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CHEMICAL AND PHYSICAL ATTRIBUTES OF THE SOIL CULTIVATED WITH CACAO INTERCROPPED WITH COVER CROPS

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The use of cover crops is recommended to produce straw to protect the soil, improve fertility through nutrient cycling, soil structuring and sustainability of the productive system. In this sense, the work was developed aiming to evaluate the chemical and physical attributes of a Nitisols cultivated with cacao full-sun cacao system intercropping with cover crops. The experiment was performed in a complete randomized block design, with plots subdivided in a 2x4 factorial scheme, with five replicates. The treatments consisted of two sampling sites (rows and interrows) and cover crops: pigeon pea (*Cajanus cajan* L.), millet (*Pennisetum glaucum* L.), consortium of pigeon pea and millet and control with invasive plant growth. Samples were collected in the rows and interrows of the cacao tree for chemical and physical analysis of the soil. The cultivation of millet and invasive plants provided higher levels of calcium, sum of bases and CEC in the rows than in the interrows. The levels of K, Ca, Zn, Mn, CEC and OM were higher in the rows than interrows of cacao trees. The intercropping of cover crops in full-sun cacao system did not change the physical attributes of the soil in the initial implantation phase.

Key words: Nutrient cycling, Full-sun cacao system, Soil structure.

Atributos químicos e físicos do solo cultivado com cacaueiro consorciado com plantas de cobertura. O uso de plantas de cobertura é recomendado para formação de palhada para proteção do solo, aumento da fertilidade do solo através da ciclagem de nutrientes, estruturação do solo e sustentabilidade do sistema produtivo. O trabalho foi desenvolvido com o objetivo de avaliar os atributos químicos e físicos de um Nitossolo cultivado com cacau em sistema de cacau a pleno sol consorciado com plantas de cobertura. O experimento foi realizado em delineamento de blocos ao acaso, com parcelas subdivididas em esquema fatorial 2x4, com cinco repetições. Os tratamentos consistiram de duas posições de amostragem e (linha e entrelinha) e plantas de cobertura: guandu (*Cajanus cajan* L.), milheto (*Pennisetum glaucum* L.), consórcio de milheto e guandu e plantas espontâneas. A amostragem de solo foi realizada nas linhas e entrelinhas dos cacaueiros para determinação das análises físicas e químicas. O cultivo de milheto e plantas espontaneas aumentou os teores de cálcio, soma de bases e CTC do solo na posição da linha comparado à entrelinha. A construção da linha para cultivo de cacaueiro favoreceu os atributos químicos do solo expressos pelos teores de K, Ca, Zn, Mn, CTC e MO. O consórcio de plantas de cobertura com cacaueiro à pleno sol não altera os atributos físicos do solo na fase inicial de implantação.

Palavras-chave: Ciclagem de nutrientes, cacau a pleno sol, estrutura do solo.

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Introduction

Cacao farming requires good quality and high fertility soil for proper development of the root system, plants, and production maintenance (Sodré, 2017). With the addition of new technologies, full-sun cacao system has been standing out in recent years. This system consists of the cultivation of cacao in a dense form with shading only in the initial stage of implantation, until the cacao tree is established (Piasentin and Saito, 2014). In the initial phase of the system implantation, cover crops can be used interrows to keep the soil covered, favor nutrient cycling, and increase soil quality.

Cover plants favor the maintenance and recovery of the productive capacity of the soils and increase fertility by nutrient cycling. They can also influence the availability of phosphorus through the combined action of mycorrhizae and root exudates (Berude et al., 2015); adding N to the system by biological fixation (Perin et al., 2004); cycling and nutrient availability (Pereira et al., 2017; Sousa et al., 2017; Pires et al., 2020), increasing productivity over the years (Rosa et al., 2015). The choice of cover crop species to obtain such benefits depends, among other characteristics, on the potential of phytomass production and the ability to absorb and accumulate nutrients (Pacheco et al., 2011; Wolschick et al., 2016).

