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CROP PRODUCTION

Performance of fall and winter crops in a no tillage system in west Paraná State

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ABSTRACT. The long-term exploitation of natural resources by agricultural activities has resulted in the need for alternative measures to restore degraded soil. The cultivation of cover crops can generate great benefits for agricultural systems, enabling the exploitation of natural resources, including water, light and nutrients, as well as the recovery of degraded soils. This work aimed to assess the coverage rate, fresh mass and dry mass of cover crops from fall and winter as well as the floristic composition of the weeds. The work was conducted in field conditions in soil classified as eutroferric Red Oxisol in the region of the city of Palotina, Paraná State, Brazil, using a random block experimental design with four replications. The treatments consisted of seven cover cultures: wild radish, linseed, triticale, rye, rapeseed, crambe, oats and fallow. The species with the highest coverage rates and fresh mass and dry mass values were wild radish, rapeseed and crambe. In the floristic and phytosociological data, the species with the highest incidence were *Amaranthus retroflexus*, *Commelina benghalensis* L., *Brachiaria plantaginea* and *Gnaphalium spicatum*.

Keywords: natural resources, crop rotation, weeds.

Desempenho de culturas de outono e inverno no sistema de plantio direto no oeste do Estado do Paraná

RESUMO. A exploração dos recursos naturais, pelas atividades agrícolas ao longo do tempo resultou na necessidade de buscar medidas alternativas para recuperação do solo degradado. O cultivo de plantas de cobertura é uma alternativa que gera grandes benefícios aos sistemas agrícolas, viabilizando a exploração dos recursos naturais, água, luz e nutrientes e recuperação de solos degradados. O objetivo deste trabalho foi avaliar o percentual de taxa de cobertura, massa fresca e massa seca das culturas de cobertura de outono e inverno e a composição florística de plantas daninhas. O trabalho foi conduzido em condições de campo em solo classificado como Latossolo Vermelho eutroférrico, na região do município de Palotina, Estado do Paraná, Brasil. O delineamento experimental utilizado foi o de blocos ao acaso, com quatro repetições, os tratamentos foram constituidos por sete culturas de coberturas: nabo forrageiro, linhaça, triticale, centeio, canola, crambe, aveia; e área de pousio. As espécies que apresentaram os maiores valores de taxa de cobertura, massa fresca e massa seca foi o nabo forrageiro, canola e crambe. No levantamento florístico e fitossociológico, as espécies com maior incidência foram *Amaranthus retroflexus*, *Commelina benghalensis* L., *Brachiaria plantaginea* e *Gnaphalium spicatum*.

Palavras-chave: recursos naturais, rotação de culturas, plantas daninhas.

Introduction

For a long time, agricultural activity was restricted by the existing natural resources, and dueto constant exploitation of these resources for crop production over time, it became necessary tore place the extracted nutrients. Changes in soil properties resulting from inappropriate management are reflected in plant growth and development and can negatively impactscrop yields (Sanches, Maggi, Genú, & Muller, 2014).

The constant search for sustainable management alternatives aimed at maintaining the physical, chemical and biological structure of the soil as well as favoring the utilization of available natural resources is of great importance to agricultural production systems (Blainski, Tormena, Fidalsk, & Guimarães, 2008).

The use of crops to provide soil coverage is an approach that creates great benefits for agricultural systems by encouraging the exploitation of natural resources, including water, light and nutrients, in addition to controlling nematodes, recovering the physical properties of the soil, increasing soil fertility and organic matter content, diversifying and increasing the populations of microorganisms in the soil, and favoring nutrient recycling and mobilization (Correia & Durigan, 2008).

To select an appropriate soil cover crop, it is necessary to perform a careful technical evaluation that considers some very important aspects, such as the history of the area to be planted, the objective of the plantation, the degree of adaptation of the species to the region and the economic viability of its cultivation. Other important factors include the availability of seeds on the market, the appropriate machinery for management, the maintenance of biodiversity and environmental preservation (Gazola & Cavariani, 2011).

The diversification of the crop species used to provide soil cover assists in the control of common weeds; in soybean cultivation, this mostly occurs at the beginning of the implementation of a no-tillage system due to the great competitive ability of the cover crops against the weeds, which affects the phytosociology of the system (Gomes, Bevilaqua, Silva, & Monquero, 2014; Krenchinski, Albrecht, Cesco, Rodrigues, & Cordeiro, 2015).

Another important feature is the coverage of the soil by the dead plant matter that remains after the cultivation of cover crops; it creates a physical barrier that can control weed germination and emergence. In fact, some species of cover plants can facilitate weed control by releasing allelopathic chemical compounds that inhibit seed germination (Gomes Junior & Christoffoleti, 2008).

