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A N I N T E R N A T I O N A L J O U R N A L

Variation on the Amount of Winter Cover Crops Residues on Weeds Incidence and Soil Seed Bank during an Agricultural Year

Márcia Maria Mauli[1], Lúcia Helena Pereira Nóbrega[1*], Danielle Medina Rosa[1], Gislaine Piccolo de Lima[1] and Ricardo Ralish[2]

[1]Centro de Ciências Exatas e Tecnológicas; Universidade Estadual do Oeste do Paraná; Cascavel - PR - Brasil.
[2]Departamento de Agronomia; Universidade Estadual de Londrina; Londrina – PR – Brasil

ABSTRACT

This study analyzed possible interferences associated to the amount of crop residues produced by the black oats and the consortium of black oats, common vetch and forage turnip on weeds incidence and soil seed bank. It was a field trial with seven treatments and five replications. The cover crop was sown at throwing, cut at 100 days and residues were put on each respective plot, using a proportion of normal amount of produced straw, either its half and double. The heaviest weights were obtained from cover crop consortium and their application decreased weeds incidence in such area. The seeds bank and other analyzed parameters did not show statistical differences. According to these results, it was concluded that winter cover crop could be used in crops rotation with soybean.

Key words: no-tillage system, seeds bank, weeds incidence

INTRODUCTION

Soybean culture, until the 1940's was considered economically insignificant to Brazilian farmers and due to its small produced volume, it did not take part of statistical surveys. Nevertheless, its expansion was observed in the 1970's and 1980's, with higher expansion in the traditional southern areas (Tanaka and Mascarenhas, 1992). It is among the four more produced grain crops worldwide, and Brazil ranks second in production, with the state of Paraná as the second largest producer, accounting for 22.6% of national production (Seprotec, 2007). According to Miyazawa et al. (2002), the black oat residues are very efficient for lime mobilization in soil. Crop rotation management has been recommended for it as it is produced in large areas. It can also improve some erosion that can be found on soil. Crop rotation consists on alternating species in the same area for productivity and soil recovery (Rezende et al., 2003). This practice also allows controlling the weeds species in a given culture that is usually infested with the plants that have the same requirements and growth habits (Lorenzi, 2006). The cover crops are alternatives to the crop rotation system. Furthermore, they leave residues on soil, which are decomposed and considered as an essential biological process, influenced by several factors (Calegari, 2006). According to Dias et al. (2003), cover crops residues reduce the availability of Cu^{2+} (Copper) and Zn^{2+} (Zinc) in

[*]Author for correspondence: lhpn@unioeste.br

the soil through organic metal complexing reactions, which increase the availability of S (Sulphate) and B (Borate) through competition with organic anions by adsorption sites of soil, especially in radish (*Raphanus sativus* L.) and black oat (*Avena strigosa* Schreb) species. Thus, the suitable management of such species may reduce Cu^{2+} and Zn^{2+} toxicity and also increase S and B availability in soil.

Black oat (*Avena strigosa* Schreb) can be used for crop rotation as it is a grass with high tillering capacity, fresh weight production and improves the physical and chemical properties of the soil. It has an important role on grain production, so it is a good alternative to winter crop and in crop rotation systems (Calegari, 1992). According to EMBRAPA (2004), it has a good amount of crop residues, helps on soil particles aggregation, withstands fungal attack and has good carbon/nitrogen content. Portas (2007) has pointed out that black oat is the only species that can be planted in crop rotation with no restriction for the previous crop and without causing problems for the next one. It also reduces weeds population because of its allelopathyc effect and, according to Miyazawa et al. (2002), the oat residue has great efficiency on lime mobilization in soil.

The common vetch (*Vicia sativa* L.) is a leguminous (Family *Fabaceae*), with good growth and is also recommended for crop rotation, since it provides an effective protective cover to the soils. It also assists in nitrogen reduction due to the high capacity of fixing atmospheric nitrogen by the development of bacteria on their roots (Calegari, 1992).

