SOIL PROTECTION BY USED OF COVER CROPS CONSORTIA
AND SINGLE CULTIVATION

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Abstract: The no-till system has been growing over the years and for this system to be successful, it is essential to maintain permanent vegetation cover over the soil, an adequate crop rotation system with minimal overturning. A strategy for soil protection is to introduce species of cover crops in winter under single or intercropping. The objective was to evaluate the rate of soil cover by intercropping between black oats (Avena strigosa L.) and forage turnip (Raphanus sativus L.) at different sowing densities, as well as the isolated species in terms of soil protection under no-tillage. The study was conducted at the Federal Technological University of Paraná (UTFPR), campus Santa Helena, with a randomized block design, with five treatments and three repetitions. The treatments were: 100% black oats (BO); 100% forage turnip (FT); 75% BO + 25% FT; 50% BO + 50% FT and 25% BO + 75% FT. The cover crops were sown in May 2019. The percentage of soil cover from 21 to 91 days after sowing (DAS) was evaluated using the photographic method, with weekly collection of images in an area delimited by a metallic frame (25 m²), positioned on the ground at two fixed points per plot. The coverage rate quantification was estimated by overlaying a grid with 100 points of intersection over each image. The rate of soil cover by consortia and single crops did not show a statistically significant difference. To 49 days, consortia had coverage equal to or greater than 70%, while for single species, this percentage was reached at 56 DAS and 70 DAS, for BO and FT, respectively. All treatments showed high potential for soil protection and coverage rate from 70 DAS.

Keywords: Soil cover rate. Green adubation. Vegetal cover.

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Resumo: O sistema de plantio direto vem crescendo com o passar dos anos e para o sucesso neste sistema é fundamental a manutenção de cobertura vegetal permanente sobre o solo, adequado sistema de rotação de culturas com o mínimo revolvimento. Uma estratégia para proteção do solo é introduzir espécies de plantas de cobertura no inverno em cultivo solteiro ou consorciadas. O objetivo foi avaliar a taxa de cobertura do solo pela consorciação entre aveia preta (Avena strigosa L.) e nabo forrageiro (Raphanus sativus L.) em diferentes densidades de semeadura, bem como as espécies isoladas quanto a proteção do solo em plantio direto. O estudo foi conduzido na Universidade Tecnológica Federal do Paraná (UTFPR), câmpus Santa Helena, com delineamento de blocos ao acaso, com cinco tratamentos e três repetições. Os tratamentos foram: 100% aveia preta (AP); 100% nabo forrageiro (NF); 75% AP + 25% NF; 50% AP + 50% NF e 25% AP + 75% NF. As plantas de cobertura foram semeadas em maio de 2019. Avaliou-se a porcentagem de cobertura do solo dos 21 aos 91 dias após a semeadura (DAS), através do método fotográfico, com coleta semanal de imagens em área delimitada por quadro metálico (25 m²), posicionado sobre o solo em dois pontos fixos por parcela. A quantificação da taxa de cobertura foi estimada pela sobreposição de um quadriculado com 100 pontos de interseção sobre cada imagem. A taxa de cobertura do solo pelos consórcios e cultivos solteiros não apresentou diferença estatística significativa. Aos 49 dias consórcios apresentaram cobertura igual ou superior a 70%, enquanto para as espécies solteiras, esse percentual foi atingido aos 56 DAS e 70 DAS, para AP e NF, respectivamente. Todos os tratamentos apresentaram elevado potencial de proteção do solo e de taxa de cobertura a partir de 70 DAS.

1 INTRODUCTION

Actually the productive sector has been seeking technologies for the systems of agricultural production with ecological perspective, profitable and socially fair with a great preoccupation with conservation and environment preservation. With this, it seeks to use natural resources such as: water, soil, fauna and flora in a more responsible way and with a more agroecological view or at least sustainable for the agricultural sector (ESPINDOLA et al., 2004).

The sustainable, agroecological, productive and environmentally balanced/correct agriculture is based on conservation conduct. For this, it is very important to perform the correct handling of the soil through crop rotations, use of consortia with cover plants and green fertilization, to fight pests through biological control, as well as in the proper application of natural resources (ESPINDOLA et al., 2004).