The use of cover crops can also improve soil physics. The improvement in the physical attributes of the soil promoted using cover plants favors the development and productivity of the main crops. However, the physical attributes will be influenced by the continuous use of cover crops in the long term. After two cycles of cover crops in rice and soybean rotation system in Brazilian Cerrado, there was improve soil physical properties in relation to fallow, especially in the 0-0.10 m soil layer (Nascente and Stone, 2018).

The cultivation of perennial species associated with cover crops, especially fruit, is already a common practice which improves soil quality and needs adequate management to avoid competition with the crop of economic interest. However, in an intercropping with cacao, this practice is insipient and needs evaluations, especially in the southern region of Bahia, which depends heavily on the cultivation of cacao and where the cultivation of full-sun dense cacao has been increasing lately.

The use of legumes in the cultivation of full-sun cacao is a practice to increase productivity, and also a strategy to decrease wind speed and favor the increase of soil moisture (Vanhove et al., 2016). In a study carried out in Peru, the use of cover crops intercropped with under cacao agroforestry showed an improvement in soil quality, assessed by microbial attributes, promoting the sustainability of cacao cultivation systems (Buyer et al., 2017) and increased of P cycling in the surface layer of the soil (Hall et al., 2010). On the other hand, Tondoh et al. (2015), evaluated over a chronosequence (5, 10 and 20 years) the conversion of traditional cultivation systems into full-sun cacao systems and observed a reduction in soil quality, especially for total organic carbon, nitrogen and capacity of cation exchange over the years.

In general, cover crops improve soil quality. However, there is little information about their use in cacao production systems.Thus, this work was carried out with the aim to evaluate the chemical and physical properties of the soil after the use of cover crops in a system of production of full-sun cacao.

Materials and Methods

The experiment was carried out in an area of 1,200 m^2 located at CEPEC (Cacao Research Center), research unit of CEPLAC (Department of the Executive Committee of the Cacao Crops Plan), in Ilhéus, BA, Brazil. Inserted in the central corridor of the Atlantic Forest, formed by the dense ombrophilous forest, belonging to the neotropical zone (Veloso, Rangel Filho and Lima, 1991). According to the Köppen classification, the climate in the regionis Af - hot and humid tropical forest without dry season, with an average rainfall of 1,300 mm, distributed throughout the year, average temperature of 23°C and air relative humidity of 80%. The soil of the experimental area was classified as Nitisol (IUSS, 2015).

During the study period, temperature and precipitation data were collected at the CEPEC meteorological station, located near the experimental area (Figura 1).

Before sowing the cover plants, disturbed soil samples were collected in the rows and interrows of the cacao plants, in the 0-20 cm layer, in which the soil fertility analysis (macro and micronutrients) was performed (Table 1) according to the methodology described in EMBRAPA (2009).

