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Vol. 11(35), pp. 3299-3306, 1 September, 2016
DOI: 10.5897/AJAR2016.10982
Article Number: 9E19BE260257
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Selectivity and efficiency of herbicides in warm season turfgrass varieties

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Received 13 March, 2016; Accepted 17 August, 2016

Weed infestations and the few post-emergent control alternatives available are some of the main problems in the management of ornamental and sports lawns. Given the exposed, the study aims to evaluate the selectivity of five herbicides to four grass varieties: *Paspalum notatum* (bahia grass), *Cynodon dactylon* (bahama grass- ITG6), *Zoysia japonica* (japanese lawn grass) and *Zoysia japonica* (imperial – ITG5), as well as the control efficiency of those upon nutsedge (*Cyperus rotundus*) and sudan grass (*Urochloa decumbens*). The following herbicides were applied in the recommended doses: sulfentrazone + diuron, isoxaflutole, triclopyr, 2,4-D and halosulfuron. Visual phytotoxicity symptoms in turfgrass and weed control were performed at 7, 14, 21, 28, 35 and 42 days after herbicide application and, at the end of the evaluations, was quantified the dry weight. The herbicides sulfentrazone + diuron and isoxaflutole were not selective to any turfgrass, although sulfentrazone + diuron controlled *C. rotundus* and *U. decumbens* species and isoxaflutole controlled only *U. decumbens.* However, halosulfuron and 2,4-D herbicides were selective to all of grasses and promoted weed species control. The herbicide triclopyr was selective to *P. notatum*, *Z. japonica* and *Z. japonica*– ITG5, and it can be used to control *C. rotundus* and *U. decumbens.*

Key words: *Urochloa decumbens, Cynodon dactylon*–ITG6*, Cyperus rotundus, Paspalum notatum, Zoysia japonica*.

INTRODUCTION

Warm-season (C4) grass species are the most adaptable to Brazil's environmental conditions. The main turfgrasses used in tropical regions are *Cynodon* spp., *Zoysia* spp., *Penicillium notatum, Axonopus compressus* (lawn grass), *Stenotaphrum secundatum* (st Augustine grass) *Pennisetum clandestinum* (kikuyu grass) (Gurgel, 2003).

During the grass field formation, the presence of weeds is one factor that interfere the most to diminish its aesthetic quality and its usage, depreciating the garden's value. The aesthetic value is defined by its beauty and the value the garden adds to the scenery. In addition, the usability is the durability of a given field to sports or reduction in the erosion effects (McElroy and Martins, 2013), due its unique characteristics such as fast growth, deep and penetrating root system, and high tolerance to adverse conditions (Xiao et al., 2011).

Among the weeds that infest gardens are sudan grass (*Urochloa decumbens*) and nutsedge (*Cyperus rotundus*). *C. rotundus* is a weed that occurs during the entire cycle of several commercial crops and has a difficult management (Silveira et al., 2010) due to its competition capabilities and its aggressiveness, as well as its control and eradication difficulty. *Urochloa* species are weeds of perennial cycle and slower growth (Bianco et al., 2005) and also of hard control due factors inherent to the species such as morphological characteristics and the large amount of seed produced (Santos et al., 2012).

In turfgrasses, besides the difficulty of controlling weed, the current shortage of post-emergent products registered for the crop is another problem too. The availability of different mechanisms of action is an essential factor for crop management to reduce selection pressure and to create alternatives of control. Post emergence control of grass weeds is a great challenge, since few selective herbicides to grasses actually may affect these weed species to death. As so, too little alternatives may be used in post-emergence when control is necessary (Unruh et al., 2013). Selectivity refers to the capacity of a particular herbicide to eliminate weeds found in a crop, without affecting yield (Velini et al., 2000).

