weedcontrol journal

RESEARCH ARTICLE

Tolerance of tifton 85 and jiggs (*Cynodon dactylon* L.) to post-emergent herbicides

Tolerância de tifton 85 e jiggs (*Cynodon dactylon* L.) à herbicidas pós-emergentes

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Abstract: **Background**: The genus *Cynodon* has great forage potential, but the management of its cultivars in Brazilian growing conditions is scarce.
Objective: The objective was to evaluate the tolerance of Tifton 85 and Jiggs to different herbicides at post-emergence.
Methods: The experiment was carried out in pots in a greenhouse. Two experiments were carried out, with Tifton 85 and Jiggs forages using twelve treatments, eleven herbicides (2,4-D, diuron, atrazine, fluazifop-p-butyl, glyphosate, nicosulfuron, imazethapyr, clethodim, haloxyfop-p-methyl, lactofem, tembotrione) and a control without the application. The herbicides injury were evaluated at 7, 14, 21, 28, 35 and 50 days after application (DAA), the index of chlorophyll a and b and the regrowth capacity of forage plants 60 days after cutting.
Results: From 14 DAA, the herbicide glyphosate, followed by fluazifop-p-butyl, showed high herbicide injury to both grasses and with a significant reduction in the chlorophyll index of the Tifton 85 plants. The forages treated with glyphosate did not show regrowth 60 days after cutting.
Conclusions: Tembotrione had no influence on regrowth of Tifton 85. 2,4-D, atrazine, clethodim and lactofem had no negative effect on regrowth of Jiggs 60 days after cutting, indicating good strategies in the chemical management of weeds in Tifton 85 and Jiggs pastures, respectively.

Keywords: chemical control, herbicide injury, forages, pasture management.

Resumo: **Introdução**: O gênero *Cynodon* possui grande potencial forrageiro, mas o manejo de suas cultivares em condições de cultivo brasileiras é escasso.
Objetivo: Este trabalho teve como objetivo avaliar a tolerância do Tifton 85 e Jiggs a diferentes herbicidas em pós-emergência.
Métodos: O experimento foi conduzido em vasos, em casa de vegetação. Foram conduzidos dois experimentos utilizando as forrageiras Tifton 85 e Jiggs com doze tratamentos, sendo onze herbicidas (2,4-D, diurom, atrazina, fluazifope-p-butílico, glifosato, nicosulfurom, imazetapir, cletodim, haloxifope-p-metílico, lactofem, tembotriona) e uma testemunha sem aplicação. Foram avaliadas a fitotoxicidade dos herbicidas aos 7, 14, 21, 28, 35 e 50 dias após a aplicação (DAA), os teores de clorofila a e b e a capacidade de rebrota das forrageiras 60 dias após o corte.
Resultados: A partir dos 14 DAA o herbicida glifosato, seguido pelo fluazifop-p-butil, apresentaram elevada fitotoxicidade aos capins e com significativa redução nos teores de clorofila das plantas de Tifton 85. As forrageiras tratadas com glifosato não apresentaram rebrota aos 60 dias após o corte.
Conclusões: O herbicida tembotriona não teve influência sobre a rebrota do Tifton 85. O 2,4-D, atrazina, cletodim e lactofem não tiveram nenhum efeito negativo sobre a rebrota do Jiggs aos 60 dias após o corte, indicando boas estratégias no manejo químico de plantas daninhas em pastagens de Tifton 85 e Jiggs, respectivamente.

Palavras-chave: controle químico, fitotoxicidade, forrageiras, manejo de pastagens.

Journal Information:
ISSN: 2763-8332
Website: https://www.weedcontroljournal.org/
Jornal da Sociedade Brasileira da Ciência das Plantas Daninhas

How to cite: Araújo FC, Gomes JVA, Lopes JS, Dias PAS, Freitas MAM. Tolerance of tifton 85 and jiggs (*Cynodon dactylon* L.) to post-emergent herbicides. Weed Control J. 2025;24:e202500851.
https://doi.org/10.7824/wcj.2025;24:00851

Approved by:
Editor in Chief: Cristiano Piasecki
Associate Editor: Daniel Valadão Silva

Conflicts of interest: The authors declare no conflicts of interest regarding the publication of this manuscript.

Received: January 31, 2024
Approved: March 11, 2025

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1. Introdução

Grasses of the genus *Cynodon* are known forage in Brazil for their nutritional benefits to animals, especially for their high content of protein and digestible fiber. In addition, they adapt to different environments and are flexible to use in tropical conditions for grazing as hay and as silage (Rezende et al., 2015; Brighenti et al., 2020).

