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Cover crops and concentrations of carbon and nitrogen in Amazonian soil

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Abstract

The present study aimed to evaluate the potential of dry matter production by cover crops and their effects on the dynamics of organic matter, organic carbon and nitrogen in the soil. This study contributes to minimize the effect of climate change and improve agricultural production systems. The experiment was conducted under field conditions, in the experimental area of the Federal Institute of Education, Science and Technology of Rondônia, Colorado do Oeste Campus, in the municipality of Colorado do Oeste, RO, Brazil. The experimental design was completely randomized, arranged in a factorial scheme, with four replications, consisting of six species of cover crops cultivated in pre-season (*Crotalária ochroleuca, Crotalária spectabilis, Mucuna pruriens, Cajanus cajan, Canavalia ensiformis and Lablab purpureus*) and four sampling depths (0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm). The production and macronutrient contents in the dry mass of shoots of the different cover crops were evaluated, as well as the dynamics of organic matter, organic carbon and N in the soil at different sampling depths. The species *Crotalaria ochroleuca* and *Crotalaria spectabilis* showed great potential for dry matter production, while Lablab *purpureus* bean stands out in the extraction of nutrients such as P, K and Ca at full flowering. Lablab bean and Jack bean as cover crops were the most efficient strategies to promote the increase in the input of OM, C and N forms in the soil. NH_4^+-N and NO_3^--N contents were higher in the surface layers of the soil. Management with cover crops promoted gradual accumulation of SOM, which made it possible to influence the maintenance and increase of C and N concentrations in the soil and contributed to minimizing environmental impacts and increasing the quality and sustainability of soils and agricultural production systems.

Keywords: soil management; organic matter; N; soil quality; sustainability.

Introduction

In the context of global climate change resulting from the increase in the concentrations of greenhouse gases in the atmosphere, especially carbon dioxide (CO_2), soil and its different forms of use and management are constantly in focus and have attracted the attention of the scientific community, mainly because the soil is considered a source or sink of atmospheric CO_2, depending on the management adopted.

The conversion of natural ecosystems into agricultural systems involves a series of activities that affect the rates of addition and decomposition of soil organic matter (SOM) (Zinn et al., 2005). In agricultural systems, land use and management act by modifying both the input and the output of C from the soil to the atmosphere. Thus, the highest rates of SOM decomposition observed in areas under cultivation occur due to soil physical disturbances (Loss et al., 2015; Rosset et al., 2014a; 2014b; Sales et al., 2018), which imply disruption of macroaggregates (reduces the physical protection of SOM), exposing previously protected OM to microbial processes, thus contributing to increase the rates of CO_2 emission to the atmosphere (Zinn et al., 2005). In addition, SOM is an important reservoir of potentially available forms of nitrogen for plants, mainly nitric N (NO_3^--N) and ammoniacal N (NH_4^+-N) (Rangel et al., 2007), since most of the soil N is in organic form, and the mineralization of SOM, which encompasses the processes of amination and ammonification, is responsible for the conversion of 2 to 5% of organic N into mineral N per year.

In this context, conservation agriculture can help to maintain or even increase the concentrations of C (Falcão et al., 2020, Alavaisha et al., 2019; Nijmeijer et al., 2019) and N in the soil, contributing to minimize climate change, as well as improving production systems, since it advocates the maintenance of crop residues on the surface with no turning of the soil, promoting gradual decomposition and accumulation of organic material in the surface horizon of the soil (Lal, 2018; Salton et al., 2008).

Notably, in the last decade, the Amazon biome has constantly suffered with the advance of agricultural extensions, and agricultural production is interested in the effects of soil management on the contents of C and N from SOM, constituting a strategy for the maintenance or increase of soil quality, sustainable land use and reduction in the impact of agricultural activities on the environment. Although the dynamics and quality of SOM are widely studied in Brazilian soils, the results generated in an Amazonian biome are scarce. Therefore, evaluating changes in the dynamics of C and N, resulting from anthropic interventions in agricultural ecosystems, and understanding the relationships with soil cover play an important role in the monitoring of soil quality and deepening of sustainable technological development for the region.

In view of the above, the present study aimed to evaluate the potential of dry matter production by cover crops and their effects on the dynamics of organic matter, organic carbon and nitrogen in the soil, with a view to contributing to minimize climate change and improve agricultural production systems

Results and discussion

The results did not show significant effects of the double interaction between cover crops and sampling depth for any of the variables studied, and the results with significant effect ($p \leq 0.05$) for cover crops (Figure 2, 3, 4 and 5) or sampling depth (Figure 6 and Table 2) are presented independently.

