CROP MANAGEMENT AND ITS EFFECTS ON WEED OCCURRENCE

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Abstract

The objective was to evaluate weed phytosociology and similarities between crop management systems in the Chapadões region. The experiment was conducted at in agricultural area located in the municipality of Chapadão do Sul, MS, during the 2016/17 harvest. Three crop managements strategies were used: (1) cotton/soybean/Urochloa, (2) millet/soybean/millet and (3) millet/soybean/crotalaria. A phytosociological survey of weeds was carried out during soybean cultivation and cover crops growth, in succession. The evaluation area for each management strategy was 0.5 ha. Soybean surveys were carried out in October and January, while the cover crop surveys were performed in February and May. The relative frequency (RF), relative density (RD), relative abundance (AR), and relative importance (RI) of weeds, Venn diagram, and Jaccard and Sorenson similarity indices were evaluated. The management area represented by the cotton/soybean/Urochloa rotation had fewer weed species than others. The species Cenchrus echinatus, Digitaria insularis, Digitaria sanguinalis, Eleusine indica and Commelina benghalensis had the highest phytosociological indeces among the monocotyledons. Attention is required for managing the dicotyledons Amaranthus deflexus, Conyza canadensis and Senna obtusifolia despite their low indices because of herbicide resistant cases. The highest indeces of similarity were found between managements areas 2 and 3, which did not rely on cotton cultivation prior to soybeans.

Keywords: Germination Flow. Monocotyledons. Phytosociology. Seed Bank.

1. Introduction

Competition with weeds affects crop development by reducing access to resources such as water, light, and nutrients (Brighenti 2010), thereby resulting in decreased crop productivity (Braz et al. 2010) and consequently, economic losses (Vendruscolo et al. 2017). Identifying species as well as understanding their cycles, propagation methods, and growth habits within conventional or direct sowing systems enables the adoption of management strategies, thus minimizing losses (Adegas et al. 2010; Santos et al. 2015), which can range from 23%–70% of grain productivity (Vidal and Merotto Júnior 2001). In cultivated areas with different cultures, monocot and dicot weed species have been observed to be predominantly from the families Poaceae and Asteraceae, respectively (Silva et al. 2019; Ávila et al. 2020; Machado et al., 2020; Santos et al. 2015; Schmidt et al. 2020).

It is important to study weed communities (Pitelli 2015) to understand competition between them. It is important to examine whether competition is intraspecific or interspecific in order to devise more efficient control strategies (Santos et al. 2015), because no single herbicide has sufficient action spectrum to control all weed species (Brighenti et al. 2003). Thus, knowledge of weed communities in cultivated areas can facilitate their chemical management. It is important to note that the use of herbicides can have a major effect on production costs (Richetti 2015), can affect entire ecosystems (Myers et al. 2016; Van Bruggen et al. 2018), and can select weeds in the area, due to successive application of glyphosate. (Procópio et al. 2007). It is therefore important to prioritize the diversified use of herbicides with different active principles (Soares et al. 2010).

Knowledge of species diversity is important to understanding weed dynamics in relation to crops during different growing seasons. To gain this knowledge, phytosociological surveying is performed, which comprises the study of plant communities to establish a comprehensive understanding of the composition and distribution of plant species in an area (Guglieri-Caporal et al. 2010; Concenço et al. 2013). However, when crop rotation or succession is performed, it is necessary to determine which crops will result in a positive relationship of phytosociological indices for weed management (Ferreira et al. 2010).

Occupying agricultural areas with off-season crops potentiates weed suppression compared to allowing areas to remain fallow (Lima et al. 2014). Alternate cultivation systems can be adopted such as harvest/interim/harvest, or harvest/green/manure. The mulch left by the previous crop is a physical control, which has an important role in weed control (Castro et al. 2011). The total weed population can be significantly affected by mulch levels (Lima et al. 2014), regardless of the presence of herbicide, or the evaluation period. Each ton of cover added to the soil can lead to the control of ~4.0% of the total weeds (Oliveira et al. 2001).

Understanding germinal flow dynamics, phytosociological characteristics of weeds within a complex production system characterized by large agricultural areas, and associated management strategies (ranging from crop rotation or succession to the rotation of active ingredients) facilitates formulation of the most appropriate weed management strategies. Thus, the objective of this study was to evaluate weed phytosociology and similarities between crop management systems in the Chapadões region.