In Brazil, the Tifton 85 and Jiggs cultivars of the *Cynodon dactylon* species are successfully cultivated. Tifton 85 is a well-known cultivar recommended for feeding high-producing animals (Pedreira, 2010; Silva et al., 2017) due to its high forage production potential, with high productivity, leaf/stem ratio and nutritional value. It was obtained from the cross of Tifton 68 (*C. nlemfuensis*) with a genotype of *C. dactylon* introduced from South Africa (Burton et al., 1993). Jiggs is a Bermudagrass cultivar and its origins are unknown, since there is no record of the release of this cultivar (Aguiar et al., 2014). However, this forage has spread relatively quickly, mainly among dairy cattle and horse breeders (Pedreira, 2010), especially due to its large accumulation of forage and high nutritional value (Vendramini et al., 2010).

Weed infestations in pastures have detrimental effects, impacting forage quality and, consequently, animal weight gain. Weeds compete for essential resources such as light, water, CO_2 and nutrients, making pasture management difficult. Their presence reduces quality and productivity for animal grazing, and can also host pests and pathogens and release allelopathic substances (Martinelli et al., 2019).

Weed control in *Cynodon* fields is fundamental and complex, since there is little information about the genus in the literature, especially regarding the chemical management of weeds. Additionally, the market for selective herbicides registered for forage species is very limited, especially when targeting grassy weeds in pastures, as these belong to the same botanical family (Brighenti et al., 2020).

For these forage grasses to reach their full potential, they require specific edaphoclimatic conditions, with greater demands on water availability and high soil fertility (Rezende et al., 2015), justifying pests and weed management and the use of correctives, fertilizers and irrigation. This study becomes of great relevance and aims to evaluate the tolerance of *Cynodon dactylon* cv. Tifton 85 and cv. Jiggs to post-emergence herbicides as a chemical control strategy for managing weed infestations in pasture areas.

2. Material and Methods

The experiments were carried out in pots in a greenhouse, at Instituto Federal Goiano, Campus Urutaí, located at 17°29'03" South latitude, 48°12'47" West longitude and 733 m altitude, between the months of April to December 2017. The soil used was an Oxisol with a clayey texture. The results of the chemical analysis of the soil sampling, carried out in the 0-20 cm layer were: pH $CaCl_2$: 5.10; P: 3.3 mg.dm^{-3} (Mehlich-1); K: 62 mg.cm^{-3}; Ca^{2+}: 1.3 cmolc.dm^{-3}; Mg^{2+}: 0.4 cmolc.dm^{-3}; Al^{3+}: 0.0 cmolc.dm^{-3}; CTC (T): 4.9 cmolc.dm^{-3}; sum of bases: 1.7 cmolc.dm^{-3}; H+Al: 3.0 cmol.dm^{-3} and organic matter: 1.2 dag.kg^{-1}. Physical analysis revealed 41% of clay, 14% silt and 45% sand. Based on these results, liming was performed at a dose of 0.75 kg of limestone and fertilization with 200 g of formulated fertilizer 08-30-10 (NPK) per m^3 of soil.

Tifton 85 and Jiggs seedlings were produced in expanded polystyrene trays through vegetative propagation and then transplanted into polyethylene pots with a capacity of 12 L. Two experiments were conducted, with Tifton 85 and Jiggs forages separately, both in the completely randomized experimental design, with four replications. Each experimental unit was represented by a single pot, containing four plants. Automated irrigation occurred twice a day, manual control of weeds was performed, and topdressing fertilization with 7 g of urea per pot, divided into two applications, the first after planting and the second at pre-tillering. At 60 days after transplanting, the Tifton 85 and Jiggs plants reached an approximate height of 40 cm, when the herbicides were applied.

Eleven herbicides were applied: 2,4-D at 1,209 g e.a. ha^{-1}, diuron at 2,000 g i.a. ha^{-1}, atrazine at 2,000 g i.a. ha^{-1}, fluazifop-p-butyl at 156.25 g i.a. ha^{-1}, glyphosate at 1,080 g e.a. ha^{-1}, nicosulfuron at 62.5 g i.a. ha^{-1}, imazethapyr at 100 g i.a. ha^{-1}, clethodim at 101.6 g i.a. ha^{-1}, haloxyfop-p-methyl at 60.8 g i.a. ha^{-1}, lactofem at 144 g i.a. ha^{-1}, tembotrione at 84 g i.a. ha^{-1} and a untreated control, totalizing twelve treatments.

The herbicides were applied with a costal sprayer pressurized with CO_2, with a constant pressure of 2.4 kgf.cm^{-2}, equipped with a Magno ADIA 110.015 flat-jet four-point bar, spaced 0.5 m apart, with equivalent spray consumption. at 200 L ha^{-1}. During application, the height of the bar was maintained at 0.50 m from the plants.