Radish (*Raphanus sativus* L.) belongs to *Brassicaceae* family, which has high capacity for nutrients recycling, especially nitrogen and phosphorus. As it has a fast growth, it competes with weed plants, reducing spending on herbicides or weeding (Portal do Governo do Estado de São Paulo, 2007). It has a tap root system, very deep, reaching more than two meters, hence, it can be used for on decompact soil and oxygenation (EMBRAPA, 2004).

Allelopathy is one of the effects promoted by dry matter decomposition of cover crops. Interference among the plants, in this case, occurs by the substances that are produced and released into the environment, either through living tissues or by the decomposition of dead ones (Lorenzi, 2006). Allelopathy is the ability of plants to produce the chemical substances that can influence others, in a feasible or unfeasible way, when released into the environment (Rice, 1977).

According to Weih et al. (2008), allelopathyc activity can be used as an alternative instead of chemical control use in order to suppress the weeds in agro-ecosystems. This is against the society's demand for pesticide-free environments and development of greener products for the consumption and, as a consequence, there is less risk of toxicity (Alves et al., 2002). The allelopathyc effect of cover crops also depends on the type of plant waste that remains in soil and of the weeds that grow on such area. Thus, to control the weeds, it is important that the residues present harmful allelochemicals to those ones and that they can also be released into soil at some concentrations that inhibit the weeds development (Almeida, 1991).

Choosing carefully the winter cover crops, their allelopathyc effects can be used to reduce the weeds infestation in spring and summer crops, so that the use of pesticides can be decreased, while the economic viability can increase for the farmers (Almeida, 1991). According to Nóbrega et al. (2009), the consortium of cover crops – black oats, radish, vetch and rye and single black oats showed possible allelopathyc effects in laboratory experiments, as they interfered on soybean emergence. In addition, the rates of emergence, emergence percentage in sand and fresh weight of hypocotyls were also negatively affected by cover crops. Martins (2006) analyzed the extracts of the same cover crops, consorted and single, and observed a negative interference on the germination of soybean seeds, as well as on the primary roots growth irrespective of the concentration of the extracts. This indicated a possible allelopathyc effect. However, the reduction on weeds number might be associated to several factors such as the physical barrier provided by crop residues on soil that affected the sunlight passage (Theisen et al., 2000) and decreased thermal and hydric amplitude of soil (Ferreira et al., 2000; Furlani et al., 2008). They could also be associated with the biological factors such as soil microbiota (Colozzi Filho and Andrade, 2006) and chemical factors, such as allelopathyc substances released from plant residues (Ferreira et al., 2000; Almeida, 1991).

The cropping systems also modify the richness and composition of seeds banks of soil in agricultural areas (Favareto and Medeiros, 2006). The seeds bank, according to Almeida-Cortez (2004), can be defined as the “store of available seeds on soil, from surface to deeper layers in a given area and time”. The entry (dispersion) and output (germination or death) of seeds determine the bank accumulation (Almeida-Cortez, 2004). The size and composition of seeds bank reflect which management should be adopted to control the weeds in an area. A reduction in such bank can mean less problems with the weeds in agricultural areas and thus, farmers can save some money, especially for herbicides; the environment will be healthier as there will be less application of chemicals (Monquero and Christoffoleti, 2005). However, despite its importance, this area needs basic information as well as further more methodological studies aiming at finding out which they are and how manipulated environmental factors act out in order to allow the total or no seeds germination (Martins and Silva, 1994). Thus, it is important to develop and improve the techniques to control the weeds based on seeds bank of soil to get economic viability and that can be used in emerging then technologies such as precision agriculture (Voll et al. 2003). In this context, this study examined whether the change in residues amount, provided by the plants of cover crops, affects weeds incidence and seeds bank of soil.

