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Scientific paper

Winter cover crops, plant biomass production and soil resistance[1].

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Abstract

This study aimed to compare results obtained with winter cover plants, in its first crop cycle, in the resistence to soil physical properties and biomass productivity of the plant. Four species of soil cover plants were used: vetch (*Vicia sativa* L.), radish (*Raphanus sativus* L.), ryegrass (Lolium multiflorum Lam) and black oat (*Avena strigosa* Schreb). It was developed in Guarapuava, PR, in the CEDETEG *Campus* of the Midwestern State Universisty (UNICENTRO). It was carried out the monitoring of a cycle of these crops in the fall/winter of 2010. The soil resistence data were obtained with the penetrometer of impact in its period of greatest development (flowering). It was observed that the use of cover plants in its first crop cycle did not promote changes in soil penetration resistance. The crops of radish presented the best production of vegetal biomass.

Keywords: soil physics, organic matter.

Plantas de cobertura de inverno, produção de biomassa vegetal e resistência do solo

Resumo

Este trabalho objetivou comparar resultados obtidos com plantas de cobertura de inverno, em seu primeiro ciclo de cultivo, na resistência a penetração do solo e na produtividade de biomassa vegetal. Foram utilizadas quatro espécies de plantas de cobertura de solo: ervilhaca (*Vicia sativa* L.), nabo forrageiro (*Raphanus sativus* L.), azevém (*Lolium multiflorum* Lam.) e aveia preta (*Avena strigosa* Schreb). A pesquisa foi desenvolvida em Guarapuava, PR, no Campus CEDETEG da Universidade Estadual do Centro-Oeste (UNICENTRO). Realizou-se o acompanhamento de um ciclo destas culturas no outono/inverno de 2010. Os dados de resistência do solo foram obtidos com o penetrômetro de impacto no seu período de maior desenvolvimento (floração). Observou-se que a utilização de plantas de cobertura, no seu primeiro ciclo de cultivo, não promoveu alterações na resistência a penetração do solo. A cultura do nabo forrageiro apresentou a melhor produção de biomassa vegetal.

Palavras chave: física do solo; matéria orgânica, plantas de cobertura.

Plantas de cobertura de invierno, producción de biomasa vegetal y resistencia del suelo.

Resumen

Este estudio tuvo como objetivo comparar los resultados obtenidos con los cultivos de cobertura de invierno en su primer ciclo de cultivo en la resistencia a la penetración y la productividad de la biomasa vegetal. Se utilizaron cuatro especies vegetales como cobertura del suelo: veza (*Vicia sativa* L.), rábano (*Raphanus sativus* L.), raigrás (*Lolium multiflorum* Lam) y avena (*Avena strigosa* Schreb). La investigación fue desarrollada en Guarapuava, PR, en el campus de la Universidade

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Estadual do Centro Oeste (UNICENTRO). Se realizó el seguimiento de un ciclo de estos cultivos en el otoño / invierno de 2010. Los datos sobre la resistencia del suelo se obtuvieran con el penetrómetro de impacto en el período de mayor desarrollo vegetativo (floración). Se observó que el uso de cultivos de cobertura en su primer ciclo, no cambió la resistencia del suelo a la penetración. El cultivo de rábano forrajero presentó la mejor producción de biomasa vegetal.

Palabras clave: Física del suelo, materia orgánica, plantas de cobertura.

Introduction

The mechanical resistance of the soil to penetration is identified as a major limiting factor to the development and establishment of crops, for it expresses the degree of soil compaction (RICHARDT et al., 2005). Works such as of GENRO JUNIOR et al. (2004) highlight the importance of checking the penetration resistance (PR) in the identification of compacted layers in the soil. However, several restrictions have been presented regarding the indication of critical values of PR for the development of plants (SINNETT et al., 2008), being the main reasons arising from the influence of moisture, density and soil texture in the data achieved.

MEROTO and MUNDSTOCK (1999) found that PR of 2.00 MPa resulted in reduction of dry matter mass of the root, the aerial part and root length of wheat. BEUTLER and CENTURION (2004) observed that the average diameter and dry matter mass of soybean roots increased to a value of PR of 2.07 MPa and 1.99 MPa, respectively. However, DE MARIA et al. (1999) reported that a PR of 2.09 MPa, evaluated in the field, could determine the reduction in root growth of soybean.

Possible indicative of compaction, as measured by PR data are important processes, especially when demonstrate critical limits, that is, when the soil decreases the amount of water available and impairs the root growth, confining the roots above the compacted layer, thereby reducing the volume of soil exploited by the roots, the amount of air, water and nutrients available, limiting the productivity of crops (GENRO JUNIOR, 2009).