The most utilized species of cover crops in the western region of Paraná State are wild radish (*Raphanus sativus* L.), oat (*Avena sativa* L.), linseed (*Linumu sitatissimum* L.), rye (*Secale cereal* L.), triticale (*Tritico secale* Wittmack), rapeseed (*Brassica* spp. L.), and crambe (*Crambe abyssinica* (Hochst)).

In this context, the objective of this study was to evaluate the cover agerate and the amount of fresh matter and dry matter of cover crops in the fall and winter as well as the floristic composition of the weeds.

Material and methods

The experiment was conducted in field conditions in soil classified as eutroferric Red Oxisol with a clay texture in an experimental area in the city of Palotina, Paraná State, Brazil, at 24° 20' 51" S latitude, 53° 45' 14" W longitude, and 356 meters above sea level.

A randomized block experimental design with four replications was used, and the treatments consisted of seven cover crops: wild radish (*Raphanus sativus* L.), linseed (*Linumu sitatissimum* L.), triticale (*Triticum turgid cereale* (Kiss), rye (*Secale cereale* L.), rapeseed (*Brassica* spp. L.), crambe (*Crambe abyssinica* (Hochst), oat (*Avena sativa* L.), and fallow. The experimental plots were 4.2 meters long by 4 meters wide for a total of 16.8 m^2 each.

The crops were cultivated in the same way, and each species was grown in the same locale for the two years of the study. One seeder with a spacing of 0.45 meters was used for furrowing; the same amount of soil was displaced to create rows with a spacing of 0.225 meters, into which the cover crop seeds were deposited manually. During the crop development period, no management was necessary, but during the desiccation period, glyphosate herbicide was used at a concentration of 1,440 grams of equivalent acid per hectare.

The coverage rate of the crops was evaluated 50 days after emergence using digital photography. Pictures were taken using a 0.50 x 0.50 m template, and in laboratory, a 100-pointgrid was superimposed on each picture using the computer program Corel Draw X5. The amount of cover was quantified and expressed as a percentage by counting the intersecting points of the grid with vegetation.

To determine the amounts of fresh and dry matter in the above ground portions of the plants, samples were collected during the flowering stage from the border of each plot; the total area sampled was 0.25 m^2. The samples were weighed while fresh and then weighed again after drying in a forced-air circulation oven at 65°C for 72 hours or until a constant weight was reached to determine the dry matter weight of the samples. The data were expressed in kg ha^{-1}.

The floristic survey of the weeds was performed using the square inventory technique, in which a 1.0 x 1.0-meter square was placed over an area of 1 m^2. A 1-m^2 point from each plot containing cover crop residues was sampled for a total of 4 samples (4 m^2) for each cover crop species, and this sampling scheme made it possible to measure the weeds in each treatment. The survey was performed 30 days before the soybean was sown; the data were subjected to analysis of variance, and the means were compared by Tukey's test at the 5% level of probability.

Results and discussion

Wild radish, oat, and crambe showed the largest average rates of soil coverage in 2013 (Table 1), and their rates differed significantly from that of the fallow area, which was only populated with weeds. In 2014 (Table 1), wild radish showed a soil coverage rate of 100%, but that rate did not differ significantly ($p \leq 0.05$) from those of the other species, except the fallow treatment. According to Correia and Durigan

(2008), the rapid growth of cover species reduces weed populations by promoting shady conditions, which causes the weeds to rot due to the lack of light. This demonstrates the importance of soil cover and is consistent with the studies by Moraes, Agostinetto, Vignolo, Santos, and Panozzo (2009), who found that wild radish covered the largest area of soil, reaching, at minimum, 50% of the coverage needed under the no tillage system, which differed significantly from the fallow treatment.

Table 1. Percent soil coverage by cover crop species during the years of cultivation (2013 and 2014) in the city of Palotina, Paraná State.

Treatment	2013	2014
Wild radish	78.25 a	100.00 a
Linseed	73.00 ab	85.50 a
Oat IPR 126	84.75 a	98.25 a
Rye 186	71.25 ab	80.75 ab
Rapeseed	76.00 ab	91.75 a
Fallow	56.50 b	64.75 b
Triticale 111	69.25 ab	84.00 ab
Crambe	83.25 a	98.75 a
Average	74.03	87.96
CV%	11.75	9.63
DMS	20.63	20.09

*Means followed by the same letters in a column are not significantly different at the 5% level of probability by Tukey's test.

