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WINTER COVER CROPS ON WEED INFESTATION AND MAIZE YIELD[1]

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ABSTRACT – The establishment of commercial crops in succession to winter cover crops that leaves a dense straw layer provides significantly suppression of weeds. The objective of this work was to evaluate the suppressive potential of winter cover crops on weed infestation in maize and its effect on the yield of the maize sown in succession. The experiment was conducted in the 2012/2013 crop season, in an area of the UFSM Campus Frederico Westphalen, State of Rio Grande do Sul. Four different species of cover crops (black oat, ryegrass, vetch and forage radish) were seeded and a fallow area was used as control. Evaluations to quantify the dry matter and chemical desiccation were performed at the full flowering period of the cover crops. Maize was sown in no-tillage system, in succession to the cover crops. The incidence and shoot dry matter of weeds (g 0.25 m^{-2}) was evaluated 15 days after the maize emergence. The main weed species in the area were: morning-glory (*Ipomoea grandifolia*), wild poinsettia (*Euphorbia heterophylla*), large crabgrass (*Digitaria sanguinalis*) and purple nutsedge (*Cyperus rotundus*). In general, vetch and ryegrass were the winter cover crops that better suppressed the weeds evaluated. The best maize yield was found in the area previously covered with ryegrass, inferring a relation between the cover crop and suppression of weeds and crop yield.

Keywords: Integrated management. Suppressing potential. *Zea mays*. Crop residues.

EFEITO DE COBERTURAS DE INVERNO SOBRE A INFESTAÇÃO INICIAL DE PLANTAS DANINHAS E PRODUTIVIDADE NA CULTURA DO MILHO

RESUMO – O estabelecimento de culturas comerciais em sucessão a coberturas de inverno, com presença de densa camada de palha, proporciona significativa supressão de plantas daninhas. O objetivo deste trabalho foi avaliar o potencial supressor de coberturas de inverno sobre a incidência inicial de plantas daninhas na cultura do milho e seu efeito na produtividade da cultura semeada em sucessão. Um experimento foi conduzido no ano agrícola de 2012/2013, em área experimental da UFSM, Campus de Frederico Westphalen RS. Foram utilizadas quatro diferentes espécies de cobertura de inverno (aveia-preta, azevém, ervilhaca e nabo) semeadas em faixas, além da testemunha mantida em pousio. No pleno florescimento das coberturas foi realizada a quantificação da massa seca e a dessecação das mesmas. O milho foi semeado em sistema de plantio direto em sucessão às coberturas. Aos 15 dias após a emergência do milho foi avaliada a incidência e a massa seca de parte aérea das plantas daninhas presentes (0,25 m²). As principais espécies daninhas presentes na área foram: corriola (*Ipomoea grandifolia*), leiteiro (*Euphorbia heterophylla*), milhã (*Digitaria sanguinalis*), tiririca (*Cyperus rotundus*). De forma geral, a ervilhaca e o azevém foram as coberturas de inverno com maior capacidade supressora sobre as plantas daninhas avaliadas. O melhor desempenho produtivo do milho foi observado sobre a palhada de azévem, inferindo para um relação de supressão de plantas daninhas e produtividade da cultura.

Palavras-chave: Manejo integrado. Potencial supressivo. *Zea mays*. Palhada.

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INTRODUTION

Maize has great importance on global energy security. It is mainly used as food for animals and humans from low-income classes. However, in recent decades, maize became also a raw material for industries, where it is used for production of ethanol and processed foods (DUARTE; MATTOSO; GARCIA, 2015). Maize production has achieving gains in productivity each crop because the growing global demand, but also significant losses due to failures in management, in particular the lack of adequate control of weeds that infest this culture.

Yield losses caused by the presence of weeds in maize crops range from 10 to 80% (VARGAS; PEIXOTO; ROMAN, 2006). Silva et al. (2015) reported a reduction in crop yield of about 10% in the presence of 10 plants m^{-2} of purple nutsedge, which represented 960 kg ha^{-1}. Other studies report yield loss of 5 Mg ha^{-1} compared to areas with hoeing for weed control (SEVERINO; CARVALHO; CHRISTOFFOLETI, 2005). Competition with weeds may also result in reduced accumulation of total dry matter of up to 89% in the presence of *Euphorbia heterophylla* (CARVALHO et al., 2011).

The reduction of maize productivity due to weeds is related to the weed species that exist in the area, its density, cultural stage in which there is competition and climate and soil conditions (VARGAS; PEIXOTO; ROMAN, 2006). Moreover, the period of coexistence between the weeds and the crop completely changes the competitiveness of these weed species, which has greater impact on early development stages of maize (KARAM et al., 2010).