Herbicide tolerance evaluations of Tifton 85 and Jiggs were carried out at 7, 14, 21, 28, 35 and 50 days after application (DAA), using a visual herbicide injury scale (visual control). For this evaluation, grades from 0 to 100% were assigned in comparison to untreated control, in which 0 % represents no damage and 100 % the death of the plants (Kuva et al., 2016). The visual assessment was performed by four evaluators, considering the average of the grades as the final grade. At the same time, the chlorophyll index a and b in Tifton 85 forage were evaluated, using an electronic meter of chlorophyll index SPAD 502, in three expanded leaves of each plant per pot. It was not possible to carry out the same evaluation in Jiggs because it did not have enough leaf blade area for evaluation. The regrowth capacity of the forage plants was evaluated 60 days after cutting by the shoot dry matter determination. The forage plants were cut and placed in paper bags, then they were dried in forced air circulation ovens at 60 °C for 72 hours and subsequently weighed on a scale with two decimal places.

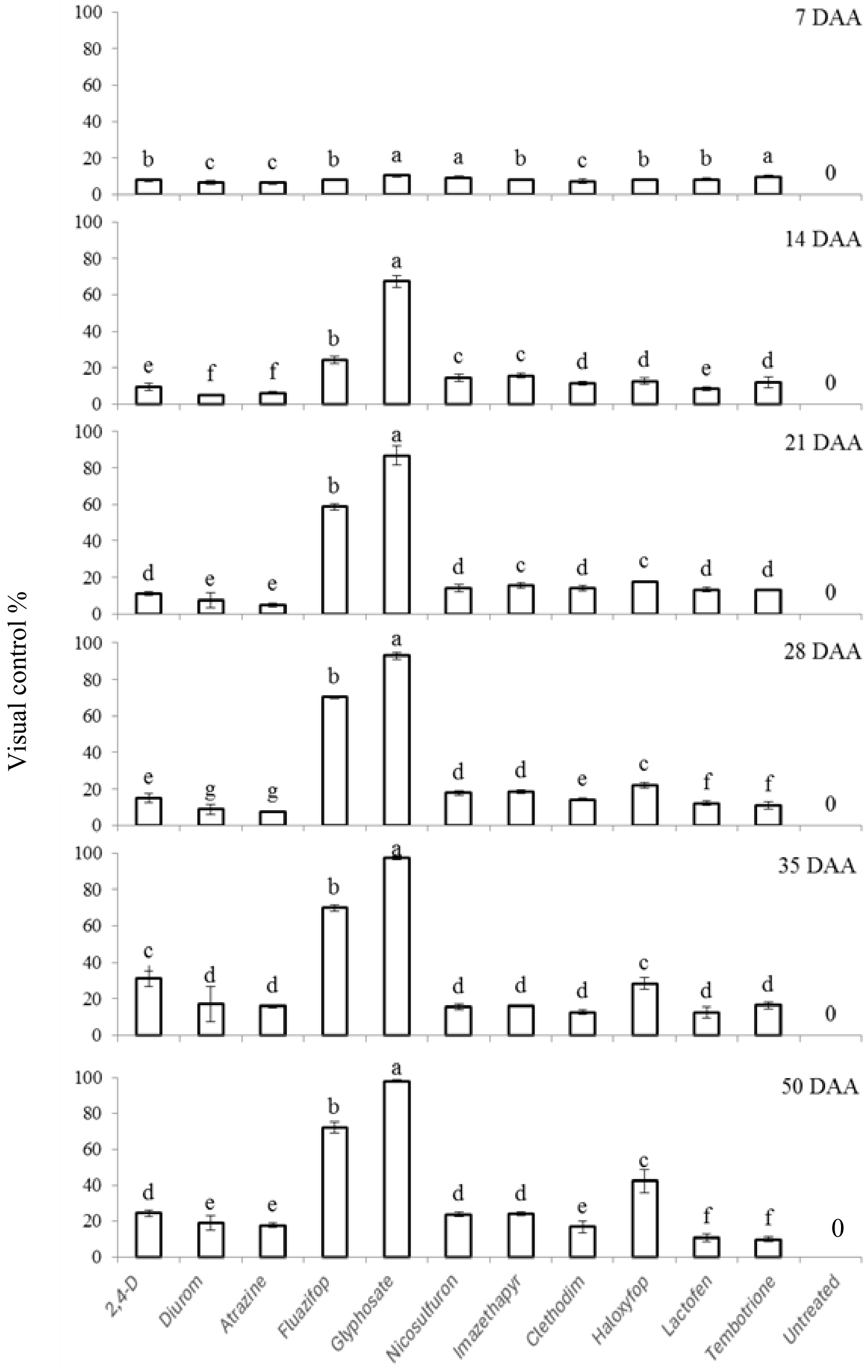
The data obtained were subjected to the Shapiro-Wilk normality test and the Bartlett test to verify the homogeneity of variances. As the data presented the assumptions of the analysis of variance, the analysis of variance were performed and, when significant, the Scott-Knott test was performed for comparisons between means (α=5%).

