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Structuring of a Haplortox by Cover Crops and Their Effects on the Yield of Soybean Grains

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Abstract

The intense agricultural machinery traffic over the plantation ground can lead the erosion and growth difficulty. The goal of this study was to evaluate the soya bean yield after the implantation of species named “recoverable”, of soil structure. The experiment was developed in plots of 20 m × 25 m, located in the Agronomic Institute of Parana (IAPAR), in Santa Tereza do Oeste, Paraná. The plots were cultivated by direct sowing of the following species, considered as treatments: sunn hemp (*Crotalaria juncea*), rattlebox (*Crotalaria spectabilis*), velvet bean (*Mucuna aterrima*), pearl millet (*Pennisetum glaucum*), pigeon pea (*Cajanus cajan*), dwarf pigeon pea (*Cajanus cajan*) beside them no-tillage and no-cover crop planting traditional system (control). Soil samples were collected from 0-10 cm, 10-20 cm, and 20-30 cm-layers with 4 repetitions on each treatment. Soil density and porous soil space were also determined. The plot yield of soybean grains was evaluated over an area of 4.5 m^2 for each treatment and grain moisture corrected to 13%. The treatments’ mean yields were compared using the Tukey test at 5% probability. The dwarf pigeon pea and the rattlebox were the most efficient cover crops in the reduction of soil bulk density in 0-10 and 10-20 cm depths. The soybean grain yield did not differ between the evaluated treatments, possibly due to the good precipitation conditions during the soybean growing cycle.

Keywords: soil bulk density, no-tillage and no-cover crop planting system, soybean grain yield

1. Introduction

The search for an adequate management system has attracted interest from researchers and agricultural producers. A suitable system seeks to use the best cost-benefit ratio, better machine-ground interaction and soil preservation, and better production (Llanillo et al., 2006).

The no-tillage system (NTS) is the system that has been used in the region, since there is less soil disturbance and greater conservation of soil physical characteristics. According to Ferreira et al. (2011) a soil without its structure stable may present complications in plant growth and development.

The NTS aims at three aspects: conservation of the structure, elevation of organic matter, and possibility of crop rotation in short periods of the year. The absence of soil revolving, crop rotation and permanent soil cover with plants or cultural remains improve the soil structural condition. However, the use of soil under this management system is often associated with intense machine traffic, which contributes to altering the soil structural quality, which leads to increased compaction (Bergamin et al., 2010).

For Assis et al. (2009), the compaction can be defined as the alteration in the physical structure of the soil that reduces the internal spaces that are normally occupied by water and air, which according to Silva and Cabeda (2006) results in a cohesive mass in the soil matrix. This operation results in the expulsion of air from the pores, causing a rearrangement of the particles, making the soil denser and less porous (Curi et al., 1993).

One of the ways to change the negative effects of soil compaction has been the use of soil cover crop species with a more vigorous and profound root system, which are able to reduce the density and increase the porous space.

The soybean crop (*Glycine max* (L.) Merrill), is one of the most cultivated crops worldwide. In Brazil, soybean cultivation was implemented over 50 years, and its production is mainly focused on oil and feed production (EMBRAPA, 2018). The soybean crop (*Glycine max* (L.) Merrill) is currently the main crop in Brazil. According to data from CONAB (2018), Brazil had a harvest in December with 119.43 million tons in 2018, in addition the country is consolidated as the second world soybean producer, with an average of 3500 kg ha^{-1}. Of this amount, the state of Paraná contributing with a harvest of approximately 19.00 million tons.

Thus, the objective of this work was to evaluate the impact of the use of plant species recovering soil structure, density and total porosity and its benefits on soybean grain yield.

2. Material and Methods

2.1 Experimental Area

The experiment was conducted at the Agricultural Institute of Paraná [Instituto Agronômico do Paraná- IAPAR], located at the Experimental station of Santa Tereza do Oeste-Paraná. The soil was an Oxisol, clayey texture, soft-wavy relief, and basalt substrate (EMBRAPA, 2013). The climate of the region was temperate mesothermic and humid, and classified Cfa type (Köppen).