2. Material and Methods

The study was performed in the *Fazenda Campo Bom* agricultural area, located in the municipality of Chapadão do Sul, MS, which has an average altitude of 810 m, during the 2016/2017 harvest. The climate is humid tropical (Aw) according to the Köppen classification, with well-defined seasons; a dry period exists from May–September (autumn/winter), and rainfall happens from October–April (spring/summer). Its annual temperature varies between 13 °C and 28 °C, average precipitation is 1,850 mm, and average annual relative humidity is 64.8% (Castro et al. 2012). Rainfall data and monthly air temperature were recorded during the experiment (Figure 1).
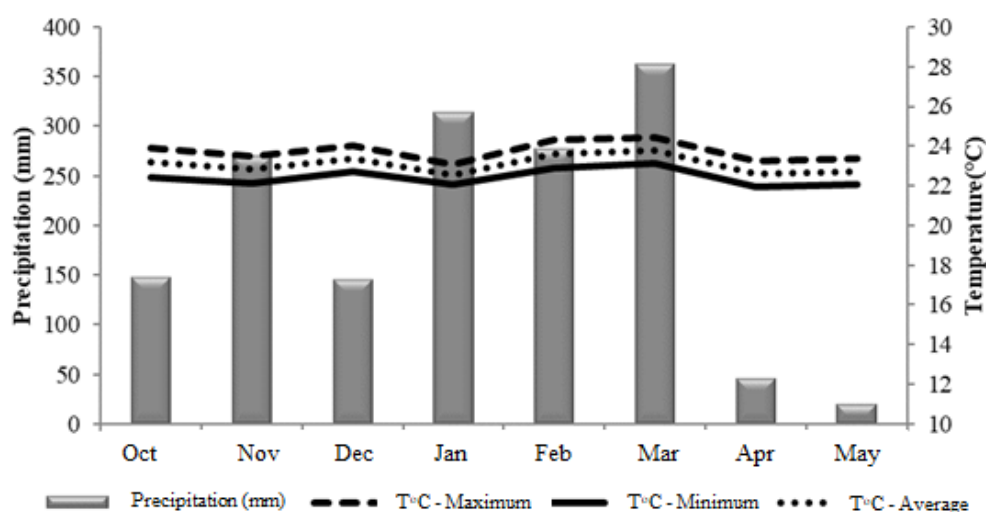

Figure 1. Precipitation (mm) and average monthly temperature (ºC) during the study period.

Three crop management strategies were used to assess the germinal flows and to characterize the phytosociological indices: (1) cotton/soybean/*Urochloa decumbens*; (2) millet/soybean/millet; and (3) millet/soybean/*Crotalaria*. The phytosociological surveys were carried out during soybean crop management, and in cover crops during soybean succession. During the soybean crop cultivation, phytosociological surveys of weeds occurred in October, 15 days after emergence (DAE) while the crop was in stage V2, and in January, at 95 DAE with the crop in stage R7.

For the soybean harvest, the area was desiccated, and the cover crops were then planted in the management groups (1) *U. decumbens*, (2) millet, and (3) *Crotalaria*. Phytosociological weed surveys in the cover crops were then carried out in February and May.

For the weed survey, 0.5 ha areas were demarcated for each management group. Glyphosate potassium and Clethodim herbicides were used during soybean cultivation.

To measure and identify the weed species present in the evaluation area, Braun-Blanquet's (1979) square method was used, which involves randomly choosing and evaluating 1 m². The frequency, relative frequency, density, relative density, abundance, relative abundance, and relative importance index for each species were then calculated for each system, and for each weed, according to the formulas proposed by the Mueller-Dombois and Ellenberg (1974) methodology.

$$\text{Frequency (F)} = \frac{\text{no. of squares where the species was found}}{\text{total no. of squares}}$$

$$\text{Relative Frequency (RF)} = \frac{\text{frequency of the species x 100}}{\text{total frequency of the species}}$$

$$\text{Density (D)} = \frac{\text{total no. of individuals of a species}}{\text{total no. of squares}}$$

$$\text{Relative Density (RD)} = \frac{\text{density of the species x 100}}{\text{total density of the species}}$$

$$\text{Abundance (A)} = \frac{\text{total no. of individuals of a species}}{\text{total no. of squares where the species was found}}$$

$$\text{Relative Abundance (RA)} = \frac{\text{abundance of the species x 100}}{\text{total abundance of the species}}$$

$$\text{Relative Importance Index (RI)} = (RF) + (RD) + (RA)$$

A floristic similarity analysis was also carried out using a Venn diagram (Figure 2), which uses superimposed circles to illustrate the logical relationships between two or more sets of items, highlighting how the items are similar and different. The DivEs v4.0 program (Rodrigues 2017) was also used to calculate the Sorensen (SI) and Jaccard (JS) similarity indices (Table 5), and provided the calculated floristic similarity between the three management areas during the surveyed months; index values range from 0–1; 1 when all species are common and 0 when there are no common species (Odum 1985).