In 2013 (Table 2), the largest amounts of fresh matter were produced by wild radish, rapeseed and crambe, and they differed significantly from that produced by linseed, oat IPR 126, rye, and triticale as well as the fallow treatment (which was occupied by weeds). The same species produced the largest average values of dry matter in 2014 (Table 2), significantly differing from the other species and the fallow treatment. Some *Brassica* species, like the wild radish, accumulated the most dry and fresh matter, which is consistent with the data of Morais, Santos, and Rossetto (2014).

Table 2. Dry and fresh matter (kg ha^{-1}) of cover crop species during two years of cultivation (2013 and 2014) in the city of Palotina, Paraná State.

	Fresh matter		Dry matter	
Treatment	2013	2014	2013	2014
Wild radish	30210.00 a	33550.00 a	4375.00 a	5412.00 a
Linseed	13490.00 c	14740.00 c	3000.00 ab	3200.00 bc
Oat IPR 126	23760.00 c	24890.00 b	2650.00 bc	3530.00 b
Rye 186	10630.00 cd	12780.00 cd	2530.00 bcd	3190.00 bc
Rapeseed	25775.00 ab	28440.00 ab	3490.00 ab	4420.00 ab
Fallow	4770.00 d	4810.00 e	1085.00 d	1709.00 cd
Triticale 111	5655.00 d	7145.00 de	1190.00 cd	893.75 d
Crambe	25590.00 ab	29250.00 ab	2675.00 bc	4220.00 ab
Average	17485.00	19450.62	2624.00	3321.90
CV%	14.84	14.83	24.26	20.72
DMS	6157.13	19450.62	1510.26	1633.08

*Means followed by the same letters in a column are not significantly different at the 5% level of probability by Tukey's test.

The high accumulation of both types of matter under wild radish culture is due to the high precocity of this crop; 105 days after seeding, the fresh matter of wild radish shows a decreasing trend due to the senescence of the oldest leaves. In another study by Müller et al. (2001), the wild radish, beyond its accumulation of dry matter in its aerial part, stood out from the other cover species due to its greater accumulation of root dry matter and root length density, which promotes the unpacking and aeration of the soil.

In 2013 (Table 2), the production of dry matter differed significantly between treatments; wild radish showed the highest values, which differed from the dry matter yields of oat IPR 126, rye, triticale, crambe and the fallow treatment. The same result was observed in 2014, during which the wild radish produced the most dry matter compared to the other species and the fallow. The characteristics of rapid growth and high growth capacity in the wild radish make it an excellent option for sowing when a high degree of soil coverage is desired.

Generally, the best cover crops were wild radish, rapeseed and crambe, all of which exhibited rapid growth as evidenced by the soil coverage rate at 50 days as well as the high production of dry and fresh matter at flowering.

The floristic composition of the weeds present among the wild radish (Table 3) included five families in 2013 and ten families in 2014 represented by five species and thirteen species, respectively. Despite the high production of dry matter and rapid coverage rate by the wild radish, there was a high incidence of weeds under this crop, especially in 2014. This can be explained by the low carbon/nitrogen (C/N) ratio of the wild radish. Rizzardi and Silva (2006) and Balbinot Junior, Moraes, and Backes (2007) claim that larger weed infestations are due to a low C/N ratio, which results in a high decomposition rate that exposes the soil in a shorter period of time, in comparison to other species such as black oat, despite the elevated production of dry matter. However, Rizzardi and Silva (2006), affirm that some cover crops exhibit low weed emergence due to the release of allelopathic substances, even during the stage of straw decomposition.

The floristic composition of the weeds in the linseed treatment (Table 4) was the most diverse among the cover crops, with twelve species of weeds in 2013 and eleven in 2014. The incidence of weeds under this crop was only lower than that under fallow in 2013 and only lower than that under the fallow system and wild radish in 2014; eight families were observed in the two sampling years.

Table 3. Floristic composition of weeds in wild radish crop residues in 2013 and 2014 in the city of Palotina, Paraná State.

Scientific name	Common name	Family
	2013	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Bindes spp.	Beggarticks	Asteraceae
Brachiaria plantaginea	Marmalade grass	Poaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
Solanum americanum	Glossy nightshade	Solanaceae
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
	2014	
Bindes spp.	Beggarticks	Asteraceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Ipomoea triloba L.	Littlebell	Convolvulaceae
Euphorbia heterophylla	Milkweed	Euphorbiaceae
Leonurus japonicus	Chinese motherwort	Lamiaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Digitaria sanguinalis	Hairy crabgrass	
Brachiaria plantaginea	Marmalade grass	
Cenchrus echinatus L.	Southern sandspur	
Eleusine indica	Goosegrass	Poaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
Solanum americanum	Glossy nightshade	Solanaceae

Table 4. Floristic composition of weeds in linseed crop residues in 2013 and 2014 in the city of Palotina, Paraná State.