The data on rainfall, minimum temperature, maximum temperature and average temperature during the development of soybean crop, from November 2014 to March 2015, are presented in Figure 1.

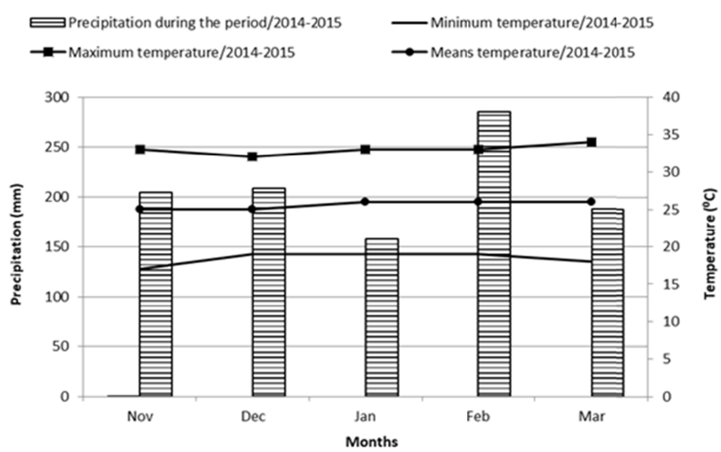

Figure 1. Rainfall, minimum temperature, maximum temperature and average temperature of soybean crop from November 2014 to March 2015

2.2 Characterization of the Treatments and Experimental Design

The experimental area consisted of seven plots, six plots with implantation of species called “reclaimers” of the structure: sunn hemp (*Crotalaria juncea*), rattlebox (*Crotalaria spectabilis*), velvet bean (*Mucuna pruriens*), pearl millet (*Pennisetum americanum*), pigeon pea (*Cajanus cajan*), dwarf pigeon pea (*Cajanus cajan*) In addition to the control (NTTS no-tillage and no-cover crop planting traditional system). The experimental plots were of 20 m × 25 m. The treatements were arranged a completely randomized block desing with 4 repetitions.

2.3 Evaluation of the Treatments

The undisturbed soil samples were collected from each of the 0-10; 10-20, and 20-30 cm-layers, with two collection points and two repetitions per layer. Soil density and total soil porosity were determined in the Soil Physics Laboratory of the State University of Western Paraná, Cascavel Campus-PR.

The sowing of the soil cover species was carried out on March 27, 2014 in a no-tillage system. The management of the cover species occurred when the plants were in full bloom.

Soybean cultivar NK7059 (Vmax RR) was sown in the first week of November and the seeds were treated before sowing with 0.3 L of Cropstar + 0.3 L of Vitamax-Thiram for 100 kg of seeds. At sowing the spacing was

0.45 m between lines, totaling 16 seeds per linear meter. The fertilization was performed with application of 300 kg ha^{-1} of the formulation 02-20-20 of N-P-K.

The evaluation of soil density and that of porous space were performed according to the methodology recommended by EMBRAPA (2011).

The soybean grains harvest was performed manually on the 10/03/15, on 4 lines of 2.5 meters, with a spacing of 45 cm between lines, over 4 replications (4.5 m^2) per plot. The seeds were cleaned, freed of all impurities, and their weight was corrected to 13% moisture.

2.4 Statistical Analysis of the Data

The analysis of variance for soil density and total soil porosity and the means of the treatments were compared by Tukey test at 5% probability were performed using the statistical program Sisvar (Ferreira, 2011).

3. Results and Discussion

The mean values of soil density and total soil porosity in the layers of 0-10 cm, 10-20 cm, and 20-30 cm-layers, under the cultivation of soil cover species, were presented in Tables 1 and 2, respectively.