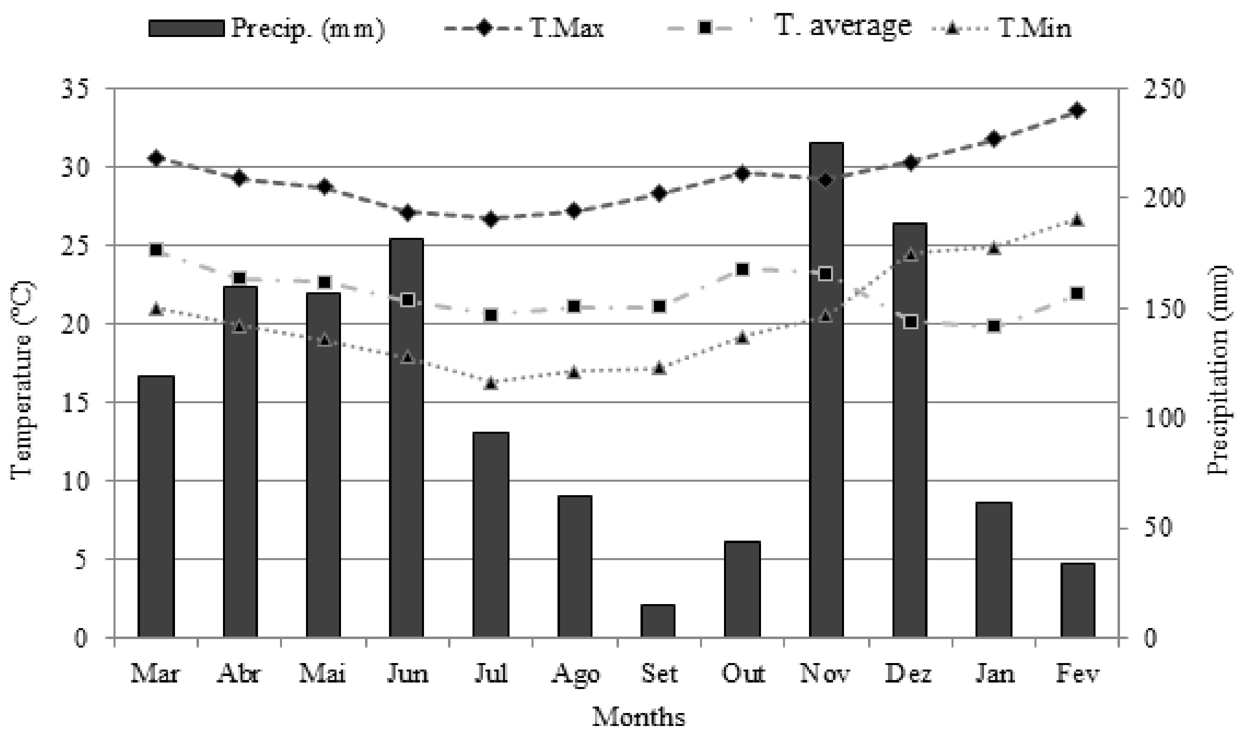

Figure 1. Temperature and rainfall precipitation registered in the experimental area during the study period. Precip.: precipitação; T.max: maximum temperature; T.média: average temperature; T.min: minimum temperature.

Table1. Soil chemical attributes on the rows (R) and inter-rows (IR) before cover crops sowing

	pH	Al	H+Al	Ca	Mg	K	SB	CEC	BS	m	P	Fe	Zn	Cu	Mn	MO	Sand	Silt	Clay
			---------- cmol$_c$dm^{-3} ------------------						--- % ---		---------------- mg dm^{-3} --------------						----- g kg^{-1} -----		
R	5,5	0,3	5,4	5,8	4,8	0,14	10,7	16	66,1	2,8	8,2	330,2	1,9	0,5	47,2	25,4	456	380	164
IR	5,5	0,7	5	5	4,5	0,08	9,6	14,6	64,7	7,9	11,7	348,6	1,6	0,7	32,7	17,2	475	350	175

pH: hydrogen potential; Al: aluminum; H+Al: Potential acidity; Ca: calcium; Mg: magnesium; K: potassium; SB: sum by base; CEC: cation exchange capacity; BS: base saturation; m: saturation by aluminum; P: phosphorus; Fe: iron; Zn: zinc; Cu: copper; Mn: manganese; MO: organic matter.

The study was performed in a complete randomized block design, in a split plot with five replicates. The treatments constituted a 2x4 factorial scheme, with two sampling sites (plot): rows and interrows and four combinations of cover plants (subplot): pigeon pea (*Cajanus cajan* L.), millet (*Pennisetum glaucum* L.), consortium of pigeon pea and millet and control with invasive plants growth. The experimental plots measured 15m^2.

The initial preparation of the area consisted of plowing and harrowing, mobilizing the soil up to 0,20m in depth.The cacao planting rows were built manually in the shape of a trapezoid or ridges with a base width of 1.0m and a height of 0.60m.The cacao trees, originated from the genetic material CCN-51, CEPEC-2002 and BN-34, were transplanted in the area six months before, with 1.5m x 2.0m spacing. At the time of the cacao planting, fertilization was carried out with 50 grams of simple super phosphate (20% P_2O_5) and one liter of earthworm humus.