3. Results and Discussion

Tifton 85

The tolerance of Tifton 85 to herbicides was influenced by the applied treatments ($p<0.05$), for all evaluated periods (Figure 1). A slight herbicide injury was observed in Tifton 85 plants at 7 days after application (DAA) for all herbicides, with means varying between 6.3 and 10.3%. At 14, 21, 28, 35 and 50 DAA, greater herbicide injury was observed in plants treated with glyphosate, with averages from 67.4 to 97.9%. The fluazifop-p-butyl also stood out with injury averages between 24.3 and 71.9% at 14, 21, 28, 25 and 50 DAA.

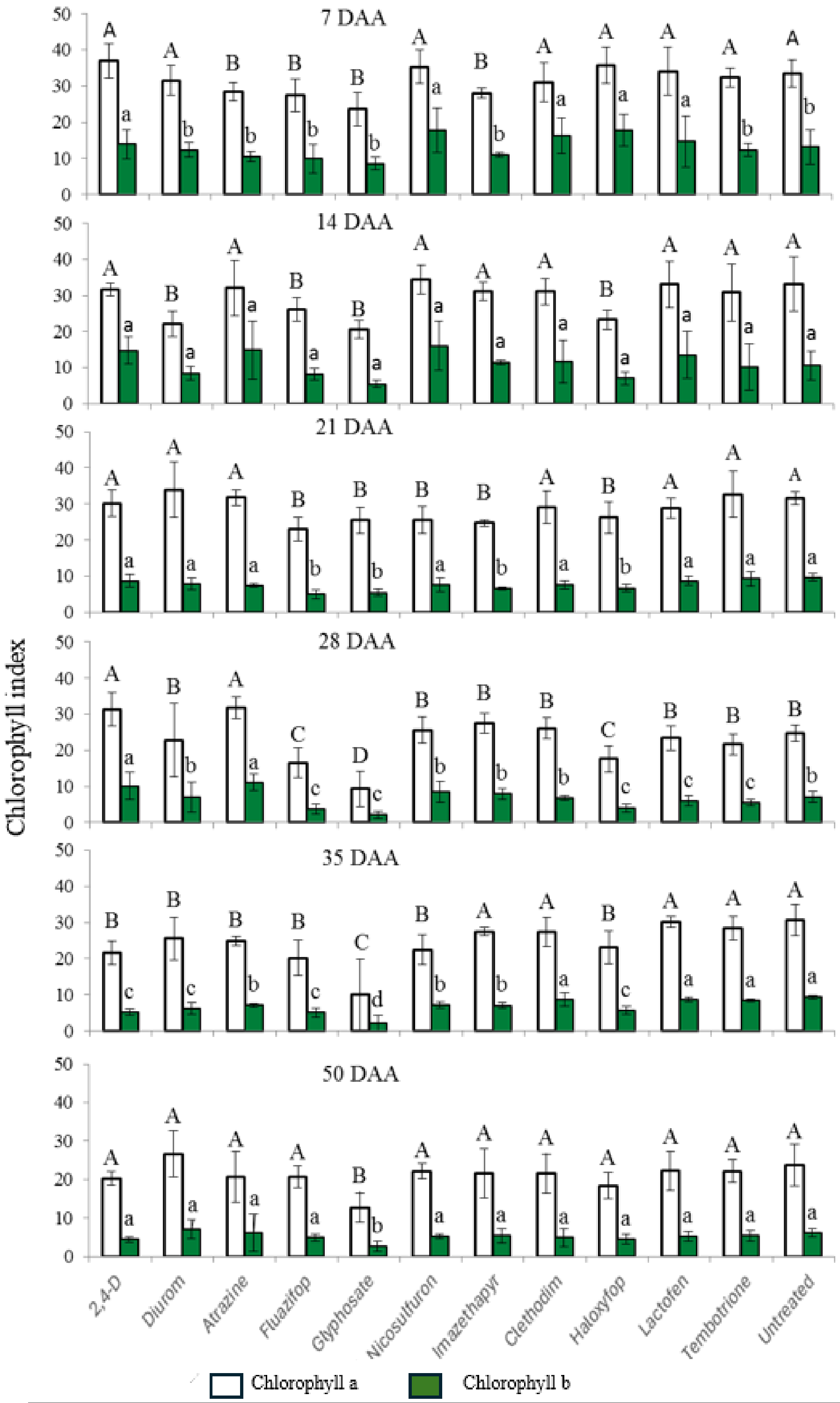
Haloxyfop-p-methyl also caused relevant injury to Tifton 85, with a maximum observed at 50 DAA with 42.3% damage (Figure 1). The other herbicides caused a low percentage of injury throughout the evaluations, with averages ranging from 7.9, 10.5, 11.6, 13.1, 17.2 and 18.2% at 14, 21, 28, 35 and 50 DAA, respectively. Lactofem and tembotrione, followed by atrazine, diuron and clethodim were the ones that caused the lowest herbicide injury rates in Tifton 85.