Scientific name	Common name	Family
	2013	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Conyza bonariensis	Horseweed	
Bindes spp.	Beggarticks	
Gnaphalium spicatum	Cudweed	
Sonchus oleraceus	Sowthistle	Asteraceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Euphorbia heterophylla	Milkweed	Euphorbiaceae
Brachiaria plantaginea	Marmalade grass	
Cenchrusechinatus L.	Southern sandspur	Poaceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
Solanum americanum	Glossy nightshade	Solanaceae
	2014	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Bindes spp.	Beggarticks	Asteraceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Euphorbia heterophylla	Milkweed	Euphorbiaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Digitaria sanguinalis	Hairy crabgrass	
Brachiaria plantaginea	Marmalade grass	
Cenchrus echinatus L.	Southern sandspur	
Eleusine indica	Goosegrass	Poaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
Solanum americanum	Glossy nightshade	Solanaceae

Under oat cultivation, seven species from six families were observed in the two years of sampling; therefore, the weed population remained stable throughout the study.

Two weed species, *Commelina benghalensis* L. and *Brachiaria plantaginea*, only appeared with the second year of oat cultivation, whereas *Sonchus oleraceus* and *Richardia brasiliensis* did not appear in the second year.

The high percentage of soil cover and the good straw production under oat cultivation were associated with the long period of degradation of this crop due to its high ratio C/N (Steiner, Fey, Zoz, & Costa, 2009), and its allelopathic effect (Araújo & Rodrigues, 2000) can explain the stability of the number of weeds found in the oat IPR 126 plots (Table 5).

Table 5. Floristic composition of weeds in oat IPR 126 crop residues in 2013 and 2014 in the city of Palotina, Paraná State.

Scientific name	Common name	Family
	2013	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Bindes spp.	Beggarticks	
Sonchus oleraceus	Sowthistle	Asteraceae
Ipomoea triloba L.	Littlebell	Convolvulaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
Cenchrus echinatus L.	Southern sandspur	Poaceae
	2014	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Bindes spp.	Beggarticks	Asteraceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Ipomoea triloba L.	Littlebell	Convolvulaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Brachiaria plantaginea	Marmalade grass	Poaceae
Cenchrus echinatus L.	Southern sandspur	

The rye plots (Table 6) presented an incidence of eight weed species in 2013 and five species in 2014. The number of families did not change over the two years, with five families observed each year.

From 2013 to 2014, four species of weeds were suppressed: *Gnaphalium spicatum*, *Conyza bonariensis*, *Sonchus oleraceus*, and *Richardia brasiliensis*. One new species emerged in 2014, *Commelina benghalensis* L.

Table 6. Floristic composition of weeds in rye crop residues in 2013 and 2014 in the city of Palotina, Paraná State.

Scientific name	Common name	Family
	2014	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Bindes spp.	Beggarticks	
Sonchus oleraceus	Sowthistle	
Conyza bonariensis	Horseweed	
Gnaphalium spicatum	Cudweed	Asteraceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Cenchrus echinatus L.	Southern sandspur	Poaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
	2014	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Bindes spp.	Beggarticks	Asteraceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Cenchrus echinatus L.	Southern sandspur	Poaceae

The floristic composition of the weeds in the rapeseed crop residues included nine species in 2013, but this number decreased to six in 2014 (Table 7).

The weed species that were not found in 2014 were *Sonchus oleracus*, *Gnaphalium spicatum*, and *Richardia brasiliensis*. Six families were observed in 2013 and five in 2014. Rapeseed has potential allelopathic effectson weeds, as in the case of *Bindes* spp. (Rizzardi, Rizzardi, Lamb, & Johann, 2008), and this can be linked to the lack of tree weed species after the second year of seeding.

Table 7. Floristic composition of weeds in rapeseed crop residues in 2013 and 2014 in the city of Palotina, Paraná State.

Scientific name	Common name	Family
	2013	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Sonchus oleraceus	Sowthistle	
Gnaphalium spicatum	Cudweed	
Conyza bonariensis	Horseweed	
Bindes spp.	Beggarticks	Asteraceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Cenchrus echinatus L.	Southern sandspur	Poaceae
	2014	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Conyza bonariensis	Horseweed	
Bindes spp.	Beggarticks	Asteraceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Cenchrus echinatus L.	Southern sandspur	Poaceae

In the fallow system, fifteen species and ten families were found in 2013, and fourteen species and nine families were found in 2014 (Table 8).

