Pre-sowing application of combinations of burndown and pre-emergent herbicides for *Conyza* spp. control in soybean

Aplicación en la pre-siembra de mezclas de herbicidas desecantes y pre-emergentes para el control de *Conyza* spp. en la soya

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ABSTRACT

Together, *Conyza bonariensis*, *C. canadensis* and *C. sumatrensis* show 105 reported cases of biotypes resistant to herbicides like glyphosate, paraquat, and acetolactate synthase (ALS) inhibitors. The application of pre-emergent herbicides combined with burndown herbicides is believed to be effective in controlling *Conyza* spp. during soybean pre-sowing management. The objective of this study was to evaluate the efficacy of sulfentrazone/diuron, imazethapyr/flumioxazin, and diclosulam in mixtures with diquat, paraquat, or glufosinate on the control of *Conyza* spp. Two field experiments were conducted in a randomized block design with four replicates. Treatments consisted of the application of pre-emergent plus burndown herbicides, besides the weedy control treatment (without application), for a total of 10 treatments. The control of *Conyza* spp. was evaluated at 7, 14, 21, 28, and 35 d after herbicide application, and symptoms of injury in soybean plants were evaluated at 14, 21, 28, and 35 d after herbicide application. The herbicides sulfentrazone/diuron, imazethapyr/flumioxazin, and diclosulam in combination with burndown herbicides diquat, paraquat, or glufosinate were effective in controlling *Conyza* spp. in the pre-sowing management of soybean, highlighting good options for pre- and post-emergent herbicide rotations. Mixtures with diclosulam showed a higher potential for injury to soybean plants than sulfentrazone/diuron and imazethapyr/flumioxazin.

Key words: diclosulam, flumioxazin, glufosinate, *Glycine max*, imazethapyr, sulfentrazone, weeds.

RESUMEN

Juntas, *Conyza bonariensis*, *C. canadensis* y *C. sumatrensis* presentan 105 casos reportados de biotipos resistentes a herbicidas tales como glifosato, paraquat y los inhibidores de la acetolactato sintasa (ALS). Se cree que la aplicación de herbicidas pre-emergentes en mezclas con desecantes es efectiva para controlar *Conyza* spp. en el manejo pre-siembra de la soya. El objetivo de este estudio fue evaluar la eficacia de sulfentrazona/diuron, imazetapir/flumioxazin y diclosulam, en mezcla con diquat, paraquat o glufosinato, en el control de *Conyza* spp. Se realizaron dos experimentos de campo en diseño de bloques al azar con cuatro repeticiones. Los tratamientos consistieron en la aplicación de herbicidas pre-emergentes en mezclas con desecantes, además del tratamiento control (sin aplicación), para un total de 10 tratamientos. El control de *Conyza* spp. se evaluó a los 7, 14, 21, 28 y 35 d después de la aplicación del herbicida, y se evaluaron los síntomas de daño en las plantas de soya a los 14, 21, 28 y 35 d después de la aplicación del herbicida. Los herbicidas sulfentrazona/diuron, imazetapir/flumioxazin y diclosulam en mezclas con diquat, paraquat o glufosinato, fueron efectivos para controlar *Conyza* spp. en la pre-siembra de la soya, destacando buenas opciones para la rotación de herbicidas antes y después de la emergencia. Las mezclas con diclosulam mostraron un mayor potencial de daño a las plantas de soya que sulfentrazona/diuron y imazetapir/flumioxazin.

Palabras clave: diclosulam, flumioxazin, glufosinato, *Glycine max*, imazetapir, sulfentrazona, malezas.

Introduction

Glyphosate has become the most widely used herbicide in grain crops with the adoption of glyphosate-tolerant crops, such as Roundup Ready® soybean. This intensive use leads to the selection of herbicide-resistant weed biotypes. There are currently 53 weed species with cases of glyphosate-resistant biotypes worldwide (Heap, 2021).

