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Nutrient Cycling by Cover Species and Yield of Soybean Grains in a Clayey Oxisol Under No-Tillage System

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Abstract

The objective of this work was to evaluate the impact of changes in soil management and crop rotation on a clayey Oxisol under no-tillage system in nutrient cycling and soybean yield. The experiment was conducted in the 2014/2015 harvest, at the Agronomic Institute of Parana (IAPAR), at the Experimental Station of Santa Tereza do Oeste, in a clayey Oxisol, in a completely randomized design with four replicates. The management systems evaluated were: no-tillage system (control), no-tillage system with scarification (NTSS) and no-tillage system with gypsum application (NTSG), and six treatments involving crop rotation with species reclaimers of structure: pearl millet, dwarf pigeon pea, sunn hemp, pigeon pea, rattlebox and velvet bean. The attributes/chemical characteristics of the soil were evaluated: phosphorus (P), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), organic carbon (C), soil acidity (pH), aluminum (Al^{3+}), potential acidity (H^++Al^{3+}), base sum (BS), cation exchange capacity (CEC), base saturation (V), aluminum saturation (Al*) in the layers 0-0.05, 0.05-0.10, 0.10-0.20 and 0.20-0.40 m, after the application of treatments and cultivation of soil cover species. Statistical analysis was performed by analysis of variance (ANOVA) and the means of the treatments compared by the Tukey test at 5 % of significance. The pigeon pea provided higher phosphorus cycling (63.67 mg dm^{-3}), velvet bean, larger magnesium cycling (4.25 cmolc dm^{-3}) and higher values of organic carbon (27.67 g dm^{-3}) in the layer of 0.05-0.10 m. The yield of grains, number of plants per meter and mass of 100 soybean grains did not present significant differences among the evaluated treatments.

Keywords: soil cover species, chemical attributes, soil management systems

1. Introduction

With the population growth and consequent demand for food the exploitation of the soil became intensive. According to Betioli Júnior et al. (2012), one of the ways to increase the structural quality of the soil is through the conservation and continuous contribution of cultural residues to the soil surface. These cultural residues can bring, besides the chemical benefits, improvements in the physical quality of the soil.

In this way, the search for a cropping system that provides the improvement in the structure of the soil over time, with less environmental impact, is essential for modern agriculture. In this context, it is essential to adopt a cropping system that contributes to the improvement of soil quality, increasing crop productivity and reducing the final cost of production (Melo et al., 2007).

The conservation systems are recommended to associate the reduction of soil mobilization with the rotation of different crops; permanent maintenance of the ground cover; integrated management of pests, diseases and weeds; the selection of plant species and the development of more productive and adapted varieties and cultivars; to more rational fertilizer systems (EMBRAPA, 2010).

Roscoe et al. (2006) state that the accumulation of vegetal residues on the surface contributes to the maintenance of good soil physical conditions, such as the increase of water retention capacity, aggregate stability, total porosity, macro and microporosity.

Among the soil cover species, legumes (*Fabaceae*) such as *Crotalaria juncea* and *Crotalaria spectabilis* can be mentioned, because they are plants with rapid vegetative growth, efficient in the production of biomass and extraction of nutrients, besides being adapted to the conditions of low fertility from soil (Fontanétti et al., 2006; Vargas et al., 2011). However, *Cajanus cajan* (L.) Millsp.) has a lower C/N ratio, but it has the capacity to recycle high amounts of nutrients and can be part of the rotation, since they promote the release of nutrients during its decomposition, providing short-term benefit (Torres, Pereira, & Fabian, 2008).

The pigeon pea (*Cajanus cajan*), native to Africa, has high adaptability to the tropical environment and can fix atmospheric nitrogen (Silveira et al., 2005).

The millet (*Pennisetum glaucum* (L.) R. Br.) has also been constituted as a good cover crop option, providing high amounts of dry mass, allowing the success of the no-tillage system (NTS) (Carneiro et al., 2008). It is a species with higher C/N ratio, allowing a slow decomposition of the residues, and greater soil protection (Torres, Pereira, & Fabian, 2008).

The velvet bean (*Mucuna pruriens* (L.) DC) also contributes to the improvement of the chemical and physical properties of the soil, with emphasis on the increase of macronutrients and increase of the organic matter on the soil (Teodoro et al., 2011).