The sowing of cover crops was carried out at the beginning of May 2018, with the incorporation of seeds using a hand tool.The quantities of seeds used were: pigeon pea: 45 kg ha^{-1}; millet: 35 kg ha^{-1}; pigeon pea + millet consortium: 9.0 + 5.0 kg ha^{-1}; control with invasive plant growth.

At 45 days after sowing, the percentage of soil cover considering a sampling area of 0.45m^2 was estimated. Four replicates were performed per treatment and a percentage scale of grades from 0 to 100% was established, where zero corresponds to the absence of vegetation cover over the soil and 100 to the complete coverage of the soil, following the methodology of Gazziero, Velini and Osipe (1995).

Soil sampling for fertility purposes was carried out in the 0-0,20m layer, 30 days after cutting the cover crops. The following determinations were carried out on soil samples: pH in water, macronutrients (Ca^{2+}, Mg^{2+}, P e K^{+}), fertility parameters (Al^{3+}, H+Al, SB, V, CEC, m) and organic matter (OM) following Embrapa's (2009) methodology.

Disturbed and undisturbed soil samples were also collected in the 0-0,10m, layer to analyze the physical attributes of the soil. In disturbed samples, granulometric analysis was performed according to the methodology of Gee and Bauder (1986). Undisturbed samples were collected using volumetric cylinders of approximately 100 cm^3. In these samples, bulk density (Bd) and total porosity (Tp) were determined. Bd was calculated by the ratio of the dry soil mass and the volume of the cylinder (Blake and Hartge, 1986). Tp was calculated by the ratio of bulk density to particle density. Based on petrotransfer functions (PTF), the saturated hydraulic conductivity of the soil (Ksat), the field capacity (FC) and the permanent wilting point (PWP) were estimated. The following criteria were used to choose the PTF: i) availability of predictive attributes in the database, and ii) similarity between the climate of the regions where the PTF was developed and the climate of the study site. Thus, Ksat, (equation 1), was determined according to the function proposed by Jabro (1992). FC (equation 2) and PWP (equation 3) were determined according to Van Den Berg et al. (1997). The available water (AW) was determined by the difference between the water content in the FC and in the PWP according to equation 4.

$$\text{Ksat} = \exp.\,(11{,}56 - 0{,}81 * \text{LOG}(S) - 1{,}09 * \text{LOG}(A) - 4{,}64 * (\text{Bd}) \quad (1)$$

$$\text{FC} = (0{,}5 * A + 5{,}1) / 100 \quad (2)$$

$$\text{PWP} = (-0{,}5 + 0{,}34 * A) / 100 \quad (3)$$

$$\text{AW} = (\text{FC} - \text{PWP}) * \text{Bd} * 30 * 10 \quad (4)$$

Where: A: clay; S: silt; FC: field capacity; PWP: permanent wilting point and Bd: bulk density.

The data of chemical and physical attributes were submitted to analysis of variance by the F test and the treatment means compared by the Scott-Knott's test at 5% probability.

Results and Discussion

Percentage of soil coverage

The percentage of soil coverage (PSC) was higher in the cultivation rows than interrows, except for invasive plants (Figure 2). Possibly due to the better chemical and physical condition of the soil in this location of the plots, resulting from the transfer of the topsoil from interrows to the rows of the cacao plants at the time of the construction of the ridges. On the other hand, among the types of cover, there was a higher PSC in the consortium of pigeon pea + millet, both in the rows and interrows. The lowest PSC (22,3%) was observed in the treatment with pigeon pea (Figure 2). In agricultural rotation system the mix millet + pigeon pea + *brachiaria* produced the highest biomass (Nascente and Stone, 2018).

In general, the use of cover crops with vigorous growth, such as millet, allows greater and faster soil coverage. Higher percentage of soil coverage and higher dry mass yield was observed in a intercropping between Poaceae and Fabaceae (Neto et al., 2012; Marangoni et al., 2017).

Soil chemical attributes after cover crops cultivation

For soil chemical atributtes there was interaction of cover crops and sampling site for the attributes: H+Al, Ca, SB, CEC and OM. There was also effect of the sampling site for Al, Ca, K, SB, CEC, m, Zn, Cu, Mn and OM. And there was no effect of cover crops (Table 2).

