PLANTA DANINHA

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS

<http://www.sbcpd.org>

ISSN 0100-8358 (print)
1806-9681 (online)

Article

Interference of the Association Oxyfluorfen + Flumioxazin and the Addition of Mineral Oil on a Phytosociological Survey

Interferência da Associação de Oxyfluorfen + Flumioxazin e Adição de Óleo Mineral No Levantamento Fitossociológico

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ABSTRACT - Phytosociological studies are extremely important for the management of weeds in cultivated areas. Thus, the goal of this work was to evaluate the interference of mineral oil associated with oxyfluorfen and flumioxazin, through the phytosociological survey of weeds. Therefore, this experiment was conducted in a 2 x 5 + 1 factorial design and with four replications; the following oxyfluorfen + flumioxazin associations were evaluated: 240 + 50, 192 + 40, 144 + 30, 96 + 20 and 48 + 10 g a.i. ha^{-1}, with and without the addition of mineral oil, including a control sample without application. Thirty days after the application, plant density, frequency and abundance of species were determined, and so were frequency, density and relative abundance, as well as the importance value index. Results indicate that the application of the mixture oxyfluorfen + flumioxazin, regardless of the addition of the mineral oil, provided a great population of Poaceae. The species *Digitaria horizontalis* and *Brachiaria decumbens* showed a higher importance value index in all treatments. Families with greater representation as for number of species were Poaceae, Asteraceae, Fabaceae and Rubiaceae. The addition of oil and different doses of the mixture oxyfluorfen + flumioxazin did not affect the population of weeds, compared to the mixture without mineral oil.

Keywords: phytosociology, similarity index, herbicide association, adjuvants.

*RESUMO - Estudos fitossociológicos são de fundamental importância para o manejo de plantas daninhas em áreas cultivadas. Assim, o objetivo deste trabalho foi avaliar a interferência de óleo mineral associado ao oxyfluorfen e flumioxazin no levantamento fitossociológico de plantas daninhas. Para isso, realizou-se este experimento em esquema fatorial 2 x 5 + 1 e quatro repetições, sendo avaliadas as associações de oxyfluorfen + flumioxazin: 240 + 50, 192 + 40, 144 + 30, 96 + 20 e 48 + 10 g i.a. ha^{-1}, com e sem a adição de óleo mineral, adicionando-se um controle sem aplicação. Aos 30 dias após a aplicação, determinou-se a densidade de plantas, frequência e abundância das espécies, frequência, densidade e abundância relativa, além do índice de valor de importância. Os resultados indicam que a aplicação da mistura oxyfluorfen + flumioxazin, independentemente da adição do óleo mineral, proporcionou elevada população de espécies de Poaceae. As espécies de **Digitaria horizontalis** e **Brachiaria decumbens** apresentaram maior índice de valor de importância em todos os tratamentos avaliados. As famílias com maior representatividade em relação ao número de espécies foram Poaceae, Asteraceae, Fabaceae e Rubiaceae. A adição de óleo e as diferentes doses da mistura oxyfluorfen + flumioxazin não interferiram na população de plantas daninhas, em comparação com a mistura sem o óleo mineral.*

Palavras-chave: fitossociologia, índice de similaridade, associação de herbicidas, adjuvantes.

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Received: October 19, 2016
Approved: March 1, 2017

Planta Daninha 2018; v36:e018169151

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Doi: 10.1590/S0100-83582018360100030

INTRODUCTION

Oxyfluorfen [2-chloro-á,á,á-trifluoro-p-tolyl-3-ethoxy-4-nitrophenyl ether] is an herbicide registered in Brazil for cotton, irrigated rice, coffee, sugarcane, citrus, eucalyptus and pine cultures, commonly used in the pre- or post-emergence of dicot and monocot weeds, inhibiting the protoporphyrinogen oxidase. Moreover, oxyfluorfen is poorly leached because it is slightly soluble in water (0.116 mg L^{-1}) and may be strongly retained in soil colloids (K_{foc} = 7,566 L kg^{-1}), with the possibility of a six-month residual effect (Rodrigues and Almeida, 2011, Mantzos et al., 2014).

