PLANTA DANINHA

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS

<http://www.sbcpd.org>

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

Article

Cultivation Systems, Vegetable Soil Covers and their Influence on the Phytosocyology of Weeds

Sistemas de Cultivo, Coberturas Vegetais de Solo e sua Influência na Fitossociologia de Plantas Daninhas

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ABSTRACT - Phytosociological studies are groups of methods that aim at the identification, composition and distribution of plant species in a community. The objective of this study was to identify and quantify the main weeds found in beans, maize and soybean cultivated in no-tillage and conventional systems. The experimental design was a randomized block one, with four replications. Experiments were conducted during three consecutive years, with summer crop (bean, maize and soybean) treatments, no-tillage system (NTS) composed by the covers, black oat, vetch and forage radish, in addition to their intercrop. In the conventional planting system (CTS), the area was left fallow in the off-season. The shoot dry matter of the covers was evaluated in each crop. The evaluated variables were: frequency, density, abundance, dry matter and the importance value index of the species in the area. Eighteen species of weeds and 12 families were identified, with Asteraceae and Poaceae families showing the highest number of individuals. The shoot dry matter production presented a difference among the covers; the cover black oat alone and intercrop with radish and vetch stood out, with the highest averages in the 3 years of the experiments. Cropping systems and different cover crops within the no-tillage system interfered in the number of encontered species. The emergence of *Euphorbia heterophylla* was favored, while the emergence of *Lolium multiflorum* was inhibited. *E. heterophylla* was the most encountered in the NTS areas, and its germination was negatively influenced by soil mobilization. The intercrop of black oat and vetch provided maximum weed control in soybean.

Keywords: phytosociological parameters, crop systems, *Euphorbia heterophylla, Vicia sativa, Avena strigosa, Raphanus sativus*.

RESUMO - Estudos fitossociológicos são grupos de métodos que visam a identificação, composição e a distribuição de espécies de plantas em uma comunidade. O objetivo deste trabalho foi identificar e quantificar as principais plantas daninhas presentes em feijão, milho e soja cultivados sob diferentes coberturas vegetais em sistemas de plantio direto e convencional. O delineamento experimental adotado foi o de blocos casualizados com quatro repetições. Foram conduzidos experimentos em três anos consecutivos, sendo os tratamentos constituídos pelas culturas de verão (feijão, milho e soja), sistema de plantio direto composto pelas coberturas, aveia-preta, ervilhaca e nabo forrageiro, além do consórcio destas. No sistema de plantio convencional, deixou-se em pousio a área na entressafra das culturas. Avaliou-se a massa seca da parte aérea das coberturas, em cada safra agrícola. As variáveis avaliadas foram: frequência, densidade, abundância, massa seca e índice de valor de importância das espécies presentes na área. Foram identificadas 18 espécies de plantas daninhas e 12 famílias, sendo

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Received: March 3, 2017
Approved: June 1, 2017

Planta Daninha 2018; v36:e018176776

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Doi: 10.1590/S0100-83582018360100099

as famílias Asteraceae e Poaceae as que apareceram com maior número de indivíduos. A produção de massa seca da parte aérea apresentou diferença entre as coberturas, destacando-se a cobertura de aveia-preta solteira e consorciada com nabo forrageiro e ervilhaca, com as maiores médias nos três anos de condução dos experimentos. Os sistemas de cultivo e as diferentes culturas de cobertura dentro do sistema de plantio direto interferiram no número de espécies encontradas. No sistema de plantio direto a emergência de ***Euphorbia heterophylla*** *foi favorecida, enquanto a emergência de* ***Lolium multiflorum*** *foi inibida. A espécie* ***E. heterophylla*** *foi a mais encontrada nas áreas conduzidas no sistema de plantio direto, e sua germinação foi influenciada negativamente pela mobilização do solo. O consórcio de aveia-preta e ervilhaca proporcionou o máximo controle de plantas daninhas na cultura da soja.*

Palavras-chave: parâmetros fitossociológicos, sistemas de cultivo, *Euphorbia heterophylla*, *Vicia sativa*, *Avena strigosa*, *Raphanus sativus*.

INTRODUCTION

In recent years, the advancement of the no-tillage system (NTS) in relation to the conventional tillage system (CTS) has contributed in several aspects to the Brazilian agriculture, mainly in reducing erosion and by controlling pests in cultivation systems (Silva et al., 2009). NTS is essentially adopted in annual crops such as bean, maize and soybean, which together represent 93% of the area planted for grain production in Brazil (Conab, 2017).

Culture rotation, biomass production and soil cover were considered basic requirements for the implementation, maintenance and feasibility of NTS in any region of Brazil (Andrioli et al., 2008). Several species are used for the production of plant residues in the NTS, in different regions of Brazil: the most important are black oat, lupine, hairy and common vetch, forage radish, velvet bean, rattlepod, signalgrass, pigeon pea, foxtail millet, cowpea, millet, forage peanut and sunflower (Andrioli et al., 2008; Silva et al., 2009).

In the conventional farming system, the soil is mobilized more intensively, with plows and/or disc plows. Due to this mobilization, weed seeds can also be distributed along the soil profile, giving rise to persistent weed seed banks (Guersa and Martinéz-Guersa, 2000).

The intercropping of plant species for soil cover, as well as promoting weed management, also provides improvements in nutrient amounts, mainly by the biological fixation of nitrogen and the low C/N ratio of species belonging to the Fabaceae family, making these nutrients available faster for soil solution (Doneda et al., 2012).

Plant species capable of producing high amounts of plant mass, such as *Urochloa ruziziensis*, are more capable of influencing the weed flora by suppressing weeds (Sodré Filho et al., 2008). This management practice can be a strong ally in the control of herbicide resistant species, as is the case of *Conyza bonariensis*, because it reduces considerably the light entry into the soil, thus making it difficult for most weed to emerge (Paula et al., 2011).