Regarding said information, the experiment was conducted aiming to evaluate the selectivity of herbicides on bahia grass (*Paspalum notatum*), bermuda grass (*Cynodon dactylon* – ITG6), japanese lawn grass (*Zoysia japonica*) and imperial grass (*Zoysia japonica* – ITG5) associated to sudan grass and nutsedge control.

MATERIALS AND METHODS

The experiment was conducted in Jaboticabal, São Paulo, located at 21°14'05" S latitude and 48°17'09" W longitude, at a 615 m altitude, from January to August 2015, using 120 plastic boxes with 5.44 liter capacity (35.5 x 25.5 x 6 cm) filled with soil collected from the arable part of an oxisol. The soil chemical characteristics are described in Table 1, according to Raij et al. (2001).

Turfgrass varieties evaluated in the experiment were: *P. notatum* (bahia grass), *C. dactylon* (bermuda grass – ITG6), *Zostera Japonica* (japanese lawn grass) and *Z. Japonica* ITG5 (ITG5 - imperial), which were planted as pads in 96 boxes, using 24 boxes for each variety. On the 24 remaining boxes were sown *U. decumbens* (sudam grass) and planted tubercles of *C. rotundus* (nutsedge). For Sudam grass sowing, 30 seeds m^{-2} were deposited on the length direction of the boxes and, parallel to it, 50 nutsedge tubercles m^{-2} were planted. Fertilizer was applied at an amount of 400 kg ha^{-1} NPK fertilizer 4-20-20 and soil's capacity was maintained at 100%.

Applied herbicides upon the grasses and weeds were: sulfentrazone (600 g a.i.ha^{-1}) + diuron (3840 g a.i.ha^{-1}), isoxaflutole (190 g a.i.ha^{-1}), triclopyr (1.19 g a.i.ha^{-1}), 2,4-D (1612 g a.i.ha^{-1}) and halosulfuron (112,5 g a.i.ha^{-1}), with a control plot in which no herbicides were applied. The herbicides were applied 35 days after planting/sowing (DAS) on the boxes, when the weeds showed 4 to 5 leaves and the garden grasses were visually rooted, with buds and covered the entire box. A CO_2 constant pressure backpack sprayer was used equipped with a XR 11002 nozzle. The equipment was adjusted at 2.2 bar pressure to spray the equivalent of 200 l.ha^{-1} herbicide solution. The herbicides were applied at closed environment, with humid substratum, 27°C temperature and air humidity of 74%.

Phytotoxicity symptoms on the grasses were evaluated visually, adopting a visual scale of one to nine, in which 1 equals the absence of toxicity and 9 equals the death of the plants (Ewrc, 1964). Such evaluation was performed every 7 days after herbicide application and repeated until 42 days after application (DAA). Visual evaluations of the weed control were performed at 40 DAA, in which they were attributed control grades ranging from 0 to 100% depending on the symptoms' intensity (ALAM, 1974), according to Table 2.

At 42 DAA, the plants were collected in order to analyze the dry matter (to estimate growth). For the garden grasses, a 10x10 cm pad was collected from each box, taking only the live part (which was not affected by the herbicide), from which were separated the leaves and roots/rhizomes, that after being washed, were placed in forced air circulation stoves at 70°C to dry for 72 h.

The experimental design used for each grass and weed was the complete randomized design, with five treatments (herbicides) and four replications. The statistical analysis was performed separately for each species. Data found was submitted to the variance analysis through F-test and means compared through Tukey test at 95% probability, using the AgroEstat software (Barbosa and Maldonado, 2010).

RESULTS AND DISCUSSION

Bahia grass

It may be observed that, for bahia grass, among the evaluated treatments, sulfentrazone + diuron and isoxaflutole herbicides were the most phytotoxic treatments, because they induced initial symptoms of foliar chlorosis and yellowed leaves with white spots,

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Table 1. Results of collected soil chemical analysis.

pH	M.O.	P	K	Ca	Mg	H+Al	SB	T	V
$CaCl_2$	g.dm^3	resin mg.dm^3	------------------------------mmol$_c$.dm^{-3}------------------------------						Percentage (%)
5.6	18	125	4.6	42	15	28	61.6	89.6	69

Analysis Laboratory of Soil and Plant, Department of Soils and Fertilizers, Faculdade de Ciências Agrárias e Veterinárias/UNESP - Jaboticabal-SP.