Since the 1990s, the No-Tillage System (NTS) has been a tool widely used among producers as a form of soil conservation and consequently ensuring greater productivity in their cultivars (CRUZ et al., 2014).

The term "no-tillage" meaning the cultivation practice directly inserted into the land, without the obligation to revolving the soil, originated in the 1950s in England and in the United States (ANDRADE et al., 2018). In Brazil, the main character who transformed agriculture in recent decades was rural producer Herbert Bartz, resident of Rolândia - Paraná. In 1972 Herbert visited the United States and from there imported agricultural implements which he used on his property based on the NTS (ANDRADE et al., 2018).

Established as the greatest technological innovation of agriculture in recent times, the NTS has been improving according to each region in which it is practiced, that is, it creates regional identity, according to the environmental supply of growth factors. In the soil, straw from cover crops along with residues of commercial crops creates a beneficial environment for plant growth for...
successor crops, thus contributing to better production and maintenance of the soil over time, thus ensuring the success of this system (ALVARENGA et al., 2001).

The no-tillage system is based on three principles: crop rotation, permanent coverage (dead or alive) and minimal soil revolving, becoming an alternative to constant soil handling (EMBRAPA VEGETABLES, 2011). Depending on the species used, the amount of biomass present, environmental conditions and the activity of macro and microorganisms, the straw deposited on the soil surface consists of a nutrient reserve, which can be made available quickly and intensely or slowly (ROSOLEM et al., 2003).

One of the characteristics of the SPD besides the non-revolving of the soil, is the production of plant biomass for the cover of the same. The choice of plant species to be used for this purpose depends very heavily on some factors, among which, the potential for phytomass production, the ability to absorb and accumulate nutrients are the main ones. Factors that are related to nutrient cycling that are very important for the soil-plant process, as they increase availability for successor crops (ALBUQUERQUE et al., 2013).

Due to soil wear, the gradual increase in the price of inputs and the drop in productivity, farmers returned to use, after many years using only the "technological packages", green fertilization practices and cover plants (RUFATO et al., 2006).

The use of this conservation practice is an important tool to improve the chemical, physical and biological quality of the soil, helping in the protection of the surface, in the contribution of phytomass from the aerial part and roots, in improving soil fertility and nutrition of plants with nutrient cycling and assisting in the gradual increase of organic matter in the soil (WOLSCHICK et al., 2016).

Soil cover may be natural or implanted, permanent or periodic, green or dead (mulch) (PHILIPOVSKY et al., 2004). For green fertilization and/or cover plants species from various botanical families, covering the soil at time intervals,
or throughout the year (PERIN et al., 2003) and can be used for soil recovery, protection and favoring the productivity of successor crops.

Depending on the management techniques, climatic, edaphic, phytosanitary conditions, and also the root system, the dry matter production of the species used for soil cover will be higher or lower (CARVALHO et al., 2013).

Because they have a high biomass production capacity and a high C/N ratio, which helps to reduce the rate of decomposition and the slower release of nutrients into the soil (SILVA et al., 2012), makes the plants of the poaceae family (grasses), among them, black oats be the main cover plant used in the southern region of Brazil in rotation with crops of commercial interest (GIACOMINI et al., 2004).

Among its characteristics, black oats had an annual cycle, with uniform development and good tillering, with cylindrical stems, erect and little hairy, with fasciculated roots (CALEGARI et al., 1993). Inflorescence is a panicle, it may or may not have aristated glumes (FONTANELI et al., 2009). Possible cycle from 70 to 130 days until flowering (PIRAÍ SEEDS, 2012). It is a species of autumn/winter, widespread in the southern region of Brazil (DERPSCH; CALEGARI, 1985). It is used for the production of grains intended for animal feed, as forage for pasture, silage and hay, and also as a cover plant, offering rapid soil coverage (BURLE et al., 2006). It assists in the absorption of nutrients, mainly potassium, from deeper layers and makes it available on the soil surface (BOER et al., 2007).