3. Results

A total of 4267 weeds, comprising 25 species and distributed in 12 families (Table 1), were recorded in the weed community surveyed during the studied months. Where soybeans were present monocotyledon classes prevailed, comprising 81% of species. For the cover crops *Urochloa decumbens*, millet, and *Crotalaria*, the dicotyledons predominated, comprising 52% of the weeds found, in relation to monocotyledons (48%).

Table 1. Scientific names, common names, families, and botanical classes of the 25 weed species found in the rotation system. Chapadão do Sul, MS, 2016/2017.

Scientific name	Family	Class
Urochloa decumbens	Poaceae	Monocotyledon
Urochloa mutica	Poaceae	Monocotyledon
Cenchrus echinatus	Poaceae	Monocotyledon
Digitaria insularis	Poaceae	Monocotyledon
Digitaria sanguinalis	Poaceae	Monocotyledon
Eleusine indica	Poaceae	Monocotyledon
Eragrostis pilosa	Poaceae	Monocotyledon
Pennisetum purpureum	Poaceae	Monocotyledon
Commelina benghalensis	Commelinaceae	Monocotyledon
Cyperus rotundus	Cyperaceae	Monocotyledon
Alternanthera tenella	Amaranthaceae	Dicotyledone
Amaranthus deflexus	Amaranthaceae	Dicotyledone
Acanthospermum hispidum	Asteraceae	Dicotyledone
Bidens pilosa	Asteraceae	Dicotyledone
Conyza canadensis	Asteraceae	Dicotyledone
Taraxacum officinale	Asteraceae	Dicotyledone
Ageratum conyzoides	Asteraceae	Dicotyledone
Ipomoea triloba	Convolvulaceae	Dicotyledone
Chamaesyce hirta	Euphorbiaceae	Dicotyledone
Euphorbia heterophylla	Euphorbiaceae	Dicotyledone
Senna obtusifolia	Fabaceae	Dicotyledone
Sida rhombifolia	Malvaceae	Dicotyledone
Phyllanthus niruri	Phyllantaceae	Dicotyledone
Portulaca oleracea	Portulacaceae	Dicotyledone
Richardia brasiliensis	Rubiaceae	Dicotyledone

In the first weed survey for soybean crop at 15 DAE, the number of species found in management area 1 (cotton/soybean/*Urochloa*) was lower than found in treatments 2 (millet/soybean/millet) and 3 (millet/soybean/*Crotalaria*) (Table 2). Thus, the first survey in management area 1 demonstrated that weeds such as *D. insularis, E. indica,* and *C. benghalensis*, (with relative frequency and density indices above 10% (Table 2)) are plants that are well distributed, and have high populations in the area; this fact was maintained in the last survey with the inclusion of *D. sanguinalis* (Table 3).

At 95 DAE, *S. obtusifolia* was observed within management areas 2 and 3, with frequency and density indices of 45.3% and 14.2%, respectively (Table 3); indices increased in relation to soybean development (Tables 2 and 3).

Table 2. Species, relative frequency (RF), relative density (RD), relative abundance (RA), and relative importance (RI) of weeds under different management strategies at 15 DAE in a soybean crop in Chapadão do Sul, MS, 2016/2017.

October (15 DAE)												
	Management 1				Management 2				Management 3			
	Cotton/Soy/*Urochloa*				Millet/Soy/Millet				Millet/Soy/Crotalaria			
Species	RF	RD	RA	IR	RF	RD	RA	IR	RF	RD	RA	IR
	%	%	%	%	%	%	%	%	%	%	%	%
B. decumbens	-	-	-	-	-	-	-	-	3.2	2.4	9.0	14.6
C. echinatus	-	-	-	-	3.0	0.4	1.3	4.7	12.9	51.8	48.2	112.9
D. insularis	17.1	17.8	19.9	54.8	11.9	40.0	34.7	86.6	-	-	-	-
E. indica	22.9	56.5	47.3	126.7	11.9	23.7	20.5	56.2	11.3	6.6	7.0	24.9
E. pilosa	-	-	-	-	3.0	0.3	0.9	4.1	-	-	-	-
P. purpureum	-	-	-	-	4.5	1.2	2.7	8.3	-	-	-	-
C. benghalensis	22.9	18.4	15.4	56.7	11.9	14.0	12.1	38.0	12.9	13.2	12.3	38.4
C. rotundus	-	-	-	-	7.5	3.0	4.1	14.6	-	-	-	-
A. deflexus	5.7	2.4	7.9	16.0	9.0	2.8	3.3	15.1	3.2	0.4	1.7	5.3
B. pilosa	8.6	2.1	4.7	15.3	-	-	-	-	3.2	0.5	2.0	5.8
C. canadenses	8.6	1.0	2.3	12.0								
A. conyzoides	-	-	-	-	4.5	0.9	2.1	7.5	8.1	9.4	13.9	31.4