The current agricultural crop system uses basically chemical control for weed management (KARAM et al., 2010). The repetitive use of herbicides, in under or over dosing and inadequate application conditions, may decrease the performance of products, select these molecules for resistance and cause environmental damages. The reduction and rational use of these products can be achieved by adopt an integrated weed management, using preventive and cultural practices. One of the most effective cultural practices is the use of soil cover crops, also known as winter coverages in southern Brazil, and the formation of a dense straw layer by the no-tillage system, which is the practice that has better effect in suppressing weeds (BALBINOT JR.; MORAES; BACKES, 2007).

The use of cover crops preceding the culture of interest during the winter in southern Brazil can reduce the density of weeds, as well as modify the population present in the area (CORREIA; DURIGAN; KLINK, 2006). This result is due to the vegetation coverage and maintenance of plant residues on the soil surface, reducing the emergence and establishment of weeds, from physical, chemical or allelopathic effects (MONQUERO et al., 2009). Moreover, the presence of straw on the soil from cover crops is a beneficial practice that improve soil properties, providing the soil protection against erosion, water conservation, increasing the soil biological activity and nutrient cycling efficiency (DANTAS; PINTO FILHO; PEREIRA, 2009).

Species used as cover crops must have some specific properties, especially high dry matter production of shoot (SANCHEZ, 2012), which is important for a uniform soil cover, and a C:N ratio balanced, not decomposing quickly and exposing the soil in the early stages of the crop in succession. The soil exposure favors the establishment of weeds and makes it susceptible to erosion, while a relative high C:N can extract nitrogen from the system, reducing its availability for the crop in succession (RIZZARDI; SILVA, 2006).

The adoption of management practices that puts the culture in an advantageous competitive position compared to weeds, such as the use of cover crops, is a viable alternative to reduce the dependence on herbicides (TOLLENAAR et al., 1994). Moreover, this practice is a fundamental tool in integrated weed managements, providing competitive advantages, favoring the culture and suppressing weeds (BALBINOT JR.; FLECK, 2005). In this context, the objective of this work was to evaluate the suppressive potential of cover crops on weed infestation and its effect on the yield of maize sown in succession.

MATERIAL AND METHODS

The experiment was conducted from May 2012 to April 2013 in the Santa Maria Federal University (UFSM), *Campus* Frederico Westphalen (270°39'26"S, 530º42'94"W and altitude of 490 m), in a distropherric Red Latosol soil. A randomized strip-plot experimental design was used with four replications with treatments consisting of four cover crops (black oat, *Avena strigosa*; ryegrass, *Lolium multiflorum*; vetch, *Vicia sativa*; forage radish, *Raphanus sativus*) that were seeded in strips and a fallow area was used as control. The experimental units had 56 m^2 (11,2 m x 5 m).

The cover crops were broadcast seeded in May 25, 2012. The densities used were 80 kg ha^{-1} (black oat), 25 kg ha^{-1} (ryegrass), 60 kg ha^{-1} (vetch) and 15 kg ha^{-1} (forage radish), which provided a good establishment of the crop. The growth and development of cover crops were monitored until the full flowering period, when the dry matter production from four samples of 0.25 m² of each crop were evaluated. These samples were dried in a forced-air oven at 60°C to a constant weight. Two herbicide application, with a 20-day interval, were used for desiccation of the cover crops, glyphosate (1080 g ha^{-1}) and sethoxydim (230 g ha^{-1}).

The maize (hybrid 30B39, RR and LL) was manually sowed 14 days after the last desiccation (November 11, 2012) at density of 70,000 plants ha^{-1} with 400 kg ha^{-1} of NPK (5-20-20), and 160 kg ha^{-1} of urea was applied as top dressing fertilization.

The number of weeds per area (plants m^{-2}) was evaluated 15 days after the maize emergence (DAE). This period is the most critical for the maize competition with weeds, thus, the greatest damage caused by weeds is in the maize early stage of development (RIZZARDI et al., 2014). The weed species were identified, quantified and collected for dry matter evaluation with four replications of 0.25 m² per plot. The samples were dried to constant weight at 60°C in a forced-air oven. Subsequently, the chemical control with glyphosate (1080 g ha^{-1}) were performed (17 DAE). The maize height (cm) was evaluated 15 and 39 DAE.

The maize harvest was performed 167 days after sowing (DAS) in an area of 14.4 m² per plot. Twenty random plants per plot within this area were evaluated for stem diameter (cm), ear insertion height (m) and plant height (m) in the field. The number of grains per ear, number of grain rows per ear, number of grains per grain row, ear length (cm) and ear diameter (cm) were evaluated in the laboratory.