Dry matter production and chemical composition of shoots of cover crops

The cultivation of *Crotalaria ochroleuca* promoted the best results for dry matter production (15.40 $t.ha^{-1}$), not differing statistically from *Crotalaria spectabilis* (13.88 $t.ha^{-1}$) (Figure 2). This production and subsequent input of dry matter in the soil can cause significant changes in its physical and chemical characteristics, maintenance and/or elevation of soil organic matter contents, and maintenance of soil temperature, besides favoring the development and yield of agricultural species in subsequent crops (Andrade Neto et al., 2008; Boer et al., 2008). However, the lowest dry matter production was obtained by *Canavalia ensiformes* (3.0 $t.ha^{-1}$) (Figure 2) and was even below the minimum amount of dry matter deposited annually for adequate soil cover in no-tillage system. The low initial rainfall observed in the region during plant establishment (30 first days – November) may be related to the low dry matter production by this cover crop (Figure 1). These results fully corroborate those found by Araújo et al. (2021), who observed higher dry matter production in the cultivation of *Crotalaria spectabilis* and *Crotalaria ochroleuca* in the 2019/2020 season, while *Canavalia ensiformis* showed lower production, and partially corroborate the results obtained by Pereira et al. (2017), who observed high dry matter production for *Crotalaria spectabilis* and Jack bean, and low dry matter production for black velvet bean, which makes it possible to infer that dry matter production capacity is directly related to edaphoclimatic conditions, soil fertility and agricultural year.

Despite the high capacity for dry matter production by *Crotalaria ochroleuca*, it is verified that its capacity to absorb and accumulate P, K and Ca in the leaves at full flowering was lower and differed statistically from those of the other cover crops. The opposite is observed for *Lablab purpureus*, whose contents of P, K and Ca in the leaves were on the order of 1.84 g/kg^{-1}, 24.62 g/kg^{-1} and 13.11 g/kg^{-1}, respectively (Figure 3). However, Lablab bean can be indicated as an excellent cover crop species because it has high capacity to extract nutrients from the soil even with low input of dry matter and may contribute to significant incorporation of nutrients after biomass decomposition. Similar results were obtained by Araújo et al. (2021) when studying nutrient cycling by different cover crops in an Amazonian environment.

Dynamics of organic matter, organic carbon and N in soil in response to the management with cover crops

The species *Lablab purpureus* and *Canavalia ensiformis* were efficient and statistically superior ($p \leq 0.05$) to the other cover crops in terms of input of organic matter, organic carbon, C/N ratio (Figure 4A, 4B and 4C). This indicates the importance of using cover crops with potential for C entry into the system, and consequently increased stocks of C and N, contributing to the improvement of chemical, physical and biological characteristics of the soil (Bell and Moore, 2012) and minimizing the impact of agricultural activities on the environment. The amount of residues entering the system influences the rate of addition of C to the soil (Johnston et al., 2009), and the frequency and magnitude of this process depends not only on the quality of the residues deposited on the soil surface (Magalhães et al., 2016), but also on time of management (Salton et al., 2008) and climatic conditions (Koven et al., 2017).

Correlated with OM and C concentrations in the soil, residues of legume crops such as *Lablab purpureus* and *Canavalia ensiformis* have a significant impact on total contents of N, NH_4^+-N and NO_3^--N in soil, and the contribution of these species were on the order of 2995 kg/ha of total N, 77 kg/ha of NH_4^+-N and 56 kg/ha of NO_3^--N in the soil, differing statically from the other species of cover crops (Figure 5A, 5B and 5C). This process is regulated by soil management and notably by the species that are included in the schemes of soil cover and crop rotation. Therefore, greater use of legumes and the introduction of species with higher biomass production cause greater storage of total N in the soil (Mielniczuk et al., 2003), providing more favorable conditions in the upper layers, and over the time of adoption, in its deeper layers, as well as ecosystem balance. The current technical recommendation of fertilization for the corn and/or bean crop is 150 kg/ha of N. Based on the results of the present study, reductions of 50% and 35% in the amount of N applied in the form of NH_4^+ and NO_3^- in the soil, respectively, can be inferred in the case of a crop in succession. The higher ammonium content in the plots can be explained by the low C/N ratio of these legume species, so the mineralization of organic matter is more intense, and ammonium is more rapidly released to the soil (Aita et al., 2007; Aranda et al., 2011).

Dynamics of organic matter, organic carbon and N in soil in response to sampling depth

The contents of OM, organic carbon, C/N ratio and N fractions in the soil were statistically significant ($p \leq 0.05$) as a

Table 1. Chemical attributes of the soil before the installation of the experiment at different depths.