Species												
I. triloba	14.3	1.8	2.5	18.6	7.5	1.6	2.2	11.2	8.1	4.5	6.6	19.2
C. hirta	-	-	-	-	3.0	0.4	1.3	4.7	-	-	-	-
E. heterophylla	-	-	-	-	-	-	-	-	8.1	1.4	2.1	11.6
S. obtusifolia	-	-	-	-	7.5	1.4	2.0	10.9	9.7	2.2	2.8	14.7
S. rhombifolia	-	-	-	-	9.0	7.5	8.7	25.1	8.1	3.3	4.9	16.3
P. oleracea	-	-	-	-	3.0	0.8	2.7	6.5	-	-	-	-
R. brasiliensis	-	-	-	-	3.0	2.2	7.6	12.8	11.3	4.3	4.6	20.1

Table 3. Species, relative frequency (RF), relative density (RD), relative abundance (RA), and relative importance (RI) of weeds under different management strategies at 95 DAE in a soybean crop in Chapadão do Sul, MS, 2016/2017.

January (95 DAE)

Species	Management 1 Cotton/Soy/Urochloa				Management 2 Millet/Soy/Millet				Management 3 Millet/Soy/Crotalaria			
	RF %	RD %	RA %	IR %	RF %	RD %	RA %	IR %	RF %	RD %	RA %	IR %
U. decumbens	3.1	0.3	1.1	4.6	-	-	-	-	-	-	-	-
D. insularis	12.5	39.6	33.6	85.7	20.0	31.9	23.3	75.3	13.3	73.1	71.5	157.9
D. sanguinalis	12.5	13.4	11.4	37.3	6.7	8.3	18.3	33.3	-	-	-	-
E. indica	9.4	2.0	2.3	13.7	16.7	11.1	9.7	37.5	11.7	5.7	6.4	23.7
C. benghalensis	21.9	9.7	4.7	36.3	13.3	12.5	13.7	39.5	13.3	7.8	7.6	28.7
A. deflexus	9.4	13.4	15.2	38.0	-	-	-	-	-	-	-	-
B. pilosa	6.3	14.4	24.5	45.2	-	-	-	-	-	-	-	-
A. conyzoides	-	-	-	-	3.3	1.4	6.1	10.8	8.3	0.3	0.4	9.0
I. triloba	3.1	0.3	1.1	4.6	13.3	9.7	10.6	33.7	8.3	1.8	2.8	13.0
E. heterophylla	-	-	-	-	3.3	1.4	6.1	10.8	8.3	1.3	2.0	11.7
S. obtusifolia	-	-	-	-	13.3	15.3	16.7	45.3	10.0	1.8	2.4	14.2
S. rhombifolia	6.3	1.3	2.3	9.9	3.3	5.6	24.3	33.2	8.3	5.7	8.9	23.0
P. oleracea	-	-	-	-	3.3	1.4	6.1	10.8	-	-	-	-
R. brasiliensis	15.6	5.4	3.6	24.6	3.3	1.4	6.1	10.8	11.7	0.8	0.9	13.3

Within the system using soybean, followed by *U. decumbens* (management area 1), *C. echinatus*, *D. sanguinalis*, and *E. indica* showed RD indices higher than the RF and IR indices >40% (Table 4). This behavior was maintained for *D. sanguinalis* in the May evaluation (Table 5).

Table 4. Species, relative frequency (RF), relative density (RD), relative abundance (RA), and relative importance (IR) of weeds in crop succession in Chapadão do Sul, MS, 2016/2017.

February

Species	Management 1 Cotton/Soy/Urochloa				Management 2 Millet/Soy/Millet				Management 3 Millet/Soy/Crotalaria			
	RF %	RD %	RA %	IR %	RF %	RD %	RA %	IR %	RF %	RD %	RA %	IR %
C. echinatus	10.0	31.9	41.0	82.8	5.9	10.0	17.9	33.8	7.0	39.5	60.6	107.2
D. insularis	-	-	-	-	11.8	16.7	15.0	43.4	11.3	6.2	5.9	23.4
D. sanguinalis	20.0	28.9	18.6	67.5	-	-	-	-	9.9	4.9	5.4	20.2
E. indica	10.0	14.8	19.0	43.9	-	-	-	-	9.9	1.2	1.4	12.4
C. benghalensis	20.0	15.6	10.0	45.6	14.7	12.2	8.8	35.7	11.3	25.9	24.9	62.1
C. rotundus	10.0	0.7	1.0	11.7	5.9	5.6	10.0	21.4	-	-	-	-
A. tenella	-	-	-	-	5.9	2.2	4.0	12.1	-	-	-	-
A. deflexus	10.0	5.9	7.6	23.5	-	-	-	-	-	-	-	-
A. hispidum	-	-	-	-	-	-	-	-	-	-	-	-
B. pilosa	10.0	0.7	1.0	11.7	-	-	-	-	-	-	-	-
C. canadenses	-	-	-	-	-	-	-	-	2.8	1.2	4.7	8.8
A. conyzoides	-	-	-	-	5.9	4.4	8.0	18.3	9.9	9.9	10.8	30.6
I. triloba	-	-	-	-	14.7	27.8	19.9	62.4	7.0	1.2	1.9	10.2
C. hirta	-	-	-	-	5.9	6.7	12.0	24.5	-	-	-	-
E. heterophylla	-	-	-	-	8.8	4.4	5.3	18.6	5.6	3.7	7.1	16.4
S. obtusifolia	-	-	-	-	8.8	5.6	6.6	21.0	7.0	1.2	1.9	10.2
S. rhombifolia	-	-	-	-	5.9	2.2	4.0	12.1	11.3	1.2	1.2	13.7
P. niruri	-	-	-	-	5.9	2.2	4.0	12.1	-	-	-	-