The vegetation cover is fundamental to the soil, according to PRADO et al. (2002), the presence of these residues on the soil surface presents benefits of physical-chemical order and biological protection against erosion, improve nutrient recycling, allelopathic effects on pests and inhibit the emergence of weeds. ALVARENGA et al. (2001) argue that the amount of 6 Mg ha^{-1} of waste can be considered adequate for a good soil coverage. Other authors, such as CAMARA et al. (2002), found that the scarification operation caused a superficial incorporation of these crop residues, reducing by 30% the soil cover.

The plants are the main responsible for the addiction to the soil of primary organic compounds from the photosynthesis, using solar energy, CO_2 from the atmosphere, water and soil nutrients (RIBEIRO et al., 2011). The organisms, with emphasis on heterotrophic microorganisms, which obtain energy for its development by the decomposition of crop residues (biomass) and soil organic matter (SOM), releasing CO_2 into the atmosphere, nutrients, and a variety of secondary organic compounds derived microbial metabolism, which begin to compose the soil organic matter (VEZZANI, 2001).

The stocks of MOS are determined by the ratio between the input and loss of the production system, whereas plants, by action of its root system (SILVA and MIELNICZUK, 1997b), and by the fungal hyphae (MILLER and JASTROW, 1990) potentiate the interactions in the formation of stable aggregates, mainly by the approach of particle exudations well distributed in the soil matrix and physical union of aggregates of different sizes. The interactions with the minerals and formations of aggregates decreases the action of decomposer microorganisms, contributing to the accumulation of organic compounds in the soil, being this process of physical protection of organic matter more intense in soils not plowed (FELLER and BEARE, 1997; SIX et al. 1999). The organic matter stocks presents rapid fall when the soil is subjected to tillage systems with intensive plowing (Silva et al., 1994), due to increased losses by hydric erosion and microbial oxidation.

The extensive use of cover crops by farmers promotes sequestration of considerable atmospheric carbon, being directly related to the importance of soil organic matter. The increase in this amount of carbon fixed in the soil can be increased in cropping systems where the vegetable biomass is not withdrawn from the crops, affirm author like BAYER et al. (2004), BERTOL et al. (2004) and SILVA et al. (2006). In these cultivation systems is used a minimal amount of operations, from the soil preparation to the necessary crop treatments, to create conditions to seed germination and establishment of the crop (CURI et al. 1993).

Material and Methods

The experiment was conducted during 2010 in Guarapuava, municipality geographically located in southern Brazil, in the South Central region of the state of Paraná. Its installation is the Campus CEDETEG - UNICENTRO on the experimental field of the Department of Agronomy, with coordinates of latitude 25° 23 ‘36’’ S and longitude 51° 27’ 19’’ W, and altitude of 1,025 m. The regional climate by Köeppen classification is of the Cfb type, mesothermal subtropical humid without dry season, and with cool summers, with average annual temperature of 17 °C and average annual rainfall of 1961 mm (IAPAR, 2000).

The soil near the experimental area (Table 1) was classified as Brown Oxisol and morphologically characterized. From this it was made his physical description and analysis of the soil profile. Due to the experiment site stay in the Potato Research Unit and Microclimate, the commercial cultivation earlier was potato (*Solanum tuberosum*) in the conventional system, but the area used was in fallow and unused for more than 12 months, since the last activity was the potato harvest on April 12, 2009.

Due to the potatoes is a demanding crop, many fertilizer residues remain in the soil after its harvest, thus, fertilization was not used for deployment of the experiment, because for the cultivation of potatoes, was made the soil amendment and fertilizer according to the soil chemical analysis.

The experimental design was a randomized block with 5 replicates, divided into 20 plots of 5.0 x 4.0 meters (20 m^2 each), with spacing of 1.5 meters between plots and 2.0 meters between blocks.

For installation of the experiment, was applied glyphosate herbicide at a dosage of 1.08 kg ha^{-1} of a. i. with the help of backpack sprayer, and after complete desiccation of the plants, it were subjected to mechanical mowing (tractor with mowing close to the ground), seeking to adapt the site for planting of winter cover crops. The fragmented straw was removed from the surface with manual rakes, with the purpose of enabling the sowing to haul of the treatments.

The amount of seed of the species of coverage (treatments) was estimated using the recommendation of the supplier of seeds, Commercial Seed Lopes Ltda. Santo Angelo, RS.

To determine the required amount of seeds, was performed tests of seed germination in the laboratory, by placing 100 seeds on filter paper moistened with distilled water and in the form of a roll, with four replications, and left in a moist chamber for seven days at 25 ^{o}C. After this time, we calculated the percentage of seeds germinated, and the average was used to determine the amount of seed per plot. The treatments were sown to haul on April 29, 2010, and the incorporation performed with manual rakes. The seeds did not receive any inoculants.