The weeds hairy fleabane (*Conyza bonariensis*), horseweed (*C. canadensis*), and Sumatran fleabane (*C. sumatrensis*) are among the main weeds found worldwide (Trainer *et*

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al., 2005). They are annual herbaceous plants with high seed production and are found in various agricultural environments, such as grain crops (Lorenzi, 2014). Altogether, they have 105 reported cases of biotypes that are resistant to herbicides, such as glyphosate, paraquat, and acetolactate synthase (ALS) inhibitors (Heap, 2021). Recent studies showed that there are biotypes of *C. sumatrensis* with resistance to paraquat (Zobiole *et al.*, 2019) or 2,4-D (Queiroz *et al.*, 2020), and multiple resistance to glyphosate, chlorimuron, and paraquat (Albrecht, Pereira, *et al.*, 2020).

Thus, it is necessary to use other herbicides, such as pre-emergent herbicides, and different modes of action that are effective in controlling hard-to-control weeds, whether herbicide-tolerant or resistant (Mueller *et al.*, 2014). Studies highlight the efficacy of pre-emergent herbicides in controlling *Conyza* spp. in soybeans. These include flumioxazin (Zimmer *et al.*, 2018), diclosulam (Braz *et al.*, 2017), diuron (Moreira *et al.*, 2010), sulfentrazone (Zimmer *et al.*, 2018), and imazethapyr (Hedges *et al.*, 2019).

In addition to the use of pre-emergent herbicides for the effective management of *Conyza* spp., burndown herbicides should be used in combination in situations with the presence of these weeds prior to soybean sowing. Among these herbicides, diquat (Weaver *et al.*, 2004), paraquat, and glufosinate (Zobiole *et al.*, 2018) stand out.

The application of pre-emergent herbicides combined with burndown herbicides is believed to be effective in controlling *Conyza* spp. in the pre-sowing management of soybean. Therefore, the present study aimed at evaluating the efficacy of pre-emergent herbicides sulfentrazone/diuron, imazethapyr/flumioxazin, and diclosulam in combination with burndown herbicides diquat, paraquat, or glufosinate on the control of *Conyza* spp.

Materials and methods

Two field experiments were carried out in the city of Palotina, state of Parana, Brazil, at coordinates 24°20'44.54" S, 53°51'50.93" W (experiment 1) and 24°20'48.89" S, 53°51'37.58" W (experiment 2) during the 2018-19 growing season.

For both experiments, the soil was classified as clay texture, with 63% clay, 19% silt, and 15% sand. The climate of the region is temperate humid with hot summers (Cfa), according to the Köppen classification (Aparecido *et al.*, 2016), and the weather conditions for the experimental period are illustrated in Figure 1. The area in experiment 1 was previously cultivated with maize and in experiment 2 with wheat. Both areas were infested with *Conyza* spp. plants up to 15 cm high and with 16 leaves. No flowering plants were observed at the time of application, and plant density was 17 and 20 *Conyza* plants m^{-2} in experiments 1 and 2, respectively.

The treatments consisted of different herbicide applications in a randomized block design with four replicates (Tab. 1). Application of treatments occurred on October 15, 2018 with sowing of soybean cultivar Monsoy® 5947 IPRO (Monsanto Co. do Brasil, São Paulo, SP, Brazil) on the same day, immediately after application. Herbicides were applied using a CO_2 pressurized backpack sprayer (Pulverizador Pesquisa - Herbicat Ltda, Catanduva, SP, Brazil) equipped with six AIXR 110.015 nozzles at a pressure of 2.5 kgf cm^{-2}