| R. brasiliensis | 10.0 | 1.5 | 1.9 | 13.4 | - | - | - | - | 7.0 | 3.7 | 5.7 | 16.4 |

Table 5. Species, relative frequency (RF), relative density (RD), relative abundance (RA), and relative importance (IR) of weeds in crop succession in Chapadão do Sul, MS, 2016/2017.

May

Species	Management 1 Cotton/Soy/Urochloa				Management 2 Millet/Soy/Millet				Management 3 Millet/Soy/ Crotalaria			
	RF %	RD %	RA %	IR %	RF %	RD %	RA %	IR %	RF %	RD %	RA %	IR %
U. mutica	-	-	-	-	-	-	-	-	1.4	0.4	2.4	4.1
C. echinatus	-	-	-	-	21.1	5.1	3.1	29.3	-	-	-	-
D. insularis	-	-	-	-	-	-	-	-	8.5	4.4	4.5	17.4
D. sanguinalis	25.0	16.0	19.4	60.4	10.5	2.6	3.1	16.2	5.6	20.0	30.9	56.6
E. indica	-	-	-	-	10.5	66.7	80.6	157.8	8.5	4.2	4.3	17.0
C. benghalensis	25.0	16.0	19.4	60.4	-	-	-	-	7.0	1.9	2.4	11.3
C. rotundus	-	-	-	-	-	-	-	-	1.4	0.2	1.2	2.8
A. tenella	-	-	-	-	-	-	-	-	2.8	0.6	1.8	5.2
A. deflexus	-	-	-	-	-	-	-	-	2.8	2.7	8.3	13.7
B. pilosa	37.5	64.0	51.6	153.1	-	-	-	-	1.4	0.6	3.5	5.5
C. canadenses	-	-	-	-	-	-	-	-	2.8	0.4	1.2	4.4
T. officinale	-	-	-	-	-	-	-	-	1.4	0.2	1.2	2.8
A. conyzoides	-	-	-	-	-	-	-	-	11.3	33.0	25.5	69.7
I. triloba	-	-	-	-	26.3	23.1	11.2	60.5	5.6	3.0	4.7	13.4
C. hirta	12.5	4.0	9.7	26.2	-	-	-	-	11.3	9.7	7.5	28.5
E. heterophylla	-	-	-	-	15.8	2.6	2.1	20.4	11.3	9.7	7.5	28.5
S. obtusifolia	-	-	-	-	-	-	-	-	11.3	12.4	9.6	33.2
S. rhombifolia	-	-	-	-	-	-	-	-	1.4	0.4	2.4	4.1
P. niruri	-	-	-	-	-	-	-	-	1.4	0.2	1.2	2.8
P. oleracea	-	-	-	-	-	-	-	-	2.8	0.8	2.4	5.9
R. brasiliensis	-	-	-	-	-	-	-	-	9.9	4.8	4.2	18.8

Soybeans were cultivated from October–January, for which the Venn diagram showed three common weeds among the three treatments studied (Figure 2): *E. indica, C. benghalensis,* and *I. triloba*. However, the interactions over the months for which the crop covers were present showed *C. echinatus* and *C. benghalensis* occurring in isolation in February, and *D. sanguinalis* in May.

The Jaccard and Sorensen similarity indices (Table 6) contribute to understanding the Venn diagram (Figure 2). The similarity coefficient varies from 0 to 1, being maximum when all species are common to both managements and minimum when there are no common species. The Venn diagram allows the visualization of which species were interacting in different management areas. There is a strong similarity between the management areas during soybean conduction, and higher coefficients at the end of cultivation (January); less similarity was seen between management areas 1 and 3. During the planting of cover, the coefficient values were lower, with the greatest similarity observed at the beginning of cultivation (February) (Table 6).