The differentiated effects of soil tillage systems and the action of herbicides on weeds may alter the botanical composition of the community (Jakelaitis et al., 2003). The floristic evolution of the community occurs according to the intensity, the regularity and the time of use of the system and, depending on the intensity of these changes, it may affect the management, control and competition of this community over the culture (Favero et al., 2001).

According to Concenço et al. (2013), the direct phytosociological study can be classified as a group of ecological assessment methods whose objective is to provide an overview of the composition and distribution of plant species in a community. The method was first developed to describe the plant species found in a certain place and has been playing a fundamental role in the study of weed dynamics in agricultural areas (Guglieri-Caporal et al., 2010).

The tested hypothesis was that soil covers composed of black oat, vetch and forage radish, implanted in winter alone or intercropped, together with the no-tillage system, would have a suppressive impact on the appearance of weeds in summer crops (beans, maize and soybean). In light of this, the objective of this study was to identify and quantify the weeds found in bean, maize and soybean crops grown under different plant cover in no - tillage and conventional systems.

MATERIAL AND METHODS

Twelve field experiments were conducted in the municipality of Quatro Irmãos - Rio Grande do Sul state, in the 2013/14, 2014/15 and 2015/16 crops, at the geographical location: latitude 27º44"43'S, longitude 52º25"49'W, altitude 680 m and climate Cfa (temperate humid with hot summer), according to the classification of Köppen. The soil of the experimental area was classified as eutrophic Ta Haplic Cambisol (Embrapa, 2013), and presented the following physicochemical characteristics before the implementation of the experiments: water pH: 5.7; SMP: 5.9; MO: 3%; P: 3.7 mg L^{-1}; K: 120.0 mg L^{-1}; Ca: 18.3 $cmol_c$ kg^{-1}; Mg: 6.5 $cmol_c$ kg^{-1}; H+Al: 4.9 $coml_c$ kg^{-1}; Al: 0 $cmol_c$ kg^{-1}; effective CEC: 25.1 $cmol_c$ kg^{-1}: CEC pH7: 30.0 $cmol_c$ kg^{-1}; V: 84%; and clay: 30%. The average monthly rainfall in the experimental area was 263, 186 and 315 mm for the 2013/14, 2014/15 and 2015/16 crops, respectively.

The experimental design was a randomized block one with four replications. The treatments are set out in Table 1. Summer crops (beans, maize and soybean) were preceded by cover crops established in the winter, alone or intercropped. In the fallow area, the conventional tillage system (CTS) was used to prepare the soil, using a disk plow and a leveling grid. Immediately after the preparation, summer crops were sown.

The vegetation existing in the fallow area consisted mainly of the species *Lolium multiflorum*, *Conyza bonariensis* and *Raphanus sativus*. The sowing of winter cover crops and summer crops in the no-tillage system (NTS) was carried out according to the principles of minimum soil mobilization, crop residue production and crop rotation. The desiccation of the plant cover was done 30 days before the sowing and establishment of winter and summer crops, with the use of glyphosate at the dose of 1.08 kg ha^{-1} of acid equivalent (a.e.) together with sethoxydim at the dose of 0.22 kg ha^{-1}. The plots consisted of six lines, spaced 0.47 m apart and 10 m long, totaling an area of 28.2 m^2 per experimental unit.

The seed densities adopted for winter soil cover were: 130 plants m^{-2} of black oat, 100 plants m^{-2} of forage radish, 170 plants m^{-2} of vetch, 90 + 50 plants m^{-2} of black oat + vetch, 90 + 30 plants m^{-2} of black oat + forage radish and 170 + 35 plants m^{-2} of vetch + forage radish. Sowing, both for winter cover crops and summer crops, was carried out with the aid of a seeder/fertilizer. A 200 kg ha^{-1} dose of the 08-24-12 formula (N-P-K) was applied as a fertilizer in the sowing furrows and 45 kg ha^{-1} of N were applied on winter crops as cover fertilizer. As for summer crops, seeding density was 30 m^{-2} for soybean (cv BMX Alvo) in the first two years and 35 plants for the third agricultural crop (cv BMX Ativa), 21 bean plants m^{-2} (AG 8041 PRO, SX 7331 VIP and P1630H, for the first, second and third crop seasons, respectively). The fertilization in the sowing furrow was 350 kg ha^{-1} of the 05-30-15 formula (N-P-K) on bean, maize and soybean crops in the three agricultural seasons. Cover fertilization was 45 and 122 kg ha^{-1} of N for beans and maize, respectively.

Weed control in the bean crop was made with the aid of a commercial mixture composed of the herbicides fluazifop-p-buthyl + fomesafen at a dose of 0.25 + 0.25 kg ha^{-1}. The commercial mixture of the herbicides atrazine + simazine at the dose of 1.25 + 1.25 kg ha^{-1} was used on the maize crop. On the soybean crop, the herbicide glyphosate was used at the dose of 1.08 kg ha^{-1} a.e.

The shoot dry matter (DM) quantification of winter cover crops was carried out in an area of 0.25 m^{-2}. Plants were then transferred to the soil after flowering. The obtained samples were packed in Kraft-type paper bags and later placed in a forced air circulation oven, at a temperature of 60 ± 5 °C, until the material reached constant weight.

The evaluation of the specific composition of the weeds in each treatment was made 30 days after the harvest of summer crops, and the identification of the species was carried out at the beginning; later, the number of individuals was counted. Finally, weed dry matter accumulation was determined. The number of plants m^{-2} and the determination of the dry matter were performed in an area of 0.25 m^2, obtained with the help of a square sized 0.5 x 0.5 m, which was launched in each experimental unit. Weeds were identified by species, counted, cut close to the soil, separated and placed in Kraft paper bags, for further determination of their dry matter. Dry matter was obtained after drying the samples in a forced air circulation oven at 65 ^{o}C until the material reaches constant weight.

Before the implementation of the experiment, a phytosociological survey of the area was performed, 30 days after harvesting the 2012/13 crop season (Table 4), when sowing the bean crop. Before bean sowing, the area was used to graze animals in the winter period, and in the summer, it was used for the implantation of annual crops such as maize and/or soybean.