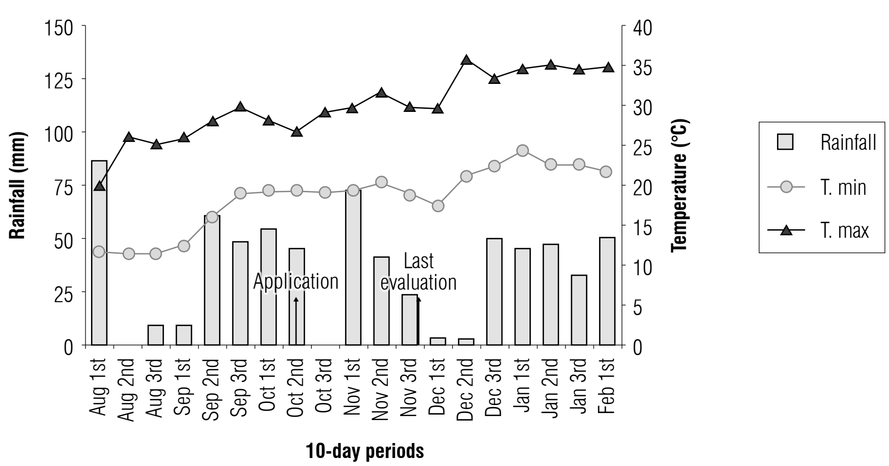

FIGURE 1. Rainfall and minimum and maximum temperature for the experimental sites. 2018/19 season, Palotina, PR, Brazil.

and a speed of 3.6 km/h, providing an application volume of 150 L ha^{-1}. For experiment 1, the climatic conditions during the application were as follow: temperature of 27.3ºC, relative air humidity of 61.5%, and wind speed of 6.4 km/h. For experiment 2, the conditions were as follow: temperature of 29.5ºC, relative air humidity of 60.2%, and wind speed of 7.0 km/h.

The experimental units were composed of 3 x 5 m parcels; soybean sowing was carried out after the application of the treatments with 13 seeds m^{-1}. Six soybean lines were sown in each parcel with a spacing of 0.45 m. The evaluations were carried out in the useful area of the parcel, discarding the external lines and the first and last meters.

The control of *Conyza* spp. plants was assessed at 7, 14, 21, 28, and 35 d after herbicide application (DAA). Injury symptoms in soybean plants were assessed at 14, 21, 28 and 35 DAA. These assessments were carried out through visual analysis at each experimental unit considering significantly visible symptoms in the plants, according to their development. Scores from 0 to 100% were assigned, where 0 represented the absence of symptoms and 100% the death of the plant (Velini *et al*., 1995). The treatment without application (without herbicide effect) was used as a reference for evaluations, always with a score of 0, whether for weed control or injuries to soybean plants, as in other studies (Braz *et al*., 2017; Chahal & Jhala, 2019; Guerra *et al*., 2020).

Data were tested by analysis of variance and F-test ($P \leq 0.05$) according to Pimentel-Gomes and Garcia (2002). The means of the treatments were compared by the Tukey test ($P \leq 0.05$) using the Sisvar 5.6 program (Ferreira, 2011).

Results

In experiment 1, all herbicide treatments were effective in controlling *Conyza* spp., with values higher than or equal to 83.8% at 7 DAA for all treatments. No differences were detected between herbicide treatments, and all of them were superior to the weedy control treatment (without application) throughout all evaluations. It is worth noting the control for all combinations at 35 DAA with values of at least 94.3% (Tab. 2).

As observed for experiment 1 (area previously cultivated with maize), in experiment 2 (area previously cultivated with wheat) herbicide treatments were effective in controlling *Conyza* spp. with no differences between combinations from 21 to 35 DAA. Some differences were observed between herbicide treatments at 7 and 14 DAA; however, all exhibited weed control of at least 89.0%. At 35 DAA, a control of *Conyza* spp. of at least 94.8% was observed for all herbicide treatments (Tab. 3).

For experiment 1, at 14 DAA, no differences were detected between treatments regarding injury symptoms in soybean plants. Treatments with diclosulam caused stronger symptoms, up to 10.3% at 21 DAA; these were superior to almost all other treatments from 21 to 35 DAA. For the treatments composed of the application of sulfentrazone/diuron and imazethapyr/flumioxazin, injury symptoms were 3.8% to 4.3% and 2.3% to 2.5%, respectively at 35 DAA (Tab. 4).

TABLE 1. Herbicide mixture treatments applied in pre-sowing of soybean to control *Conyza* spp. 2018/19 season, Palotina, PR, Brazil.

