced by treatments.

According to Fioreze et al. (2011), soybean yield is highly affected by soil water deficit. The most sensitive period to water deficit is thepod-formation and pod-filling stage, and the least sensitive is the vegetative and flowering stage (Pejic et al., 2011). In this research, the stress occurred in the reproductive phase significantly affected soybean LA and RDM in relation to plants grown under field capacity (Table 4). Accordingt o He et al. (2017), a water stress of 30%, in soybean plants, caused a reduction of 31% in the total roots of the crop. However, RDM is not considered a good trait to assess drought tolerance (Thu et al., 2014).

In the coexistence of *U. brizantha* cv. Marandu with soybean plants, a significant interaction of orage plant and glyphosate was observed only for NL (Table 5). When using only the glyphosate subdoses, yielded higher values of LA, RDM, DMS, and TLDM in soybean as a function of the herbicide-induced suppression in the forage (Table 5). The coexistence of the forage with soybean affected NL and RDM, while the water deficit affected the RDM of soybean plants (Table 6).

Table 5 - Plant height (PH), stem diameter (SD), mean number of leaves (NL), mean number of lateral branches (NLB), total leaf dry mass (TLDM), stem dry mass root dry matter (SDM), leaf area (LA) and total chlorophyll (TC) of soybean plants, cultivated with and without water stress, in the presence and absence of *Urochloa brizantha* cv. Marandu, with and without glyphosate subdose.

Experiment 2 – Soybean RR x *Urochloa brizantha* cv. Marandu						
Glyphosate	Forage		Means	Forage		Means
	Without	With		Without	With	
	PH (cm)			SD (mm)		
Without	29,35*	29,22	29,28	5,12	4,74	4,93
With	31,53	30,00	30,77	5,29	5,27	5,28
Means	30,44	29,61		5,20	5,00	
CV (%)	8,60			12,09		
	NL per pot			NLB per pot		
Without	42,95bA	32,15bB	37,55	10,35	9,45	9,90
With	48,85aA	51,00aA	49,92	10,80	10,50	10,65
Means	44,95	41,57		10,57	9,97	
CV(%)	21,34			16,86		
	TLDM (g per pot)			SDM (g per pot)		
Without	2,88	2,17	2,52 b	4,48	3,81	4,14 b
With	3,58	3,44	3,51 a	5,39	4,90	5,14 a
Means	3,23	2,80		4,93	4,35	
CV(%)	30,61			25,07		
	RDM (g per pot)			LA (cm^2 per pot)		
Without	3,69	2,52	3,10 b	1469,25	1175,30	1322,27 b
With	3,93	3,50	3,71 a	1784,30	2055,13	1919,97 a
Means	3,81 A	3,01 B		1626,77	1615,21	
CV(%)	24,98			38,85		

* Means followed by the same lowercase letter between upper and lower case columns are statistically the same as the F test ($p > 0.05$).

Table 6 - Plant height (PH), stem diameter (DC), mean number of leaves (NMF), mean number of lateral branches (NMRL), total leaf dry mass (MSTF), stem dry mass root dry matter (MSR), leaf area (AF) and total chlorophyll (CT) of soybean plants, cultivated with and without water stress, in the presence and absence of *Urochloa brizantha* cv. Marandu, with and without glyphosate subdose.

Experiment 2 – Soybean RR x *Urochloa brizantha* cv. Marandu						
Glyphosate	Without forage Field capacity		Means	With forage Field capacity		Means
	50%	100%		50%	100%	
			PH (cm)			
Without	28.75*	29.96	29.35	27.76	30.68	29.22
With	32.20	30.87	31.53	28.91	31.10	30.00
Means	30.47	30.41		28.33	30.89	
CV(%)			8.60			
			SD (mm)			
Without	5.05	5.12	5.085	4.38	5.11	4.74
With	5.47	5.19	5.330	5.10	5.44	5.27
Means	5.26	5.16		4.74	5.27	
CV(%)			12.09			
			NL per pot			
Without	41.00	44.90	42.95	31.60	32.70	32.15
With	49.50	48.20	48.85	46.10	55.90	51.00
Means	45.25	46.55		38.85	44.30	
CV(%)			21.34			
			NLB per pot			
Without	10.20	10.50	10.35	9.00	9.90	9.45
With	11.10	10.50	10.80	10.10	10.90	10.50
Means	10.65	10.50		9.55	10.40	
CV(%)			16.86			
			TLDM (g per pot)			
Without	6.93	8.97	7.95	5.76	7.33	6.54
With	10.13	9.08	9.60	7.66	10.09	8.87
Means	8.53	9.02		6.71	8.71	
CV(%)			30.61			