The herbicide flumioxazin [*N*-(7-fluoro-3,4-dihydro-3-oxo-4-prop-2-ynyl-2H-1,4-benzoxazin-6-yl)cyclohex-1-ene-1,2 -dicarboxamide], belonging to the phthalimide group, also acts to inhibit the protoporphyrinogen oxidase and is registered for potato, sugarcane, maize, onion, garlic, citrus, cotton, coffee, soybean and bean cultivations; it must be applied in the post-emergence of dicot weeds and some monocots. Flumioxazin presents low water solubility (0.786 mg L^{-1}), absence of volatility and usage throughout the year, regardless of the pluviometric regime, as it has low leaching and persistence (DT50 = 17.9 days) in the soil (Ferrell and Vencill, 2003; Rodrigues and Almeida, 2011).

Both mentioned herbicides need to be applied under specific environmental conditions; when used in associations, they potentiate the weed control spectrum. The use of adjuvants, such as mineral oil, is necessary. According to Vieira et al. (2015), the use of adjuvants added to the mixture has helped applying herbicides, since these substances increase the efficiency, protection and absorption of molecules. On the other hand, little is known about the use of mineral oil in the application of pre-emergence herbicides aiming at a better management of weed communities.

Phytosociological surveys are essential for the management of weeds in cultivated areas. These studies allow determining the importance degree of these plants in specific areas through phytosociological indices such as frequency, density, and abundance (Concenço et al., 2013). In order to understand the applicability of these surveys to weed science, as well as their validity, it is necessary to choose appropriate and ecologically based methods, since cultivated areas present a relatively distinct group of selection factors, when compared to natural environments (Gomes et al., 2010; Mendes et al., 2014). Therefore, the goal of this study was to evaluate the interference of mineral oil associated with oxyfluorfen and flumioxazin in the phytosociological survey of weeds.

MATERIAL AND METHODS

The survey was conducted in Tangará da Serra - Mato Grosso state, between March and April 2014; the site had been fallow for two years, after the cultivation of *Brachiaria brizantha* cv. Marandu and maize (*Zea mays*). The soil was classified as Red Latosol according to Embrapa (2013), and the physical-chemical characteristics are described in Table 1.

The randomized block design was used, arranged in a 2 x 5 + 1 factorial design and four replications. Oxyfluorfen + flumioxazin mixtures were evaluated: 240 + 50, 192 + 40, 144 + 30,

Table 1 - Physical-chemical characteristics of the soil used in the test. Tangará da Serra – Mato Grosso state, 2014

pH	Al^{3+}	$H^{+} + Al^{3+}$	$Ca^{2+} + Mg^{2+}$	Ca^{2+}	K^{+}	P
(H_2O)	($cmol_c\ dm^{-3}$)					($mg\ dm^{-3}$)
6.09	0.020	5.94	2.46	1.09	0.24	10.14

OM	CEC	V	Sand	Silt	Clay
($g\ dm^{-3}$)	($cmol_c\ dm^{-3}$)	(%)	($g\ kg^{-1}$)		
10.34	8.64	31.26	253	137	610

96 + 20 and 48 + 10 g a.i. ha^{-1}, with and without the addition of mineral oil (214 g ha^{-1}), including a control sample without the application of herbicides and mineral oil. Before the application, the area had weeds at the vegetative and reproductive stages; harrows were created to facilitate the application of treatments during pre-emergence. Treatments were applied with the help of a CO_2-based backpack sprayer equipped with four XR 110.02 tips and a flow rate of 200 L ha^{-1}. During the application, plots were isolated at a 60 cm height with plastic canvas, in order to avoid the influence of wind.