	7 DAA	14 DAA	21 DAA	28 DAA	35 DAA
CV(%)	30.86	43.66	17.57	32.64	17.45

Figure 1. Visual injury (%) of *Cynodon dactylon* cv. Tifton 85 at 7, 14, 21, 28, 35 and 50 days after application (DAA) of eleven post-emergence herbicides. Means followed by the same letter in each evaluation time do not differ by the Scott-Knott test (α=0.05). CV (%): coefficient of variation.

Significant differences ($p<0.05$) were found in the contents of chlorophyll a and b in Tifton 85, for all evaluated times, except for the contents of chlorophyll b at 14 DAA, when the means did not differ from each other (Figure 2). It was observed that glyphosate had the greatest impact in reducing the contents of chlorophyll a and b in this forage in all evaluated periods, with averages of 23.6; 20.6; 25.5; 9.3; 10.0 and 12.54 FCI (Falker Chlorophyll Index) of chlorophyll a and 8.6; 5.5; 5.5; 2.2; 2.3 and 2.6 FCI of chlorophyll b, at 7, 14, 21, 28, 35 and 50 DAA, respectively. Fluazifop-p-butyl herbicide also showed low chlorophyll contents, reaching the lowest contents at 28 DAA.



		7 DAA	14 DAA	21 DAA	28 DAA	35 DAA	50 DAA
CV (%)	Chlorophyll a	13.86	17.07	14.54	19.35	18.94	22.07
CV (%)	Chlorophyll b	30.86	43.66	17.57	32.64	17.45	38.41

Figure 2. Chlorophylls a and b index present in the leaves of the forage *Cynodon dactylon* cv. Tifton 85 at 7, 14, 21, 28, 35 and 50 days after application (DAA) of eleven post-emergence herbicides. Means followed by the same uppercase or lowercase letter at each evaluation time do not differ from each other, for chlorophylls a and b, respectively, by the Scott-Knott test (α=0.05). CV (%): coefficient of variation.

Considering all evaluation times, the highest contents of chlorophyll a and b in Tifton 85 were observed for 2,4-D, clethodim, lactofem and tembotrione, in addition to the control without herbicide application (Figure 2). It should be noted that these herbicides were also those that presented medium to low visual herbicide injury (Figure 1).

Chlorophyll is one of the elements linked to the photosynthetic efficiency of plants (Taiz et al., 2017) and, consequently, to the adaptability of plants to different environments. Chlorophylls control the amount of solar radiation absorbed by plants, with a strong relationship between their foliar contents and photosynthetic rates and, consequently, the yield of cultivated plants (Streit et al., 2005; Barbieri Junior et al., 2010). The reduction in foliar chlorophyll content is likely associated with the increased herbicide injury to Tifton 85 plants. Since chlorophyll content is positively correlated with plant productivity (Segatto et al., 2017), herbicide-induced injury may reduce the productivity of Tifton 85 treated with these compounds.

Glyphosate is a non-selective, systemic herbicide used to control annual and perennial weeds, which is absorbed by photosynthetically active structures in plants (Parecido et al., 2015) and inhibits the enzyme EPSPS (Enol Pyruvil Shiquimate Phosphate Synthase), which participates in the synthesis of the aromatic amino acids such as tyrosine, tryptophan and phenylalanine (Ruas et al., 2012). The deleterious effect on Tifton 85 plants treated with glyphosate was evident by the reduction in the foliar chlorophylls contents and the increased herbicide injury. By 35 DAA, after the period of action of the herbicide, the treated plants exhibited senescence.

Previously, other works pointed to medium to low herbicide injury of Tifton-85 to glyphosate with regrowth and reestablishment of the forage (Santos et al., 2008, 2010). However, recently, Brighenti et al. (2020) observed that glyphosate was one of the herbicides with the greatest phytotoxic effect on Tifton 85 plants and African star grass (*C. nlemfuensis*), corroborating the results of the present study.