After the collection of the samples, the area of the experiment was desiccated with the application of glyphosate at the dose of 1.08 kg ha^{-1} a.e., together with sethoxydim at the dose of 0.22 kg ha^{-1}, in order to eliminate weeds and avoid possible feeding of the seed bank in the soil.

After collecting the plants in the areas, the data obtained for each species were used to determine their phytosociological indices (Table 2). These indices were calculated according to the equations proposed by Müeller-Dombois and Ellenberg (1974).

After collecting the plants in the areas, it was possible to estimate: frequency (FRE) - allows evaluating the distribution of the species in the plots; density (DEN) - number of plants of each species per unit area (0.25 m^{-2}); abundance (ABN) - informs about the concentration of species in the area; Relative Frequency (RFR), Relative Density (RDE), relative abundance (RAB) and relative dry matter (RDM) - determine the relation of each species with others found in the area; and importance value index (IVI) and relative importance value index (RIVI) - indicate which species are most important within the studied area (Table 2).

As for the dry matter of the cover crops, the analysis of variance was performed; when significant, means were compared through the Tukey's test at $p \leq 0.05$. For phytosociological indices, the descriptive analysis was adopted.

Table 1 - Management systems and crop rotation used in the three years of implementation of the experiments

Summer crop	Plant covers		
	2013/14	2014/15	2015/16
BEAN	Black oat + radish	Black oat + Forage radish	Vetch
BEAN	Forage radish	Forage radish + vetch	Black oat
BEAN	Fallow[1]	Fallow	Fallow
MAIZE	Forage radish + vetch	Black oat	Forage radish
MAIZE	Vetch	Vetch	Black oat + vetch
MAIZE	Fallow	Fallow	Fallow
SOYBEAN	Black oat	Forage radish	Black oat + forage radish
SOYBEAN	Black oat + vetch	Black oat + vetch	Vetch + forage radish
SOYBEAN	Fallow	Fallow	Fallow

(1) In the winter period, the area was left at fallow (spontaneous vegetation), and the conventional planting summer crops was performed.

Table 2 - Formulas used to determine phytosociological indices

FRE= Number of squares where the species was found / Total number of squares
DEN= Total number of individuals of the species / Total number of squares
ABN= Total number of individuals of the species / Total number of squares where the species was found RFR= Frequency of the species x 100 / Total frequency of the species
RDE= Density of the species x 100 / Total species density RAB= Abundance of the species x 100 / Total abundance of species
RDM= Dry mass of the species x 100 / Dry mass of total species IVI (importance value index) = RFR + RDE + RAB + RDM RIVI (relative importance value index)= IVI x 100 / IVI total of all species

RESULTS AND DISCUSSION

The phytosociological survey allowed the identification of 12 weed families and 18 species in the three harvests of the experiments (Table 3). The Asteraceae and Poaceae families were the ones that presented the highest number of species, both of which were also reported as the most common in the sunflower (Adegas et al., 2010), maize (Oliveira et al., 2014) and pepper (Cunha et al., 2014) crops.

Table 3 - Distribution of weeds by family and species collected in no-tillage and conventional cropping systems and different crops

Family	Scientific name	Common name
Asteraceae	*Bidens pilosa*	Blackjack
	Conyza bonariensis	Buva
	Gnaphalium spicatum	Cudweed
	Sonchus oleraceus	Sowthistle
Amaranthaceae	*Amaranthus lividus*	English wild amaranth
Brassicaceae	*Raphanus sativus*	Radish
Commelinaceae	*Commelina benghalensis*	Benghal dayflower
Convolvulaceae	*Ipomoea indivisa*	Morning glory
Euphorbiaceae	*Euphorbia heterophylla*	Fireplant
	Chamaesyce hirta	Asthma plant
Lamiaceae	*Stachys arvensis*	Staggerweed
Rubiaceae	*Richardia brasiliensis*	Mexican clover
Malvaceae	*Sida rhombifolia*	Arrowleaf sida
Oxalidaceae	*Oxalis corniculata*	Creeping woodsorrel
Poaceae	*Urochloa plantaginea*	Plantain signalgrass
	Digitaria ciliaris	Southern crabgrass
	Lolium multiflorum	Ryegrass
Solanaceae	*Solanum americanum*	American black nightshade

The dry matter production of the shoot of each plant cover is described in Table 4. The phytosociological parameters of the weed species are described in Tables 5, 6, 7, 8, 9, 10, 11, 12 and 13.

Shoot dry matter production (DM) of soil plant covers

The DM production of soil cover crops may change, as shown in Table 4. In the 2013/14 harvest, the species used as plant cover that presented the highest DM production was vetch, intercropped or not with black-oat and forage radish. Intercropping becomes an interesting alternative to increase DM production. No significant differences were observed between the DM production of black oat intercropped with forage radish during the three harvests of the experiments, and forage radish does not contribute to the increase of this variable.

Forage radish was the cover crop with the lowest DM yield: 1.55 and 1.40 Mg ha^{-1}, respectively, in the first two crops; the fallow also presented greater DM, composed by the species *L. multiflorum*, *C. bonariensis* and *R. sativus* (Table 4). In the third year the production was higher, possibly due to environmental conditions such as precipitation and adequate temperatures, which helped the best establishment of the crop. In the latter period, the spontaneous vegetation found in the fallow area was the one that contributed least to the production of DM. According to Valicheski et al. (2012), black oat produced approximately 6 Mg ha^{-1} of dry matter, while forage radish did not exceed 3 Mg ha^{-1}, in soil without compaction. With the increase of compaction, both species produced a lower amount of matter.

Table 4 **-** Shoot dry matter (DM) production by the soil plant covers during summer crops, in the 2013/14, 2014/15 and 2015/16 harvests, when the experiments were conducted

Soil cover	Shoot dry matter (Mg ha^{-1}) HARVEST		
	2013/14	2014/15	2015/16
Black oat	4.69 bc	5.34 ab	7.11 a
Black oat + forage radish	4.07 cd	4.31 ab	6.81 ab
Black oat + vetch	6.41 a	6.27 a	5.87 c
Vetch + forage radish	5.50 ab	6.36 a	4.91 d
Forage radish	1.55 e	1.40 c	5.11 d
Vetch	5.62 ab	5.64 ab	6.61 b
Fallow	3.23 d	3.67 b	2.73 e
VC (%)	11.45	19.20	3.57

Means followed by different letters in the column for each crop differ from one another by Tukey's test ($p \leq 0.05$).