Performed	N	MO	CO	pH	P	K	Ca	Mg	H+Al	Al	SB	CTC	V
	mg/dm^{-3}	g/dm^{-3}		$CaCl_2$	mg/dm^{-3}		------------------mmolc/dm^{-3}--------------						(%)
0-10	1253.5	11.4	4.62	4.9	4	81.9	29	8	30	1	40	70	57
10-20	1090.9	5.3	3.08	5.0	1	58.5	36	4	25	1	41	66	62
20-30	888.3	4.2	2.44	5.3	1	42.9	37	3	20	0	40	60	67
30-40	842.3	3.1	1.80	5.5	1	27.3	35	2	17	0	37	54	69

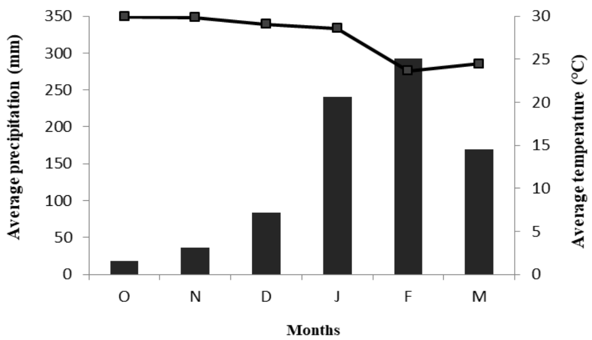

Figure 1. Monthly averages of rainfall (mm) and temperature (°C), recorded at the weather station of the National Institute of Meteorology, from October 2020 to March 2021.

Table 2. Changes in the contents of total N, NH_4^+-N and NO_3^--N as a function of the different sampling depths.

Performed	N-total	N-NH4$^+$	N- NO3$^-$
	___________mg/kg___________		
0-10	1810.37 a	39.39 a	27.93 a
10-20	1528.7 b	38.67 a	24.79 a
20-30	871.06 c	34.69 b	19.84 b
30-40	871.79 c	34.66 b	19.64 b
Média	1270.48	36.85	23.05
CV (%)	22.52	9.32	28.15

*Means followed by the same letter in the columns do not differ statistically from each other by Tukey's test at 5% probability level.

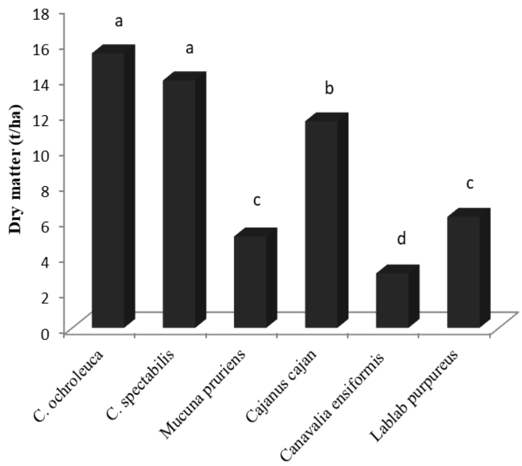

Figure 2. Dry matter production by different cover crops. *Means followed by the same letter in the bars do not differ statistically from each other by Tukey's test at 5% probability level.