Interaction between cover crops and sampling site (row and interrow)

The potential acidity was lower interrows of millet cultivation compared to the row (Table 3). Contrary to this result, Rabelo et al. (2019), demonstrated that the potential acidity is not influenced by millet cultivation at a depth of 0-20 cm.

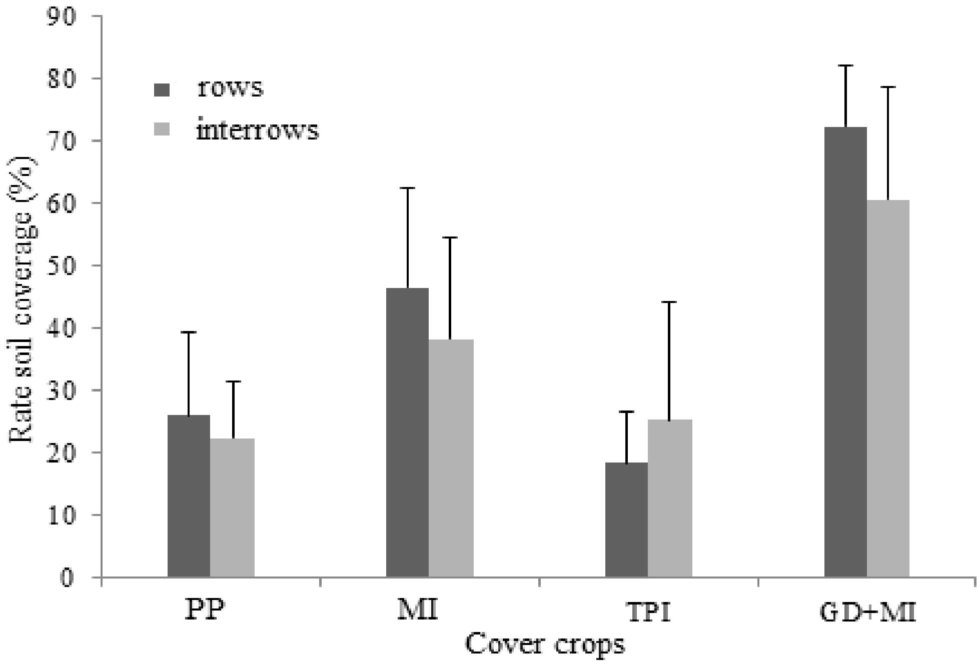

Figure 2. Percentage of coverage at 45 days after sowing for treatments: pigeon pea (PP), millet (MI), invasive plants (IP) and consortium of pigeon pea + millet (PP + MI) in two positions (rows and interrows). Line above the bars indicates standard deviation.

Table 2. Analysis of variance of soil chemical attributes after intercropping of cover crops in the row and interrows of the cacao plants

VF	DF	Medium Squares								
		pH	Al	H+Al	Ca	Mg	Ca/Mg	K	SB	CEC
Blocks	4	0,039^{ns}	0,755**	3,507^{ns}	10,497**	0,803^{ns}	0,512**	0,0034^{ns}	13,475**	25,188**
Cover crops (C)	3	0,009^{ns}	0,084^{ns}	0,266^{ns}	2,298^{ns}	0,887^{ns}	0,021^{ns}	0,0004^{ns}	6,467^{ns}	4,600^{ns}
Error 1	12	0,040	0,071	1,291	1,252	0,321	0,054	0,0011	2,258	3,788
Sampling site (S)	1	0,100^{ns}	2,970**	1,892^{ns}	19,881**	1,936^{ns}	0,289^{ns}	0,0042*	36,100**	57,600**
C x S	3	0,002^{ns}	0,029^{ns}	2,180*	2,780*	0,537^{ns}	0,058^{ns}	0,0005^{ns}	6,167*	13,667*
Error 2	16	0,025	0,131	0,599	0,848	0,552	0,071	0,0008	1,713	2,588
CV1 (%)	-	3,6	50,6	21,1	20,6	13,7	17,7	32,3	15,4	12,9
CV2 (%)	-	2,9	68,6	14,4	17,0	18,0	20,3	27,0	13,4	10,7