Table 8. Floristic composition of weeds in a fallow area in 2013 and 2014 in the city of Palotina, Paraná State.

Scientific name	Common name	Family
	2013	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Conyza bonariensis	Horseweed	
Sonchus oleraceus	Sowthistle	
Bindes spp.	Beggarticks	
Gnaphalium spicatum	Cudweed	Asteraceae
Euphorbia heterophylla	Milkweed	Euphorbiaceae
Leonurus japonicas	Chinese motherwort	Lamiaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Ipomoea triloba L.	Littlebell	Convolvulaceae
Digitaria sanguinalis	Hairy crabgrass	
Brachiaria plantaginea	Marmalade grass	
Cenchrus echinatus L.	Southern sandspur	Poaceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
Solanum americanum	Glossy nightshade	Solanaceae
	2014	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Conyza bonariensis	Horseweed	
Bindes spp.	Beggarticks	Asteraceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Euphorbia heterophylla	Milkweed	Euphorbiaceae
Leonurus japonicas	Chinese motherwort	Lamiaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Digitaria insularis	Sourgrass	
Digitaria sanguinalis	Hairy crabgrass	
Brachiaria plantaginea	Marmalade grass	
Cenchrus echinatus L.	Southern sandspur	
Eleusine indica	Wiregrass	Poaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
Solanum americanum	Glossy nightshade	Solanaceae

The fallow system has the potential to generate large weed populations, which are accompanied by high seed production and the elevation of the seed banks of these species. This poses a challenge to the cultivation of the next crop, and spending on weed control must be elevated relative to the cost of soil cover age management. In the fallow system in this study, the lack of a cover crop left the soil uncovered, favoring local weed emergence and development due to the high incidence of light (Lima, Timossi, Almeida, & Silva, 2014). According to Castro, Cruciol, Negrisola, and Perim (2011), cover species can control approximately 54.9 to 97.7% of weeds control; efficient control occurs when the cover crop produces up to 6 t ha^{-1} of straw (Lima et al., 2014).

The crop residues in the triticale treatment (Table 9) resulted in a floristic composition of ten weed species in seven families in 2013, but in 2014, only five species distributed in three families were sampled. The species that were not present in 2014 after triticale cultivation in 2013 were *Amaranthus retroflexus, Conyza bonariensis, Gnaphalium spicatum*, *Oxalis latifolia*, and *Richardia brasiliensis*. Triticale was the cover species that most decreased the number of weed species and families from the first production cycle to the next, despite being one of the crops with a lower degree of dry matter deposition in the soil. Because it is a plant with high growth as well as a high C/N ratio, the decomposition process is slow, and the straw persists in the soil for a longer time, hindering the emergence of weeds (Balbinot Junior et al., 2007). Therefore, triticale is one valid option for an autumn-winter cover crop.

Table 9. Floristic composition of weeds in triticale crop residues in 2013 and 2014 in the city of Palotina, Paraná State.

Scientific name	Common name	Family
	2013	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Conyza bonariensis	Horseweed	
Bindes spp.	Beggarticks	
Sonchus oleraceus	Sowthistle	
Gnaphalium spicatum	Cudweed	Asteraceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Brachiaria plantaginea	Marmalade grass	Poaceae
Cenchrus echinatus L.	Southern sandspur	Poaceae
Richardia brasiliensis	Brazilian calla-lily	Rubiaceae
	2014	
Bindes spp.	Beggarticks	
Sonchus oleraceus	Sowthistle	Asteraceae
Commelina benghalensis L.	Tropical spiderwort	Commelinaceae
Brachiaria plantaginea	Marmalade grass	
Cenchrus echinatus L.	Southern sandspur	Poaceae

In the crambe residues, five weed species in four families were observed in 2013, and six species and five families were observed in 2014. Crambe was one of the cover crops that presented the smallest population of weeds compared to the others.

The floristic composition of the weeds varied with the years of the experiment. In 2013, the fallow (Table 8) and the linseed (Table 4) treatments presented the largest number of species, fifteen and twelve, respectively, and the largest number of families, a total of ten, was also observed in the fallow system. In 2014, the largest number of weed species, fourteen, was sampled in the fallow system (Table 8), followed by wild radish (Table 3) with thirteen species and linseed with eleven.

Table 10. Floristic composition of weeds in crambe crop residues in 2013 and 2014 in the city of Palotina, Paraná State.