Table 6 - Continuity

Experiment 2 – SoybeanRR x *Urochloa brizantha* cv. Marandu						
Glyphosate	Without forage Field capacity 50%	 100%	Means	With forage Field capacity 50%	 100%	Means
			SDM (g per pot)			
Without	3.93	5.03	4.48	3.33	4.29	3.81
With	5.83	4.95	5.39	4.22	5.58	4.90
Means	4.88	4.99		3.77	4.93	
CV(%)			25.07			
			RDM (g per pot)			
Without	3.35	4.05	3.70	2.20	2.83	2.51
With	3.82	4.04	3.93	3.05	3.94	3.49
Means	3.58 B	4.04 A		2.62 B	3.38 A	
CV(%)			24.98			
			LA (cm^2 per pot)			
Without	1370.94	1567.55	1469.24	1191.53	1159.06	1175.29
With	1864.73	1704.92	1784.82	1479.25	2631.01	2055.13
Means	1617.83	1636.23		1335.39	1895.03	
CV(%)			38.85			

* Means followed by the same lowercase letter between upper and lower case columns are statistically the same as the F test (p > 0.05).

Glyphosate application was effective in the suppression of both forages intercropped with soybean plants, given the reduction of PH, number of tillers per plant (NTP), shoot dry mass (SDM), and root dry mass (RDM) (Table 7). There was no effect of the interaction between product use and soil water levels for these variables. Pezzopane et al. (2015), evaluating several *U. brizantha* genotypes with respect to water deficit, observed that the cultivar Marandu was the most affected, with a 34% reduction in production. Santos et al. (2013) and Kroth et al. (2015) stated that *U. brizantha* cv. Marandu is sensitive to water deficit and, under this condition, it develops a deep root system as an adaptation mechanism to water stress.

Table 7 - Number of tillers per plant (NPP), dry shoot mass (MSPA) and root dry mass (RRM) of RR soybean plants, cultivated with and without water stress, in the presence and absence of *Urochloa ruziziensis* and *Urochloa brizantha* cv. Marandu, with and without glyphosate subdose application.

Glyphosate	Experiment 1 – Soybean RR x *Urochloa ruziziensis* Field capacity 50 %	 100 %	Means	Experiment 2 – Soybean RR x *Urochloa brizantha* Field capacity 50 %	 100 %	Means
			PH (cm)			
Without	37,45	39,61	38,53 a	41,59	45,81	43,70 a
With	16,47	19,07	17,77 b	17,98	18,4	18,19 b
Means	26,96	29,34		29,79	32,11	
CV(%)		17,01			24,19	
			NLB per pot			
Without	2,73	2,40	2,56a	3,07	3,27	3,17 a
With	1,33	1,26	1,30b	1,67	1,87	1,77 b
Means	2,03	1,83		2,37	2,57	
CV(%)		26,43			17,87	
			TLDM (g per pot)			
Without	2,68	3,06	2,87 a	3,35	4,37	3,86 a
With	0,23	0,23	0,23 b	0,33	0,53	0,43 b
Means	1,46	1,64		1,84	2,45	
CV(%)		39,63			40,77	
			RDM (g per pot)			
Without	1,93	2,00	1,97 a	2,84	3,52	3,18 a
With	0,14	0,12	0,13 b	0,25	0,42	0,34 b
Means	1,03	1,06		1,55	1,97	
CV(%)		55,94			54,72	

* Means followed by the same letter between the lines are statistically the same by the F test (p > 0.05).

Conclusions

The use of glyphosate suppressed the competitive capacity of forages, benefiting the soybean in coexistence. In the absence of suppression, forages affected the physiological and morphological variables of soybean, with *Urochloa ruziziensis* being the most competitive when compared to *Urochloa brizantha* cv. Marandu.

The photosynthesis and transpiration rates, stomatal conductance, *Ci/Ca* ratio, number of leaves and tillers per plant, root dry mass, and leaf area were the variables affected by forage interference in soybean plants.

Water deficit affected the physiological and morphological characteristics of soybean, mainly root dry mass, without interfering in forage growth.

Acknowledgements

The present work was carried out with the support of the Coordination of Improvement of Higher Education Personnel - Brazil (CAPES) - Financing Code 001; and the Federal Institute of Education, Science and Technology of Goiás (IF Goiano).

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