Table 2. ALAN grade scale used to evaluate the effectiveness of weed control.

Percentage	Grau de controle
0-40	None or poor
41-60	Regular
61-70	Enough
71-80	Good
81-90	Very good
91-100	Excelent

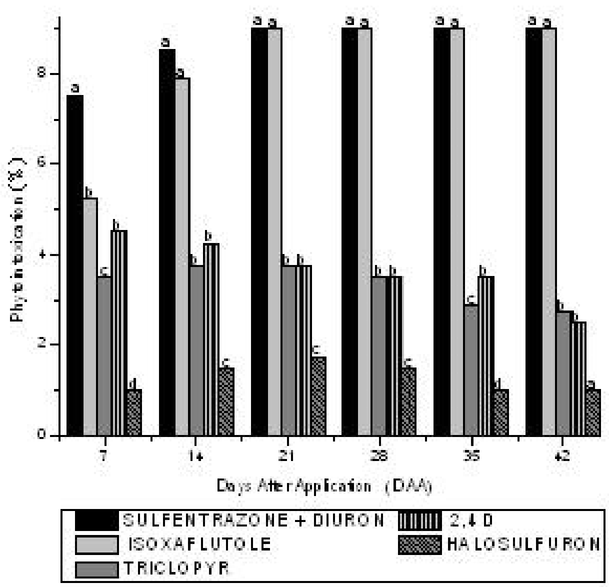

Figure 1. Phytointoxication of *P. notatum* submitted to herbicide application after 7, 14, 21, 28, 35 and 42 days.

respectively, at 14 DAA, causing the death of the specimens at 42 DAA (Figure 1). The application of triclopyr gave a brand level of toxicity (3.5) at 7 DAA, with foliar chlorosis. This symptom progressed slowly (3.75) until the 21 DAA, and after this, the species were recovered and, at 42 DAA, the symptoms were very brand (2.75).

Freitas et al. (2003) verified that the usage of triclopyr showed a phytotoxicity of 4 (0.96 kg a.i.ha^{-1}) and 10% (1.20 kg a.i.ha^{-1}) on bahia grass, at 10 DAA, and that at 20 DAA there was no phytotoxic effect of this treatment. In the 2,4-D treatment, the herbicide caused a foliar chlorosis effect (7DAA) with toxicity level of 4.5, but the plants recovered from this initial damage at the 35 DAA, and at the 42 DAA, the toxicity level was 2.3 (Figure 1). Akanda et al. (1997), studying the effects of 2,4-D upon the chemical control of *P. notatum* observed that the herbicide lead to brand symptoms (≤2.0%) until the 35 DAA evaluation, and after this period, the symptoms did not evolve and the plants recovered. Machado et al. (2010), evaluating the effect upon other species (white clover), showed it promoted a toxicity level of 60% at 21 DAA and, at 84 DAA, the symptoms were reduced to 22%. The authors also show that moderate symptoms induced only a little reduction in the productivity. It may be observed that these symptons of 2,4-D upon bahia grass had a reduction on its growth too (around 50% in aerial part).

Halosulfuron caused the least phytotoxical symptoms when compared to the other treatments. The highest toxicity level occured at 21 DAA, being considered as very brand (1.75). At the end of the evaluations, the foliar chlorosis symptoms reduced, being zero at 42 DAA (Figure 1). These results showed an elevated selectivity degree of this herbicide upon the bahia grass. Costa et al. (2010) observed that the halosulfuron application at 112.5 g a.i. ha^{-1} induced severe phytotoxicity levels at 7 DAA. However, at 14 DAA, the symptoms degraded to brand levels, disapearing at the 26 DAA.