Forage turnip is another plant widely used for soil cover, because, in addition presenting low cost of seeds, it has rapid initial development and short cycle (AMADO et al., 2002). Belonging to the family of brassicaceas, the forage turnip has an annual cycle, herbaceous, erect and very branched with rough hair (SILVA et al., 2007). Possible pivoting and deep root system, in some cases with a tuberous root (DERPSCH; CALEGARI, 1992; BURLE et al., 2006). Its inflorescences are located in the terminal parts of the stem, in long racemes, with predominantly white flowers, sometimes purple or white with purple or lilac
hues (PEREIRA, 2006). Flowering occurs between 70 to 80 days after sowing (DERPSCH; CALEGARI, 1985), having a long flowering period, lasting more than 30 days (BELIVAQUA et al., 2008). As a soil cover plant, crop management must take place between 110 and 120 days after sowing (full bloom), before seed maturation, thus preventing it from becoming an invasive plant (BELIVAQUA et al., 2008). Forage turnip has a characteristic of high dry matter productivity and high concentration of nutrients in the aerial part (SILVA et al., 2007). In addition to these described families, others are also used as soil cover species.

In general, the used of cover plants is of paramount importance and when cultivated in a consortium way the benefits can be even greater. In the consortium cultivation of species plants that have different characteristics result in the exploration of distinct soil layers, thus contributing to the favoring of different soil biota groups, differentiated nutrient cycling (CARVALHO et al., 2013), also help in the physical structuring of the soil and in the production of dry matter with different C/N relation.

In this context, many studies evaluate soil protection by the deposition and maintenance of dry matter produced after the maintenance of soil surface cover, however, in new or newly established no-tillage systems, in which there is no history of straw in soil cover, it is extremely important to establish species or consortia of cover plant species, which present potential for rapid soil coating by plant development, so that they protect the soil from the impact of rain drops, competition with invasive species, attenuation of soil temperature to favor microorganisms and edaphic fauna, among other benefits.

Thus, the objective of this work was to evaluate the initial performance of consortia between black oats (*Avena strigosa* L.) and forage turnip (*Raphanus sativus* L.) at different sowing densities, as well as species in single cultivation in relation to the rate of soil cover during plant development for soil protection.
2 DEVELOPMENT

2.1 Materials and Methods

The experiment was conducted in the experimental area belonging to the Federal Technological University of Paraná (UTFPR), Câmpus Santa Helena, located at 24º50’S and 54º20’W, at an orthometric altitude of approximately 236 m. The soil of the region is predominantly of the Type Red Latosol (BHERING et al., 2008; EMBRAPA, 2013). The climate of the region is classified as Cfa (with hot summer) without a defined dry season, with an average annual temperature between 20°C and 22°C, according to Koppen (ALVARES et al., 2013).

The climatic data of rainfall and minimum and maximum air temperature related to the experimental period were obtained from the SIMEPAR meteorological station unit installed in Santa Helena-PR city, as detailed in Graph 1.

Graph 1 - Monthly averages of minimum and maximum daily air temperatures (°C) and rainfall (mm) during the evaluation period of the experiment. UTFPR campus Santa Helena-PR, 2019.

Source: The authors, 2020.
The experiment was arranged in a randomized block design, with five treatments and three replications, totaling 15 experimental plots with dimensions of 5.0 x 5.0 m (25m²) each, totaling 375 m² of cultivated area.

The treatments consisted of systems using the consortium between forage turnip and black oats, in different sowing densities for each species, as well as their species in exclusive (single) cultivation. The sowing density used for the coating plants in single cultivation was 100 kg ha⁻¹ of black oats seeds (BO) and 25 kg ha⁻¹ of forage turnip (FT), considering the recommendations for sowing haul (LIMA FILHO et al., 2014) and the percentage of specific germination of the seed lot. The treatments are presented below, with the respective sowing densities used in each consortium:

1. Black Oats - *(Avena strigosa* Schreb) -100% BO;
2. Forage Turnip - *(Raphanus sativus* L.) - 100% FT
3. Forage Turnip (75%) + Black Oats (25%)
4. Forage Turnip (50%) + Black Oats (50%)
5. Forage Turnip (25%) + Black Oats (75%)

The percentages used to compose consortia refer to the amount of seeds recommended per hectare for each crop in exclusive cultivation. The sowing of winter cover species (black oats and forage turnip) was carried out on May 16, 2019 at haul, with posterior weeding and manual tear out of the infesting plants present in total area, to incorporate seeds into the soil.