In each plot, in the flowering of crops, on August 05, 2010, we performed the cutting of all species, and the vetch was also sampled for being the moment determined in the planning. We evaluated the penetration resistance using the device Penetrometer of Impact, Model IAAP / Planalsucar (STOLF, 1998), with three measurements per plot, providing the data that were entered in PNRT - Program for Calculating Soil Resistance to the Penetrometer of Impact, generating a file with the resistance from 0 to 0.50 m in MPa (PNRT, 1991).

Table 1. Results of analyzes of soil characteristics near the site of the experiment.

Horizon	Depth	AG[3]	AF[4]	Silt	Argil	Dp[1]	Ds[2]	Porosity (%)		
	cm	g kg^{-1}				g cm^{-3}		Total	Macro	Micro
A	0 – 30	140	70	70	720	2.5	1.0	60.0	9.5	50.5
AB	30 – 50	100	60	50	790	2.5	0.9	63.2	11.9	51.3
BA	50 – 79	100	50	40	810	2.5	0.9	63.8	12.0	51.8
Bw$_1$	79 – 113	100	50	20	830	2.6	0.9	64.5	11.7	52.8
Bw$_2$	113 – 140	90	50	40	820	2.6	0.9	65.2	13.4	51.8

[1] Density of the particle; [2] Density of the soil; [3] Thick sand; [4] Thin sand

For data collection, the soil was with 29% of average gravimetric moisture obtained from five soil samples collected up to 0.50 m of depth, divided into 3 layers, with readings of 28% in the surface layer, 29% in the intermediate and 31% in the deepest. The samples were homogenized separately packed in airtight plastic container and taken to the laboratory. Were weighed, placed in numbered aluminum cans and were dried at 105 º C for 48 hours. Once removed from the oven, were placed in a desiccator to cool and reweighed (EMBRAPA, 1997).

On August 6, 2010, we collected samples of plants, retiring the individuals corresponding to 0.25 m² of each plot, according to the methodology of the wood square described by CHAILA (1986), respecting the 0.40 m area of borders and places of collection of soil samples.

This collect was made in order to calculate the dry biomass of crops. For both were collected whole specimens by cutting up the soil around the template 0.25 m² to a depth of 0.40 m, needed to have access to the largest amount possible of the root system, disrupting the soil around the roots and collecting the whole plant. The plastic packages with the plants, identified by plot, were taken to the laboratory and separated the the aerial part and roots, weighed fresh and clean of soil particles, packed in paper bags and placed in an oven at 35 º C for 24 hours and then elevated the temperature to 65 °C, staying long enough to reach the constant weight of the material being weighed again. Data were obtained separated from the aerial part and root system, and transformed into Mg ha^{-1}.

Statistical analyzes were performed with the aid of the ASSISTAT Software (SILVA, 2011). Initially the data were subjected to the Bartlett's test to verify that all the variances were homogeneous. These data were subjected to analysis of variance, and the averages of treatments were compared by Tukey test ($P < 0.05$) (ZIMMERMANN, 2004).

Results and Discussion

Significant differences occurred in the production of dry biomass between the cover crops evaluated (Table 2). Stands out the cultivation of forage turnip, which had the highest productivity of aboveground biomass and total, and the ryegrass and oats which had a good productivity in the aerial part, but significantly lower. The oat showed similar results of total biomass of turnips, and vetch crop, had the lowest results, probably due to this crop so later and be in the beginning of flowering, while the other treatments were already in advanced stage.

Similar results on dry matter yield in intercropping systems were obtained by SILVA et al. (2007), who claim that the turnip was the dominant species among black oat, vetch, forage turnip, oats + vetch, oats + turnip, vetch + turnip and oat + vetch + turnip, contributing with the largest share of total income of dry matter of the aerial part of species of ground cover.

In the productivity of dry root biomass produced by the crops evaluated, it can be seen that significant difference occurred between the averages of these treatments, demonstrating that these species produce different amounts of root mass and therefore exploit different volumes of soil in their growth. The oat crop showed the best results in the production of root biomass, very superior to the other treatments.

The residues of these crops will make up the main source of organic carbon in the soil, and several studies have indicated that the management given to the soil is the determining factor in the stock of organic carbon (URGUIANA et al., 2005). Thus, the quantification of such stocks promoted by plant biomass in crop rotation systems is important for evaluating the capacity of these production systems, in getting carbon from the atmosphere and, thereby, contribute to the reduction of greenhouse gas (SALTON, 2005).