VF	DF	Medium Squares								
		BS	m	P	Fe	Zn	Cu	Mn	OM	CS
Blocks	4	72,088ns	102,088**	178,663**	20665,7**	8,308**	0,958*	3668,4**	204,479**	10213,7*
Cover crops (C)	3	72,467ns	17,367ns	58,833ns	1903,5ns	0,874ns	0,403ns	355,4ns	2,670ns	1506,6ns
Error 1	12	46,488	10,804	32,563	2255,8	0,483	0,218	594,4	8,226	2303,1
Sampling site (S)	1	102,400ns	448,900**	28,900ns	180,6ns	7,656**	1,024*	10080,6**	850,084**	5382,4ns
C x S	3	3,400ns	11,367ns	56,567ns	251,7ns	0,493ns	0,377ns	37,1ns	31,215*	3610,1ns
Error 2	16	27,213	20,875	71,713	1912,7	0,404	0,132	953,1	6,846	2524,0
CV1 (%)	-	10,6	53,4	67,5	15,2	24,7	25,6	24,6	14,8	22,6
CV2 (%)	-	8,1	74,2	100,2	14,0	22,5	19,9	31,2	13,5	23,7

VF: Variation factor; DF: degree of freedom; pH: Potential hydrogen; Al: aluminum; H+Al: potential acidity; Ca: calcium; Mg: magnesium; Ca/Mg: calcium/magnesium ratio; K: potassium; SB: sum of bases; CEC: cation exchange capacity; BS: base saturation; m: aluminum saturation; P: phosphor, Fe: iron; Zn: zinc; Cu: copper; Mn:manganese; OM: organic matter, CS: coarse sand. CV: coefficient of variation; **,*Significant at the 1 and 5% probability level by the F test, respectivamente; ns: Não significativo.

Table 3. Interactions of cover crops and sampling site (rows (R) and interrows(IR)) in a full-sun cacao system

Treatments	H+Al		Ca^{+2}		CEC		SB		OM	
	---------------------------- $cmol_c dm^{-3}$ ----------------------------								$mg\ dm^{-3}$	
	R	IR	R	IR	R	IR	R	IR	R	IR
Invasive plants	6,0 ns A	5,2 A	5,6 aA	3,9 bB	16,0 aA	12,4 bB	10,0 aA	7,2 bB	24,40 aA	13,44 bB
Pigeon pea	5,3 A	5,2 A	6,0 aA	5,2 aA	16,0 aA	14,8 aA	10,8 aA	9,8 aA	21,68 aA	17,76 aB
Pigeon pea+Millet	4,9 A	5,6 A	6,0 aA	5,7 aA	15,6 aA	15,8 aA	10,4 aA	10,2 aA	24,32 aA	13,28 bB
Millet	6,0 A	4,5 B	6,6 aA	3,9 bB	17,2 aA	12,2 bB	11,4 aA	7,8 bB	25,26 aA	14,30 bB

Means followed by the same lowercase letter in the columns and uppercase in the rows do not differ from each other by Scott-Knott test ($p < 0,05$). ns: not significant. H+Al: potential acidity; Ca: calcium; CEC: cation exchange capacity; SB: sum of bases; OM: organic matter.

The levels of Ca^{+2}, SB and CEC in the treatments with millet and invasive plants, were higher in the rows compared to the interrows, with differences between these positions of cacao cultivation. The attributes SB and CEC, for these treatments, presented similar values to observed in the initial soil analysis (Table 1). As for the element Ca^{+2}, after the cultivation of millet, the values increased in the row in relation to the initial soil analysis. Cover crops have high levels of Ca^{+2} in plant tissues and favor the cycling of this nutrient in the soil, which will be a source for successor plants grown in the same area (Souza Júnior et al., 1999). However, in a study evaluating the release of nutrients from millet straw of the same cultivar used in this study, a slow release of Ca^{+2} (32.5%) was observed up to 120 days after covering management (Teixeira et al., 2011).