Phytotoxicitysymptoms occurring in the species regarding the herbicide application are related to the lesser production of aerial parts dry matter. As for the roots/rhizomes dry matter production, the herbicides triclopyr, 2,4-D and halosulfuron did not differ from the control plot (Table 3).

Bermuda grass

For bermuda grass, it was observed that sulfentrazone + diuron and triclopyr were the most phytotoxic herbicides, providing severer phytotoxicity symptoms – 7.3 and 8,

Table 3. Herbicide effect upon dry matter of leaves and roots/rhizomes of *P. notatum* evaluated after 42 days.

Treatment	Aerial parts (g)	Roots/Rhizomes (g)
Sulfentrazone + Diuron	0.00[c]	0.00[b]
Isoxaflutole	0.00[c]	0.00[b]
Triclopyr	2.76[ab]	13.13[a]
2,4-D	2.01[b]	16.03[a]
Halosulfuron	2.40[ab]	16.91[a]
Control	4.62[a]	15.66[a]
CV(%)	46.94	37.20
MSD	2.07	8.60
F	14.65**	17.77**

Means followed by same letter in a column do not differ statistically through Tukey test ($p<0.05$); CV (%) = coefficient of variation; MSD = minimal significant difference.

Table 4. Herbicide effect upon dry matter of leaves and roots/rhizomes of *C. dactylon* ITG6 evaluated after 42 days.

Treatment	Aerial parts (g)	Roots/Rhizomes (g)
Sulfentrazone + Diuron	0.00[b]	0.00[c]
Isoxaflutole	1.98[a]	7.84[b]
Triclopyr	0.00[b]	0.00[c]
2,4-D	2.16[a]	9.20b
Halosulfuron	2.30[a]	12.57[ab]
Control	3.36[a]	17.11a
CV(%)	41.75	30.98
MSD	1.53	5.42
F	15.75**	32.04**

Means followed by same letter in a column do not differ statistically through Tukey test ($p<0.05$); CV (%) = coefficient of variation; MSD = minimal significant difference.

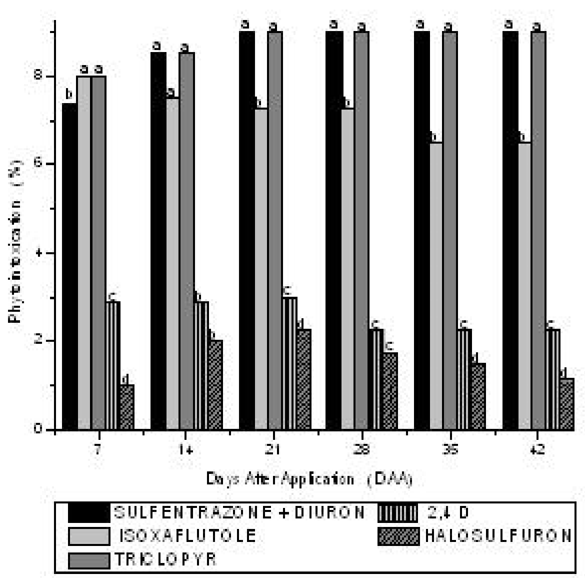

Figure 2. Phytointoxication of *C. dactylon* – ITG6 submitted to herbicide application after 7, 14, 21, 28, 35 and 42 days.

respectively – at 7 DAA. These symptoms are characterized by the yellowing and foliar discoloration, respectively. The symptoms evolved during the length of the experiments evaluations, causing all the plants to be dead at the 42 DAA evaluation (Figure 2).