Thus, crop rotation with cover crops can be considered an alternative to restore soil quality in areas degraded by intense cultivation (Santos et al., 2014; Zotarelli et al., 2012). This is because rotation can promote nutrient cycling and improve soil structure (Tejada, Hernandez, & Garcia, 2008).

Thus, with the implementation of different soil cover species, the greater the contribution of vegetal residues on the soil and the greater the nutrient cycling for the subsequent crops. And consequently, these positive effects could be reflected on grain yield.

In this context, the objective of this work was to evaluate the impact of changes in soil management and crop rotation on a clayey Oxisol under no-tillage system in nutrient cycling and soybean grain yield.

2. Material and Methods

2.1 Location of the Experiment and Characterization of the Area

The experiment was conducted at the Agronomic Institute of Parana (IAPAR), at the Santa Tereza do Oeste experimental station, with a longitude of 53º29′37″ W, latitude 24º50′42″ S, and average altitude of 607 meters.

The climate of the region, according to the Köppen classification, is subtropical humid, with average annual precipitation of 1840 mm (IAPAR, 1994). The soil was classified as a Dystroferric Red Latosol (EMBRAPA, 2018), of clayey texture (Table 1).

The results of the soil granulometry in the three soil layers are presented in the Table 1.

Table 1. Soil granulometry[1] of the experimental area in the three layers evaluated

Layer	Soil granulometry		
	Sand	Clay	Silt
m	----------	$g\ kg^{-1}$	----------
0.0-0.1	44.9	561.1	394.1
0.1-0.2	38.7	641.9	319.4
0.2-0.3	24.7	706.2	269.1
Mean	36.1	636.4	327.5

Note. [1] Pipette method (USDA, 1972).

The information regarding the history of the experimental area can be found in Table 2.

Table 2. Harvest history of the last four years of the experimental area

Harvest	Summer crop	Winter crop
2010	Soybean and bean	Oats
2011	Corn	Oats
2012	Soybean and bean	Wheat and oats
2013	Soybean	Oats and rye

Before the installation of the experiment, chemical analyzes were performed for initial characterization of the soil, which can be found in Table 3.

Table 3. Initial chemical characterization of the soil before the implantation of the experiment in the 0-0.20 m layer in the year 2010

P	C	pH	Al^{3+}	H^{+}+Al^{3+}	Ca^{2+}	Mg^{2+}	K^{+}	BS	CEC	V	Al*
mg dm^{-3}	g dm^{-3}	$CaCl_2$		--------------------------- $cmol_c$ dm^{-3} ---------------------------						--------- % ---------	
23.6	32.72	4.70	0.32	9.00	4.20	3.00	0.44	7.64	16.64	45.91	4.02

Note. BS: Base sum, CEC: Cation exchange capacity, V: Base saturation, Al*: Aluminium saturation.

2.2 Description of Treatments

The design was completely randomized with 9 treatments of 20 × 25 meters. Six treatments involving cover species and two treatments involving management changes of the no-tillage system simulating the practice of farmers in the western region of Paraná, besides the traditional no-tillage system without alterations of management: no-tillage system (NTS-control), no-tillage system with scarification (NTSS) and no-tillage system with gypsum application (NTSG). The reclaimers species of structure were pearl millet (*Pennisetum americanum*) (PM), dwarf pigeon pea (*Cajanus cajan*) (DPP), sunn hemp (*Crotalaria juncea*) (SH), pigeon pea (*Cajanus cajan*) (PP), rattlebox (*Crotalaria spectabilis*) (R) and velvet bean (*Mucuna pruriens* (L.) DC) (VB).

In the treatments with different management systems were implanted the culture of crambe (*Crambe abyssinica*).

Table 4 shows the amounts of cover seed (kg ha^{-1}) sown in the treatments.

Table 4. Description of the crops used, sowing density, line spacing and sowing density

Treatments	Seed quantity (kg ha^{-1})	Line spacing (m)	Seeds/m
Pearl millet	20	0.17	81
Dwarf pigeon pea	30	0.45	27
Sunn hemp	25	0.17	14
Pigeon pea	50	0.45	33
Rattlebox	15	0.17	24
Velvet bean	70	0.45	8
Crambe	12	0.34	113

2.3 Treatment Evaluation and Statistical Analysis

The collection of soil samples for evaluation of soil chemical attributes after the implantation of cover species and changes in management of no-tillage system occurred randomly in two points per treatment in the layers of 0-0.05, 0.05-0.10, 0.10-0.20 and 0.20-0.40 m.