In order to collect weeds, a sample square measuring 1 m^2 placed in the center of each plot was used, measuring 3 x 4 m and with a height of 0.3 m. Evaluations were conducted 30 days after application (DAA); in each sample, the weeds contained in the squares were counted and identified. The collected plants were classified in situ at family and species level, with the help of specialized literature (Lorenzi, 2014). Due to the great size of the vegetative and reproductive structures of some plants, exsiccates of these botanical samples were not performed.

Data were analyzed according to Martins (1978), calculating plant density (Den), frequency (Fre) and abundance of the species (Abu). Starting from these calculations, the analyses of relative frequency (Frr), relative density (Der) and relative abundance (Abr) were determined, representing the importance of a given species in relation to the sum of importance values within the study area.

The sum of the relative values corresponds to the Importance Value Index (IVI), which establishes an integration parameter of the partial variables, in order to combine them into a single and simple expression, determining the relative importance of each species (Lamprecht, 1964). While calculating phytosociological parameters, the following equations were used:

Fre = (n. of plots containing the species/ total n. of used plots) x 100

Frr = (species frequency/species total frequency) x 100

Den = total n. of individuals per species/total collection area

Der = (species density/total species density) x 100

Abu = total n. of individuals per species/ total n. of plots containing the species

Abr = (species abundance/species total abundance) x 100

IVI = Frr + Der + Abr

In order to calculate the similarity of weed populations, the Similarity Index (SI) (Sorensen, 1972) was used, based on the equation:

S.I. = (2a / b) x 100

where "a" is the number of common species in the area, and "b" represents the total number of species in the area. SI values were expressed as a percentage, where the maximum (100%) represents when all species are common in the area, and the minimum (0%) represents when there are no common weed species.

RESULTS AND DISCUSSION

In the phytosociological survey, 24 weed species were identified, belonging to nine botanical families, composed by Amaranthaceae, Asteraceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Malvaceae, Poaceae and Rubiaceae (Table 2). Species from the Poaceae and Asteraceae families are commonly found in different production areas, such as sugarcane cultures (Oliveira and Freitas, 2008), pastures (Inoue et al., 2012), rice (Silva et al., 2013), coffee (Maciel et al., 2010) and cassava cultures (Pinoti et al., 2010).

Table 3 shows the number of weed species after day 30 DAA from the association of oxyfluorfen and flumioxazin, with and without the addition of mineral oil. In the treatments with oil addition, after the application of oxyfluorfen (240 g ha^{-1}) + flumioxazin (50 g ha^{-1}), the main species found were from the family Poaceae (5), and the least amount of species was from the families Amaranthaceae (1), Commelinaceae (1) and Cyperaceae (1). There are reports in literature that these herbicides do not present satisfactory control on weeds from the genus *Poaceae* (Cesarin et al., 2013, Carvalho et al., 2014), whereas for the other previously mentioned genera there is high efficiency (Rozanski et al., 2004 ; Carvalho et al., 2014).

Table 2 - Weed species identified in the phytosociological survey on day 30 DAA of the combination oxyfluorfen + flumioxazin, with and without the addition of oil. Tangará da Serra - Mato Grosso state, 2014