Scientific name	Common name	Family
	2013	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Bindes ssp.	Beggarticks	
Conyza bonariensis	Horseweed	Asteraceae
Oxalis latifolia	Garden pink-sorrel	Oxalidaceae
Brachiaria plantaginea	Marmalade grass	Poaceae
	2014	
Amaranthus retroflexus	Redroot pigweed	Amaranthaceae
Bindes ssp.	Beggarticks	Asteraceae
Cammelina benghalensis L.	Tropical spiderwort	Commelinaceae
Leonurus japonicus	Chinese motherwort	Lamiaceae
Digitaria sanguinalis	Hairy crabgrass	
Brachiaria plantaginea	Marmalade grass	Poaceae

In 2013, wild radish (Table 3), oat IPR 126 (Table 5) and crambe (Table 10) presented the smallest number of species of weeds with five, seven and five, respectively, as well as the number of families, five, six and four, respectively. In 2014, however the cover crops with the smallest number of weed species were triticale (Table 9) and rye (Table 6), both with five species and three and five families, respectively.

Under oat cover (Figure 1C), the species with the highest IVI values were *Commelina benghalensis* L. (84.75), *Oxalis latifolia* (58.41) and *Bindes* spp. (53.23). With rye (Figure 1D), the weeds *Amaranthus retroflexus*, *Commelina benghalensis* L. and *Oxalis latifolia* presented the highest IVI values of 84.76, 76.72, and 43.28, respectively. For the cover species rapeseed (Figure 1E), the species with the highest IVI values were *Oxalis latifolia* (79.25), *Commelina benghalensis* L. (61.60), and *Amaranthus retroflexus* (52.94). Under the fallow system (Figure 1F), *Amaranthus retroflexus*, *Commelina benghalensis* L., and *Oxalis latifolia* presented highest IVI values of 81.03, 43.30, and 22.13, respectively. Under triticale (Figure 1G), *Commelina benghalensis* L., *Bindes* spp. and *Sonchus oleraceus* presented IVI values of 98.35, 93.58, and 41.23, respectively. Figure 1H shows the IVI values of the weed species sampled in the crambe crop residues; they are *Amaranthus retroflexus*, *Commelina benghalensis* L., and *Bindes* spp. at 124.82, 95.21, and 34.22, respectively.