The chemical attributes evaluated were phosphorus (P), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), organic carbon (C), soil acidity (pH), aluminum (Al^{3+}), potential acidity (H^{+}+Al^{3+}), base sum (BS), cation exchange capacity (CEC), base saturation (V), aluminum saturation (Al*). The determination of the analyzes was carried out at the IAPAR Soil Laboratory, according to the methodology described by EMBRAPA (1997).

The results were submitted to analysis of variance (ANOVA) and means were compared by the Tukey test at 5% of significance, by the statistical program SISVAR (Ferreira, 2011).

3. Results and Discussion

The mean Tables 5 and 6 present the mean values of soil chemical attributes, respectively, in the layers 0-0.05/0.05-0.10 and 0.10-0.20/0.20-0.40 m in the 2015 period.

In Table 5, the 0-0.05 m layer, it can be observed that there was no significant difference between the treatments, regarding the values of the chemical attributes C, Al^{3+} and Al*.

Significant differences occurred among treatments with the P-element, in which the treatment of PP (63.67 Mg dm^{-3}) differed from the NTS treatment (17.13 Mg dm^{-3}). For the pH, the DPP treatment (5.77) was different from the treatments R (4.77) and NTS (4.67), as well as from the treatment of NTSS (4.97), which did not differ from each other. For the H^{+}+Al^{3+} elements the NTS treatment (9.05 cmolc dm^{-3}) differed from the DPP treatment (4.07 cmolc dm^{-3}). For the Ca^{2+}, the treatment of DPP (8.13 cmolc dm^{-3}) was different from R treatments (4.51 cmolc dm^{-3}) and NTS (4.65 cmolc dm^{-3}). In Mg^{2+}, VB treatment (4.25 cmolc dm^{-3}) differed from the NTS treatment (2.14 cmolc dm^{-3}). A significant difference was also observed in the K-element analysis in which the DPP treatment (0.67 cmolc dm^{-3}) differed from the NTSG (0.39 cmolc dm^{-3}) and NTS (0.34 cmolc dm^{-3}) treatments. It can also be observed that there was a significant difference for BS, in which the DPP treatment (12.93 cmolc dm^{-3}) differed from the treatments R (7.36 cmolc dm^{-3}), NTSG (8.41 cmolc dm^{-3}) and NTS (7.13 cmolc dm^{-3}). Regarding CEC, VB treatment (17.35 cmolc dm^{-3}) differed from treatments with NTSG (15.12 cmolc dm^{-3}) and R (15.58 cmolc dm^{-3}), not differing from each other. Basal saturation (V), the treatment that stood out was the DPP (76.01%), differing from the treatment of NTS (44.20%) and R (47.29%), in which both also did not differ among themselves at 5% significance.

Comparing the results with the Technical Manual of the Subprogram of Soil Management and Conservation (Fuentes, 1989), it was observed that the pH values are below or sometimes well below the recommended values. which recommends pH values between 5.50 and 6.50. This fact may have occurred because the last liming of the area was carried out in 2011. Since, among the benefits of liming are the elevation of soil pH and the neutralization of toxic aluminum, which is detrimental to the development of plant roots; the supply of calcium and magnesium to plants; the best use of nutrients such as nitrogen, phosphorus, potassium, sulfur and molybdenum; the increase of the cation exchange capacity, with the release of sites of negative charges of the soil colloids, which allows the attraction of other nutrients, reducing leaching; the increase of the microbial activity and the release of nutrients of the organic matter of the soil (Santos, & Resende, 2009).

These values disagree with the values found by Freddi et al. (2017), which in relation to the soil acidity values, found values in the superficial layers, superior to 5.5, being considered ideal for the nutrient's availability of the plants and to neutralize the exchangeable aluminum.