Experiments with bean crops

Experiment 1 - 2013/14 harvest

When bean crops were managed using black oat + forage radish as cover crops, it was observed that *Euphorbia heterophylla* was the one that reached the highest values of relative frequency (RFR), relative density (RDE), relative abundance (RAB) and relative dry matter (RDM), in relation to the other species. On the other hand, the forage radish culture alone in the no-tillage system allowed *B. pilosa* to reach the highest relative importance value index (RIVI) (Table 5). *B. pilosa* is highly competitive with beans, reducing the dry matter of the crop by about 40% when flowering (Fleck et al., 2004).

It is possible to observe that NTS management interfered significantly in the phytosociology of weeds infesting the bean crop. In the fallow, *D. ciliaris* was the most prominent species (>RIVI), followed by *B. pilosa*, *E. heterophylla*, *Ipomoea indivisa* and *C. hirta*. It was also observed that in the fallow, FRE, DEN and RAB values were similar among the different species (Table 5).

When comparing the soil tillage systems and the different cover crops within NTS, the same weed species were practically observed, but forage radish, as a cover crop, allowed greater weed species diversity (Table 5). This was also observed by Jakelaitis et al. (2003) in maize and bean crops, where weed species diversity was higher in NTS compared to fallow. The greater weed species diversity when using forage radish as cover crop is due to the fact that this cover crop, when used in winter, presents a high decomposition/mineralization rate (Aita and Giacomini, 2003; Crusciol et al., 2005; Heinz et al., 2011). The shorter soil cover period may help the occurrence of greater species diversity, since it facilitates the emergence of weeds. Cover plants with short cycles may not be suitable for weed suppression (Mhlanga et al., 2015).

Experiment 2 - 2014/15 harvest

In the second experiment with the bean crop (2014/15 harvest), it was noticed that when the soil cover was made with black oat + forage radish, there was the greatest weed community, compared to the use of radish + vetch and with fallow (Table 6). RFR, RDE and RAB values were similar among the species, and the RIVI, on an average, was 28.55% for *B. pilosa* and *I. indivisa* and 21.46% for *E. heterophylla* and *S. oleraceus*. As for the system with forage radish + vetch there was a higher DEN of *B. pilosa* and *I. indivisa* plants, with no *S. oleraceus*.

Again, in the fallow, *E. heterophylla* was not found. In contrast, *C. hirta*, which comes from the same family, presented the highest RIVI value (Table 6). Some weeds are characterized by being typical of fallow areas (Albuquerque et al., 2013). *R. sativus*, which served as soil cover in the previous crop, was also found. Possibly, there was seed dispersal, and emergence was favored

Table 5 - Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in black oat + forage radish and radish in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the bean crop, 2013/14 harvest

Parameter	FRE	DEN	ABN	RFR	RDE	RAB	RDM	IVI	RIVI
Covers	Black oat + forage radish								
Euphorbia heterophylla	1.00	45.00	11.25	40.00	75.00	60.00	56.36	231.37	57.84
Chamaesyce hirta	0.75	6.00	2.00	30.00	10.00	10.67	7.66	58.33	14.58
Digitaria ciliaris	0.50	7.00	3.50	20.00	11.67	18.67	15.13	65.47	16.37
Bidens pilosa	0.25	2.00	2.00	10.00	3.33	10.67	20.84	44.84	11.21
Total	2.50	60.00	16.50	100.00	100.00	100.00	100.00	400.00	100.00
Covers	Forage radish								
Euphorbia heterophylla	0.75	3.00	0.75	15.79	5.00	3.66	23.10	47.55	11.89
Chamaesyce hirta	1.00	11.00	2.75	21.05	18.33	13.41	8.62	61.41	15.35
Digitaria ciliaris	0.50	4.00	2.00	10.53	6.67	9.76	5.47	32.43	8.11
Bidens pilosa	1.00	33.00	8.25	21.05	55.00	40.24	54.10	170.39	42.60
Ipomoea indivisa	0.25	2.00	0.50	5.26	3.33	2.44	0.33	11.36	2.84
Urochloa plantaginea	0.25	6.00	6.00	5.26	10.00	29.27	7.39	51.92	12.98
Conyza bonariensis	0.25	1.00	0.25	5.26	1.67	1.22	0.99	9.14	2.29
Total	4.75	60.00	20.50	100.00	100.00	100.00	100.00	400.00	100.00
Covers	CTS								
Euphorbia heterophylla	0.50	3.00	1.50	18.19	17.65	19.56	20.06	75.46	18.86
Chamaesyce hirta	0.50	3.00	1.50	18.19	17.65	19.56	9.38	64.78	16.19
Digitaria ciliaris	0.75	5.00	1.67	27.24	29.40	21.76	22.08	100.48	25.12
Bidens pilosa	0.50	3.00	1.50	18.19	17.65	19.56	30.44	85.84	21.46
Ipomoea indivisa	0.50	3.00	1.50	18.19	17.65	19.56	18.59	73.99	18.50
Total	2.75	17.00	7.67	100.00	100.00	100.00	100.00	400.00	100.00

Table 6 - Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in black oat + forage radish and radish + vetch in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the bean crop, 2014/15 harvest