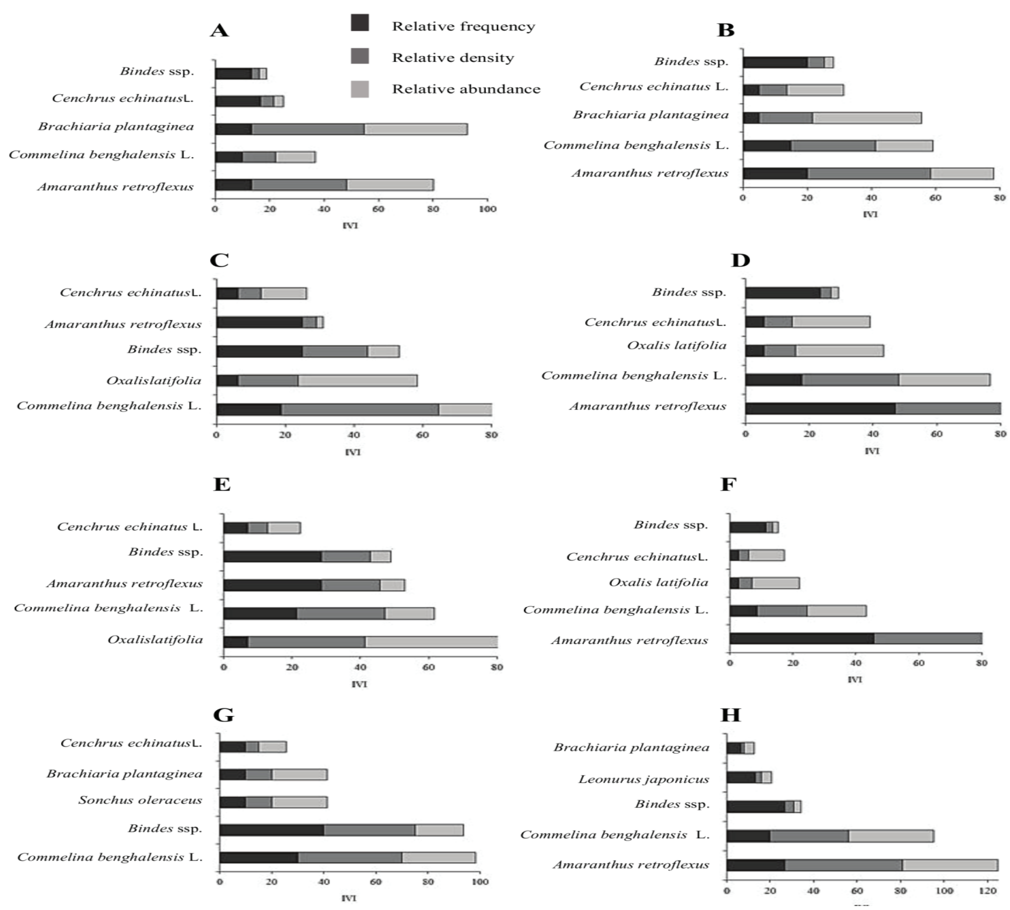

Figure 1. Importance index values of the five main species of weeds sample din wild radish, linseed, oat, rye, rapeseed, fallow, triticale and crambe crop residues (A, B, C, D, E, F, G, and H, respectively) in the city of Palotina in 2013.

The weed species *Amaranthus retroflexus* presented greater IVI values in 2013. According to Carvalho, López-ovejero, and Christoffoleti (2008), species of the genus *Amaranthus* are characterized as difficult-to-manage weeds due to various characteristics involving the size of the seed bank and the high production of seeds with long-term viability. These species exhibit an aggressive growth habit, and they are highly competitive with crops for water, light and nutrients (Knezevic , Horak, & Vanderlip, 1997). According to Carvalho et al. (2008), this aggressive growth habit is derived from the C4 carbon fixation metabolism of the plant, which enables the high estrate of net photosynthesis as well as rapid development under ideal weather conditions. In general, *A. retroflexus,* when subjected to temperatures approximately 20 to 30ºC, begins to compete for light in the space it occupies, which then becomes a more favorable environment that promotes higher germination rates of these weeds (Steckel, Sprague, Stoller, & Wax, 2004).

The presence of rye straw reduced the emergence of *Amaranthus retroflexus* seedlings by approximately 75 to 80% relative to the soil without straw (Nagabhusa, Worsham, & Yenish, 2001). In studies conducted by Gravena, Rodrigues, Spindola, Pitelli, and Alves (2004), the presence of cane straw was observed to reduce the densities of *Amaranthus* spp. when compared to bare soil.