Germination and emergence of cover plants occurred on May 24, 2019. From 21 days after sowing (DAS) the growth rate and soil cover was monitored, using the photographic method, which consists in the evaluation of digital images collected in the field. The collections were performed weekly, until obtaining the maximum soil cover by the plant development of the treatments. For this, two fixed points were demarcated in each of the plots, and through the use of a metal square 0.5 x 0.5m with known area (0.25m²) placed on the
ground on the cover plants (Figure 1), the images were captured, with positioning of the digital camera approximately one meter high, as adapted method of Rizzardi and Fleck (2004). Subsequently, the digital images were transferred to the Power point computer program, where a checkered 100 points were inserted on each image. The intersection points on the cover plants were quantified, expressing as a percentage the soil cover rate provided by the treatments.

**Figure 1** - Metallic frame used for site demarcation for collection of rate images of the soil cover. (A) 100% Turnip Forage (TF) at 35 DAS, (B) 100% TF at 63 DAS, (C) 25% TF + 75% Black Oats (BO) at 49 DAS, (D) 100% BO at 70 DAS with checkered to quantify intersection points.

The data obtained were applied to variance analysis (ANOVA) and the means compared by the Tukey test at 5% probability, using the computational program GENES (Cruz, 2006).

**2.2 Results and Discussion**

Soil cover plants showed similar behavior between the treatments tested, with no statistically significant rate difference regarding the soil cover by plant development of different species densities in the consortia, as well as in single crops over the 91 days of attendance (Table 1).
Table 1. Soil cover rate (%) winter cover plants in consortia systems and single cultivation, up to 91 days after sowing (DAS).

<table>
<thead>
<tr>
<th>COVER CROPS</th>
<th>21 DAS</th>
<th>28 DAS</th>
<th>35 DAS</th>
<th>42 DAS</th>
<th>49 DAS</th>
<th>56 DAS</th>
<th>63 DAS</th>
<th>70 DAS</th>
<th>77 DAS</th>
<th>84 DAS</th>
<th>91 DAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Black Oat (OB)</td>
<td>11.7</td>
<td>*ns</td>
<td>16.7</td>
<td>*ns</td>
<td>23.3</td>
<td>*ns</td>
<td>39.3</td>
<td>*ns</td>
<td>56.0</td>
<td>*ns</td>
<td>74.0</td>
</tr>
<tr>
<td>100% Forage Turnip (TF)</td>
<td>11.7</td>
<td>22.8</td>
<td>32.5</td>
<td>46.5</td>
<td>63.7</td>
<td>63.0</td>
<td>68.2</td>
<td>77.0</td>
<td>82.5</td>
<td>82.7</td>
<td>82.7</td>
</tr>
<tr>
<td>75% OB + 25% TF</td>
<td>11.0</td>
<td>17.2</td>
<td>27.5</td>
<td>39.5</td>
<td>70.0</td>
<td>69.2</td>
<td>81.3</td>
<td>89.0</td>
<td>91.5</td>
<td>90.7</td>
<td>92.5</td>
</tr>
<tr>
<td>50% OB + 50% TF</td>
<td>13.8</td>
<td>22.5</td>
<td>39.0</td>
<td>51.0</td>
<td>69.3</td>
<td>71.7</td>
<td>77.8</td>
<td>87.3</td>
<td>90.8</td>
<td>89.0</td>
<td>88.2</td>
</tr>
<tr>
<td>25% OB + 75% TF</td>
<td>14.7</td>
<td>22.7</td>
<td>39.5</td>
<td>55.8</td>
<td>74.3</td>
<td>76.3</td>
<td>83.2</td>
<td>91.7</td>
<td>93.7</td>
<td>93.0</td>
<td>88.3</td>
</tr>
</tbody>
</table>

CV%  37  36  42  42  28  26  17  10  8  8.8  11

*ns- Not significant by tukey test 5% (p<0.05). DAS - Days after sowing. CV – Coefficient of variation.