Parameter	FRE	DEN	ABN	RFR	RDE	RAB	RDM	IVI	RIVI
Covers	Black oat + forage radish								
Euphorbia heterophylla	0.25	2.00	2.00	14.29	25.00	40.00	7.17	86.46	21.61
Bidens pilosa	0.50	2.00	1.00	28.57	25.00	20.00	40.39	113.96	28.49
Ipomoea indivisa	0.50	2.00	1.00	28.57	25.00	20.00	40.78	114.35	28.59
Sonchus oleraceus	0.50	2.00	1.00	28.57	25.00	20.00	11.65	85.22	21.31
Total	1.75	8.00	5.00	100.00	100.00	100.00	100.00	400.00	100.00
Covers	Forage radish + vetch								
Euphorbia heterophylla	0.25	2.00	2.00	16.67	18.19	36.37	1.16	72.39	18.10
Bidens pilosa	0.50	3.00	1.50	33.33	27.27	27.27	14.99	102.86	25.72
Ipomoea indivisa	0.75	6.00	2.00	50.00	54.55	36.37	83.86	224.78	56.20
Total	1.50	11.00	5.50	100.00	100.00	100.00	100.00	400.00	100.00
Covers	CTS								
Chamaesyce hirta	1.00	9.00	2.25	80.00	75.00	42.86	72.12	269.98	67.50
Raphanus sativus	0.25	3.00	3.00	20.00	25.00	57.14	27.88	130.02	32.50
Total	1.25	12.00	5.25	100.00	100.00	100.00	100.00	400.00	100.00

due to seed coating with the soil mobilization practice (CTS), in addition to the fact that the plant emerged after the application of fluazifop-p-buthyl + fomesafen on the bean crop.

Experiment 3 - 2015/16 harvest

In the 2015/16 harvest, it was observed that *E. heterophylla* presented greater RES in the managements in NTS (vetch and black oat alone); the mobilization of soil affected by half the establishment of this species, that is, only in 50% of the collected areas this weed was found. In the systems with black oat and vetch, in NTS, this species was found in all samples, with the highest RDM and, consequently, higher IVI (Table 7).

Soil mobilization (fallow) established the greatest number of weed species, compared to the management in NTS.

The black oat cover was the most efficient in reducing the emergence of some weeds, such as *S. rhombifolia* and *C. hirta* (Table 7). According to Lima et al. (2014), the floristic composition of weeds is influenced by the residues of the cover crop. These authors found the highest DM production when using the species *Urochloa ruziziensis*, almost 10 Mg ha^{-1}, establishing a relation with the this work, where, in the management with black oat, the number of weed species was reduced, possibly due to the higher production of DM (Table 4).

In the case of RIVI, due to a higher FRE, DEN, ABN and RDM, *E. heterophylla* was the species that presented the highest values for vetch and black oat in NTS (Table 7). In the CTS, the highest RIVI was observed for the *Ipomoea indivisa* species. *E. heterophylla*, *D. ciliaris*, *B. pilosa* and *I. indivisa* were found in the three managements (vetch, black oat and fallow), and plant cover and soil mobilization did not influence its establishment.

Table 7 - Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in vetch and black oat in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the bean crop, 2015/16 harvest

Parameter	FRE	DEN	ABN	RFR	RDE	RAB	RDM	IVI	RIVI
Coberturas	Vetch								
Euphorbia heterophylla	1.00	4.25	4.25	40.00	50.00	27.87	54.95	172.82	43.21
Chamaesyce hirta	0.25	0.75	3.00	10.00	8.82	19.67	12.17	50.66	12.67
Digitaria ciliaris	0.50	1.50	2.00	20.00	17.65	13.11	26.24	77.00	19.25
Bidens pilosa	0.25	1.00	4.00	10.00	11.76	26.23	2.19	50.18	12.55
Ipomoea indivisa	0.50	1.00	2.00	20.00	11.76	13.11	4.45	49.32	12.33
Total	2.50	8.50	15.25	100.00	100.00	100.00	100.00	400.00	100.00
Covers	Black oat								
Euphorbia heterophylla	1.00	3.75	3.75	57.14	78.95	48.39	89.18	273.66	68.42
Digitaria ciliaris	0.25	0.25	1.00	14.29	5.26	12.90	6.67	39.12	9.78
Bidens pilosa	0.25	0.25	1.00	14.29	5.26	12.90	2.65	35.10	8.77
Ipomoea indivisa	0.25	0.50	2.00	14.29	10.53	25.81	1.50	52.13	13.03
Total	1.75	4.75	7.75	100.00	100.00	100.00	100.00	400.00	100.00
Covers	CTS								
Euphorbia heterophylla	0.50	0.50	1.00	18.18	15.38	14.64	40.82	89.02	22.26
Chamaesyce hirta	0.25	0.25	1.00	9.09	7.70	14.64	3.14	34.57	8.64
Digitaria ciliaris	0.50	0.75	1.50	18.18	23.08	21.96	5.06	68.28	17.07
Bidens pilosa	0.25	0.25	1.00	9.09	7.70	14.64	3.61	35.04	8.76
Ipomoea indivisa	0.75	1.00	1.33	27.27	30.77	19.47	33.69	111.20	27.80
Sida rhombifolia	0.50	0.50	1.00	18.18	15.38	14.64	13.68	61.88	15.47
Total	2.75	3.25	6.83	100.00	100.00	100.00	100.00	400.00	100.00

Experiments with maize crops

Experiment 1 - 2013/14 harvest

The predominance of *E. heterophylla*, *D. ciliaris* and *B. pilosa* in the 2013/14 harvest (Table 8) was observed for the maize crop, highlighting that these species are commonly found in Brazilian crops. In the treatments using forage radish + vetch and vetch in the NTS, *D. ciliaris* appeared as the species with the greatest IVI, besides having the highest RES in all the observations made when sowing maize. *B. pilosa* did not appear in the management with forage radish + vetch. Rotations with different cover crops and subsequent maize sowing may have an effect on weed diversity, but with a decrease of up to 92% in density (Mhlanga et al., 2015).

In the fallow system, *B. pilosa* presented the highest IVI, followed by *D. ciliaris* (Table 8). The latter is a species that deserves greater attention in maize crops, because it belongs to the same family and it can therefore compete in a similar way for the resources of the environment. In a study that evaluated the competitive ability between *D. ciliaris* and irrigated rice and soybean, Agostinetto et al. (2013) proved that weeds were more competitive than crops.