Family	Botanical code* - Scientific name	Common name
Amaranthaceae	ALRTE - *Alternanthera tenella* Colla	joyweed
	AMAVI - *Amaranthus viridis* L.	slender amaranth
Asteraceae	ACNHI - *Acanthospermum hispidum* DC.	goat's head
	BIDPI - *Bidens pilosa* L.	black jack
	ECLAL - *Eclipta alba* (L.) Hassk.	false daisy
	SENBR - *Senecio brasiliensis* (Spreng.)	flor-das-almas
Commelinaceae	COMBE - *Commelina benghalensis* L.	Benghal dayflower
Cyperaceae	CYPFE - *Cyperus odoratus* L.	fragrant flatsedge
Euphorbiaceae	CVNGL - *Croton glandulosus* L.	sand croton
	PYLTE - *Phyllanthus tenellus* Roxb.	phyllantus
Fabaceae	AESSH - *Aeschynomene denticulata* Rudd.	jointvetch
	AESSH - *Aeschynomene rudis* Benth.	zigzag jointvetch
	CASOB - *Senna obtusifolia* (L.) H.S. Irwin e Barneby	Chinese senna
Malvaceae	SIDCO - *Sida cordifolia* L.	flannel weed
Poaceae	BRADC - *Brachiaria decumbens* Stapf.	Surinam grass
	BRAPL - *Brachiaria plantaginea* (Link) Hitchc.	Alexandergrass
	CCHEC - *Cenchrus echinatus* L.	southern sandbur
	DIGHO - *Digitaria horizontalis* Willd.	Jamaican crabgrass
	ERAPI - *Eragrostis pilosa* (L.) P. Beauv.	Indian lovegrass
	PESAM - *Pennisetum americanum* (L.) Leek	pearl millet
	ZEMAY - *Zea mays* L.	maize
Rubiaceae	DIQTE - *Diodia teres* (Walter) Small	rough buttonweed
	RCHBR - *Richardia brasiliensis* Gomez	tropical Mexican clover
	BOILF - *Spermacoce latifolia* Aubl.	winged false buttonweed

*As described by Lorenzi (2014).

Table 3 - Number of weed species per family on day 30 DAA of the association oxyfluorfen + flumioxazin, with and without the addition of mineral oil. Tangará da Serra - Mato Grosso state, 2014

Family	Number of weed species per treatment												
	With oil addition						Without oil addition						Common species
	A	B	C	D	E	F	A	B	C	D	E	F	
Amaranthaceae	1	1	1	0	0	1	0	0	0	1	1	1	0
Asteraceae	2	0	0	0	2	1	1	1	1	1	3	1	0
Commelinaceae	1	1	0	0	0	1	0	0	0	0	1	1	0
Cyperaceae	1	1	0	1	1	1	0	1	1	1	1	1	0
Euphorbiaceae	0	1	0	2	2	1	1	1	0	0	2	1	0
Fabaceae	0	0	0	1	1	0	0	0	0	2	1	0	0
Malvaceae	0	1	1	1	1	1	1	0	1	1	1	1	0
Poaceae	5	4	4	4	4	3	3	4	5	5	6	3	3
Rubiaceae	0	0	0	2	1	1	1	1	0	2	0	1	0
Total	10	9	6	11	12	10	7	8	8	13	16	10	3

Respective doses of oxyfluorfen + flumioxazin: A: 240 + 50 g ha^{-1}; B: 192 + 40 g ha^{-1}; C: 144 + 30 g ha^{-1}; D: 96 + 20 g ha^{-1}; E: 48 + 10 g ha^{-1}; F: control sample without application.

Doses of oxyfluorfen (192 g ha^{-1}) + flumioxazin (40 g ha^{-1}) for the Poaceae family presented the highest number of weed species (4); however, in the families Amaranthaceae (1), Commelinaceae (1), Cyperaceae (1), Euphorbiaceae (1) and Malvaceae (1) the number of species was lower.

After application of oxyfluorfen (144 g ha^{-1}) + flumioxazin (30 g ha^{-1}), it was verified that the greatest number of weed species was from the Poaceae family (4), while the smallest number was from Amaranthaceae (1) and Malvaceae (1). The highest number of weed species after the use of a oxyfluorfen (96 g ha^{-1}) + flumioxazin (20 g ha^{-1}) dose was from Poaceae (4); on the other hand, Cyperaceae, Fabaceae and Malvaceae had the lowest number of species (1) (Table 3).