The shoot dry matter from the regrowth of the plants, evaluated 60 days after cutting (DAC), showed no regrowth for Tifton 85 plants treated with glyphosate, confirming its non-selective action on these plants (Figure 3). The herbicides fluazifop-p-butyl and haloxyfop-p-butyl also strongly affected the regrowth of Tifton-85, even though this is a forage that has a high regrowth capacity (Sunahara et al., 2017).

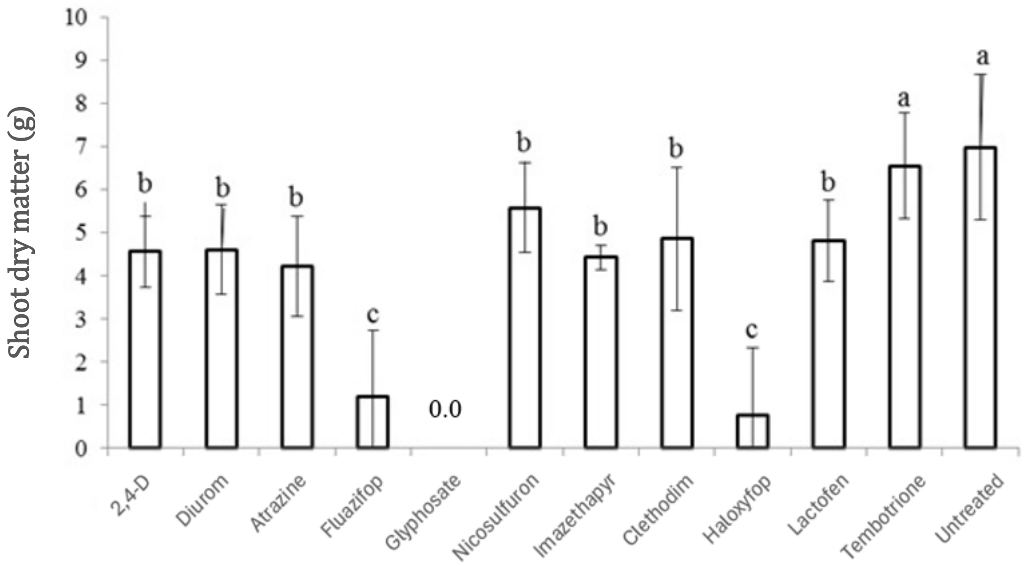


Figure 3. Shoot dry matter (g) from the regrowth of *Cynodon dactylon* cv. Tifton 85 at 60 days after cutting, depending on post-emergence herbicides application. Means followed by the same letter do not differ from each other, according to the Scott-Knott test (α=5%). Coefficient of variation: 29.45%.

The fluazifop-p-butyl and haloxyfop-p-butyl are herbicides used to control perennial and annual grasses under post-emergence conditions. They are ACCase inhibitors, reducing the synthesis of fatty acids and, consequently, of lipids in plants (López-Ovejero et al., 2005). The action of these herbicides stops the growth of the roots and shoot of the plant, the alteration of the pigmentation of the leaves, initiating a necrotic process in the meristematic regions, due to the rupture of the structure of the cell membranes, which spreads throughout the plant causing its death (Silva et al., 2005).

Tifton 85 plants treated with these graminicides had their development highly impaired. There was a great reduction in the shoot dry matter, evaluated at 60 DAC (Figure 3). This reinforces the deleterious effects on the plant evidenced by the reduction in the foliar contents of chlorophylls a and b, especially up to 35 DAC, and the high rates of herbicide injury. The results demonstrated that the application of these herbicides, under the conditions of the present work, was not enough to cause the death of Tifton

85, but drastically affected its development. Similarly, Santos et al. (2012) concluded that the use of fluazifop-p-butyl was harmful to Tifton-85 plants when applied to control *Urochloa brizantha* cv. Marandu in the Tifton-85 pasture establishment.

On the other hand, forage treated with tembotrione, which acts inhibiting hydroxyphenyl pyruvate dioxygenase (HPPD) that interfering in the synthesis of carotenoids, did not show any reduction in its regrowth capacity (Figure 3). The low rates of herbicide injury and the high contents of chlorophyll a and b in the Tifton 85 plants treated with tembotrione (Figures 1 and 2), showed the high tolerance of the forage to the herbicide and its potential use within the chemical management of weeds infesting this pasture.

Recently, Brighenti et al. (2020) reported herbicide tolerance and selectivity for Tifton 85 and *C. nlemfuensis* (African star grass) noting that herbicide tolerant forages and the use of non-phytotoxic products on pasture provide improvements in chemical weed control and increases in yield forage.