Table 8 **-** Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in forage radish + vetch in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the maize crop, 2013/14 harvest

Parameter	FRE	DEN	ABN	RFR	DER	RAB	RDM	IVI	RIVI
Covers	Forage radish + vetch								
Euphorbia heterophylla	1.00	4.00	1.00	50.00	44.40	44.40	39.29	178.09	44.52
Digitaria ciliaris	1.00	5.00	1.25	50.00	55.60	55.60	60.71	221.91	55.48
Total	2.00	9.00	2.25	100.00	100.00	100.00	100.00	400.00	100.00
Covers	Vetch								
Euphorbia heterophylla	0.50	3.00	1.33	28.57	37.50	40.30	58.16	164.53	41.13
Digitaria ciliaris	1.00	4.00	1.00	57.14	50.00	30.03	37.06	174.23	43.56
Bidens pilosa	0.25	1.00	1.00	14.29	12.50	30.03	4.78	61.60	15.40
Total	1.75	8.00	3.33	100.00	100.00	100.00	100.00	400.00	100.00
Covers	CTS								
Euphorbia heterophylla	0.25	1.00	1.00	14.29	11.11	27.25	13.70	66.35	16.59
Digitaria ciliaris	0.75	3.00	1.00	42.86	33.33	27.25	44.99	148.43	37.11
Bidens pilosa	0.75	5.00	1.67	42.86	55.55	45.5	41.31	185.22	46.30
Total	1.75	9.00	3.67	100.00	100.00	100.00	100.00	400.00	100.00

Experiment 2 - 2014/15 harvest

According to the results, there is a predominance of the *E. heterophylla* species in the management with NTS (Table 9). This fact is probably due to the seed bank of the soil and the ability of this species to emerge in environments that do not present light. It should also be considered that CTS seeds are distributed throughout the soil profile, which makes it difficult for them to establish (Schreiber, 1992; Guersa and Martinéz-Guersa, 2000; Chauhan et al., 2006).

When evaluating treatments with black oat and vetch in the NTS, it was observed that DEN reduced by half when vetch was used as plant cover, probably because it is a species belonging to the Fabaceae family and it provides a larger amount of N to maize, causing the crop to close their canopy faster, thus preventing the intake of light, which disadvantages the emergence of weeds.

In the CTS, the species *C. hirta* and *L. multiflorum* were identified, with an IRVI of 56.97 and 43.03%, respectively. *C. hirta* stood out in the CTS for the highest RDM, which resulted in higher IVI. RFR, RDE and RAB values were the same for both species (Table 9). When comparing the

Table 9 - Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in black oat and vetch in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the maize crop, 2014/15 harvest

Parameter	FRE	DEN	ABN	RFR	RDE	RAB	RDM	IVI	RIVI
Covers	Black oat								
Euphorbia heterophylla	0.50	3.00	1.50	100.00	100.00	100.00	100.00	400.00	100.00
Total	0.50	3.00	1.50	100.00	100.00	100.00	100.00	400.00	100.00
Species	Vetch								
Euphorbia heterophylla	0.50	1.50	1.50	100.00	100.00	100.00	100.00	400.00	100.00
Total	0.50	1.50	1.50	100.00	100.00	100.00	100.00	400.00	100.00
Covers	CTS								
Chamaesyce hirta	0.50	6.00	3.00	50.00	50.00	50.00	77.86	227.86	56.97
Lolium multiflorum	0.50	6.00	3.00	50.00	50.00	50.00	22.14	172.14	43.03
Total	1.00	12.00	6.00	100.00	100.00	100.00	100.00	400.00	100.00

NTS with the conventional and minimum cultivation, it was verified that the former provided lower DM and a lower weed number than the others in the raw cane culture (Soares et al., 2011), thus highlighting the largest establishment of weeds in CTS.

Experiment 3 - 2015/16 harvest

In the area where forage radish was used as a soil cover crop, *O. maizeiculata* and *C. bonariensis* were not found when in the management there were black oat + vetch in intercropping. This highlights that the higher DM production provided by the oat + vetch intercrop (Table 4), together with the longer continuity of these coverings in the soil, affected the emergence and establishment of weeds, possibly due to the suppression imposed by the physical barrier of surface waste. The use of plant cover crops, such as velvet bean, jack bean, and Brazilian jack bean, presents great potential for dry matter production and can suppress weed germination and/or emergence (Favero et al. al., 2001).

In the fallow area, weed DEN and ABN were higher than the other cover crops in the NTS. It is worth highlighting *L. multiflorum*, which was found at all collection sites with an average DEN of 26 m^{-2} plants (Table 10). This is in line with the study by Guersa and Martinéz-Guersa (2000), who found that soil plowing helps the establishment of a bank of more persistent weed seeds, due to their distribution along the profile of the soil.

The species *C. bonariensis*, *L. multiflorum* and *R. sativus* stand out in places where there is no soil cover (fallow); *L. multiflorum* showed the highest RIVI (50.94), due in particular to its DEN/ RDE, which can be observed in Table 10. Direct sowing with the presence of cultural residues on the surface reduced the emergence of *C . bonariensis* (Paula et al., 2011). According to Albuquerque et al. (2013), some weeds are characterized as typical of fallow areas, but presenting some species that are considered native to areas with major disturbances.

Experiments with soybean crops

Experiment 1 - 2013/14 harvest

When evaluating the weed community in the soybean crop during the 2013/14 harvest, it was observed that, in the NTS, the weed with the highest RIVI was *E. heterophylla*, with averages of 53.42 and 65.55%, respectively for black oat and black oat + vetch (Table 11). This weed has been difficult to control in Brazil, because it is tolerant to glyphosate and has multiple resistance to ALS and PROTOX inhibiting herbicides (Vargas et al., 2013; Prigol et al., 2014).