It was verified that under both conditions, with and without the addition of 214 g ha^{-1} of mineral oil, the total number of weed species increased, even at the lowest doses of the oxyfluorfen and flumioxazin association. With the addition of oil, the greatest number of weed species (12) was found at the oxyfluorfen + flumioxazin dose (48 + 10 g ha^{-1}). Without the addition of oil, the number of weeds at the same dose (48 + 10 g ha^{-1}) increased to 16 species (Table 3). This fact highlights that the lowest doses of oxyfluorfen and flumioxazin mixture (96 + 20 and 48 + 10 g ha^{-1}) were not enough to provide greater control over the weeds in the area. This can be justified by the behavior of these herbicides in the soil, mainly in the retention and transformation process.

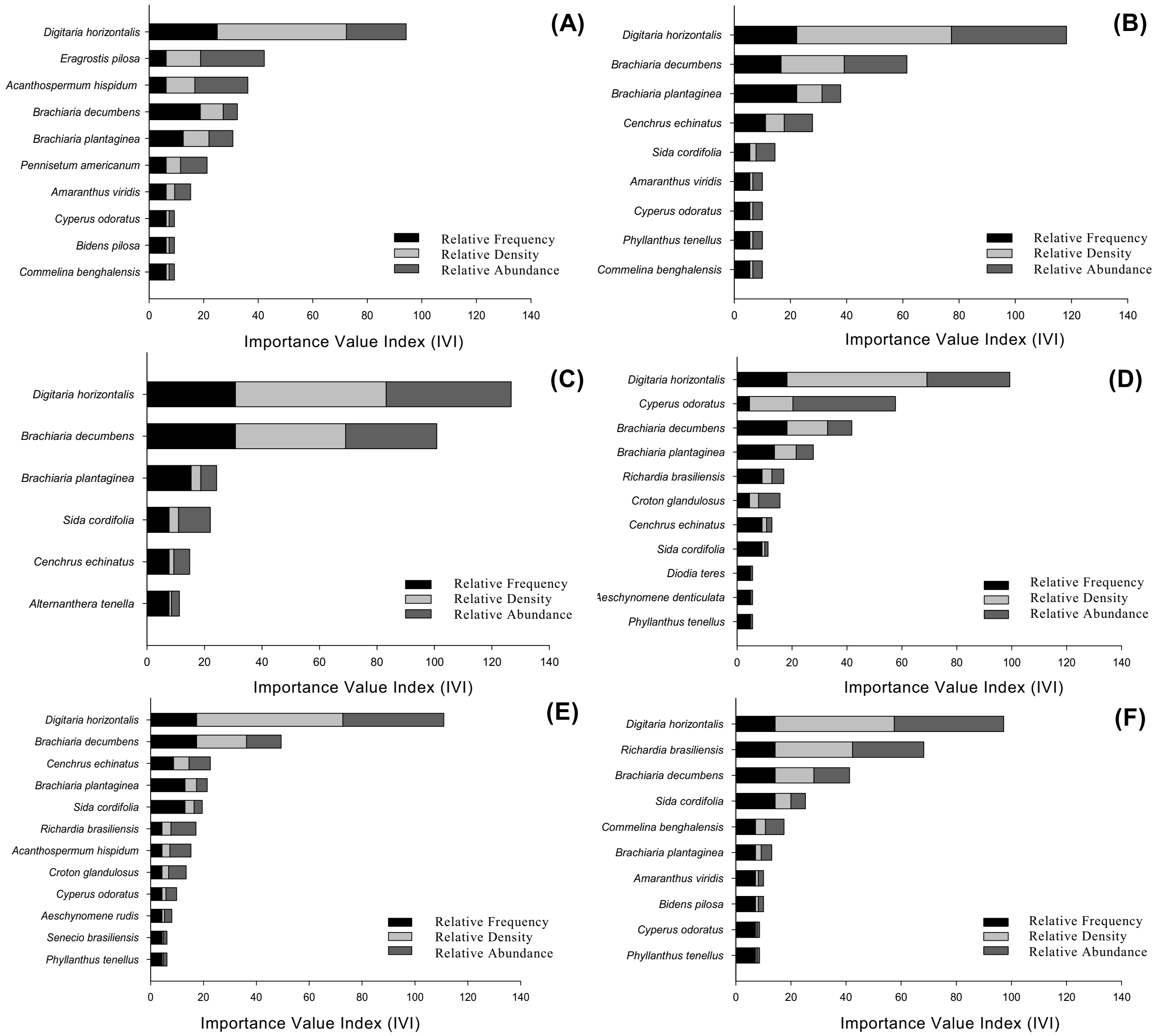
According to Hall et al. (2015), oxyfluorfen has high sorption capacity in the soil; this may have reduced the amount of herbicide available to reach the weeds in the area and provide effective control, in addition to the fact that, in smaller amounts, the degradation of the herbicide becomes more accelerated in the soil. On the other hand, Papiernik et al. (2012) stated that saflufenacil presents low sorption and relatively quick dissipation, which makes this herbicide readily available for degradation or absorption by weed roots. However, the low dose used in this work may have contributed to the quick dissipation of this herbicide and to the non-bioavailability for weeds.