Throughout the crop cycle, all crop practices were performed according to the crop needs, including insecticide and fungicide applications. The precipitation during the crop period was monitored (Figure 1) by an automatic weather station in Frederico Westphalen RS, located 50 meters from the experimental area. The total precipitation during the crop cycle was 980.8 mm, however, a water deficit was found at the flowering and grain filling periods (about 70 DAS), negatively affecting the crop yield (Figure 1).

The results were subjected to analysis of variance and, when significant, the treatment averages were compared using the Tukey test at 5% probability and, when necessary, the data were processed.

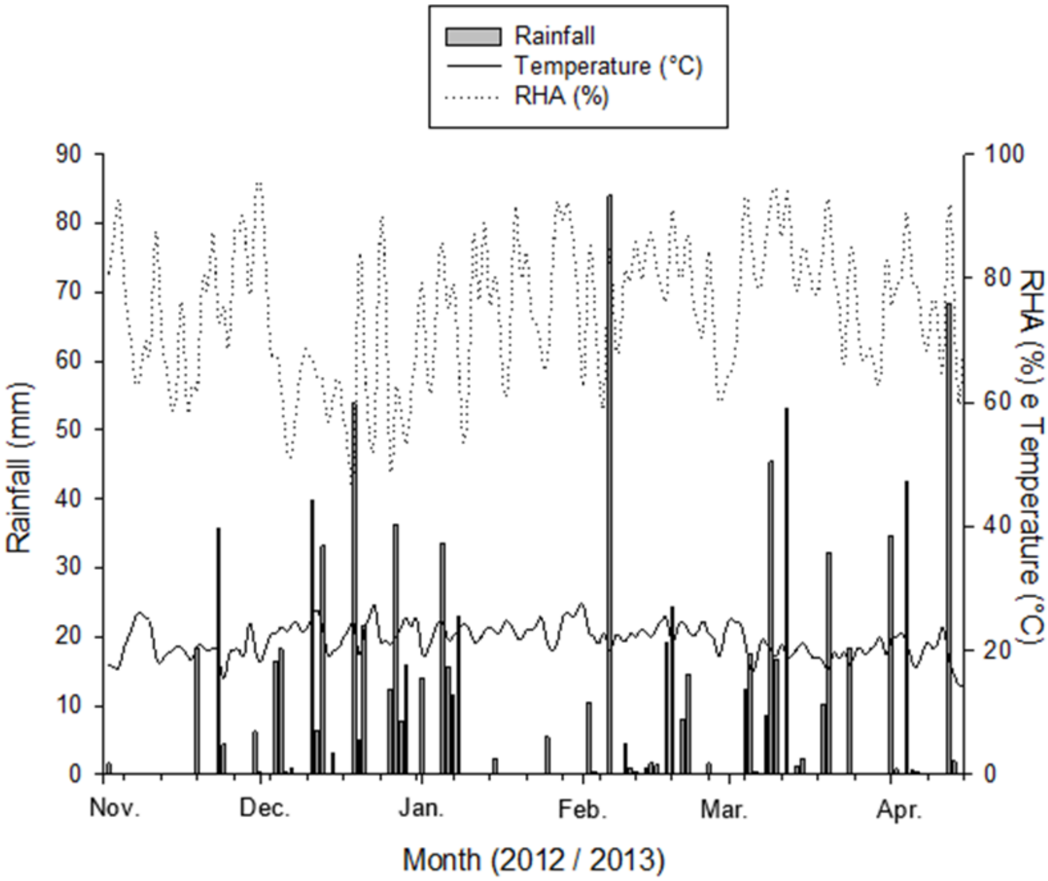

Figure 1. Precipitation (mm day^{-1}), air relative humidity (ARU%) and average daily temperature (°C) during the maize crop cycle. UFSM, Frederico Westphalen RS, 2012/13.

RESULTS AND DISCUSSION

The results showed significant effects (p≤0.05%) for the cover crop dry matter production (DM), number and dry weight of weeds, maize height and crop yield (Tables 1, 2, 3 and 4). The black oat had the highest dry matter production (4,948.7 kg ha^{-1}), while the forage radish had the lowest (2,598.8 kg ha^{-1}), below even from the fallow area (4,400.5 kg ha^{-1}) (Table 1), which can be related to its herbaceous, erect, very branched morphology, uneven leaf distribution and C:N ratio, that facilitated the decomposition, leaving the soil quickly unprotected after desiccation. The fallow area had high dry matter production because of the natural vegetation growth (no cover crop cultivated), however, the natural coverage is not homogeneous, allowing emergence of weed plants in areas with less dry matter coverage. The presence of vegetation on the soil are very useful in reducing the emergence and development of weeds and prevent the direct incidence of sunlight on the soil, affecting the germination of positive photoblastic species (LAMEGO et al., 2013).