Treatments	Trade names	Rate*
Weedy control (without application)	-	-
Sulfentrazone/diuron + paraquat	Stone® + Gramoxone® 200	245/490 + 400
Sulfentrazone/diuron + diquat	Stone® + Reglone®	245/490 + 400
Sulfentrazone/diuron + glufosinate	Stone® + Finale®	245/490 + 500
Imazethapyr/flumioxazin + paraquat	Zhetamaxx® + Gramoxone® 200	100/50 + 400
Imazethapyr/flumioxazin + diquat	Zhetamaxx® + Reglone®	100/50 + 400
Imazethapyr/flumioxazin + glufosinate	Zhetamaxx® + Finale®	100/50 + 500
Diclosulam + paraquat	Spider® 840 WG + Gramoxone® 200	25 + 400
Diclosulam + diquat	Spider® 840 WG + Reglone®	25 + 400
Diclosulam + glufosinate	Spider® 840 WG + Finale®	25 + 500

*Rates at g of acid equivalent (ae) ha^{-1} for imazethapyr and at g of active ingredient (ai) ha^{-1} for the other herbicides. Addition of 0.5% mineral oil to all treatments.

TABLE 2. Control (%) of *Conyza* spp. from 7 to 35 d after application of herbicide mixtures (DAA). 2018/19 season, Palotina, PR, Brazil (experiment 1).

Treatments	7 DAA*	14 DAA*	21 DAA*	28DAA*	35 DAA*
Weedy control (without application)	0.0 b	0.0 b	0.0 b	0.0 b	0.0 b
Sulfentrazone/diuron + paraquat	84.5 a	89.5 a	92.5 a	95.8 a	96.3 a
Sulfentrazone/diuron + diquat	85.0 a	91.5 a	95.8 a	96.0 a	96.8 a
Sulfentrazone/diuron + glufosinate	84.0 a	93.8 a	95.8 a	96.3 a	96.5 a
Imazethapyr/flumioxazin + paraquat	85.8 a	88.0 a	94.0 a	95.5 a	95.0 a
Imazethapyr/flumioxazin + diquat	85.3 a	91.3 a	93.0 a	94.0 a	94.3 a
Imazethapyr/flumioxazin + glufosinate	86.0 a	94.3 a	95.5 a	96.3 a	95.5 a
Diclosulam + paraquat	84.3 a	91.3 a	94.5 a	96.5 a	96.3 a
Diclosulam + diquat	89.0 a	94.0 a	96.3 a	97.3 a	97.0 a
Diclosulam + glufosinate	83.8 a	93.3 a	96.8 a	96.8 a	96.8 a
Mean	76.8	82.7	85.4	86.4	86.4
CV (%)	2.9	4.1	4.0	3.8	3.2

*Means followed by the same letter in the line do not differ from each other according to the Tukey test at the 5% probability level. CV - coefficient of variation.

TABLE 3. Control (%) of *Conyza* spp. from 7 to 35 d after application of herbicide mixtures (DAA). 2018/19 season, Palotina, PR, Brazil (experiment 2).

Treatmentts	7 DAA*	14 DAA*	21 DAA*	28 DAA*	35 DAA*
Weedy control (without application)	0.0 c	0.0 d	0.0 b	0.0 b	0.0 b
Sulfentrazone/diuron + paraquat	90.0 ab	91.5 bc	95.3 a	97.0 a	96.3 a
Sulfentrazone/diuron + diquat	92.8 ab	94.0 abc	97.0 a	97.0 a	96.8 a
Sulfentrazone/diuron + glufosinate	91.5 ab	96.0 a	96.3 a	98.5 a	98.3 a
Imazethapyr/flumioxazin + paraquat	92.0 ab	92.5 abc	94.3 a	95.8 a	94.8 a
Imazethapyr/flumioxazin + diquat	91.3 ab	90.5 c	95.0 a	97.0 a	96.8 a
Imazethapyr/flumioxazin + glufosinate	91.5 ab	93.5 abc	95.0 a	96.0 a	97.3 a
Diclosulam + paraquat	91.5 ab	96.0 a	96.3 a	96.5 a	96.5 a
Diclosulam + diquat	93.8 a	94.5 ab	96.5 a	96.8 a	96.8 a
Diclosulam + glufosinate	89.0 b	95.3 ab	96.8 a	97.3 a	96.8 a
Mean	82.3	84.4	86.2	87.2	87.1
CV (%)	2.1	1.9	3.0	2.1	2.4

*Means followed by the same letter in the line do not differ from each other according to the Tukey test at the 5% probability level. CV - coefficient of variation.