MATERIAL AND METHODS

The field experiment was carried out in Catanduvas city, western Paraná State, Brazil, with geographical coordinates as 25°18'16.0" S latitude, 53 ° 11' 34.1" W longitude and average altitude of 465 m. The winter cover crop seeding of black oats, vetch and radish was manual, at throwing and incorporated into soil with harrowing, with approximately 5 cm depth in July 2007. Black oats culture was implanted at 70 kg ha^{-1} rate and the consortium was in the proportion of 42 kg ha^{-1} of black oats, 21 kg ha^{-1} of common vetch and 11 kg ha^{-1} of radish. It followed the recommendations for the region adopted by Piccolo (2008). The experimental area was bigger to meet the necessary amount of straw to be used in the treatments.

Germination and purity tests were carried out with the species in the laboratory before sowing. The seeds showed 90, 84 and 75% of germination and were 100, 97 and 98% pure for black oats, vetch and radish, respectively.

During plants blossom term (at approximately 100 days), their aerial parts were cut at soil, the residues were put on their respective plots and spread evenly over the whole plot. Seven treatments were randomly arranged, with five replications each in the areas planted with black oats and consortium, forming three treatments with some amount of straw (based on fresh weight), differentiated and in each plot, five replications of each treatment were arranged in order to quantify fresh weight obtained (normal amount) from single black oats and consortium. Based on this, the amounts half and double were formed, according to the following descriptions: T1 - Control - 0 t ha^{-1}; T2 - Black oats (normal amount of produced straw) - 6.62 t ha^{-1}; T3 - Black oats (half of straw)- 3.31 t ha^{-1}; T4 - Black oats (double of straw) - 13.21 t ha^{-1}; T5 - Consortium (normal amount of produced straw) - 18.42 t ha^{-1}; T6 - Consortium (half of straw) - 9. 21 t ha^{-1}; T7 - Consortium (double of straw) - 36.84 t ha^{-1}.

The weeds incidences in cover crops at 60, 90 and 100 days after sowing of cover crops were evaluated. A 0.50 m x 0.50 m metal frame (totaling 0.25 m^2) was put in the field and the number of weeds present within the frame were counted. Leaves were separated into large and narrow. There were four replications for each plot: black oats, control and consortium. The results were expressed in number of plants per square meter. To determine the fresh and dry weights of cover crops, the metal frame was 0.50 x 0.50m and put four times in each plot to obtain the samples of their aerial parts and quantify fresh and dry weights of straw of each plot (single black oats and consortium). The plant material in the frame was cut at ground level and weighed immediately to obtained the fresh weight, packaged and then taken to the laboratory to be dried in an oven with forced air circulation at 60 °C for about 48 h. The results were expressed in t ha^{-1}. The dry fresh/weight weight ratio (FW/DW) was obtained by dividing the average value of cover fresh weight by the average value of its dry weight.

The weeds incidence in soybean was evaluated before the culture sowing, 30 days after emergence and before harvest in January, February and April, 2008, respectively. The evaluation was carried out based on the same methodology described for the weeds incidence in cover crops.

Seeds bank of soil

The soil samples, grown under different treatments (single black oats, consortium and control) were collected for observation in laboratory. The data were collected with an auger help at 20 cm depth. Five simple samples were taken out from each plot of each treatment in "W" configuration (Medeiros and Steiner, 2002). These samples were placed and mixed in a plastic bucket to form a compost sample per replication. After that they were packed, identified and brought to the laboratory. The seeds bank evaluation applied the germination methodology in tray (gerbox), which was on a table at room temperature, with daily irrigation, following methodology adapted from Brown (1992).

The seedling emergence score, classification of seedling emerged in large and narrow leaves and their removals were registered after this process. This procedure was performed at 30, 60, 90 and 120 days after soil samples collection (Lacerda et al., 2005). In order to remove the possible dormancy of remaining seeds, after identification and seedlings removal, at each interval, irrigation was stopped until the soil was dry, to be turned over in trays during a period of approximately seven days. After that period, irrigation began again, so that a new germination cycle could emerge (Medeiros and Steiner, 2002). The result was expressed as average number of plants found by repetition.

The experimental design was subdivided in the plots, with seven treatments and five replications for each treatment, totaling 35 essays, except for the weeds incidence in cover crop, fresh and dry weights and a completely randomized design (CRD) was used. The collected data were subjected to the analysis of variance and mean comparison based on Scott-Knott test at 5% significance was processed by the Sisvar program (Ferreira, 1999).