The highest levels of OM were observed in the cacao rows in all treatments. Studies demonstrate the positive effect of cover crops on the increase of OM content and, consequently, of soil quality (Carpim et al., 2008; Correia and Durigan, 2008; Cunha et al., 2011; Cardoso et al., 2014). Using cover crops in succession to annual crops in Cerrado Piauiense, Sousa et al. (2017), found an increase in soil OM levels, already in the first year of evaluation. However, another study reported that the management system in rotation with cover crops did not change the OM content (Costa, Silva and Ribeiro, 2013). But, it had the potential to increase the levels of Ca, Mg and CEC of the soil. Similarly to the study by Costa, Silva and Ribeiro (2013), we did not observe in this study contributions in the content of OM in relation to the initial analysis of soil, which can be attributed to the short period elapsed from the implementation of the system until the date of the evaluations.

However, with the continuous cultivation of cover crops, several benefits can be verified to the soil, especially related to the cycling of nutrients and increasing of the soil quality. The long-term use of cover crops intercropping with cocoa agroforestry showed an improvement in soil microbial quality (Buyer et al., 2017), which provides several benefits to the production system, including increased nutrient cycling, such as, for example, P cycling, verified by Hall et al. (2010).

Sampling site effect

The Al^{+3} content and the saturation of the soil with aluminum (m%) were higher in the interrows, a result that can be justified by the removal of the topsoil at the time of implantation of the cacao cultivation rows, so, interrows that correspond to the deepest layer of the soil showed higher levels of Al^{+3} in relation to the rows (Table 4). Higher levels of Al^{+3} in depth were also verified in this same soil by Silva et al. (1970), values greater than 0.80 cmolc dm^{-3} from 50 cm deep. Nicolodi et al. (2008), showed the effect of organic matter and its ability to complex Al^{+3} reducing the activity of this ion in the soil and effect in reducing toxicity in plants. However, our results suggest that the cover crops did not change the Al^{+3} content of the soil during the growing period.

Table 4. Soil chemical attributes in rows and interrows of a full-sun cacao system intercropped with cover crops

Sampling site	Al	K	m	Zn	Cu	Mn
	-- $cmol_c dm^{-3}$ --		%	----- $mg\ dm^{-3}$ -----		
Row	0,3 b	0,11 a	2,8 b	3,3 a	2,0 a	114,8 a
Interrow	0,8 a	0,09 b	9,5 a	2,4 b	1,7 b	83,0 b

Means followed by the same lowercase letter do not differ from each other using the Scott-Knott test ($p < 0.05$). Al: aluminum; K: potassium; m: saturation by aluminum; Zn: zinc; Cu: copper; Mn: manganese.

The K^+ contents in the soil were higher in the rows compared to interrows, however, the K^+ concentrations found in this soil are below the requirements for cacao cultivation (Chepote et al., 2013). Assessing the decomposition and release of nutrients from cover crops it was found that the release of K^+ occurs quickly, 30 days after the mowing of the cover 95% of K^+ had already been released (Teixeira et al., 2011). The available levels of micronutrients (Zn, Cu, Mn), were higher in the rows than interrows. Considering that grasses and legumes provide nutritious elements to the soil, the result of this study showed that the conditions of the planting rows apparently influenced the increase in the availability of micronutrients more than the presence of cover crops. Regarding the availability of Zn, Cunha et al. (2011) observed an increase in the Zn content available in the soil cultivated with pigeon pea in the 10-20 cm layer and also, that cover crops did not modify the zinc content in the soil surface.

Pegoraro et al. (2006) found increased levels of Zn, Cu, Fe and Mn due to the cultivation of pigeon pea and attributed this result to the action of soil biota. These authors also demonstrated the greatest increase in other cationic micronutrients in soil cultivated with pigeon pea.