As for the control sample without application (F), the Poaceae family also recorded the greatest number of species (3). In the same treatment, the amount of families increased in relation to the number of species; Amaranthaceae, Asteraceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Malvaceae and Rubiaceae were identified, when compared to the other treatments.

Generally speaking, the number of weed species was lower (58) in the treatment with the addition of mineral oil, in relation to the treatment without this addition (62) (Table 3). Therefore, the addition of mineral oil in the association of these herbicides may have presented a small positive interference compared to the control of the species. According to Vargas and Roman (2006), mineral oils increase the absorption of herbicides due to their direct action on the cuticle of plants, eliminating the barriers that reduce absorption. This may have contributed to increase herbicide efficiency, even at the lowest doses of the mixture oxyfluorfen + flumioxazin.

The mixture of oxyfluorfen and flumioxazin with the addition of mineral oil provided low efficiency in controlling *Digitaria horizontalis* (Jamaican crabgrass); this is confirmed by the high importance value index (IVI) of this species, reaching 100% or more at all the mixture doses (Figure 1). The low efficiency in controlling *D. horizontalis* by the herbicide oxyfluorfen was confirmed by Maciel et al. (2007), where control reached a maximum of 23% in different soil types and modes of absorption. Carvalho et al. (2014) also did not reach an effective control for the genus *Digitaria* with the application of oxyfluorfen on the irrigated onion culture. *D. bicornis* presented intense vegetative growth, providing great dry matter accumulation. However, Jaremtchuk et al. (2009) highlighted that *D. horizontalis* was susceptible to the application of flumioxazin (25 and 40 g ha^{-1}). These facts demonstrate the need for further studies on the biology and management of this weed, as well as for the search for other forms of control.

Despite the predominance of *D. horizontalis*, different IVI values †occurred as doses were altered, with *Brachiaria decumbens* being the second most significant at the doses oxyfluorfen + flumioxazin (192 + 40 g ha^{-1}), oxyfluorfen + flumioxazin (144 + 30 g ha^{-1}) and oxyfluorfen + flumioxazin (48 + 10 g ha^{-1}) (Figure 1). Other species having an IVI above 50% were *Eragrostis pilosa*, *Cyperus odoratus* and *Richardia brasiliensis*, with oxyfluorfen + flumioxazin (240 + 50 g ha^{-1}), oxyfluorfen + flumioxazin (144 + 30 g ha^{-1}) and oxyfluorfen + flumioxazin (48 + 10 g ha^{-1}),