RESULTS AND DISCUSSION

The means of analysis for the weed with large and narrow leaves under the cover crop in three monthly evaluations (60, 90 and 100 days after sowing) are shown in Table 1.

Table 1 - Weeds incidence (number of plants m^{-2}) of large leaves (LL) and narrow leaves (NL) in cover crops and control, evaluated at 60, 90 and 100 days after sowing, in Catanduvas - PR, 2007.

Treatment	Days after sowing					
	60		90		100	
	LL	NL	LL	NL	LL	NL
Control	72 a	5 a	103	11 a	154 a	39 a
Black oats	37b	0 a	52	2 a	91 a	37 a
Consortium	25b	6 a	8 b	4 a	15 b	0 a
CV (%)	39.1	91.0	40.2	58.5	22.4	79.3

Means followed by the same letter in column do not differ among themselves by Tukey test at 5% probability. The presented data are results of original observations followed by the letters obtained from the comparison of means with the transformation in $\sqrt{x+0,5}$

The coefficients of variation, according to Gomes (2000), showed outlier data and all of them were above 30%, except for large-leaf plants at 100 days. For large leaves, there was a significant difference among the control and other treatments at 60 and 90 days. On the other hand, there was a difference at 100 days only for the consortium with the other treatments. There was no difference for narrow leaves. Tokura and Nobrega (2006), also working with the cover crops, pointed out that the weed species were reduced in the presence of cover crops and the best were in decreasing order: black oats, canola, radish and millet. The consortium had some advantages over the single crops, such as competition against the weed species. Besides, it also increased the soil protection, because the volume of dry matter was higher and there was a decomposition of several species and an irregular and gradual release of nutrients that remained for the next crop (EMBRAPA, 2004). Table 2 presents the mean values of dry and fresh weights of cover crops.

The consortium showed the highest amount of fresh weight, thus, dry mater was higher when compared to black oats (Table 2). Balbinot Junior et al. (2004) also observed a difference in the weight production among the plants (single and consorted). They concluded that the consortium between black oats + vetch and among black oats + ryegrass + black rye + vetch + radish showed higher fresh and dry weights than the single species. This could be due to a more efficient use of environmental resources such as water, light and nutrients, depending on the use of different niches among species. According to Rezende et al. (2003), the grasses have almost 2.5 times more dry and green weights than the leguminous plants. In addition, the combination of grass and leguminous species increases the quantity and quality of dry matter produced. Hence, the consortium enhances the beneficial effects of cover crops.

Table 2 - Dry weight (DW) and fresh weight (FW) (kg ha^{-1}) and FW/DW ratio of black oats cover crop and consortium at 100 days after emergence. Catanduvas - PR, 2007.

Treatment	Fresh weight	Dry weight	DW/FW
Black oats	6623 b	1649 b	4
Consortium	18411 a	2968 a	6

Means followed by the same letter in column do not differ among themselves by Tukey test at 5% of probability

Table 3 presents the averages of weeds incidence in soybean. For cover crop factor, there was a significant difference only in the evaluation before sowing for large leaf, in which the consortium had lower infestation of weeds. Also, for the amount of straw factor for narrow leaf, there was statistical difference only in the evaluation before soybean sowing, in which only the control differed from the other amounts of straw. And observing the large leaf, on evaluations at 60 and 90 days, the control did not differ from half amount of straw and these amounts differed from normal and double. Thus, confirming the results of Oliveira et al. (2001), this concluded that for each ton of added straw, a reduction on weeds number was observed, mainly in grasses.

Table 3 - Weeds incidence (plants m^{-2}) large leaves (LL) and narrow leaves (NL) in soybean crop, grown under cover crops and straw amounts, evaluated at 60, 90 and 100 days after sowing, in Catanduvas - PR, 2007.