Table 1. Shoot dry matter production (kg ha^{-1}) of winter cover crops sampled at the full flowering period.

Cover Crop	Dry matter (kg ha^{-1})
Black Oat	4,948.7 A
Ryegrass	4,463.9 AB
Vetch	4,436.7 AB
Forage Radish	2,598.8 C
Fallow Area	4,400.5 B
Average	4,169.7
C.V. (%)	21.74

Means followed by the same letter do not differ statistically by the Tukey test ($p \leq 0.05$).

In general, all cover crops produced dry matter enough to suppressing the emergence of weeds in the crop in succession. The incidence of weeds assessed 15 DAE had high frequency of species morning-glory (*Ipomoea grandifolia*), wild poinsettia (*Euphorbia heterophylla*), large crabgrass (*Digitaria sanguinalis*) and purple nutsedge (*Cyperus rotundus*) (Table 2).

Table 2. Infestation of weeds in maize (hybrid 30B39) and shoot dry matter (SDM) of weeds. UFSM, Campus Frederico Westphalen RS, 2012/13.

Cover Crop	Weed					
	Morning-glory¹	Wild poinsettia¹	Large crabgrass¹	Purple nutsedge¹	Total ¹	SDM²
Black Oat	41.17 A	76.25 B	45.75 A	96.50 A	317.50 A	87.02 AB
Ryegrass	27.50 AB	66.50 C	03.50 B	00.25 B	126.50 B	53.95C
Vetch	51.92 A	18.00 D	07.00 B	25.50 B	114.63 B	26.80 D
Forage Radish	51.50 A	11.75 D	02.75 B	02.75 B	364.58 A	77.46BC
Fallow Area	18.19 B	136.25 A	01.75 B	67.50 B	268.08 A	108.96 A
Average	38.05	61.75	12.15	38.50	238.26	70.84
C.V. (%)	29.97	32.33	37.41	33.60	22.93	18.68

¹Total weed per m² of the plot. ² Shoot dry matter of all occurring weed treatment in g m⁻². Means followed by the same letter are not statistically different in the column by the Tukey test ($p \leq 0.05$). Data analyzed from the transformation $\sqrt{x+1}$.

The total weed infestation showed an inverse correlation to the cover crop dry matter production, denoted by the higher number of weeds in the forage radish (364 weeds m^{-2}) and fallow areas (268 weeds m^{-2}) (Table 2). Other studies reported that the cover crops *Crotalaria juncea* and *Pennisetum glaucum* provides over 97% control of weeds in tomato crops, indicating the higher suppressing potential of these species (DA SILVA; HIRATA; MONQUERO, 2009).

The black oat dry matter produced had no direct relation with reduction of weeds, presenting 4948.7 kg ha^{-1} of dry matter and total infestation of 317.5 weeds m^{-2}. The high weed infestation in the maize area that was preceded by black oat was due to the presence of purple nutsedge. The incidence of this species, unlike the others, was heterogeneous in the area, having higher densities in the black oat and fallow areas, which hindered the comparison with the other cover crops. This heterogeneity in agricultural areas is due to this species spread mechanisms, which is based on its vegetative reproduction (PEREIRA; MELLO, 2008).

The dry matter of shoots followed the number of weeds per meter, with the highest values during the maize crop found in the fallow (108.96 g m--$^{-2}$) and black oat (87.02 g m--$^{-2}$) areas (Table 2). Vetch was the cover crop that most negative influenced the weed shoot matter production, which had only 26.08 g m^{-2}. Similar results were found by Lamego et al. (2013), in their study, the vetch used as cover crop had practically no germination and development of *Conyza bonariensis* compared the control, which had 147 weed plants m^{-2}. Therefore, considering the dry matter produced by the cover crops (Table 1), the weed species incidence and dry matter production (Table 2), ryegrass and vetch best suppressed the weed incidence and development. Besides the physical effect, the ryegrass and vetch may have contributed to the weed germination suppression through chemical or allelopathic effect (GOMES; CHRISTOFFOLETI, 2008).

The cover crops significantly ($p \leq 0.05\%$) influenced the maize height averages, which was evaluated in three stages of development (Table 3). The cover crop that most influenced the maize height was the vetch, increasing in 4.5% at 39 DAE and in 3.6% at the end of the crop cycle compared to the fallow area and with significant differences in all periods evaluated, and differences of about 20 cm at the end of the crop cycle compared to the forage radish.