The Venn diagram (Figure 2) shows a greater diversity of species during planting of the soybean crop, with greater similarity between species at the beginning and end of the cultivation, when compared to the coverage crops. Of the weed species that occurred simultaneously in the three management areas, 4 and 6 species were found at the beginning and end of soybean cultivation, respectively, and 2 and 1 species at the beginning and end of the cover cultivation, respectively.

Table 6. Sorensen and Jaccard similarity coefficient of weeds in crop rotations in Chapadão do Sul, MS, in the 2016/2017 harvest.

Index	Soy						Cover					
	October			January			February			May		
	1/2	1/3	2/3	1/2	1/3	2/3	1/2	1/3	2/3	1/2	1/3	2/3
Jaccard	0.29	0.46	0.50	0.50	0.43	0.75	0.18	0.33	0.50	0.12	0.20	0.13
Sorenson	0.45	0.63	0.67	0.67	0.60	0.86	0.30	0.50	0.67	0.22	0.33	0.24

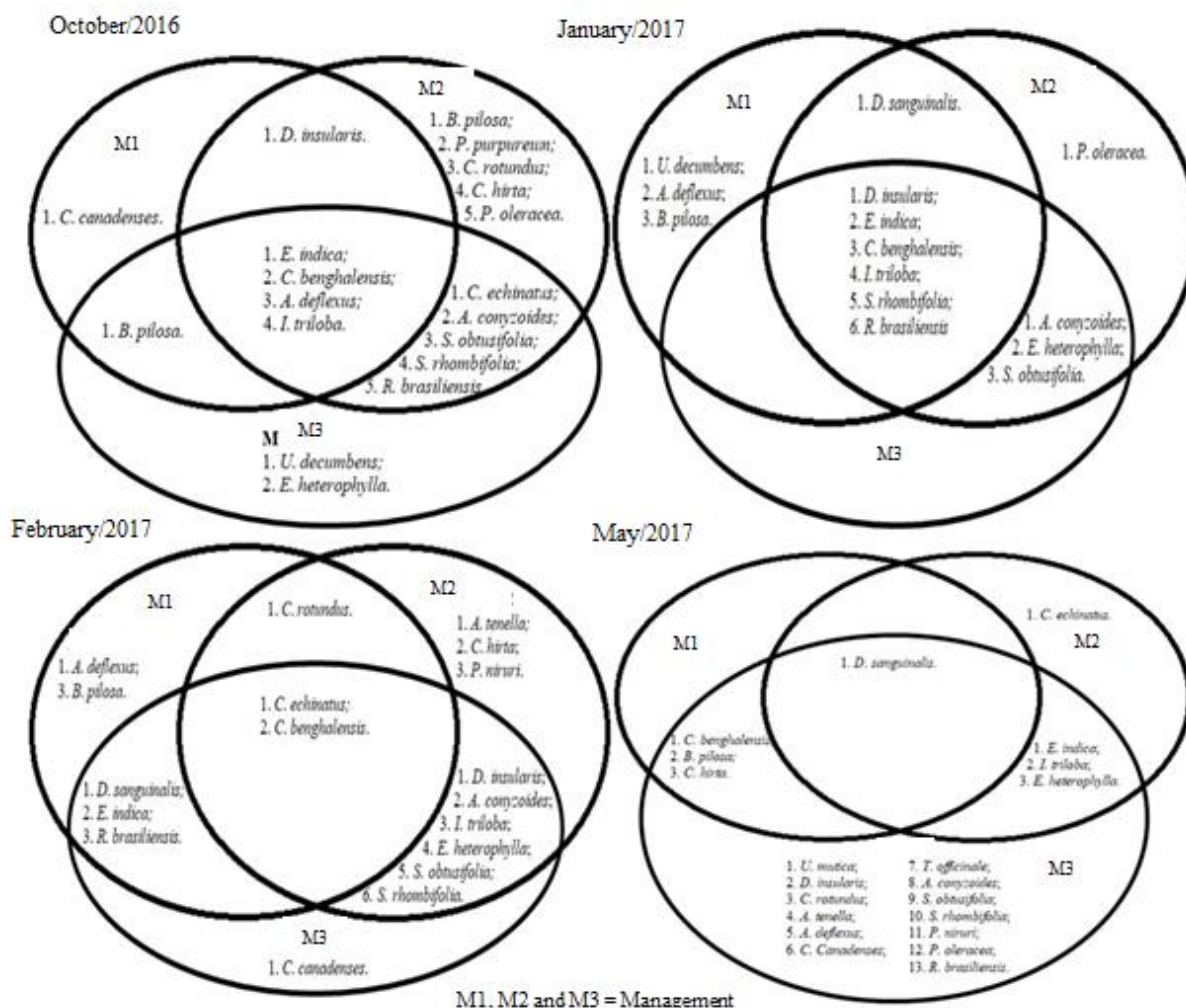1/Management 1; 2/Management 2; 3/Management 3.