Some papers show triclopyr toxicity effect upon *Cynodon* species. McElroy and Breeden (2006) evaluating its effect at 1.23 kg a.e.ha^{-1}, attained a 47% suppressing effect upon this species. McElroy et al. (2005) observed that the application of triclopyr + clopyralid reducing soil cover about 56%, at 21 DAA and, these injuries were associated mainly by the herbicide triclopyr. Johnson and Duncan (2001) found that applications of triclopyr cause injuries around to 30% at 2 DAA. 2,4-D and halosulfuron provoked the least phytotoxicity upon the bermuda grass, such as with bahia grass. Symptoms at 21 DAA evaluation were classified as brand (3.5) and very brand (2.3), respectively, attaining a toxicity level near 2 (2,4-D) and 0 (halosulfuron) at 42 DAA (Figure 2).

It is noticed that dry matter on 2,4-D treated plants, for aerial parts and roots, was slightly inferior than the obtained for halosulfuron, but no significant difference was shown for aerial parts through the statistical analysis (Table 4). Data obtained from the halosulfuron application shows this herbicide was selective for bermuda grass.

Isoxaflutole caused severe symptoms at 7 DAA and 14 DAA, causing the death of 85% of the grass pad. In the remaining evaluations, the initial symptoms were reduced and the plant growth restarted indicating, at 42 DAA, a moderate recovery with almost strong toxicity level (6.5). These symptoms caused roots/rhizomes dry mass loss by about 54%, when it was compared to control, however no differences occurred to aerial parts dry mass (Table 4).

Japanese lawn grass

Herbicides sulfentrazone + diuron and isoxaflutole were the most phytotoxical, causing initial symptoms of foliar chlorosis and yellowed leaves, causing death of the plants at 42 DAA (Figure 3). Triclopyr application caused moderate phytotoxicity symptoms (4) at 7 and 14 DAA,

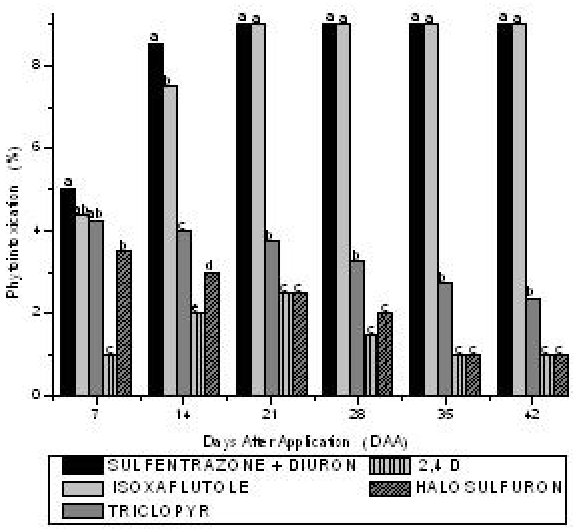

Figure 3. Phytointoxication of *Z. japonica* submitted to herbicide application after 7, 14, 21, 28, 35 and 42 days.

Table 5. Herbicide effect upon dry matter of leaves and roots/rhizomes of *Z. japonica* evaluated after 42 days.

Treatment	Aerial parts (g)	Roots/Rhizomes (g)
Sulfentrazone + Diuron	0.00^{b}	0.00^{d}
Isoxaflutole	0.00^{b}	0.00^{d}
Triclopyr	3.89^{a}	10.15^{bc}
2,4-D	6.16^{a}	21.52^{a}
Halosulfuron	6.11^{a}	17.87^{ab}
Control	3.88^{a}	13.12^{b}
CV(%)	36.76	31.40
MSD	3.01	12.76
F	12.33*	8.13**

Means followed by same letter in a column do not differ statistically through Tukey test ($p<0.05$); CV (%) = coefficient of variation; MSD = minimal significant difference.

being characterized as foliar chlorosis and tissue necrosis. However, during the evaluations, the symptoms reduced and, at the 42 DAA, the phytotoxicity level was very brand (2.4). During the evaluations, it was noticed that triclopyr caused a reduction of 20% in the grass pads, having a slight growth recovery toward the end of evaluations , which may be noticed by the lower roots dry matter value when compared to 2,4-D and halosulfuron (Table 5). About the herbicide selectivity of 2,4-D and halosulfuron, the toxicity level was equal to 0 and 3.5 (brand), respectively, at 7 DAA. From 21 DAA, both 2,4-D and halosulfuron had their symptoms reduced along the evaluations, disappearing at the 42 DAA. Analyzing data from dry matter of aerial parts and roots, it may be observed that the allocation was similar to control.