Soil physical attributes after cover crops cultivation

There was no significant effect on the physical attributes of the soil. The bulk density (Bd) varied from 1.10 to 1.30 g $cm^3 cm^{-3}$ among treatments (Table 5). These values do not limit the development of cultivated plants, which is 1.6 g cm^{-3} according to Beutler et al. (2004). As described by Andrade and Stone (2009), for the textural class of the soil this study (medium sandy), Bd is within the limits appropriate to the root development of plants, allowing good access to water and nutrients. It is worth noting the lower Bd in the row, which may be related to the higher OM content of the soil, in this sampling site, which implies greater biological activity in the soil, providing better structuring and a larger amount of pores. Studying a Acrisols with high Bd, Reinert et al. (2008), observed that the growth of cover crops was not affected by Bd. These is a property that indirectly affects the development of plants, in addition, Bd is altered by soil granulometry, organic carbon levels and, mainly, soil management (Letey, 1985).

Table 5. Soil physical attributes in rows and interrows of a full-sun cacao system intercropped with cover crops

Treatments	Local	Bd g cm^{-3}	Tp cm^3 cm^{-3}	Ksat mm h^{-1}	AW cm^3 cm^{-3}
Pigeon pea	Row	1,2	0,48	34	0,081
	Interrow	1,3	0,45	19	0,085
Millet	Row	1,1	0,51	38	0,083
	Interrow	1,3	0,45	21	0,083
Pigeon pea+Millet	Row	1,2	0,50	36	0,083
	Interrow	1,3	0,46	29	0,082
Invasive plants	Row	1,2	0,49	35	0,082
	Interrow	1,3	0,44	16	0,086

Bd: bulk density; Tp: Total porosity; Ksat: saturated hydraulic conductivity; AW: available water.

The Tp values ranged from 0.44 to 0.51cm^{-3}, and were higher in the rows than interrows, a result also related to the higher levels of OM in the row. For this textural soil class (medium sandy), these Tp values are within acceptable limits for good plant development (Andrade and Stone, 2009).

The little influence of cover crops on soil Tp occurs due to the good structure of the studied soil (Nitisol) and the absence of compaction in the application of cultural treatments, because during the experimental period, there was no machine traffic and / or animals. In this way, the natural structure of the soil was partially preserved, reflecting the good Tp. In general, the presence of poaceae improves the porosity, structure and aggregation of the soil through the supply of organic matter (Garcia and Rosolem, 2010; Giubergia, Martellotto and Lavado, 2013; Sales et al., 2016). However, in this study, the Tp was not altered by the cover plants and sampling sites.

Ksat values ranged from 16 to 38 mm h^{-1}. In general, higher Ksat was observed in the row of cacao plants, which may be related to the removal of the top layer of soil interrows that caused the pore discontinuity with reduced Ksat. The reduction in pore continuity also reduces gas exchange, infiltration and water storage in the soil profile, compromising the soil-water-plant relationship (Pagliai et al., 1995). While in the row due to lower Bd and higher Tp, Ksat favored. Soil density and porosity influence Ksat (Ribeiro et al., 2007) as they compromise the pore arrangement.

The AW ranged from 0.081 to 0.086 cm^3 cm^{-3} for the different treatments and sampling position, without significant differences. Higher AW values were expected in the rows of cacao plants due to the higher content of organic matter in this location. However, AW can be influenced by Bd, OM content and also by the clay content. In this case, the lower AW content may be related to the soil texture, because for the evaluated layer the soil has a medium sandy texture.Therefore, the lower amount of clay in the soil can reduce the influence of OM on water retention without altering AW (Beutler et al., 2004).

It can be said that the chemical and physical attributes evaluated after the use of cover crops intercropped with cacao trees are within the limits established and adequate for the development of the plants. However, to observe positive effects on these attributes, requires a longer usage time, in which there would be a contribution both in the cycling of nutrients and in the structuring of the soil.

Conclusions

The cultivation of millet and invasive plants provided higher levels of calcium, sum of bases and CEC in the row than interrows of cacao trees.

The construction of the row for cultivating cacao favored the chemical attributes of the soil expressed by the contents of K, Ca, Zn, Mn, CEC and OM.

The intercropping of cover crops in full-sun cacao system did not change the physical attributes of the soil in the initial implantation phase.

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