Figure 2. Venn diagram, illustrating the exclusive and shared weed species in the soybean crop and its successions in Chapadão do Sul/MS in the 2016/2017 harvest.

4. Discussion

Identifying weed species present in no-tillage and minimum tillage areas is important because the knowledge allows for weed control based on the infestation characteristics and intensity of each weed (Albuquerque et al. 2013; Zanuncio et al. 2013).

The weed species spectrum found in this survey (Table 1) does not differ from what occurs in soybean production fields, both in terms of monocotyledons such as *Urochloa plantaginea*, *U. decumbens*, *Cenchrus echinatus*, *Digitaria* spp*.,* and *Eleusine indica*, as well as dicotyledons, including *Alternanthera. tenella*, *Amaranthus* spp., *Cardiospermum halicacabum*, *Bidens pilosa*, *Commelina* spp, *Conyza* spp., *Euphorbia heterophylla*, *Ipomoea* spp., *Raphanus raphanistrum*, *Richardia brasiliensis*, *Sida* spp., and *Silene latifolia,* among many others (Karam et al. 2012).

The species *Ageratum conyzoides, B. pilosa*, *Commelina benghalensis*, *C. echinatus*, *Digitaria insularis*, *Digitaria sanguinalis*, *E. indica*, *Ipomoea triloba*, and *Senna obtusifolia* presented relative importance indices >30% in most management systems. Notably, management of the areas directly interferes with the germinal flow; some species stand out in each collection season due to several factors, including species characteristics, climate, seed bank, crop development, and the control period (Albuquerque 2006).

The families with the highest occurrence rates were Poaceae and Asteraceae, followed by Amaranthaceae and Euphorbiaceae (Table 1). Similar to these data, weed phytosociology in soybean cultivation was verified in two soil management systems, with high density of the species *Brachiaria plantaginea, Euphorbia heterophylla, Ipomoea* sp., *Cyperus rotundus,* and *Digitaria horizontalis* (Fialho et al. 2011). Additionally, in an area where there was resistant soybean and susceptible to glyphosate, 16 weed species belonging to 10 families were found, the main species belonging to Poaceae and Asteraceae, with 5

and 3 species, respectively. The main species found were *Bidens* spp, *Conyza* spp, *Euphorbia heterophylla,* and *Commelina benghalensis* (Dias et al. 2018).

The species with relative importance indices >30% within management area 1 were *D. insularis, E. indica, C. benghalensis, D. sanguinalis, A. deflexus,* and *B. pilosa*. The research area had been using glyphosate for several years, with a drying application before sowing and one or two applications during soybean cultivation, depending on field evaluation. Continued pressure from the use of an active ingredient may have led to the selection of resistant weeds. It is known that the repeated and continuous use of glyphosate results in tolerant weeds such as *Commelina* sp., and resistant species such as *C. bonariensis, C. canadensis*, *C. sumatrensis,* and *D. insularis* being selected (Bianchi, Vargas, and Rizzardi 2008). It is necessary to have criteria within this management area, mainly due to the use of glyphosate, as 48 cases of weed species with resistance to this active ingredient have been reported (HEAP, 2020a), 16 of which are in Brazil (HEAP, 2020b).

This trend presence of *S. obtusifolia* in the management areas 2 and 3 reveals that the species was well distributed in these areas, suggesting that attention towards its management is needed, as it can cause losses to soybean yield of 30% when there are three plants per m^2. The presence of weeds can reduce crop productivity; however, sufficient information is not available on species diversity. It was found that the presence of one *B. plantaginea* plant per m^2 can reduce the productivity of a soybean crop by 50% (Silva et al. 2009).

A. deflexus was present in all three management areas during the first survey, but with relative importance indices <20%, prevailing only in management area 1. Its RI increased in the second round of sampling, at which point the soybeans were already at the end of their cycle (Table 3). Carvalho and Christoffoleti (2008) found five species of *Amaranthus* spp. (among them *A. deflexus)*, with a density of 40 plants per m^2, suggesting that the species present in greater density may not necessarily possess greater competition strength. High vigor during initial growth, efficient root system, seed dormancy, and the ability to host phytopathogens are the factors that also need to be considered.

Even with a relative importance index <15%, Poinsettia/Milkweed (*E. heterophylla*) was present in management areas 2 and 3 (Table 2 and 3), and monitoring it was necessary due to its resistance to PROTOX and ALS inhibitors (HEAP, 2020a). In a study by Meschede et al. (2002), in the State of Paraná daily yield losses of 5.15 kg ha^{-1} of a soybean crop were observed with the presence of *E. heterophylla*, while its absence represented a daily productivity gain of 7.27 kg ha^{-1}.