TABLE 4. Crop injury (%) of soybean plants from 14 to 35 d after application of herbicide mixtures (DAA). 2018/19 season, Palotina, PR, Brazil (experiment 1).

Treatments	14 DAA ^{ns}	21 DAA*	28 DAA*	35 DAA*
Weedy control (without application)	0.0	0.0 a	0.0 a	0.0 a
Sulfentrazone/diuron + paraquat	4.3	7.3 bc	6.5 d	4.3 d
Sulfentrazone/diuron + diquat	3.0	6.3 b	6.0 cd	3.8 bcd
Sulfentrazone/diuron + glufosinate	3.0	7.0 bc	6.3 d	4.0 cd
Imazethapyr/flumioxazin + paraquat	3.3	5.3 b	4.3 b	2.3 b
Imazethapyr/flumioxazin + diquat	3.5	6.0 b	4.8 bc	2.5 bc
Imazethapyr/flumioxazin + glufosinate	3.0	6.0 b	4.5 b	2.5 bc
Diclosulam + paraquat	2.8	9.3 cd	8.5 e	6.5 e
Diclosulam + diquat	3.0	9.3 cd	8.5 e	6.3 e
Diclosulam + glufosinate	4.5	10.3 d	8.8 e	6.5 e
Mean	3.0	6.7	5.8	3.9
CV (%)	21.2	14.8	9.2	18.2

*Means followed by the same letter in the line do not differ from each other according to the Tukey test at the 5% probability level. ns - not significant, means do not differ from each other by the F-test at the 5% probability level. CV - coefficient of variation.

TABLE 5. Crop injury (%) of soybean plants from 14 to 35 d after application of herbicide mixtures (DAA) during the 2018/19 season, Palotina, PR, Brazil (experiment 2).

Treatments	14 DAA*	21 DAA*	28 DAA*	35 DAA*
Weedy control (without application)	0.0 a	0.0 a	0.0 a	0.0 a
Sulfentrazone/diuron + paraquat	2.8 bc	7.5 d	7.8 c	4.5 cde
Sulfentrazone/diuron + diquat	2.3 bc	7.0 d	7.8 c	5.0 def
Sulfentrazone/diuron + glufosinate	2.5 bc	7.0 cd	7.8 c	4.3 cd
Imazethapyr/flumioxazin + paraquat	1.5 b	4.3 b	4.0 b	2.0 ab
Imazethapyr/flumioxazin + diquat	2.3 bc	5.3 bc	5.0 b	2.8 bc
Imazethapyr/flumioxazin + glufosinate	2.0 bc	5.0 b	5.5 b	2.8 bc
Diclosulam + paraquat	2.3 bc	7.8 d	9.0 c	6.5 ef
Diclosulam + diquat	2.3 bc	4.8 b	5.3 b	3.3 bcd
Diclosulam + glufosinate	3.0 c	7.8 d	9.0 c	6.8 f
Mean	2.1	5.7	6.1	3.8
CV (%)	25.7	14.0	14.3	23.0

*Means followed by the same letter in the line do not differ from each other according to the Tukey test at the 5% probability level. CV - coefficient of variation.

Table 5 shows the injury symptoms in soybean plants due to herbicide application for experiment 2. Differences between treatments were observed in all evaluations. Symptoms were up to 9% (at 28 DAA), while at the last assessment (35 DAA) they ranged from 2.0% to 6.8%, in general with greater potential for injury to the application of diclosulam.