In the different management systems, the soil is considered acidic in the 0 0.5 m layer when the pH is lower 7. The base saturation is high. when the value V > 50% (Ferreira et al., 2017). As for phosphorus, Silva, Lavagnolli, and Nola (2011), relate in their studies the increment of shoot and productivity of the crop with the adequate availability of phosphorus, for the authors the higher the available phosphorus, the greater of the shoot length of culture. For the K-element, this is within a range considered good, with mean values close to 0.31 cmolc dm^{-3} (Martins, 2016).

In Table 5, for the 0.05-0.10 m layer, it can be observed that there was no significant difference between the treatments at 5% of significance regarding the chemical attributes/characteristics: P, pH, Al^{3+}, Ca^{2+}, H^{+}+Al^{3+}, Mg^{2+}, K^{+}, BS, V and Al^{3+}.

Differences occurred in relation to C, where VB treatment (27.67 g dm^{-3}) presented the highest value, differing from PM and NTSG treatments, which presented the lowest values with results of 19.99 and 19.48 g dm^{-3}, respectively.

Regarding the CEC values, the VB treatment resulted in the highest value (16.41 cmolc dm^{-3}), differing from the lowest (13.91 cmolc dm^{-3}) in the NTSG treatment. When analyzing the carbon values, it was observed that the soil of the experimental area has values considered from medium to high, since, according to the manual of management, values between 20 g dm^{-3} and 35 g dm^{-3} are considered high (Martins, 2016). These values do not corroborate those found by Resende et al. (2014), that when analyzing the chemical parameters in different soil types (soybean crop and vegetation cover in three soil areas, designated Cerradão, Cerrado and Campo Cerrado) pointed out that the treatments did not differ among them in terms of the chemical attributes in the 0.0-0.2 m layer, being poor in Ca^{2+}, Mg^{2+}, K^+ and P, presenting high values of active acidity determined in $CaCl_2$, low values of potential CEC, sum of bases and percentage of saturation by bases.

Table 5. Soil chemical attributes in the 0-0.05 and 0.05-0.10 m layers, after the cultivation of soil cover species and management changes in the no-tillage system

Treat.	P	C	pH	Al^{3+}	H^++Al^{3+}	Ca^{2+}	Mg^{2+}	K^+	BS	CEC	V	Al*
	mg dm^{-3}	g dm^{-3}	$CaCl_2$	---------------------------			cmol$_c$ dm^{-3}			----------------------------	------- %	--------
0-0.05 m soil layer												
PM	29.43ab	24.41	5.17abc	0.00	6.05ab	6.92ab	2.77ab	0.61ab	10.29ab	16.34abc	62.87abc	0.00
DPP	35.73ab	25.71	5.77a	0.00	4.07b	8.13a	4.13ab	0.67a	12.93a	17.00ab	76.01a	0.00
SH	29.43ab	26.23	5.60ab	0.00	4.53ab	6.77ab	3.89ab	0.51ab	11.17ab	15.70bc	70.99ab	0.00
PP	63.67a	27.53	5.03abc	0.01	6.39ab	5.67ab	3.13ab	0.61ab	9.40ab	15.79abc	59.45abc	0.12
R	18.60ab	28.83	4.77c	0.08	8.22ab	4.51b	2.41ab	0.44ab	7.36b	15.58bc	47.29bc	1.24
VB	20.57ab	30.64	5.13abc	0.02	6.34ab	6.28ab	4.25a	0.48ab	11.01ab	17.35a	63.42abc	0.20
NTSS	29.93ab	25.71	4.97bc	0.01	7.03ab	6.10ab	2.53ab	0.52ab	9.15ab	16.18abc	56.56abc	0.11
NTSG	22.40ab	25.71	5.03abc	0.06	6.72ab	5.33ab	2.68ab	0.39b	8.41b	15.12c	55.59abc	0.92
NTS	17.13b	27.79	4.67c	0.22	9.05a	4.65b	2.14b	0.34b	7.13b	16.18abc	44.20c	3.80
Mean	29.61	26.95	5.13	0.04	6.49	6.04	3.10	0.51	9.65	16.14	59.60	0.71
CV (%)	52.7	8.1	5.1	201.8	22.9	16.9	22.7	18.7	16.4	3.5	15.4	224.1
DMS	44.67	6.25	0.75	0.26	4.24	2.93	2.02	0.27	4.52	1.62	26.23	4.55
0.05-0.10 m soil layer												
PM	15.07	19.99b	4.80	0.06	7.79	4.90	2.55	0.45	7.90	15.69abc	50.23	0.90
DPP	18.03	22.59ab	5.03	0.07	7.05	5.65	2.79	0.47	8.91	15.97ab	55.75	0.91
SH	9.80	21.29ab	4.90	0.20	7.60	3.63	2.37	0.47	6.47	14.06bc	46.14	3.74
PP	18.40	22.33ab	4.57	0.39	9.27	3.55	1.82	0.44	5.81	15.08abc	38.30	9.73
R	12.70	23.63ab	4.53	0.56	9.36	2.98	1.53	0.33	4.85	14.21bc	34.82	15.55
VB	8.83	27.67a	4.63	0.11	9.72	4.38	1.94	0.38	6.70	16.41a	40.80	1.66
NTSS	17.73	25.45ab	4.83	0.08	7.88	5.05	2.23	0.43	7.71	15.59abc	49.36	1.23
NTSG	10.10	19.48b	4.80	0.22	7.78	3.89	1.94	0.31	6.14	13.91c	44.26	5.06
NTS	19.23	23.11ab	4.27	0.80	10.76	2.45	0.98	0.25	3.69	14.44abc	25.64	18.55
Mean	14.43	22.84	4.71	0.28	8.58	4.05	2.02	0.39	6.46	15.04	42.81	6.37
CV (%)	69.5	11.3	7.4	145.2	24.2	29.6	36.8	30.6	30.5	4.70	31.00	172.7
DMS	28.69	7.40	1.00	1.15	5.94	3.44	2.12	0.34	5.64	2.02	37.97	31.48