Table 2. Dry biomass (Mg ha^{-1}) of different species of cover crops of winter in flowering stage.

Dry Biomass	Oat	Ryegrass	Turnip	Vetch	Average	CV(%)²	MSD³
Aerial Part	9.12 b1	6.40 b	12.73 a	2.41 c	7.66	19.00	2.74
Roots	2.66 a	1.97 b	1.35 c	0.34 d	1.58	19.00	0.58
Total	11.78 a	8.37 b	14.08 a	2.75 c	9.24	19.00	2.86

[1] *Averages followed by the same lowercase letter in the lines do not differ significantly by Tukey test ($p < 0.05$);* [2] *Coefficient of variation;* [3] *Minimum Significant Difference.*

The use of the crops studied is already consecrated among producers, and it is observed that the turnip showed high yields of dry biomass, putting this crop as the best in productivity, and the oat crop with emphasis on production of dry biomass of roots. This large amount of dry biomass (aerial part) will compose the organic carbon of the soil increasing the organic matter content in the surface layer and increasing the stability of the aggregates (FLORES et al., 2008).

However, the vetches had lower productivity in the same period of growth, probably due to having shown a slower growth and be at the beginning of its flowering. According to DA ROS and AITA (1996), the vetch residues, as single crop, disappear quickly, even when left in the soil surface, due to the ease with which are decomposed by microbial population, contrary to those of oats, which persist for a longer time.

The evaluation of soil as its resistance to penetration is shown in Table 3. No differences were found between the means of soil resistance presented by each treatment, on each layer individually evaluated. The treatments with cover crops of winter did not cause significant changes in soil resistance in individual layers from 0.0 to 0.50 m, thus having no possibility to verify which species would be more efficient to promote an improvement of this physical attribute of the soil, already in the first cultivation cycle.

It is observed that the highest values of resistance, although not characterize any kind of impediment to the development of the crops, occurred in layers from 0.10 to 0.30 m showing that in these layers is occurring a principle of accumulation of tension imposed by traffic of machinery and equipment. This is a subsuperficial layer characteristic of obstacle in most advanced cases of accumulation of tension, both for the growth and root penetration as for water infiltration into the soil. In a study conducted by MORETI et al. (2006), with objective of studying the influence of different systems of managements on water movement and resistance of Latossolo Vermelho[1] concluded that for the resistance to penetration, was no significant difference among the treatments studied, which were two systems of sowing (direct and conventional), before and after the implementation of cover crops, organic and mineral fertilizers.

Different studies have demonstrated that soil resistance may be changed in the cultures in rotation with cover crops in successive years, such as REINERT et al. (2008), which observed a reduction in soil density through the use of cover crops only in the most superficial layer, as well as FRANCHINI et al. (2009) showed that it is possible to improve the structure of the layers of soil, without mechanical intervention and, thereby, increase the root development and water availability for soybeans. DEBIASE (2008) reported the effectiveness of cover crops in improving soil physical characteristics, after four years of conduction of the experiment in Argisol, previously physically degraded by cattle trampling. Like DEXTER (2004) states that the resistances of the soil along with soil density are physical attributes that directly influence the root growth and, consequently, the aerial part of the plants. When increasing the penetration resistance of the soil, the root system presents reduced development, which may impair the productivity of the area.

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[1] Brazilian soil classification

Table 3. Resistance of cultivated soil with different species of plants of winter covers at the flowering stage.

Layer (m)	Oat	Ryegrass	Turnip	Vetch	Average	CV (%)[2]	MSD[3]
	Resistence to soil penetration (MPa)						
0.00 – 0.10	0.81 a[1]	0.90 a	0.85 a	0.88 a	0.86	13.74	0.22
0.10 - 0.20	1.33 a	1.27 a	1.28 a	1.36 a	1.31	9.81	0.24
0.20 – 0.30	1.00 a	1.09 a	1.06 a	1.04 a	1.05	12.51	0.24
0.30 – 0.40	0.91 a	0.92 a	0.83 a	0.91 a	0.89	8.07	0.13
0.40 – 0.50	0.92 a	0.92 a	0.90 a	0.92 a	0.91	11.94	0.20

[1] *Averages followed by the same lowercase letter in the lines do not differ significantly by Tukey test ($p < 0.05$);*

[2] *Coefficient of variation;* [3] *Minimum Significant Difference.*

Conclusions

The culture of forage turnip has the highest productivity of dry biomass, while the vetch had the lowest result.

In the productivity of dry root biomass, the oat presents the best results, while the vetch had the lowest productivity.

The first cycle of cultivation of cover crops does not promote changes in soil penetration resistance.

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