Jiggs

In Jiggs cultivar, the percentage of herbicide injury at 7 DAA was also low in all treatments, with means ranging between 3.3 and 8.0% (Figure 4). At all times evaluated, the highest percentage of herbicide injury was caused by the herbicide glyphosate, with a maximum of 98.3%, followed by the herbicide fluazifop-p-butyl, with averages of up to 79%, similar to that observed for the cultivar Tifton 85. The diuron herbicide also caused high injury in Jiggs plants, especially from 28 DAA onwards, reaching a maximum of 53% at 50 DAA. On the other hand, the other herbicides caused the lowest visual rates of injury in Jiggs plants, with no significant difference between them in the last two evaluation times.

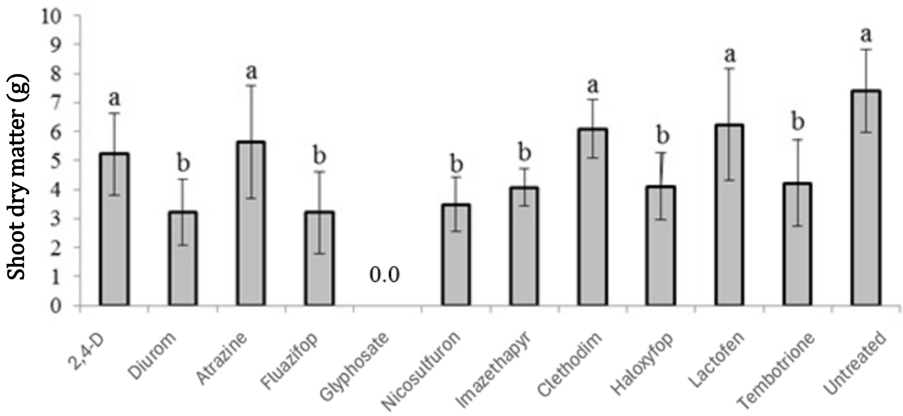


Figure 4. Visual injury (%) of *Cynodon dactylon* cv. Jiggs 85 at 7, 14, 21, 28, 35 and 50 days after application (DAA) of eleven post-emergence herbicides. Means followed by the same letter in each evaluation time do not differ by the Scott-Knott test (α=0.05). CV (%): 29.45 % coefficient of variation.

With regard to the regrowth capacity of the Jiggs plants, there was no regrowth of the Jiggs plants treated with glyphosate herbicide at 60 DAC (Figure 5). In the same way that was observed in Tifton 85 grass, Jiggs showed high rates of herbicide injury caused by glyphosate, with plant death observed from 28 DAA onwards. Great reduction in regrowth dry matter production was also noted in Jiggs plants treated with diuron, fluazifop-p-butyl, nicosulfuron, imazethapyr, haloxyfop-p-methyl and tembotrione.

Corroborating this work, Brighenti et al. (2012), testing doses of glyphosate to control African star grass (*C. nlemfuensis*) as weeds infesting a corn growing area, concluded that doses of glyphosate above 1,232 g i.a. ha^{-1} were sufficient for grass suppression.

When treated with 2,4-D, atrazine, lactofem and clethodim, Jiggs forage did not show any reduction in its ability to regrowth (Figure 5). For the herbicides 2,4-D, atrazine and lactofem, low or no herbicide injury was expected, since they are selective pesticides for grasses, commonly used in crops of this family to control broadleaf weeds.

On the other hand, Jiggs plants were tolerant to clethodim. Clethodim, fluazifop-p-butyl and haloxyfop-p-methyl are ACCase-inhibiting herbicides, commonly recommended for the control of grasses. Plants treated with the clethodim herbicide showed the lowest means of injury in the last evaluation times, with a maximum average of 23% at 50 DAA, and no reduction in their shoot dry matter at 60 DAC (Figures 4 and 5).

The relevance of this result is emphasized, which is promising as a strategy for the chemical management of weedy grasses in Jiggs pasture areas. Especially due to the common occurrence in *Cynodon* areas of grasses of the genus *Urochloa* (brachiaria), which are very competitive weed species (Santos et al., 2010). Possibly, Jiggs' tolerance to clethodim is due to the difficult translocation of the herbicide inside the plant, inhibiting the molecule to achieve its site of action. The absence of work on tolerance of Jiggs forage to herbicides reinforces the need for additional work.

The results obtained were promising and show the existence of herbicides with low or no herbicide injury to Tifton 85 and Jiggs forages as an important alternative for chemical control of weeds in areas of these forages.