Discussion

In this study, the pre-sowing application of sulfentrazone/diuron (premix formulation) in combination with diquat, paraquat, or glufosinate was effective in controlling *Conyza* spp. Similar results were observed by Zimmer *et al.* (2018), where pre-sowing application of sulfentrazone (195 g ai ha^{-1}) in a mixture with halauxifen (5 g ai ha^{-1}) + glyphosate (1,120 g ae ha^{-1}) + cloransulam (25 g ai ha^{-1}) provided 94% control of *C. canadensis* at 35 d after application. Sulfentrazone was effective in different management programs to control *Amaranthus tuberculatus* (Schryver *et al.*, 2017) and other weeds. Sulfentrazone has a variable half-life (34-116 d) according to soil moisture and temperature and is less persistent under conditions of higher humidity and higher temperature (40°C); these aspects interfere with its residual period (Brum *et al.*, 2013). Additionally, sulfentrazone has a spectrum of action on eudicotyledonous weeds and some grasses (Rodrigues & Almeida, 2018). These studies, and the results of the present study, indicate the effectiveness of sulfentrazone in different mixtures on the control of weeds.

The application of diuron with mixtures was effective in controlling *Conyza* spp. in the present study. In other research, a control of 91% of *C. bonariensis* at 30 DAA was observed with the application of diuron (200 g ai ha^{-1}) at mixtures (Paula *et al.*, 2011). Other studies also highlight the effectiveness of diuron in controlling *Conyza* spp. in different combinations (Lamego *et al.*, 2013; Santos *et al.*, 2015). Diuron is an herbicide that is especially effective for the control of eudicotyledons and some grasses. In the present study, diuron was effective in controlling *Conyza* spp. in a premixture with sulfentrazone. The half-life can vary from 40 to 91 d and is generally more persistent in soils with higher levels of clay and organic matter (Rocha *et al.*, 2013). This characteristic helps to explain the results of this study.

The pre-sowing application of imazethapyr/flumioxazin (premix formulation) was also effective for controlling *Conyza* spp. in this study. Similar results were observed by Albrecht, Albrecht, *et al.* (2020), who found that this premix formulation obtained a control of about 80% of *Conyza* spp. up to 35 DAA. Imazethapyr has a soil half-life varying from 36 to 98 d (Marinho *et al.*, 2019), and flumioxazin from 13 to 18 d (Ferrell & Vencill, 2003), according to the edaphoclimatic conditions. The persistence of imazethapyr helps to explain the effectiveness of this mixture over time, especially in the emergence of plants.

Pre-sowing application of imazethapyr (100 g ae ha^{-1}) in a mixture with glyphosate, dicamba, and saflufenacil provided 93% control of *C. canadensis* 12 weeks after application (Hedges *et al.*, 2019). This herbicide, in mixture with saflufenacil, is also effective in controlling *Abutilon theophrasti*, *Amaranthus retroflexus,* and *Chenopodium album* (Underwood *et al.*, 2017). Pre-sowing application of flumioxazin (76 g ai ha^{-1}) in combination with halauxifen (5 g ai ha^{-1}) + glyphosate (1,120 g ae ha^{-1}) + cloransulam (25 g ai ha^{-1}), following glyphosate application (1,120 g ae ha^{-1}) in post-emergence soybean, provided 96% control of *C. canadensis* at 35 d after the first application (Zimmer *et al.*, 2018). The results of the present study corroborated these findings, indicating the effectiveness of imazethapyr/flumioxazin in different chemical control programs.

In the present study, diclosulam was also effective in controlling *Conyza* spp. in combination with diquat, paraquat, or glufosinate. In general, no significant differences were observed between the management adopted for the control of *Conyza* spp. in initial post-emergence (plants up to 15 cm high) and pre-emergence. This highlights the importance of rotation of mechanisms of action not only in post-emergence, but also in pre-emergence.