Note. PM: pearl millet; DPP: dwarf pigeon pea; SH: sunn hemp; PP: pigeon pea; R: Rattlebox; VB: Velvet bean; NTSS: no-tillage system with scarification; NTSG: no-tillage system with gypsum application; NTS: no-tillage system (control). Averages of treatments followed by the same lowercase letters in the column do not differ from each other by the Tukey test at 5% significance.

In Table 6, layer 0.10-0.20 m, it can be observed that there was no significant difference between the treatments regarding the chemical attributes/characteristics: P, C, pH, Al^{3+}, H^++Al^{3+}, K^+, CEC, V and Al*. The significant differences occurred for Ca^{2+}, in which NTSS was the one with the highest value (3.97 cmolc dm^{-3}), differing from the SH and PP treatments, which presented values of 1.37 and 1.17 cmolc dm^{-3}, respectively. There was also a significant difference in Mg^{2+} values, where NTSS treatment presented the highest value (1.93 cmolc dm^{-3}) differing from NTS treatments (0.50 cmolc dm^{-3}) and VB (0.67 cmolc dm^{-3}). As for BS values, NTSS was also the one with the highest value (6.25 cmolc dm^{-3}), differing from PP (2.24 cmolc dm^{-3}), VB (2.46 cmolc dm^{-3}) and NTS (2.19 cmolc dm^{-3}).

For the Ca^{2+} element, the values are in the range recommended as good to very high, with values ranging from 0.97 cmolc dm^{-3} in the layer 0.20-0.40 m to 6.97 cmolc dm^{-3} found in the 0-0.05 m layer. In relation to Mg^{2+}, values above 0.80 cmolc dm^{-3} were observed. According to Martins (2016), these values are considered high. The same author recommends that the average values should be between 0.60 and 0.80 cmolc dm^{-3}.

In Table 6, for the 0.20-0.40 m layer, it can be observed that there was no significant difference between the treatments, regarding the values of the chemical parameters: P, C, pH, Al^{3+}, Ca^{2+}, Mg^{2+}, K^{+}, V and Al*.