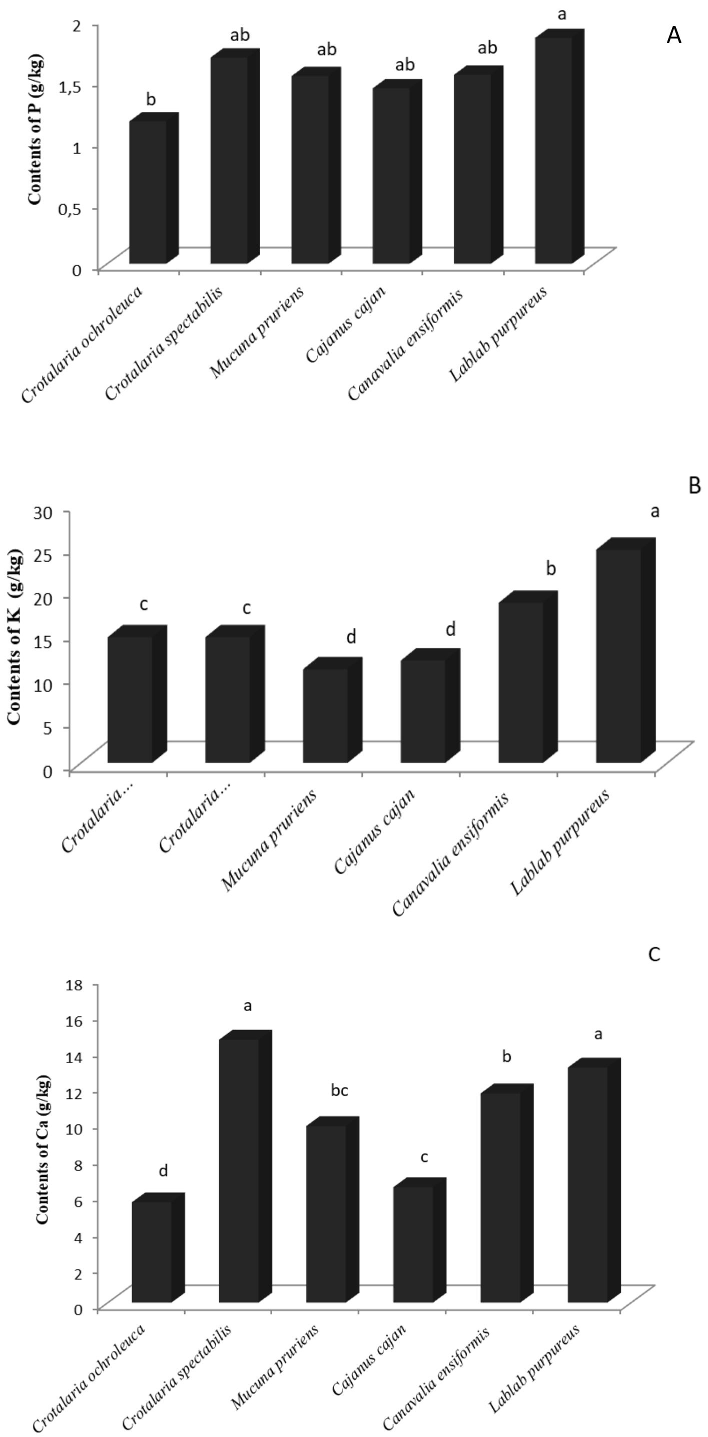

Figure 3. Contents of P (A), K (B) and Ca (C) in the shoot dry matter of different cover crops at full flowering. *Means followed by the same letter in the bars do not differ statistically from each other by Tukey test at 5% probability level.

function of the sampling depth (Figure 6 and Table 2). At the depth of 0-10 cm, the mean values of OM, OC and C/N ratio were 16.17 g/dm^{-3}, 9.4 $g/\ dm^{-3}$ and 5.26 g/dm^{-3}, respectively, statistically differing from the other sampling depths, whose values were reduced in subsurface (Figure 6A, 6B and 6C), which shows a more effective contribution in the most superficial layer of the soil. This increment in the contents of OM and organic carbon in the most superficial layer of the soil is probably associated with the fact that the natural deposition of nutrient-rich organic material from the different cover crops (Figure 2) occurs in greater quantity on soil surface. It is important to highlight that, as the soil structure is strengthened by the adoption of these management systems with inclusion of cover crops and reduced turning, the contents of OM, organic carbon, C/N ratio and N in the soil must increase, even enabling the stabilization of organic matter in the long term, according to Araújo et al. (2021), Rosset et al. (2016) and Lima et al. (2016), and minimizing the impacts on the environment.