The similarity obtained in the vegetative development of the species that make up the treatments may be related to the climatic conditions that occurred during the period (Figure 1), considering that the higher volume of rainfall (121.6 mm) occurred at the first 15 days that proceeded sowing, and were distributed in only four moments. In June, there was only 27 mm of precipitation distributed throughout the month, which corresponds to the vegetative development accompanied up to 49 DAS approximately. Subsequent collections coincided with the low rainfall that occurred in August, in which the total volume was only 6 mm, in this sense, even having totaled 154.6 mm during the development of cover plants, the irregularity in the distribution of rainfall may have impaired the adequate development by water deficit.

In this aspect, it was noticeable in the field that the irregularity and the low volume of precipitation that occurred, harmed the vegetal development of the plants and tilling in the case of grass (visual observation).

Even so, it is possible to highlight that at 21 DAS the coverage rate of the forage turnip, obtained in the present study (Table 1), is similar to the 11%
obtained by Ziech et al., (2015) at 29 DAS for the agricultural year 2011/2012, under the conditions of the Southwest region of the state of Paraná.

From 28 to 42 DAS, the forage turnip isolated and in the proportions of 50% and 75% composing the consortium, presented protection potential between 47% and 56% soil cover by plant development (Table 1). Ziech et al. (2015) in two years of attendance, verified variations rate in soil cover responses provided by treatments, even so, the results obtained by those authors for the association between black oats (60%) + common vetch (40%), presented at 42 and 43 DAS of soil cover of 50% and 62% for the agricultural years of 2010/2011 and 2011/2012, respectively. The same authors observed that for the same period, in different years of evaluation the forage turnip as a single crop presented 62% and 40% soil cover. Indicating that there is similarity with the obtained data in the present study, and also, that variations in plant development occur even if they are cultivated in the same area.

At 49 days, all the consortia tested reached coverage equal to or greater than 70%, while for the species grown in a single way, this percentage was reached at 56 DAS and 70 DAS, for AP and NF, respectively (Table 1). Thus, indicating that the combination of species may present advantageous aspects in relation to culture in isolated cultivation.

According to Ziech (2016), the intercropping between oats and other species promote in addition to physical protection by rapid soil cover, the inclusion of plant biodiversity to the system. Thus, due to the distinct characteristics of each species, there is aggregation of benefits to the productive system, such as greater nutrient cycling capacity by exploring distinct soil layers and favoring soil biota groups (CHERR et al., 2006).

Even under adverse conditions, the data obtained for soil cover by the consortia at 49 DAS and the single forage turnip (Table 1) are extremely positive, since, according to Calegari (1990), the rapid initial growth of turnip forage, is an excellent feature, as it can promote up to 70% soil cover at 60 days after its emergence. In the present study, the forage turnip reached 77% of
vegetation cover at 70 DAS, which corresponds approximately 62 days after emergence, corresponding with the expected performance for the species.

From the 56 DAS (Table 1), there was little variation regarding plant development and soil cover rate among treatments, coinciding with the low precipitation occurred in the period.

The maximum soil protection obtained by plant development in the systems tested occurred at 77 DAS (Table 1) in which the consortia presented coverage rate between 91.5% and 93.7%, for 75% BO + 25% TF and 25% BO + 75% TF, respectively. While the forage turnip and black oats in single cultivation, they presented coverage rates of 87 and 83%, respectively, maintaining these results until 91 DAS. Even under adverse conditions, the results obtained are similar to those obtained by Ziech (2016), where at 62 DAS, it obtained coverage of 95% for consortia between oats+vetch common and oat+turnip+vetch common.

In general, all treatments presented high soil protection potential through the coverage rate from 70 DAS.

3 FINAL CONSIDERATIONS

Given the current context of intensive land use in small and large areas, it is worth stressing the importance of soil conservation and protection. Thus, it is essential to use soil cover plants in rotation with commercial exploration crops.

Considering that plants of different species have different root systems and nutritional needs, the consortium between soil cover plant species promotes faster coverage, protection against raindrops, erosion and decreased leaching of nutrients, reduction of temperature fluctuations and decreased evaporation, increasing the availability of water for crops, disruption of compacted layers and promotion of aeration benefiting beneficial organisms from the soil and weed suppression. Thus, crop systems and plants used for
soil protection promote over time effects on the chemical, physical and biological conditions of the same.

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