ITG5 – Imperial grass

Regarding results obtained for Imperial grass, suulfentrazone + diuron proportioned an elevated toxicity level (4.5) already at 7 DAA. Symptoms developed along the evaluations until 21 DAA, reaching a toxicity level next to 7, considered strong. However, during the following evaluations, the initial symptoms decreased and plant growth continued, indicating a slight recovery at 42 DAA (Figure 4). As for the dry matter, a lower mass allocation regarding aerial parts of plants treated with sulfentrazone + diuron was observed, when compared to the other treatments and the control plot, and roots dry matter showed no difference from the control plot (Table 6).

Isoxaflutole applied to imperial grass at 7 DAA proportioned brand toxicity symptoms (2.5). However, the symptoms advanced and, at 21 DAA, the herbicide provoked the death of the plants (Figure 4). It is noticed that this herbicide also shows low selectivity to bahia grass, bermuda grass and japanese lawn grass. Injury symptoms were present due to the application of triclopyr being more intense at 21 DAA, reaching toxicity level of 4 (moderate symptoms). On the following evaluations, there was no evolution of symptoms, which consisted of bleached leaves, and plants continued to grow and, at 42 DAA, no more signs of the initial symptoms were observed. McElroy and Breeden (2006) after applying triclopyr (1.23 kg a.e.ha^{-1}) show the injuries were of 10% or bellow. Similar results were obtained by Lewis et al. (2012). Dry matter accumulation effects due to application were similar to the control, with slight reductions of aerial parts and roots dry matter (Table 6).

Herbicides 2,4-D and halosulfuron have the lowest toxicity levels for imperial grass. The most elevated levels were at 21 DAA, considered as brand (3) and very brand (2). On the remaining evaluations, the symtoms lessened significantly and, at 42 DAA, no injury symptom was observed (Figure 4). Data about dry matter of aerial parts and roots of these herbicides show similar matter aggregation to control (Table 6). Similar to bahia grass and bermuda grass, data from halosulfuron application shows imperial grass is also very tolerant to this herbicide.

Differences on the toxicity symptoms found between the species and cultivars may be due to their own distinctions about herbicide tolerance, given the difference

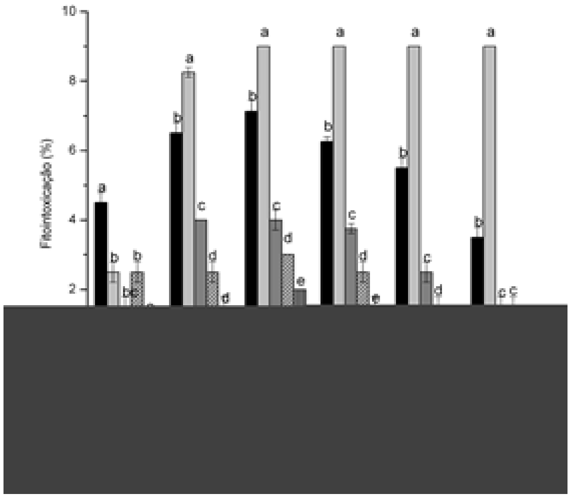

Figure 4. Phytotoxicity of *Z. japonica* – ITG5 submitted to herbicide application after 7, 14, 21, 28, 35 and 42 days.

Table 6. Herbicide effect upon dry matter of leaves and roots/rhizomes of *Z. japonica* – ITG5 evaluated after 42 days.