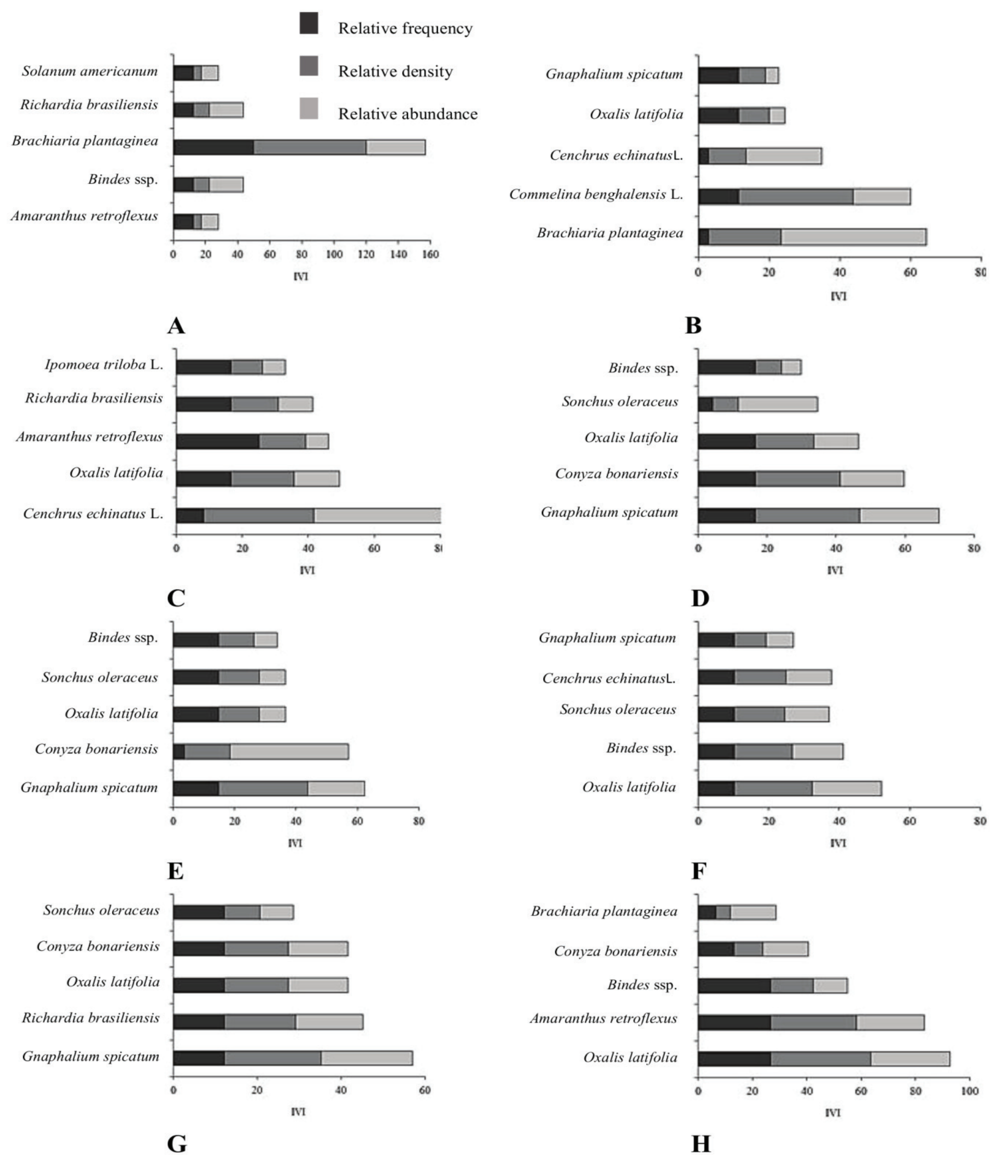

Figure 2. Importance index values of the five main species of weeds sampled in wild radish, linseed, oat, rye, rapeseed, fallow, triticale and crambe crop residues (A, B, C, D, E, F, G, and H, respectively)in the city of Palotina in 2014.

The weed species with the highest IVG in 2014 under wild radish culture (Figure 2A) were *Brachiaria plantaginea* (156.84) and *Bindes* spp. (43.55). Under linseed (Figure 2B), they were *Brachiaria plantaginea* (78.06) and *Commelina benghalensis* L. (59.14), and with oat as the cover crop (Figure 2C), the species were *Cenchrus echinatus* L. (89.54) and *Oxalis latifolia* (49.51). Using rye as a cover crop (Figure 2D), the species with the highest values were *Oxalis latifolia* (69.71) and *Bindes* spp. (59.76), and they were *Gnaphalium spicatum* (62.45) and *Conyza bonariensis* (57.08) with rapeseed (Figure 2E). For the fallow system (Figure 2F), the species were *Gnaphalium spicatum* (51.90) and *Oxalis latifolia* (41.15), and for triticale (Figure 2G), they were *Gnaphalium spicatum* (56.92) and *Richardia brasiliensis* (45.13). For crambe (Figure 2H), the species were *Gnaphalium spicatum* (92.68) and *Amaranthus retroflexus* (83.25). In 2014 the main species were *Brachiaria plantaginea*, *Gnaphalium spicatum*, *Cenchrus echinatus* L., and *Amaranthus retroflexus*.

There was a higher incidence of certain weeds, such as marmalade grass (*Brachiaria plantaginea*), in the majority of the coverage crops, because the seeds of such plants exhibit primary dormancy, which allows germination to occur (Dantas, Alves, Aragão, Rodrigues, & Cavariani, 2000) after a long period. Therefore, it can be common to find this species emerging in the middle of a culture that is already growing.

Another species that was found in large quantities was *Commelina benghalensis* L., typically known as tropical spiderwort. The dissemination of this species is favored because it is spread through the air by seed and underground through rhizomes (Voll, Brighenti, Gazziero, & Adegas, 2002). According to previous authors, the moisture in the straw of the cover crop provides excellent conditions for this weed to germinate, allowing it to also develop in an established culture due to its tolerance of shaded environments.

Generally, the wild radish, rapeseed and crambe treatments presented the best vegetal cover during the study periods, with a high rate of dry and fresh matter production. However, there was a greater incidence of weeds in cultures such as triticale and rye in the first year, but this was avoided from the first to the second year with approximately five weed species germinating under both cover crops.

Conclusion

The best cover crop species, that is, those that presented the highest coverage rate, fresh matter and dry matter values were wild radish, rapeseed and crambe.

In the floristic and phytosociological survey, the weed species with the highest incidence were *Amaranthus retroflexus*, *Commelina benghalensis* L., *Brachiaria plantaginea*, and *Gnaphalium spicatum.*

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