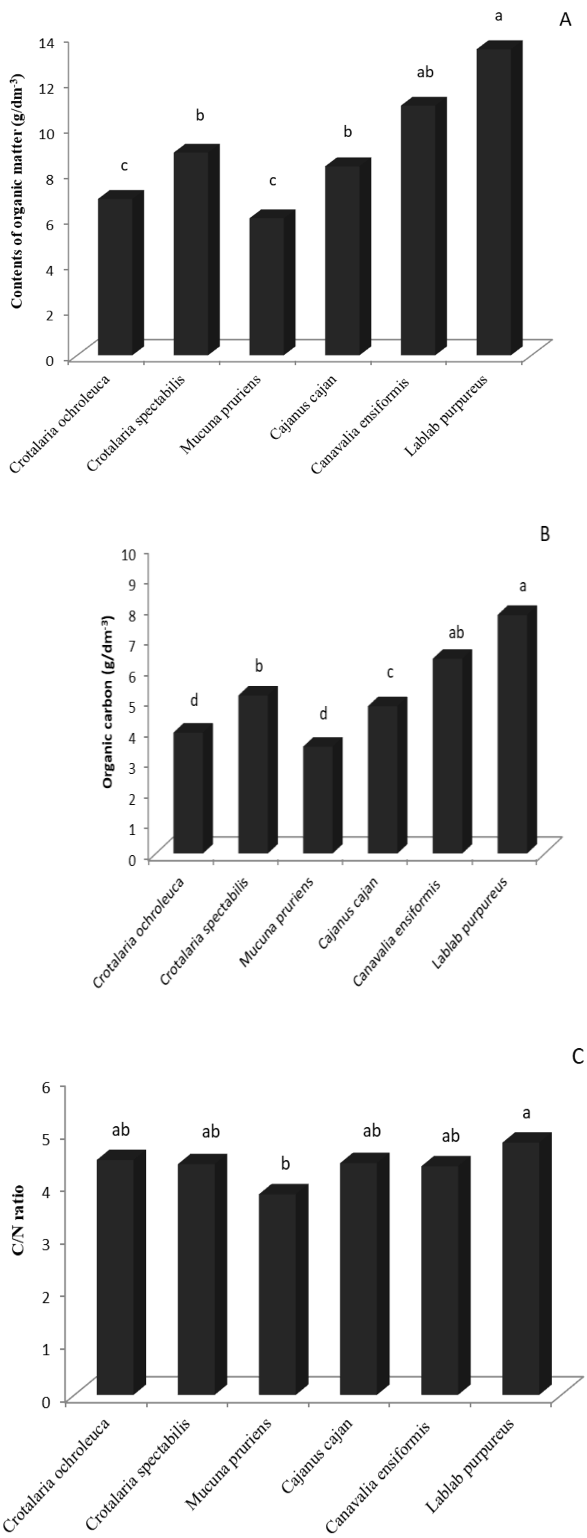

Figure 4. Contents of organic matter (A), organic carbon (B) and C/N ratio (C) in the soil in response to management with different cover crops. *Means followed by the same letter in the bars do not differ statistically from each other by Tukey test at 5% probability level.

Thus, under the edaphoclimatic conditions in which the experiment was conducted, the accumulation of total organic carbon depends fundamentally on the stabilization of soil organic matter for subsequent effects in upper layers of sampling. D'Andréa et al. (2004), studied carbon and nitrogen stocks in a Latossolo Vermelho distrófico (Oxisol) subjected to different management systems. They also found lower C contents in subsurface and higher values at the depth of 0-10 cm.

Regarding the total N contents in the soil, the correlation was positive with the C contents in the soil, especially in the surface layers (0-10 cm), since 95% of soil total N is present

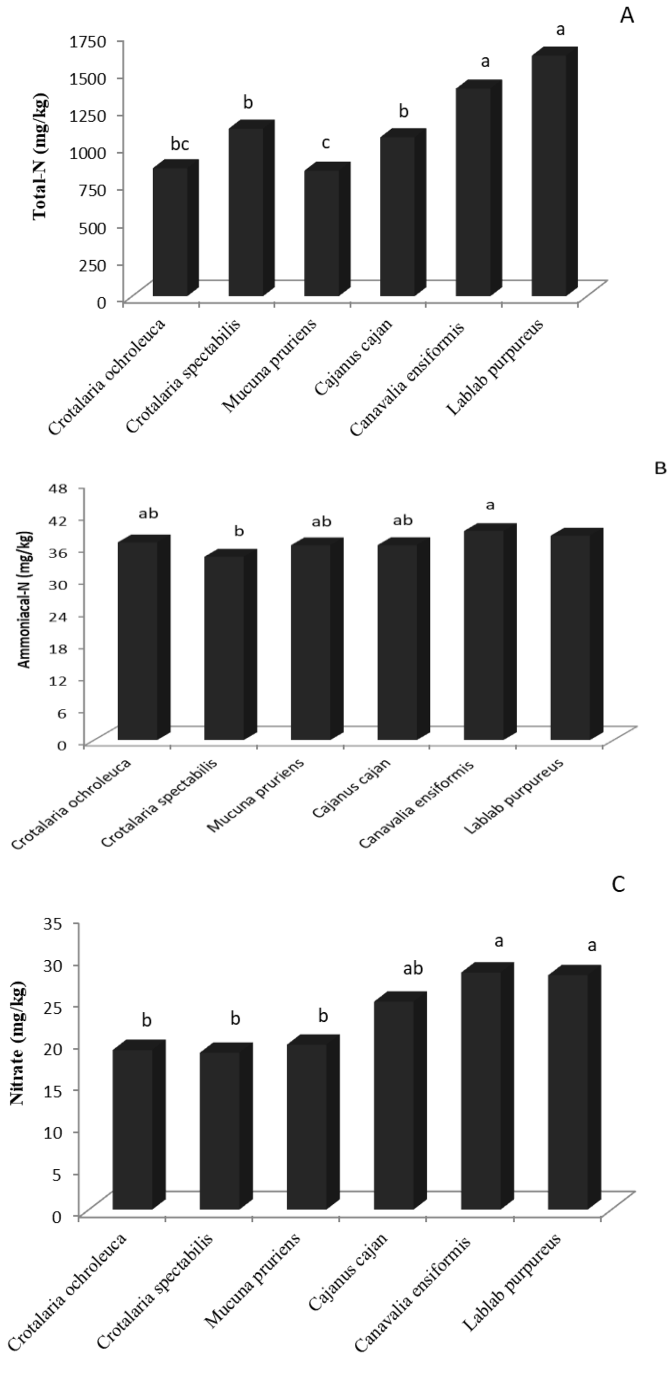

Figure 5. Total N (A), Ammoniacal N (B) and Nitrate (C) in the soil in response to management with different cover crops. *Means followed by the same letter in the bars do not differ statistically from each other by Tukey test at 5% probability level.