In general, for *B. pilosa, I. triloba, C. hirta, E. heterophylla, S. rhombifolia, P. olaracea,* and *R. brasiliensis*, the results show low frequencies and densities within the management areas and raised periods. Careful management is required of the above species, especially in areas of cotton rotation, as is the case in management area 1, as *B. pilosa* and *E. heterophylla* have been resistant to ALS inhibitor herbicides (Agostinetto and Vargas 2009). The presence of *I. triloba* and *S. obtusifolia* can lead to losses of 33% and 55% in soybean yield, respectively, as well as a 60% reduction in productivity for the Embrapa-62 cultivar (Voll et al. 2002).

The results of the weed phytosociology performed on the cover crops in succession to the main crop (Tables 4 and 5) indicate the importance of integrated weed management, as crop rotation selects, and influences weed germination following commercial uses. The biological effect of mulching can also influence the behavior of spontaneous plants, since the presence of dead cover, and the associated increase in organic matter, generates conditions for many organisms (microorganisms, insects, rodents, etc.) which can use seeds and seedlings as sources of energy to thrive (Noce et al. 2008).

From the total number of individuals found in the weed phytosociology, 67.6%, 17.9%, and 14.5% were observed in treatments 3 (*Crotalaria*), 1 (*U. decumbens),* and 2 (millet), respectively. Foltran et al. (2010) verified a lower incidence of weeds in several crop rotation systems with *Urochloa* grass in the soil, when compared to areas that presented fallow zones, or with other cover crops which produced less mulch than *Crotalaria* in their rotation system.

The IR>40% observed for some species of the Poacea family (Tables 4 and 5), indicate that they are in the area occupation pattern. Inclusively facilitating adopting localized management practices (Souza et al. 2008) can reduce the volume of applied herbicides that can reach the soil (Balastreire and Baio 2001). *C. benghalensis*, which reached an IR index >30% in all evaluated months, requires special attention in its

management because of its reproductive characteristics. Wilson (1981) reported that the difficulty of controlling plants of the Commelinaceae family can be attributed to their double reproduction mechanisms: by seed and by rooting at their nodes. According Vega et al. (2000), the difficulty of controlling this species is directly related to its development stage. When herbicide application was divided between various development stages, Krolikowski et al. (2017) did not find any difference between the treatments for stages 22 and 51. According to Fleck et al. (2008), this result shows that in order to more efficiently control this species, it is necessary to have knowledge about the development stages, densities, herbicide dose, management strategies, and application conditions.

The presence or absence of *D. insularis, I. trilobal*, and *E. indica* (Table 4 and 5) was observed in management areas 1 and 2, with IR indices >30%, indicating presence both by frequency and by density. Gazziero et al. (2012) verified that the presence of 6–8 plants per m^2 of *D. insularis* during the soybean cycle can reduce its productivity by up to 44%.

The succession with *Crotalaria* (management area 3) found large amounts of weed species, of which, most possess resistance to certain groups of herbicides. Plants with an IR index >30% in management area 3 (Table 4 and 5) such as *C. echinatus, C. benghalensis, A. conyzoides, D. sanguinalis,* and *S. obtusifolia*, had higher RD indices than RF, indicating that they are present in defined areas (reboilers), and with elevated RA.

Thus, it is important to monitor and identify germinal flows in the succession system as a way of adopting phytosanitary measures for managing the species to be planted in the crop rotation system. It is not always justified to adopt crops with economic potential as crop covering. It is often necessary to prioritize crops which can reduce the number of invasive species, such as those with colonizing or allopathic characteristics, fast between-row closing, and the ability to supply mulch in order to reduce the germinal flow, and consequently the seed bank expression.

The greatest similarity (Figure 2, Table 6) was found between management areas 2 and 3, which could be attributed to the similarities in the management of these two areas. In management area 1, the presence of cotton cultivation preceding soybean, provides a more differentiated weed control environment. The adoption of similar weed management between years of soybean cultivation was the reason for the high similarity justified by Dias et al. (2018), while the low similarity found between the initial and pre-harvest evaluations of sunflower was attributed to the different growing seasons of the two driving environments (Adegas et al. 2010).

5. Conclusions

The management area using the cotton/soybean/*Urochloa* rotation had less weed species than other areas. The species *C. echinatus*, *D. insularis*, *D. sanguinalis*, *E. indica,* and *C. benghalensis* have the highest phytosociological indices among the monocotyledons. Attention should be directed towards managing the dicotyledons *A. deflexus*, *C. canadenses*, and *S. obtusifolia*, despite low index scores because of cases of herbicide resistance. The highest indices of similarity were found between management areas 2 and 3, which did not rely on cotton cultivation prior to soybeans.

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