Table 1 showed significant differences between cover crops for soil bulk density in the layers of 0-10 cm and 10-20 cm. The smallest density values were observed for the dwarf pigeon pea (0.87 Mg m^{-3}) in the 0-10 cm-layer and rattlebox (0.98 Mg m^{-3}) in the 10-20 cm-layer, presenting a rapid restructuring capacity of the soil. Stone and Silveira (2001) also found significant differences in the soil density and total soil porosity working with different types of soil management system during the 3-year period. Spera et al (2004), also found differences in bulk density when conducting their experiments for 8 years in the production system of grain and forage crops under grazing, in a Latosol Typical dystrophic red, in Passo Fundo (RS). According to Camargo and Alleoni (1997), even the highest value of bulk density (1.16 Mg m^{-3}) found in the present experiment was below the one considered harmful for root growth. For Reinert et al. (2008), there were deformations of the root system of the cover crops, between the values of 1.75 and 1.85 Mg m^{-3}.

Table 1. Mean values of soil density under different cover crop species

Cover species	Soil density (Mg m^{-3})		
	0-10 cm-layer	10-20 cm-layer	20-30 cm-layer
Pearl millet	1.04ab	1.12ab	1.04a
Dwarf pigeon pea	0.87b	1.06ab	1.01a
Sunn hemp	1.11a	1.16a	0.98a
Pigeon pea	1.03ab	1.12ab	1.02a
Rattlebox	1.08ab	0.98b	1.02a
Velvet bean	1.01ab	1.04ab	0.97a
No-tillage and no-cover crop planting traditional system (control)	1.08ab	1.08ab	1.03a

Note. Means followed by the same letter in the column are not significantly different.

Significant differences were observed for total soil porosity in the 0-10 cm and 10-20 cm-layers (Table 2). Mazurana et al (2011) also found significant differences working on the same layers, when four management systems were studied including (i) no-tillage system, (ii) no-tillage system with scarification, (iii) management with scarifier hand roll destorroador, and (iv) scarification followed by grading in crop rotation for 7 years. The highest total porosity values were observed for the dwarf pigeon pea (64.49 %) in the 0-10 cm-layer and Rattlebox (64.80%) in the 10-20 cm-layer. According to the authors, the reduction may be associated with the performance of the different root systems of the crops that exploit the soil layers. For Andrade et al. (2009), soils with 50% of total porosity are considered ideal for agricultural production, thus, the values obtained were higher than those considered ideal, indicating that the roots system of these soil cover species promoted larger amounts of biopores for the successor culture.

Table 2. Mean values of total soil porosity under different soil cover species

Cover species	Total soil porosity (%)		
	0-10 cm-layer	10-20 cm-layer	20-30 cm-layer
Pearl millet	57.58ab	59.77ab	62.71a
Dwarf pigeon pea	64.49a	61.86ab	63.64a
Sunn hemp	54.85b	58.23b	64.50a
Pigeon pea	58.23ab	59.63ab	63.38a
Rattlebox	56.16b	64.80a	63.12a
Velvet bean	58.99ab	62.39ab	65.02a
No-tillage and no-cover crop planting traditional system (control)	56.07b	61.05ab	63.16a

Note. Means followed by the same letter in the column are not significantly different.

Table 3 shows the values related to the yield of soybean grains as a function of the different soil cover species.

Table 3. Yield of soybean grains as a function of soil cover species

Cover species	Grain yield (kg ha^{-1})
Pearl millet	3025.19a
Dwarf pigeon pea	2944.11a
Sunn hemp	2832.45a
Pigeon pea	2760.74a
Rattlebox	3035.22a
Velvet bean	2911.95a
No-tillage traditional system (control)	2672.25a

Note. Means followed by the same letter are not significantly different.

The results of grain yield of soybean crop showed no significant difference between the species of cover, possibly due to the good structural conditions of the soil and the climatic conditions which were favorable to the development of plants.

According to Embrapa (2011), the need for water that the crop needs for its productive potential is around 450 and 800 mm/cycle, depending on the species, climatic conditions, crop management and the duration of its cycle. And in the present work the precipitation was of 1,043 mm during the cycle of the soybean crop.

4. Conclusion

The dwarf pigeon pea and the rattlebox were the most efficient cover crops in the reduction of soil bulk density in 0-10 and 10-20 cm depths.

The soybean grain yield did not differ between the evaluated treatments.

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