These values corroborate with the results found by Espindola et al. (2006), which demonstrated that there were no significant differences between the cover plants as regards the accumulated Mg^{+2} values. It can be observed that there was a significant difference between the treatments when the values of H^{+}+Al^{3+} were observed, in which the NTS treatment presented the highest value (12.65 cmolc dm^{-3}), differing from NTSS treatments (7.97 cmolc dm^{-3}) and NTSG (7.39 cmolc dm^{-3}). There was also a significant difference between the treatments in the BS analysis, in which the PM treatment (3.77 cmolc dm^{-3}) differed from the SH treatment (1.25 cmolc dm^{-3}). For the CEC, there was also a significant difference between the treatments, in which treatments PM (13.49 cmolc dm^{-3}), DPP (13.52 cmolc dm^{-3}) and VB (12.99 cmolc dm^{-3}) differed from the NTSG treatment (9.59 cmolc dm^{-3}).

Table 6. Soil chemical attributes in the 0.10-0.20 and 0.20-0.40 m layers, after the cultivation of soil cover species and management changes in the no-tillage system

Treat.	P	C	pH	Al^{3+}	H^{+}+Al^{3+}	Ca^{2+}	Mg^{2+}	K^{+}	BS	CEC	V	Al*
	mg dm^{-3}	g dm^{-3}	$CaCl_2$	----------------------------- cmol$_c$ dm^{-3} -----------------------------							------ % ------	
0.10-0.20 m soil layer												
PM	8.47	19.47	4.53	0.28	9.23	3.03ab	1.89ab	0.34	5.26ab	14.49	36.02	5.60
DPP	3.60	19.74	4.30	1.05	10.89	2.63ab	1.10abc	0.29	4.03ab	14.91	27.38	22.98
SH	4.60	17.40	4.10	1.09	10.89	1.37b	0.86abc	0.28	2.50ab	13.39	19.36	31.04
PP	6.10	18.18	4.10	1.04	10.73	1.17b	0.78abc	0.29	2.24b	12.97	16.99	34.70
R	3.63	19.74	4.27	1.09	10.67	1.63ab	1.03abc	0.23	2.89ab	13.55	22.95	31.29
VB	2.03	20.51	4.10	1.03	11.88	1.5ab	0.67bc	0.23	2.46b	14.34	17.28	29.56
NTSS	3.83	18.96	4.77	0.13	7.88	3.97a	1.93a	0.35	6.25a	14.13	44.02	2.86
NTSG	2.10	15.58	4.30	0.51	8.30	1.99ab	1.03abc	0.21	3.23ab	11.53	28.35	16.37
NTS	8.63	21.04	4.10	1.17	11.41	1.52ab	0.50c	0.18	2.19b	13.60	16.55	34.26
Mean	4.78	18.96	4.28	0.82	10.21	2.10	1.09	0.27	3.45	13.66	25.43	23.18
CV (%)	125.7	16.4	7.4	73.6	20.6	42.5	39.8	38.6	38.0	9.8	41.7	80.1
DMS	17.19	8.88	0.91	1.73	6.02	2.55	1.24	0.29	3.75	3.83	30.33	53.15
0.20-0.40 m soil layer												
PM	3.37	16.10	4.33	0.50	9.72ab	2.31	1.22	0.24	3.77a	13.49a	27.60	13.13
DPP	2.00	15.06	4.17	1.16	10.57ab	1.78	0.94	0.22	2.95ab	13.52a	22.15	29.95
SH	1.67	14.28	4.00	1.27	10.52ab	0.97	0.40	0.20	1.57ab	12.09ab	13.23	44.10
PP	1.10	12.72	4.07	1.03	9.72ab	0.72	0.31	0.22	1.25b	10.97ab	11.41	46.80
R	1.10	12.46	4.30	0.74	8.67ab	1.43	0.78	0.14	2.36ab	11.03ab	22.66	28.24
VB	0.80	16.62	4.03	1.09	11.27ab	1.07	0.46	0.19	1.72ab	12.99a	13.28	38.74
NTSS	0.47	15.06	4.50	0.26	7.97b	2.03	1.16	0.22	3.41ab	11.40ab	26.65	7.40
NTSG	1.20	11.42	4.40	0.42	7.39b	1.58	0.46	0.15	2.20ab	9.59b	22.76	17.64
NTS	1.13	16.10	4.03	1.14	12.65a	0.97	0.44	0.12	1.53ab	12.85a	12.08	41.76
Mean	1.43	14.42	4.20	0.82	9.83	1.43	0.69	0.19	2.30	11.99	19.09	29.75
CV (%)	97.3	20.4	5.3	73.6	15.4	45.6	47.1	45.3	37.1	8.6	41.6	60.1
DMS	3.97	8.40	0.64	1.73	4.33	1.87	0.93	0.24	2.44	2.97	22.73	51.14

Note. PM: pearl millet; DPP: dwarf pigeon pea; SH: sunn hemp; PP: pigeon pea; R: Rattlebox; VB: Velvet bean; NTSS: no-tillage system with scarification; NTSG: no-tillage system with gypsum application; NTS: no-tillage system (control). Averages of treatments followed by the same lowercase letters in the column do not differ from each other by the Tukey test at 5% significance.