Treatment	Before seedling		30 Days		Before harvest	
Cover crop	LL	NL	LL	NL	LL	NL
Black oats	100 a	50 a	44 a	7 a	19 a	12 a
Consortium	56 b	31 a	37 a	6 a	20 a	9 a
Amount of Straw						
Control	95 a	96 b	63 a	12 a	63 a	18 a
Normal	76 a	20 a	27 b	9 a	27 b	11 a
Half	82 a	24 a	51 a	5 a	53 a	6 a
Double	61 a	12 a	20 b	2 a	20 b	5 a
CV	20.0	32.5	14.9	64.8	20.0	46.9

Means followed by the same letter in column do not differ among themselves by Tukey test at 5% probability. The presented data are results of original observations followed by the letters obtained from the comparison of means with the transformation in $\sqrt{x+0{,}5}$. LL: large leaf; NL: narrow leaf

The coefficients of variation concerning all large-leaf plants of soybean crop prior evaluations, and 30 days prior to collection, indicated data with some homogeneity average, according to Gomes (2000), as they were below 20%. On the other hand, the coefficient values for narrow leaves were above 30%, indicating higher dispersion of data. Balbinot Junior et al. (2003), evaluating two straw amounts of common vetch and control (no cover) on weeds density in maize, found out that the higher the stored amount of straw, the lower the weeds density, being more relevant in non-grass plants, as occurred in this experiment with soybean culture.

The crop residues on soil can act out with their allelopathyc effect by releasing the substances in the environment, reducing the germination and weed development of the area (Goldfarb et al., 2009). The use of cover crops with allelopathyc properties certainly will not lead to total control of weeds in crops, since it has essentially an inhibiting action that reduces or affects the weeds development. However, they will help on maintaining an ecological balance, preventing the damage to crops and the environment (Almeida, 1990).

In weeds incidence of large leaves in seeds bank of soil tilled under the cover crops and amounts of straw there was no significant difference for the examined factors (cover crop and amount of straw) in the four evaluations (30, 60, 90 and 120 days). Possibly there was seed dormancy; also, there might be for samples evaluation in a greenhouse, where temperature and photoperiod can be controlled for better germination of species. The observed effects were related to a unique harvest time, hence, more conclusive results would require longer periods of evaluation.

According to Almeida (1990), allelopathyc substances present in cover crop did not affect the seeds bank and could be considered temporary, allowing regeneration of weeds population. However, Lacerda et al. (2005) reported that the depletion of soil seed could occur by crop residues decomposition on soil, releasing volatile allelochemicals that would affect the seeds on soil plus predation by the animals. As correlation among the weed seeds on soil bank is known, the establishment of their respective emergent flora and the potential of infestation are important tools to predict the infestations as well as the development of more available programs for management of the weeds in crops (Isaac and Guimarães, 2008).

Consequently, taking into account the amount of analyzed straw, the use of normal amount was indicated (black oats - 6.62 t ha^{-1}; consortium - 18.42 t ha^{-1}) or it could be a double one (black oats - 13.21t ha^{-1}; consortium - 36.84 t ha^{-1}), which showed the best results. Since, under conditions of optimal sowing periods, higher values of fresh and dry weights could be obtained and this should be better studied. These results referred to a unique harvest time and might not be enough for definitive answers about the use of these species in relation to weeds control, hence some successive years would be indispensable to confirm these results.

The continued use of species can lead to higher results concerning the weeds so that in the future a more significant effect can be observed. Hence, the farmer should carry out some crop rotations using cover crops for several harvests, because an only crop may not be enough to produce an available green cover. However, based on the first results, in the first harvest, the use of consortium or even of a single black oats should be proposed for crop rotation with soybeans in the region where this study took place.

CONCLUSIONS

Based on these trial conditions, the use of black oats and a consortium as cover crops did not interfere statistically on the weeds incidence, both in the cover crops and soybeans. The crop residues amounts showed that the higher the amounts of soil covers, the lower the weeds incidence. If there was a chance to increase the cover crop with straw addition, infestation decreased even more. Significant results were not registered for the seed bank of soil grown under the treatments, since there was a low seedling emergence in all the treatments, including the control.

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