Table 10 - Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in black oat + forage radish and radish in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the maize crop, 2015/16 harvest

Parameter	FRE	DEN	ABN	RFR	RDE	RAB	RDM	IVI	RIVI
Covers	Forage radish								
Euphorbia heterophylla	0.75	0.75	1.00	27.27	15.79	11.11	33.02	87.19	21.80
Oxalis corniculata	0.50	1.00	2.00	18.18	21.05	22.22	30.72	92.17	23.04
Conyza bonariensis	0.25	0.25	1.00	9.09	5.26	11.11	0.85	26.31	6.58
Stachys arvensis	0.50	2.00	4.00	18.18	42.10	44.44	13.14	117.86	29.47
Solanum americanum	0.75	0.75	1.00	27.27	15.79	11.11	22.27	76.44	19.11
Total	2.75	4.75	9.00	100.00	100.00	100.00	100.00	400.00	100.00
Covers	Black oat + vetch								
Euphorbia heterophylla	1.00	1.50	1.50	50.00	42.86	27.27	69.73	189.86	47.47
Stachys arvensis	0.25	0.50	2.00	12.50	14.28	36.36	1.25	64.39	16.10
Solanum americanum	0.75	1.50	2.00	37.50	42.86	36.36	29.01	145.73	36.43
Total	2.00	3.50	5.50	100.00	100.00	100.00	100.00	400.00	100.00
Covers	CTS								
Conyza bonariensis	0.25	0.50	2.00	11.11	4.55	11.43	3.70	30.79	7.70
Lolium multiflorum	1.00	8.50	8.50	44.44	77.27	48.57	33.47	203.75	50.94
Raphanus sativus	0.50	0.50	1.00	22.22	4.55	5.71	39.63	72.11	18.03
Bidens pilosa	0.25	0.25	1.00	11.11	2.27	5.71	0.82	19.91	4.98
Oxalis corniculata	0.25	1.25	5.00	11.11	11.36	28.57	22.38	73.42	18.36
Total	2.25	11.00	17.50	100.00	100.00	100.00	100.00	400.00	100.00

Table 11 - Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in black oat and black oat + vetch in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the soybean crop, 2013/14 harvest

Parameter	FRE	DEN	ABN	RFR	RDE	RAB	RDM	IVI	RIVI
Covers	Black oat								
Euphorbia heterophylla	0.75	3.00	1.00	60.00	50.00	40.00	63.69	213.69	53.42
Conyza bonariensis	0.50	3.00	1.50	40.00	50.00	60.00	36.31	186.31	46.58
Total	1.25	6.00	2.50	100.00	100.00	100.00	100.00	400.00	100.00
Covers	Black oat + vetch								
Euphorbia heterophylla	1.00	6.00	1.50	66.67	75.00	42.86	77.67	262.20	65.55
Bidens pilosa	0.25	1.00	1.00	16.67	12.50	28.57	8.93	66.67	16.67
Commelina benghalensis	0.25	1.00	1.00	16.67	12.50	28.57	13.40	71.14	17.78
Total	1.50	8.00	3.50	100.00	100.00	100.00	100.00	400.00	100.00
Covers	CTS								
Digitaria ciliaris	0.50	2.00	1.00	33.33	22.22	14.29	73.95	143.79	35.95
Bidens pilosa	0.25	1.00	1.00	16.67	11.11	14.29	0.90	42.97	10.74
Ipomoea indivisa	0.50	2.00	1.00	33.33	22.22	14.29	6.89	76.73	19.18
Lolium multiflorum	0.25	4.00	4.00	16.67	44.44	57.14	18.26	136.51	34.13
Total	1.50	9.00	7.00	100.00	100.00	100.00	100.00	400.00	100.00

It is worth mentioning that, in addition to *E. heterophylla*, *C. bonariensis* was also found in the system containing black oat (Table 11). This species is also resistant to glyphosate (Heap, 2016). It should be noted that glyphosate is the mostly used herbicide, both in the desiccation and cleaning of soybean crops in Brazil, especially those who use the Roundup Ready® technology.

It was observed that, in the fallow, the main weed was *D. ciliaris*, and that *E. heterophylla* was not found in the area (Table 11). This fact is possibly related to soil mobilization and NTS cover, where the germination of *D. ciliaris* has been suppressed by the presence of plant residues, and *E. heterophylla* plants have found an ideal environment for their development, since they are negative photoblastic species, in addition to the transport to deeper layers, in the case of *E. heterophylla*, preventing emergence. This distribution of seeds in the soil profile is influenced by the preparation frequency, giving rise to a persistent weed seed bank (Guersa and Martinéz-Guersa, 2000); on the other hand, other species may benefit from soil plowing.

It was observed that the weed community was 100% higher during the fallow (CTS) compared to NTS with black oat, and 33% in relation to NTS with black oat + vetch (Table 11). Mauli et al. (2011) observed that the use of soil cover species, such as black oat alone, and vetch and forage radish in intercropping did not affect significantly the incidence of weeds in the soybean crop; however, the higher the dry matter production by the covers, the higher the reduction of weed infestation.

Experiment 2 - 2014/15 harvest

When comparing NTS with forage radish to CTS (fallow), weed reduction was observed when the soil was plowed, reducing the total DEN of plants by half (Table 12). With soil mobilization, *E. heterophylla* was not found (fallow), even though it was known that this weed was present in the area where the experiment was conducted.

Table 12 - Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in forage radish and black oat + vetch in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the soybean crop, 2014/15 harvest

Parameter	FRE	DEN	ABN	RFR	RDE	RAB	RDM	IVI	RIVI
Covers	Forage radish								
Euphorbia heterophylla	0.50	2.00	1.00	33.33	12.50	8.00	10.36	64.19	16.05
Chamaesyce hirta	0.25	5.00	5.00	16.67	31.25	40.00	3.40	91.32	22.83
Sonchus oleraceus	0.25	4.00	4.00	16.67	25.00	36.00	4.02	81.69	20.42
Raphanus sativus	0.50	5.00	2.50	33.33	31.25	20.00	82.23	166.81	41.70
Total	1.50	16.00	12.50	100.00	100.00	100.00	100.00	400.00	100.00
Covers	Black oat + vetch*								
Covers	CTS								
Chamaesyce hirta	0.75	6.00	2.00	60.00	75.00	50.00	38.37	223.37	55.84
Richardia brasiliensis	0.25	1.00	1.00	20.00	12.50	25.00	46.28	103.78	25.95
Bidens pilosa	0.25	1.00	1.00	20.00	12.50	25.00	15.35	72.85	18.21
Total	1.25	8.00	4.00	100.00	100.00	100.00	100.00	400.00	100.00

* No weeds were observed in this management.