in the organic form and there is greater organic activity in soil surface, decreasing with sampling depth (Table 2). An increase on the order of 556.87 kg/ha of N was observed in the 0-10 cm layer in two years of experiment, and the combination of dry matter production and nutrient accumulation resulted in greater N cycling in the soil, which was made possible by the rapid release during decomposition, since legumes have more accelerated decomposition. Regarding the inorganic N contents, higher values of NH_4^+-N and NO_3^--N were also observed in the surface layers of the soil between 0-10 cm and 10-20 cm, decreasing along the soil profile. The mean contents of NH_4^+-N and NO_3^--N at the depths of 0-10 cm and 10-20 cm were 39.09 mg/kg and 26.36 mg/kg, respectively, differing statistically from each other (Table 2). Under acidic pH conditions, the predominant chemical species is $NH4^+$, explained by the nitrification process, which is mediated by the bacteria *Nitrosomonas* and *Nitrobacter*, which are very sensitive to pH values lower than 6.0 and show zero activity at pH lower than 4.5 (Moreira and Siqueira, 2006), which justifies the higher concentrations of NH_4^+-N compared to NO_3^--N. This demonstrates that soil management with the use of cover crops is a tool that can be used to alter the contents of NH_4^+-N and NO_3^--N in the oil, as already

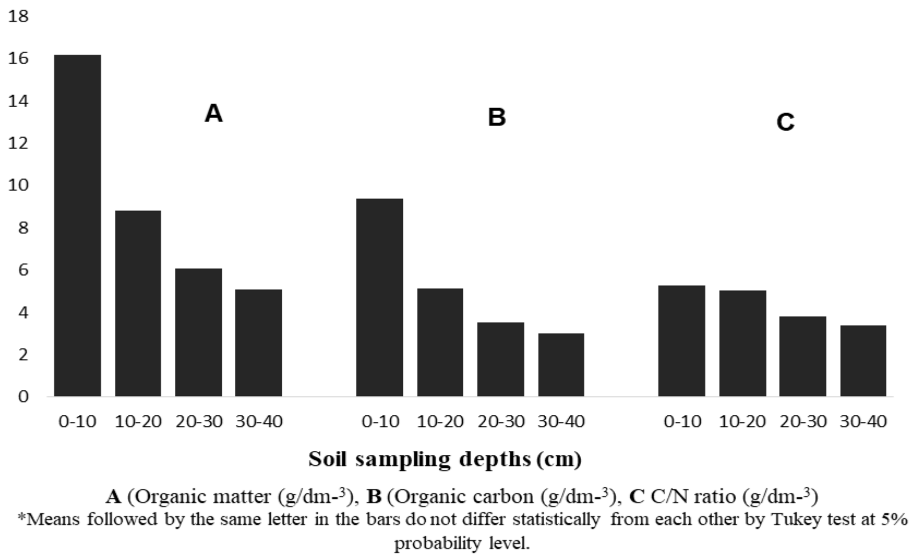

Figure 6. Organic matter (A), organic carbon (B) and C/N ratio as a function of soil sampling depths.

reported by Nascente et al. (2012 and 2013). Another point to be observed is that the highest accumulation NO_3^--N was verified in the root zone layer between 0 and 20 cm, and leaching occurred at low intensity, possibly due to the low rainfall levels in the region during the period, since the concentration in the subsurface layers was 19.74 mg/kg. That is, 33.53% less than in the surface layers of the soil, possibly tending to variations over time and with the cycle of the crops in succession. D'Andréa et al. (2004) stated that nitrate is easily leached and this leaching is directly related to the precipitated volume of water.

There is growing interest in the study of soil behavior regarding their ability to store or lose C, in the various existing management conditions due to problems of greenhouse gas emissions. Conservation practices that prioritize the contribution of MOS can contribute to the sequestration of C, especially the use of cover crops, because in addition to presenting high production of dry mass and rusticity, they have a deep and branched root system, capable of extracting nutrients from the deepest layers of the soil, potentially resulting in the partial or total replacement of mineral fertilizers by the biologically fixed N and in the improvement of the environmental quality and sustainability of agricultural systems as demonstrated in the research.

Materials and Methods

The experiment was conducted under field conditions, in the experimental area of the Federal Institute of Education, Science and Technology of Rondônia, Colorado do Oeste Campus, in the municipality of Colorado do Oeste, RO, Brazil, at the geographic coordinates of 13°06'S and 60°29'W, with an average altitude of 407 meters. According to Köppen's classification, the climate is Awa, warm and humid tropical with two well-defined seasons. Average data of temperature and rainfall during the experiment were obtained from the database of the National Institute of Meteorology (Figure 1). Chemical characterization of the soil was performed in the 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm layers using samples collected before the installation of the experiment (Table 1) in the agricultural year 2019. Particle-size analysis at 0-10 cm depth showed 343 g dm^{-3} of clay, 479 g dm^{-3} of sand and 178g dm^{-3} of silt.