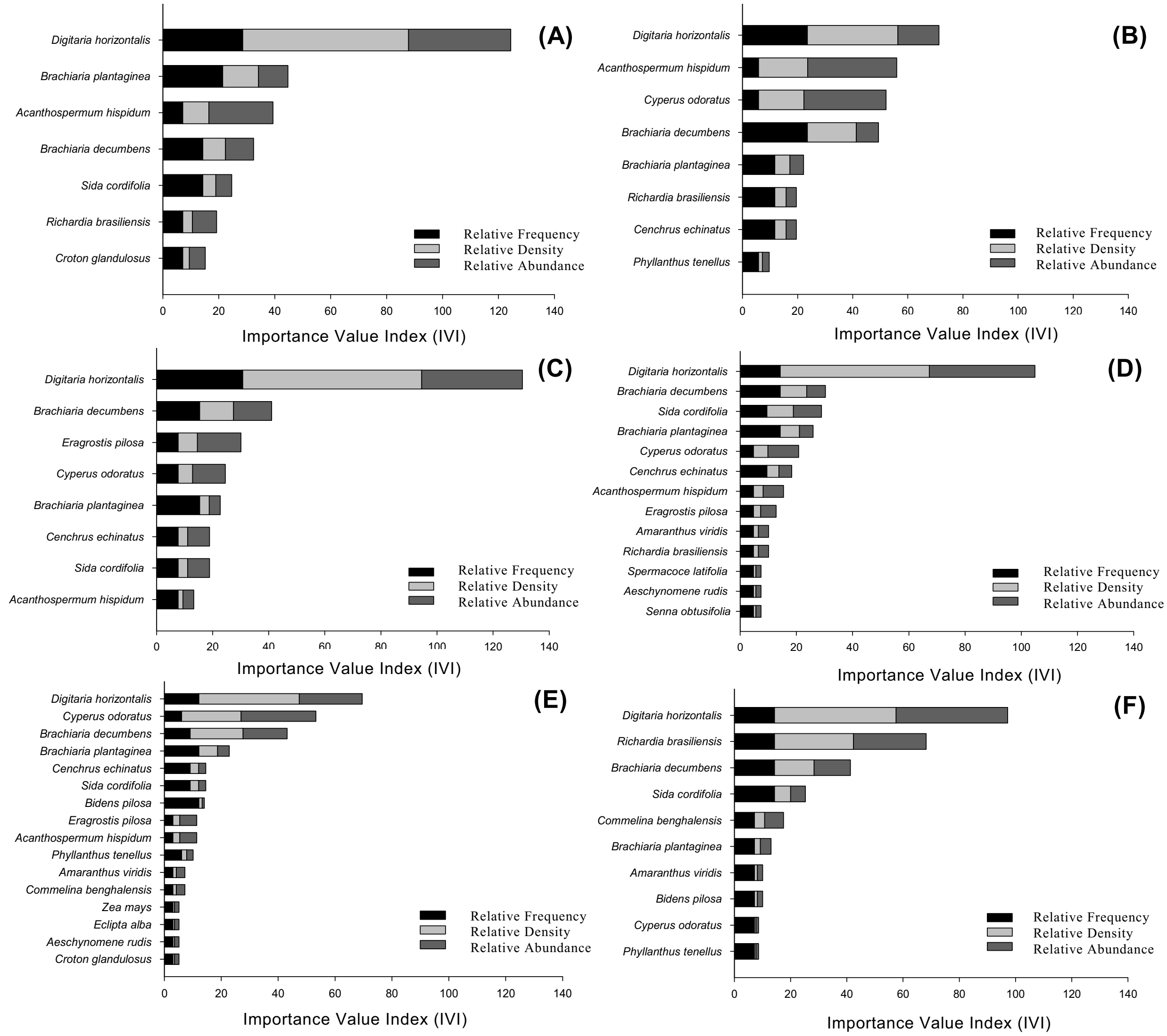
Respective herbicide doses: (A) 240 + 50 g ha^{-1}; (B) 192 + 40 g ha^{-1}; (C) 144 + 30 g ha^{-1}; (D) 96 + 20 g ha^{-1}; (E) 48 + 10 g ha^{-1}; (F) control sample without application.

Figure 1 - Importance value index (IVI) of the main weed species on day 30 DAA of the association oxyfluorfen + flumioxazin, with the addition of mineral oil. Tangará da Serra - Mato Grosso state, 2014.

respectively (Figure 1). Thus, it is possible to observe that there are different responses to the studied herbicides among the species that were found.