It was observed that NTS with black oat + vetch did not help the emergence of weeds, not even *E. heterophylla* (Table 12). The production and maintenance of DM from plant cover are directly linked to weed suppression (Mauli et al., 2011), since in this management, the production of cultural residues was the highest, as it may be observed in Table 4.

Experiment 3 - 2015/16 harvest

The species *E. heterophylla* was found in the NTS with black oat and vetch intercropped with forage radish, but this species was not found in the CTS (fallow); this indicates that soil disturbance may impair its establishment. In the NTS with black oat + forage radish, *E. heterophylla* and *D. ciliaris* were the ones presenting the highest RIVI: 23.36 and 24.40, respectively (Table 13). It is worth highlighting the presence of *D. ciliaris* in soybean crops; when in competition with the culture, it presents greater competitive ability (Agostinetto et al., 2013).

Table 13 - Means on frequency (FRE), plant density (DEN) abundance (ABN), relative frequency (RFR), relative density (RER), relative abundance (RAB), relative dry mass (RDM), importance value index (IVI) and relative importance value index (RIVI) in black oat + forage radish and vetch + forage radish in the no-tillage system (NTS) and fallow in the conventional tillage system (CTS), in the soybean crop, 2015/16 harvest

Parameter	FRE	DEN	ABN	RFR	RDE	RAB	RDM	IVI	RIVI
Covers	Black oat + forage radish								
Euphorbia heterophylla	1.00	1.25	1.25	33.33	33.33	13.51	13.27	93.44	23.36
Raphanus sativus	0.50	0.50	1.00	16.67	13.33	10.81	23.35	64.16	16.04
Sonchus oleraceus	0.25	0.25	1.00	8.33	6.67	10.81	1.09	26.90	6.73
Stachys arvensis	0.25	0.25	1.00	8.33	6.67	10.81	13.96	39.77	9.94
Digitaria ciliaris	0.25	0.75	3.00	8.33	20.00	32.43	36.85	97.61	24.40
Amaranthus lividus	0.25	0.25	1.00	8.33	6.67	10.81	7.14	32.95	8.24
Solanum americanum	0.50	0.50	1.00	16.67	13.33	10.81	4.34	45.15	11.29
Total	3.00	3.75	9.25	100.00	100.00	100.00	100.00	400.00	100.00
Covers	Vetch + forage radish								
Euphorbia heterophylla	0.50	1.00	2.00	22.22	16.00	18.18	12.71	69.11	17.28
Stachys arvensis	0.25	0.25	1.00	11.11	4.00	9.09	2.57	26.77	6.69
Ipomoea indivisa	0.25	0.75	3.00	11.11	12.00	27.27	9.51	59.89	14.97
Lolium multiflorum	0.25	0.25	1.00	11.11	4.00	9.09	3.93	28.13	7.03
Bidens pilosa	1.00	4.00	4.00	44.44	64.00	36.36	71.29	216.09	54.02
Total	2.25	6.25	11.00	100.00	100.00	100.00	100.00	400.00	100.00
Covers	CTS								
Conyza bonariensis	0.50	0.75	1.50	18.18	7.89	8.74	4.86	39.67	9.92
Lolium multiflorum	0.75	5.00	6.67	27.27	52.63	38.85	28.25	147.00	36.75
Raphanus sativus	0.25	0.50	2.00	9.09	5.26	11.65	27.25	53.25	13.31
Stachys arvensis	0.25	0.75	3.00	9.09	7.89	17.47	3.47	37.92	9.48
Oxalis corniculata	0.75	2.25	3.00	27.27	23.68	17.47	18.73	87.15	21.79
Ipomoea indivisa	0.25	0.25	1.00	9.09	2.63	5.82	17.44	34.98	8.75
Total	2.75	9.50	17.17	100.00	100.00	100.00	100.00	400.00	100.00

The NTS with the vetch + forage radish intercrop was the most efficient in reducing the number of species, but there was a predominance of *B. pilosa*, which resulted in an IVI of 216.09, more than 50% of the total species found, demonstrated by FRE, DEN, ABN and RDM (Table 13). In soybean, this species may present greater competitive ability when emerging before the culture (Manabe et al., 2014). Plant vetch residues presented a very high decomposition rate, mainly due to their low C/N ratio (Aita and Giacomini, 2003), as well as forage radish, indicating that the intercrop of these species may have accelerated the decomposition process of the residues, exposing the soil to the incidence of light and providing greater weed development.

It is worth mentioning the presence of *L. multiflorum* in the CPS (fallow), due to the spontaneous vegetation composed mainly by this species in the winter period, together with the presence of *C. bonariensis* (Table 13). These two weeds show resistance to glyphosate, and this requires mixtures of this herbicide with others of different mechanisms of action to have control efficiency. In addition, the resistance of these species to some herbicides belonging to the ACCase and ALS action mechanism, in the case of *L. multiflorum*, and FSI and FSII, in the case of *C. bonariensis* (Heap, 2016) has been proven.

Soil management systems and different covers within the no-tillage system interfered in the number of found species, helping the occurrence of species such as *E. heterophylla*, as well as reducing both the number of encountered species and the density of weeds, mainly of *L. multiflorum*. *E. heterophylla* was the most encountered species in the areas managed with NTS, and its germination was influenced negatively by soil mobilization. The intercrop of black oat and vetch proved to be a great alternative for weed control, due to the high production of DM. Soil mobilization in general helps higher density and number of weed species, regardless of the summer crop.

ACKNOWLEDGMENTS

To CAPES, CNPq, FAPERGS and FINEp, for granting financial help for the research and for granting scholarships.

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