Because this is a continued study, soil correction was performed thirty days before the first sowing of cover crops, based on the results of soil analysis in the 0-10 cm layer, using dolomitic limestone filler (RNV 97%), in order to raise base saturation to 60%. Primary tillage of the soil included plowing and harrowing (disc harrow) up to 15 cm deep, while secondary tillage included the clod-breaking operation and leveling of the experimental area. Basal fertilization was carried out with subsequent incorporation, applying 400 kg ha^{-1} of the formulation 0-20-20 to supply 120 kg ha^{-1} of P_2O_5 and 80 kg ha^{-1} of K_2O, respectively. From this correction and construction of soil fertility, the experimental premises were for minimal cultivation, without soil turning and with permanent cover. The experimental design was completely randomized, arranged in a factorial scheme, with four replications, consisting of six species of cover crops cultivated in pre-season *(Crotalária ochroleuca, Crotalária spectabilis, Mucuna pruriens, Cajanus cajan, Canavalia ensiformis e Lablab purpureus*), and four sampling depths (0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm).

The planting furrows were mechanically opened at 5 cm depth, according to the determined spacing, and sowing was performed manually. The different quantities of seeds were based on technical recommendations for the different cover crops. Each experimental unit was composed of 8 rows with 5 m length, at spacing of 0.45 m between rows and 0.20 m between plants. The six central rows were considered the usable plot, disregarding 0.5 m from each end of the plot.

At the time of full flowering, the cover crops, except for *Canavalia ensiformis* (beginning of the pod filling) were desiccated using the herbicide glyphosate (1.920 g ha^{-1} of a.i.) and then managed with a handheld brush cutter at 0.05 m height in relation to the soil surface, aiming at uniformizing the area. However, prior to desiccation, the shoot dry matter production of the different cover crops was evaluated. To determine the dry matter, a frame (0.50 m x 0.50 m) was used to demarcate the plot area, in which the sample was collected (close to the soil), weighed to determine the fresh mass, and dried in a forced air circulation oven at 65 ºC, until reaching constant weight, to determine the dry matter. The contents of macronutrients in shoot dry matter were determined according to Embrapa (2009).

To determine soil chemical attributes, soil samples were collected at depths of 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. To form the composite sample, five subsamples were collected between crop rows in each experimental unit, packed in plastic bags and taken to the laboratory. The soil samples were air-dried, passed through a 2-mm-mesh sieve, homogenized and subjected to organic matter and organic carbon evaluations using the methodology proposed by Cambardella and Elliot (1992), and the mineral N of the soil was determined by the Kjeldahl method, according to Tedesco et al. (1995).

All evaluations of the dynamics of organic matter, organic carbon and N in the soil were carried out in the second year of cultivation of the cover crops that means 2020/2021 season. After all the analyses, the data were subjected to the normality test (Shapiro-Wilk) and analysis of variance to verify the effects between covers crops and sampling depth. The means were compared by Tukey's test at 5% probability level, using the statistical program Sisvar (Ferreira, 2019).

Conclusions

The species *Crotalaria ochroleuca* and *Crotalaria spectabilis* have great potential for dry matter production, while Lablab bean stands out in the extraction of nutrients such as P, K and Ca at full flowering. Lablab bean and Jack bean as cover crops were the most efficient strategies to promote the increase in the input of organic matter, organic carbon and nitrogen forms in the soil. NH_4^+-N and NO_3^--N contents were higher in the surface layers of the soil. Management with cover crops promoted gradual accumulation of SOM, which made it possible to influence the maintenance and increase of C and N concentrations in the soil, and contributed to minimizing the environmental impacts and increasing the quality and sustainability of soils and agricultural production systems.

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References

Aita C, Giacomini S, Hubner A (2007) Nitrificação do nitrogênio amoniacal de dejetos líquidos de suínos em solo sob sistema de plantio direto. Pesq Agropecu. 42:95-102.

Andrade Neto RC, Goes GB, Miranda NO, Filho ETD, Filho FSTP (2008) Adubação verde: uma alternativa sustentável para o Brasil. Rev Verde. 3:16-20.

Aranda V, Canada M, Vidal A, Garcia J, Calero J, Delgado R, Verdejo T, Vila F (2011) Effect of soil type and management (organic vs. conventional) on soil organic matter quality in olive groves in a semi-arid environment in Sierra Mágina Natural Park (Spain). Geoderma. 164:54-63.

Araujo EO, Ribeiro J, Venturim D, Catanio J. Macieski Neto V, Freitas D, Moreira A, De Paula NRF, Costa J, Costa W, Santos K (2021) Absorption of nutrients and chemical reconditioning of red latosol by cover plants cultivated in Amazon environment. Aust Jour Crop Scie. 15:145-155.

Bell L, Moore A (2012) Integrated crop-livestock systems in Australian agriculture: trends, drivers and implications. Agric Systems. 111:1-12.