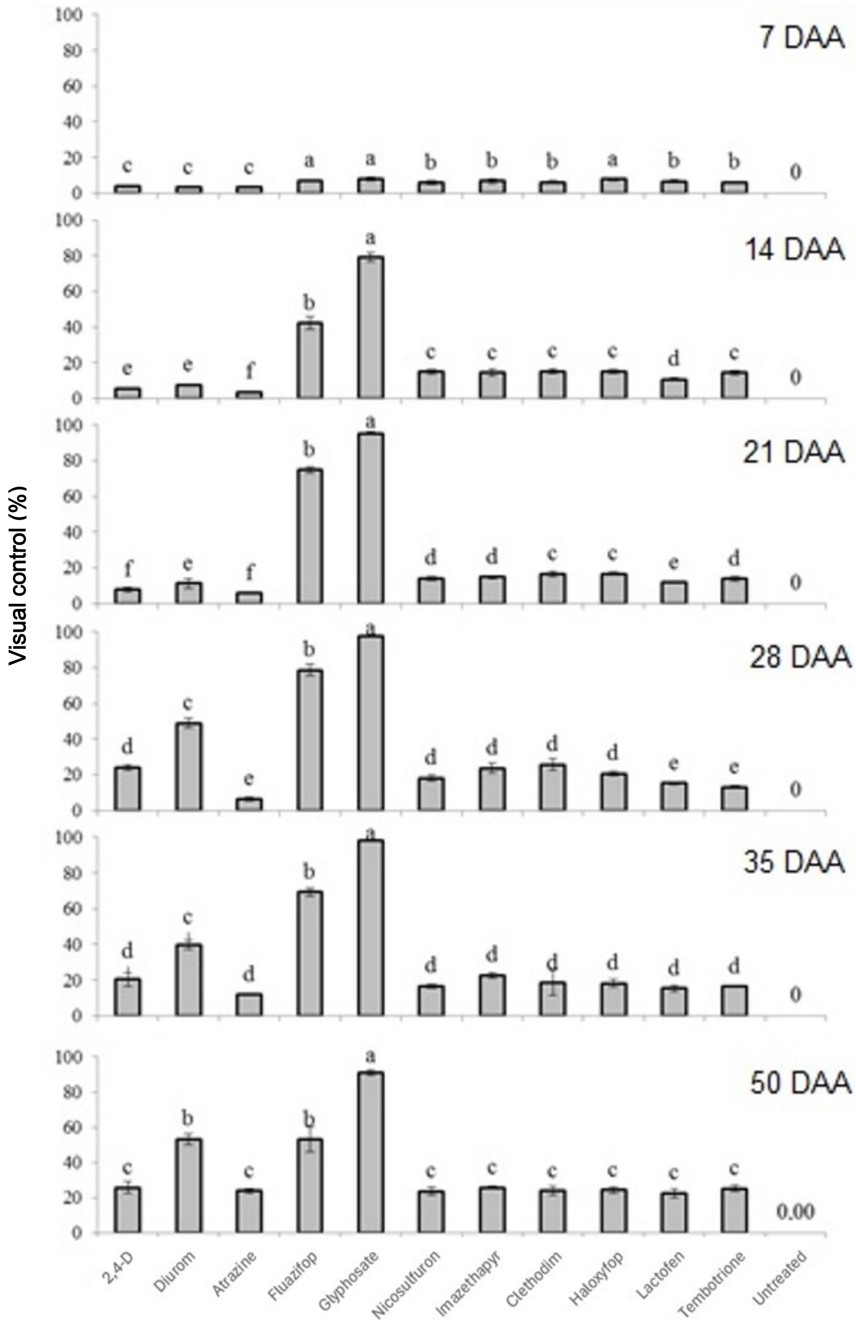


Figure 5. Shoot dry matter (g) from the regrowth of *Cynodon dactylon* cv. Jiggs at 60 days after cutting, depending on post-emergence herbicides application. Means followed by the same letter do not differ from each other, according to the Scott-Knott test (α=5%). Coefficient of variation: 29.83%.

4. Conclusions

Glyphosate and fluazifop-p-butyl exhibit high herbicide injury in *Cynodon dactylon* cv. Tifton 85 and cv. Jiggs, preventing plant survival and regrowth even 60 days after cutting. Additionally, these herbicides significantly reduce chlorophyll a and b content in Tifton 85. Tembotrione has no influence on regrowth of Tifton 85 and 2,4-D, atrazine and lactofem have no negative effect on regrowth of Jiggs 60 days after cutting. The graminicide clethodim causes the lowest herbicide injury rates in Jiggs and does not interfere with forage regrowth.

Acknowledgements

Our thanks to the Serviço Nacional de Aprendizagem Rural do Estado de Goiás (Senar/AR-GO), for the incentive to carry out the master's degree of the first author. To the Fundação de Apoio à Pesquisa do Estado de Goiás for granting scholarship to the first author. To the Programa de Pós-Graduação em Proteção de Plantas do Instituto Federal Goiano - Campus de Urutaí for the support in carrying out the field trials.

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