Diclosulam is one of the most widely used herbicides in soybean pre-sowing for controlling *Conyza* spp. and other weeds. Krenchinski *et al.* (2019) report control of up to 97.25% of *Conyza* spp. for diclosulam applied at pre-sowing in soybean, plus halauxifen + glyphosate. Other studies also report the control of *Conyza* spp. with the application of diclosulam in different combinations (Braz *et al.*, 2017; Zobiole *et al.*, 2018). This herbicide has a soil half-life varying from 16 to 87 d, according to the edaphoclimatic conditions (Lavorenti *et al.*, 2003) and provides a broad-spectrum control (Rodrigues & Almeida, 2018).

The results of this study indicated that glufosinate may be an alternative in the management of *Conyza* spp. as a tool for preventing resistance to herbicides. In this sense, it is worth mentioning the recent cases of a *C. sumatrensis* biotype reported to be resistant to paraquat (Zobiole *et al.*, 2019) or with multiple resistance to glyphosate, chlorimuron, and paraquat (Albrecht, Pereira, *et al.*, 2020) in the state of Parana, Brazil. Paraquat is a photosystem I inhibitor herbicide with the same mechanism of action as that of diquat. These two herbicides are among the main desiccants for pre-sowing application in soybean.

Several studies also highlight the efficacy of glufosinate in controlling *Conyza* spp. (Oliveira Neto *et al.*, 2010; Tahmasebi *et al.*, 2018; Zobiole *et al.*, 2018; Albrecht, Albrecht, *et al.*, 2020). This herbicide is also effective in controlling other weeds, such as *Amaranthus* spp. (Hay *et al.*, 2019), *Spermacoce latifolia* and *Richardia brasiliensis* (Gallon *et al.*, 2019). Glufosinate can be used in pre-sowing, as in the present study, and in post-emergence of tolerant transgenic cultivars (soybean, maize, and cotton with *pat* or *bar* genes).

Regarding symptoms of injury, diclosulam showed higher phytotoxic potential, especially in experiment 1, with symptoms of up to 10.3%. For the other pre-emergent herbicides, minor injuries were observed in the soybean plants. Different studies also report injury symptoms in soybean with the application of diclosulam (Osipe *et al.*, 2014; Braz *et al.*, 2017). However, plants recover from the symptoms with no effect on the agronomic performance, and this proves the selectivity of the herbicide.

Belfry *et al.* (2016) found symptoms of 8% and 2% injury for pre-sowing application of flumioxazin and sulfentrazone, respectively. Belfry *et al.* (2015) also observed symptoms of 8% and 4% injury for pre-sowing application of flumioxazin and imazethapyr, respectively. Braswell *et al.* (2015) observed up to 15% soybean injury for pre-sowing application of diuron. For these herbicides, injury symptoms up to a maximum of 5% were observed in soybean plants at the end of the evaluations. These results confirm the potential selectivity of pre-emergent herbicides for soybeans.

Conclusions

Based on the results of this study we can conclude that it is important to rotate both post-emergent and pre-emergent herbicides since there have been several reports of resistance to glyphosate and ALS inhibitors that are widely used in pre-emergence. We would like to highlight the equivalence of the different herbicide combinations in the control of *Conyza* spp. in this study, after growing maize (experiment 1) or wheat (experiment 2).

The herbicides sulfentrazone/diuron, imazethapyr/flumioxazin, and diclosulam in mixtures with burndown herbicides (diquat, paraquat or glufosinate) were effective in controlling *Conyza* spp. at pre-sowing of soybean. The choice of pre-emergent or burndown herbicides must consider the history of use of the area, the weed community, and the cost of management, among other factors. Regardless of the choice, pre-emergent herbicides in combinations with burndown herbicides are important tools for the effective management of weeds.

This study fills a gap in the research since studies with the premixes sulfentrazone/diuron and imazethapyr/flumioxazin are not easily found in the literature in contrast to other products. Glyphosate was not used in this study, which characterizes the management adopted as an alternative to this herbicide.

Author's contributions

AJPA, LPA, SNRA and AAMB designed and conceptualized the experiments; WOS, JBL and MTYD carried out the experiments, and AFMS contributed to the data analysis and wrote the article. All authors reviewed the manuscript.

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