The maize heights found in common vetch may be related to two factors, the reduction in total weed infestation (Table 2) and availability of nitrogen to the crop by cycling. The amount of nitrogen accumulated during this species cycle can reach 220 kg ha^{-1} (MONEGAT, 1991), which is rapid available. Thus, the results inferred an action of these two factors on the maize height.

Table 3. Plant height at 14 and 39 days after emergence (DAE) and at the end of the maize crop cycle grown in succession to winter cover crops.

Cover Crop	14 DAE	39 DAE	Crop Cycle End
Black Oat	79.10 A	206.40C	281.21 C
Ryegrass	76.51 AB	213.55 BC	290.62 B
Vetch	76.37 AB	224.79 A	300.59 A
Fallow Area	71.02 B	215.14 B	290.19 B
Forage Radish	58.97C	185.21D	279.89 C
Average	72.39	209.02	288.50
C.V. (%)	11.00	3.75	3.08

Means followed by the same letter do not differ statistically by the Tukey test ($p \leq 0.05$).

Vetch had the best results on agronomic characteristics for the variables grains ear (G/E), grains rows (G/R), ear diameter (E.D.) and ear insertion height (E.I.H) (Table 4). The highest maize yield was found in the area preceded by ryegrass. The R/E and S.D. was not significant different between the treatments. The better productive performance of ryegrass and vetch may be related to the lower total weed infestation after these cover crops, in the early growth period of maize and weeds (Table 2).

Table 4. Agronomic characteristics and grain yield of maize (hybrid 30B39) after winter cover crops. UFSM, Campus Frederico Westphalen RS, 2012/13.

Cover Crop	G/E	R/E²	G/R³	E.D.[4]	E.I.H.[5]	S.D.[6]	Yield[7]
Black Oat	697.2 AB	17.7 A	38.2 AB	49.9 AB	140.4 C	23.9 A	11.796.6C
Ryegrass	691.0 AB	17.5 A	39.9 AB	50.5 A	145.7 BC	23.4 A	13.527.3 A
Vetch	753.4 A	18.0 A	41.8 A	50.4 A	153.7 A	24.4 A	12.657.5 B
Forage Radish	668.4 B	17.9 A	37.1 B	48.7 B	148.4 AB	24.1 A	11.718.5 C
Fallow Area	681.8 B	17.5 A	39.3 AB	50.7 A	148.3 AB	24.0 A	12.265.8 BC
Average	694.79	17.73	39.27	50.05	147.33	23.95	12.393.14
C.V. (%)	9.35	3.86	9.61	3.18	5.20	6.47	9.13

¹Grains ear^{-1}. ²Rows ear^{-1}. ³Grains rows^{-1}. [4]Ear diameter (mm). [5]Ear insertion height (cm). [6]Stem diameter (mm). [7]Grain yield (kg ha^{-1}). Means followed by the same letter in the column are not statistically different according to Tukey ($p \leq 0.05$).

The grain yield in the fallow area was not statistically different than the black oat, forage radish and vetch areas. Rizzardi et al. (2014) reported that the productive characteristic that is most influenced by early competition between crop and weeds is the number of grains per ear, since in this period there is differentiation of reproductive structures, negatively affecting productivity. This report is consistent with the results found in the present study, in which the forage radish and fallow area presented high weed infestation in the critical period of competition, before the control (17 DAE), and the lowest number of grains per ear.

The period in which the maize crop must remain without weeds (critical period of competition) is generally between the early stages (V_2 a V_7) (RIZZARDI et al., 2014). Therefore, if no weed control measure is adopted in this period, the crop productive characteristics will be negatively affected. Thus, crop implementation in areas free from weeds is emphasized. Cover crops residues assist in the preventive weed management with more or less suppressive power depending on the characteristics of the species used.

The use of cover crops and chemical control, as carried out in this study (glyphosate application at 17 DAE) is part of integrated weed managements, which is increasingly technically and environmentally required, avoiding an exclusive dependence on herbicides. The reduction of dependence on herbicides is ensuring less environmental impact and also greater sustainability of herbicides, avoiding a high selection pressure that accelerates the resistant weeds. Several cases of weeds that are resistant to glyphosate herbicide are reported in Brazil. Therefore, the use of cover crops is a very interesting tool to integrated weed managements.

CONCLUSION

Vetch and ryegrass used as winter cover crop have suppressive effect on incidence of weeds in early stages of maize crops, which favors the adoption of integrated management methods, positively influences the crop grain yield and reduce the use of herbicides.

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