Treatment	Aerial parts (g)	Roots/Rhizomes (g)
Sulfentrazone + Diuron	2.40b	12.56a
Isoxaflutole	0.00c	0.00b
Triclopyr	3.17ab	10.48ab
2,4-D	4.50ab	13.27a
Halosulfuron	5.29a	17.50a
Control	4.01ab	14.36a
CV(%)	29.36	41.65
MSD	2.13	10.62
F	15.64**	6.41**

Means followed by same letter in a column do not differ statistically through Tukey test ($p<0.05$); CV (%) = coefficient of variation; MSD = minimal significant difference.

from plant to plant to metabolize a given herbicide, its low penetration or limited translocation along the plant (Kelley and Riechers, 2007).

Control of weeds

Regarding the control of nutsedge, sulfentrazone + diuron caused yellowing and necrosis symptoms, with a control level of 60% at 7 DAA. Along the evaluations, these symptoms evolved, causing the death of the weed at 35 DAA (Figure 5). Some papers show the efficiency of sulfentrazone on *C. rotundus* control, (Martins et al., 2009; Silva et al., 2014), however, some experiments like those of Gannon et al. (2012), applying 0.035 and 0.07 kg ha^{-1}, show unacceptable control levels of this species. For diuron, it is known that it is used for pre-emergence control on grass gardens for annual and broad-leaf weeds (McElroy and Martins, 2013).

Triclopyr shows a similar result to sulfentrazone + diuron. However, the symptoms were more severe after the 14 DAA, when it caused 60% control. Along the evaluations, the symptoms became more intense and, at 35 DAA, this herbicide caused the death of the weeds. Symptoms observed were growth paralyzation, foliar epinasty, chlorosis (Kelley et al, 2005; Grossmann, 2010), becoming yellowed and, eventually, death. Isoxaflutole was not efficient on *C. rotundus* control. Between 7 and 21 DAA, control levels were considered very low, about 20%. From the following evaluations, the initial symptoms were reduced and the plant growth restarted, indicating a recovery from the symptoms (Figure 5).

Halosulfuron and 2,4-D treatments had similar responses about the evolution of the symptoms, which increased during the evaluations. At the end of the 42 DAA evaluation, these herbicides caused a 80 and 72% control, respectively, which are considered good control levels. Durigan et al. (2005) evaluating the application of halosulfuron (0.0937, 0.1125 and 0.1312 kg ha^{-1}) and 2,4-D (2.01 kg ha^{-1}), relate halosulfuron had an 80% control and that it reduced the tubercle percentage above 92%, and the control efficacy and tubercles reduction from 2,4-D application was considered low and inconstant. Similar results were found by Oliveira et al. (2010) regarding the best performance of halosulfuron (85% control) than 2,4-D (60%) on the control and epigeal manifestations of *C. rotundus*. Brecke et al. (2005) show halosulfuron reduced the number and viability of nutseged tubercles in a mean value of 55%. About *Urochloa decumbens* control, sulfentrazone + diuron, isoxaflutole and triclopyr treatments show better results than the remaining treatments. At 7 DAA, the control was already considered good - about 80% - and at 35 DAA, these treatments caused the death of the weeds (Figure 5).

Carbonari et al. (2010) evaluating isoxaflutole application in dry and wet ways (150 and 225 g a.i. ha^{-1}) in post-emergence control of *U. decumbens* stated a mean control of 90% - for solid way at 75 and 110 DAA – 90 and 45% (wet way) at 75 and 110 DAA, respectively. It is observed that 2,4-D and halosulfuron treatments, unlike *C. rotundus* response, were not effective to control Sudan grass. Both herbicides, at the final evaluation (42 DAA) caused only a 30% mean weed control, considered insatisfactory.