These results do not corroborate with the results found by Moreti et al. (2007), when working with no-tillage and conventional tillage and six fertilizations (chicken manure fertilizer, chicken manure fertilizer + half of the recommended mineral fertilization, mineral fertilization, *Crotalaria juncea*, *Pennisetum americanum* and control). The same authors emphasized that the plants of crotalaria and millet did not alter the chemical attributes of the soil and presented similar behavior among themselves. They also state that no-tillage and conventional tillage systems were like changes in soil chemical attributes.

In general, comparing the initial soil characterization results (Table 3) with those observed after cultivation with the cover species, in the 0-0.05 m layer (Table 5), increases in P values (6.01 mg dm^{-3}), Ca^{2+} (1.84 cmolc dm^{-3}), Mg^{2+} (0.1 cmolc dm^{-3}) and K^+ (0.07 cmolc dm^{-3}) and Al reduction (0.28 cmolc dm^{-3}). While in the subsequent layers (0.05-0.10 and 0.10-0.20 m) there was reduction of the chemical elements. These results corroborate with those observed by Bilibio et al. (2010), who found higher P, Ca^{2+}, Mg^{2+} and K^+ values in the superficial layer (0-0.05 m) and that these values decrease substantially from the first sampling section for the other layers (0.05-0.15 and 0.15-0.30 m). The same authors also state that, nutrient contents accompany the organic carbon contents that decrease in depth, as they occur in soils in natural systems, due to the cycling of nutrients promoted by plants. This trend does not differ between cultivation systems.

Siqueira Neto et al. (2009) point out that the higher carbon content gives higher potential CEC values in the different soil treatments. This shows the importance of organic matter as a conditioner of soil loads.

The values for grain yield, number of plants per meter and 100-grain weight soybeans are shown in Table 7.

In Table 7 it can be observed that the results of the yield of soybean, 100-grain weight and number of plants per meter, did not present significant differences between the treatments, in the experimental conditions in which it was performed, according to Tukey's test 5 % of significance. Possibly, the good structural conditions of the soil, together with the good conditions of soil fertility and climate did not allow the occurrence of significant differences among the evaluated treatments. In addition, the precipitation was 1.043 mm during the cycle of the soybean crop. For 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. Fidalski et al. (2015) also found that there was no increase in productivity of the crops after liming and soil rotation in maize, black oat and soybean yields.

Table 7. 100-grain weight, plants per meter and grain yields of soybean in management systems and species of cover

Treatment	100-grain weight (g)	Plants per meter	Grain yield (kg ha^{-1})
PM	13.39	137.00	3025.19
DPP	13.03	133.75	2944.11
SH	13.20	145.50	2832.45
PP	12.64	129.50	2760.74
R	13.25	127.50	3035.22
VB	13.51	140.50	2911.95
NTSS	13.17	130.50	2699.59
NTSG	13.62	122.25	2861.11
NTS	12.72	139.25	2672.25
Mean	13.17	133.97	2860.29
CV (%)	3.19	7.40	8.39
DMS	1.00	23.61	571.40

Note. PM: pearl millet; DPP: dwarf pigeon pea; SH: sunn hemp; PP: pigeon pea; R: Rattlebox; VB: Velvet bean; NTSS: no-tillage system with scarification; NTSG: no-tillage system with gypsum application; NTS: no-tillage system (control). Means of treatments followed by the same letters in the column, do not differ among themselves by the Tukey test at 5% significance.

4. Conclusion

The pigeon pea provided greater phosphorus cycling, whereas the velvet bean provided greater cycling of magnesium in the soil.

The grain yield, plants per meter and 100-grain weight soybean did not differ significantly between evaluated treatments.

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