Boer CA, Assis RL, Silva GP, Braz AJB, Barroso ALL, Filho AC, Pires FR (2008) Biomassa, decomposição e cobertura do solo ocasionada por resíduos culturais de três espécies vegetais na região centro-oeste do Brasil. Rev Bras Cien Solo. 32:843-851.

Cambardella C, Elliott E (1992) Particulate soil organic matter changes across a grassland cultivation sequence. Soil Scie Soc Amer Jour.56:777-783.

D'andrea A, Silva M, Curi N, Guilherme L (2004) Estoques de carbono e nitrogênio e formas de nitrogênio mineral em um solo submetido a diferentes sistemas de manejo. Pesq Agropecu Bras. 39:179-186.

Empresa Brasileira de Pesquisa Agropecuária – EMBRAPA. Manual de análises químicas de solos, plantas e fertilizantes. - 2. Ed, Brasília., Embrapa Informação Tecnológica, 2009. 627 p.

Johnston A, Poulton P, Coleman K (2009) Soil organic matter: its importance in sustainable agriculture and carbon dioxide fluxes. Adv in Agronomy. 101:1-57.

Koven C, Hugelius G, Lawrence D, Wieder W (2017). Higher climatological temperature sensitivity of soil carbon in cold than warm climates. Nat Clim Change. 7: 817-822.

Lima CEP, Fontenelle MR, Madeira NR, Silva J, Guedes IMR, Silva LRB, Soares DC (2016) Compartimentos de carbono orgânico em Latossolo cultivado com hortaliças sob diferentes manejos. Pesq Agropecu Bras. 51:378-387.

Loss A, Basso A, Oliveira B, Koucher L, Oliveira R, Kurtz C, Lovato P, Curmi P, Brunetto G, Comin J (2015) Carbono orgânico total e agregação do solo em sistema de plantio direto agroecológico e convencional de cebola. Rev Bras Cien Solo. 39:1212-1224.

Magalhãoes SSA, Ramos FT, Webwe OLS (2016) Carbon stocks of an Oxisol after thirty-eight years under different tillage systems. Rev Bras of Eng Agri and Amb. 20:85-91.

Mielniczuk J, Bayer C, Vezzani F, Lovato T, Fernandes F, Debarba L (2003) Manejo de solo e culturas e sua relação com os estoques de carbono e nitrogênio do solo. In: Curi N, Marques J, Guilherme L, Lima J, Lopes A, Alvarez VVH. Tópicos em ciência do solo. Viçosa, MG, Sociedade Brasileira de Ciência do Solo. v.3. p.209-248.

Moreira F, Siqueira J (2006) Microbiologia e bioquímica do solo. Lavras, Universidade Federal de Lavras, 625p.

Nascente A, Crusciol C (2013) Cover crops affecting levels of ammonium and nitrate in the soil and upland rice development. Semina: Cien Agra. 34:2189-2202.

Nascente A, Crusciol C (2012) Cover crops and herbicide timing management on soybean yield under no-tillage system. Pesq Agropecu Bras. 47:187-192.

Pereira AP, Schoffel A, Koefender J, Camera JN, Golle DP, Horn RC (2017) Ciclagem de nutrientes por plantas de cobertura de verão. Rev Cien Agra. 40(4): 799-807.
Rangel O, Silva C (2007). Estoques de carbono e nitrogênio e frações orgânicas de latossolo submetido a diferentes usos e manejo. Rev Bras Cien Solo. 31:1609-1623.
Rosset J.; Lana M, Pereira M, Schiavo J, Rampim L, Sarto M, Seidel E. (2014a) Estoque de carbono, propriedades químicas e físicas do solo em sistemas de manejo com diferentes tempos de implantação na Região Oeste do Paraná, Brasil. Semina: Cien Agra.35:3053-3072.
Rosset J, Schiavo J, Atanazio R (2014b) Atributos químicos, estoque de carbono orgânico total e das frações humificadas da matéria orgânica do solo em diferentes sistemas de manejo de cana-de-açúcar. Semina: Cien Agra.35: 2351-2366.
Sales A, Silva A, Veloso C, Carvalho E, Miranda B (2018) Carbono orgânico e atributos físicos do solo sob manejo agropecuário sustentável na Amazônia Legal. Colloquium Agrariae. 14: 1-15.
Salton J, Mielniczuk J, Bayer C, Boeni M, Conceição , Fabricio A, Macedo M, Broch D (2008) Agregação e estabilidade de agregados do solo em sistemas agropecuários em Mato Grosso do Sul. Rev Bras Cien Solo. 32:11-21.
Tedesco MJ, Gianello C, Bissani CA, Bohnen H, Wokweiss SJ (1995) Análises de solo, plantas e outros materiais. 2.ª ed. Porto Alegre, UFRGS/Departamento de Solos, 174 p.
Zinn Y, Lal R, Resck D (2005) Changes in soil organic carbon stocks under agriculture in Brazil. Soil Till Res.84:28-40.