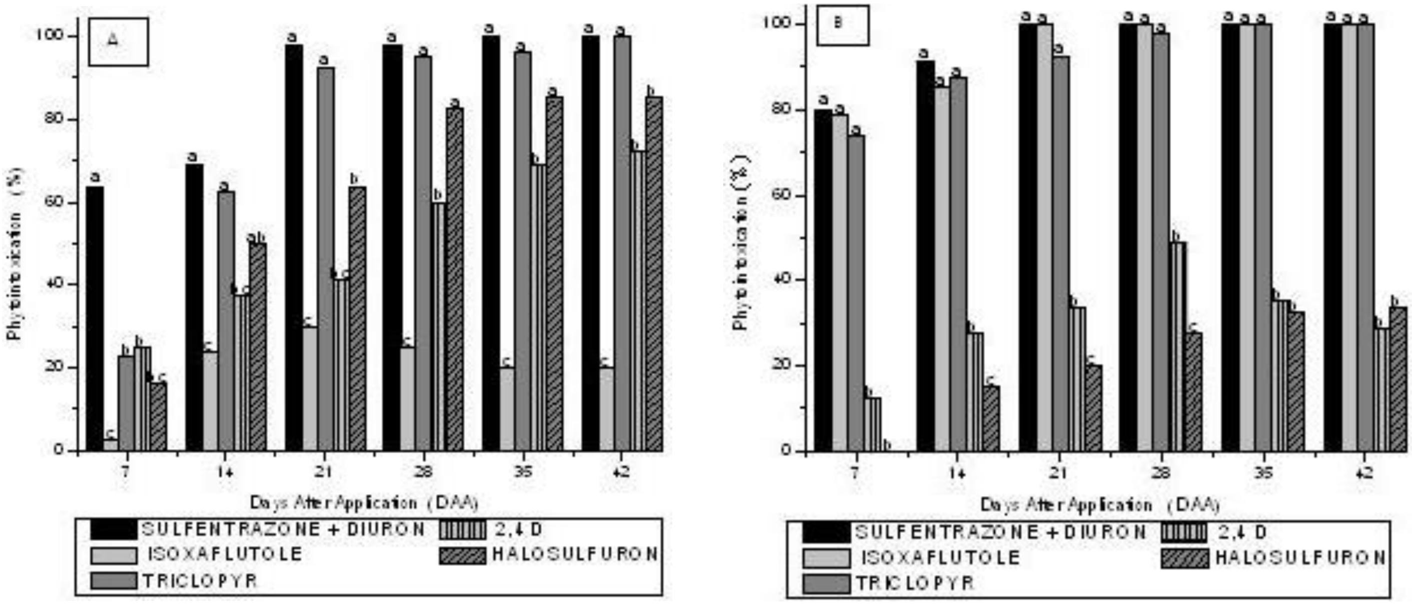

Figure 5. Percentage of control of sulfentrazone + diuron, isoxaflutole, triclopyr, 2,4-D and halosulfuron herbicides applied upon *C. rotundus* (A) *and U. decumbens* (B).

About auxin mimic herbicides, those are highly used on commercial gardens, golf courses and crops for its selectivity to grasses and its control upon dicotyledonous weeds (Song, 2014). Herbicides that have this action mechanism are mainly active on broadleaf species (McElroy and Martins, 2013). However, as it has been cited, species tolerance is dependent of many factors such as development stage, species, herbicide, among others, which may explain the control difference of grass species by auxinic herbicides.

Conclusions

The herbicides sulfentrazone + diuron and isoxaflutole were not selective to *P. notatum*, *C. dactylon* – ITG6, *Z. Japonica* and *Z. Japonica*– ITG5 grasses due to its phytotoxicity, however, sulfentrazone + diuron controlled *C. rotundus* and *U. decumbens* weeds and isoxaflutole controlled *U. decumbens.* Halosulfuron and 2,4-D were selective for all four grasses and both controlled just *C. rotundus.* The herbicide triclopyr was selective for *P. notatum*, *Z. japonica* and *Z. japonica* – ITG5, and may be used to control *C. rotundus* and *U. decumbens.*

Conflict of Interests

The authors have not declared any conflict of interests.

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