Negrisoli et al. (2009) obtained control of up to 100% for *B. decumbens* using oxyfluorfen (720 g ha^{-1}) applied on a sugarcane straw covering; this does not match the results obtained in this experiment, due to the fact that doses were lower. Results from Carbonari et al. (2009) showed that flumioxazin at the dose of 60 g ha^{-1} obtained up to 100% control for *B. decumbens* and *D. horizontalis* in application on maize and oat straw. Therefore, the higher IVI for *B. decumbens* is explained as a consequence of the low doses used in this experiment, which influenced the permanence of the herbicide in the soil and, consequently, the low control efficiency.

At doses of oxyfluorfen + flumioxazin without the addition of oil, the IVI did not change significantly; *D. horizontalis* had an IVI above 100% again (Figure 2). *B. decumbens*, *C. odoratus*, *R. brasiliensis* and *E. pilosa* also stood out for the low control efficacy of oxyfluorfen + flumioxazin on monocots in the study. Moreover, weeds with C4 carbon fixation metabolism can be more competitive due to their high photosynthetic rates, standing out in relation to other weeds with C3 metabolism (Larcher, 2000).



Respective herbicide doses: (A) 240 + 50 g ha^{-1}; (B) 192 + 40 g ha^{-1}; (C) 144 + 30 g ha^{-1}; (D) 96 + 20 g ha^{-1}; (E) 48 + 10 g ha^{-1}; (F) control sample without application.

Figure 2 - Importance value index (IVI) of the main weed species on day 30 DAA of the association oxyfluorfen + flumioxazin, without the addition of mineral oil. Tangará da Serra - Mato Grosso state, 2014.

Through the Similarity Index (SI), it was possible to report that there are similar weed species among the evaluated treatments (Table 4). In both treatments with and without the addition of mineral oil, similarity coefficients were above 50%, indicating the high similarity of the weed community in the area. This may be explained by the fact that the experiment was located in beds close to one another that previously had the same type of soil management.

It is possible to conclude that the addition of mineral oil and the different doses of oxyfluorfen + flumioxazin did not influence the dynamics of the weed population, when compared to the same mixture without mineral oil. The most representative families as for number of species were Poaceae, Asteraceae, Fabaceae and Rubiaceae. The species *D. horizontalis* presented a higher IVI, regardless of the evaluated treatment, followed by *B. decumbens*, *C. odoratus*, *R. brasiliensis* and *E. pilosa*. The similarity index was higher than 50% for the mixture oxyfluorfen + flumioxazin with and without the addition of mineral oil. The fallow study area certainly contributed to the high richness and diversity of weed species found. However, there is the need for other studies in agricultural areas, with an emphasis on the management and control of these species.

Table 4 **-** Phytosociological similarity index (SI) among treatments, on day 30 DAA of the association oxyfluorfen + flumioxazin, with and without the addition of mineral oil. Tangará da Serra - Mato Grosso state, 2014

Treatment		With oil addition						Without oil addition					
		A	B	C	D	E	F	A	B	C	D	E	F
With oil addition	A	100	63	38	27	54	70	47	55	66	61	62	70
	B		100	67	60	67	84	50	70	70	64	72	84
	C			100	59	55	50	62	57	71	53	45	50
	D				100	78	67	67	74	50	58	52	67
	E					100	64	74	80	70	72	71	64
	F						100	59	67	55	61	69	100
Without oil addition	A							100	53	67	60	52	59
	B								100	62	67	58	67
	C									100	76	67	55
	D										100	69	61
	E											100	69
	F												100

Respective doses of oxyfluorfen + flumioxazin: A: 240 + 50 g ha^{-1}; B: 192 + 40 g ha^{-1}; C: 144 + 30 g ha^{-1}; D: 96 + 20 g ha^{-1}; E: 48 + 10 g ha^{-1}; F: control sample without application.

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