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SOIL CHEMICAL VARIABLES AFTER GROWING COVER CROPS ON YELLOW LATOSOL

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Abstract: This study evaluated the chemical parameters of the soil after growing grasses and legumes in a no-till system on a dystrocohesive yellow latosol soil in the same season (fall and winter). The experiment was conducted in the field in the forage sector of the Federal University of Recôncavo da Bahia, in the municipality of Cruz das Almas - Bahia. When the experiment was set up, soil samples were taken for an initial assessment of chemical parameters. A block experiment was then set up in the same area to measure different forms of soil management with initial conditions of degradation in the area. Composite samples were collected from the depths of 0.0 to 0.20 m and 0.20 to 0.40 m. The chemical variables studied were soil pH, available phosphorus, calcium, potassium, magnesium, sodium, aluminum, sulfur, cation exchange capacity, aluminum acidity, base saturation and organic matter. The treatments were subdivided into six treatments with four replications (blocks), namely: C- Crotalaria; Brac-Brachiaria decumbens; S- Sorghum; Aru- Aruana; G- Guandú Beans; M- Millet. Microsoft Office Excel software was used to record the data, which was statistically measured using SAS® statistical software (version 9.1), using the Tukey test and compared at $P<0.05$. The results showed that there was little interaction between the variables studied and the block composed of the treatments with affinity to the sub-plots and depth. According to the coefficients of variation in the statistical test, there was little significance in the results, which allows us to state that the lack of interaction or variation was possibly due to the fact that the work of recovering the degraded soil was still in the first year of cultivation/recovery. Therefore, most of the parameters have not yet shown any effects due to the fact that the reclamation is still in its initial phase. It can therefore be concluded that despite the results found, the study showed that the treatments had no significant effect when tested at the levels accepted in the hypothesis test.

Keywords: Chemical attribute, top dressing, soil degradation, no-till farming, recovery of degraded areas

INTRODUCTION

Soil management is sustainable when chemical, physical and microbiological quality support services are maintained or improved through processes that allow nutrient cycling and maintenance in order to guarantee excellent quality, without significantly compromising their functions that make these same services or biodiversity possible (FAO, 2019).

Soil science has provided a broad scientific base of analysis for qualitative and quantitative monitoring of changes in soil management and agricultural production. In addition to water and air quality, soil quality is also one of the components that helps to measure a value for ecosystem quality (BÜNEMANN et al, 2018).

In hypothesis, this practice of using cover crops improves the condition of wear and tear in which the soil finds itself. In this context, this research sought to quantify the chemical variables studied from the interaction of factorial treatment with the cultivation of cover crops.

Sustainable practices to mitigate impacts on production systems mean minimizing damage to degraded areas. The use of cover crops to naturally supply nutrients is one way forward, as is the provision of cover to minimize erosive factors from both anthropogenic and natural causes.

Data from degraded areas around the world show that every 5 seconds the planet loses an amount of soil equivalent to a soccer field, or that 24 billion tons of fertile soil are lost every year. Consequently, around

135 million people could be displaced as a result of desertification, creating a situation of imbalance and lack of awareness in agricultural areas. The phenomenon causes more deaths and displaces more people than any other natural disaster (UN, 2019).

In Latin America, the scenario is also worrying. "Around 50% of Latin American soils are suffering some form of degradation. In Brazil, the main problems are erosion, loss of organic carbon and nutrient imbalance." Among the main problems of soil degradation are salinization, compaction, acidification and contamination, as well as other damages such as land sealing - which aggravates flooding - and loss of fertility, since degraded soils capture less carbon from the atmosphere, interfering with climate change (EMBRAPA-soils. 2015).

This scientific work studied the chemical composition of dystrocohesive Yellow Latosol after growing grasses and legumes with soil recovery potential in a no-till system.

THEORETICAL AND CONCEPTUAL BASIS

LAND USE PROTECTION STRATEGIES

According to guidelines for the sustainable management of soils, such degradation levels are associated with the impairment of the following classes: soil erosion rates (water and wind); the structure of the soil that allows air, water and heat to circulate, as well as for roots to expand; the presence of vegetation cover (plants, plant residues, etc.); the amount of organic matter in the soil.); amount of organic matter in the soil; availability and flow of nutrients suitable for maintaining or improving fertility and productivity; salinization, sodization and alkalization; concentration of contaminants (those likely to cause harm to plants, animals, humans and the environment) (FAO, 2019).

A very well used and widespread practice today is the use of cover crops, indicated for consortium and/or revitalization or recovery of degraded areas through the provision of chemical, physical and biological actions and processes (FRASCA et al, 2021).

The use of forage grasses with legumes is a technique that increases biomass and also favors subsequent crops (GARCIA et al, 2021). It is a promising alternative which, in addition to mass and plant production in a consortium of more species, boosts nutritional gains in animal feed (HANISCH et al, 2016).

With the aim of fertilization, cover plants from the legume family are preferred as green manures. They perform the function of increasing nitrogen in the soil, taking advantage of and absorbing atmospheric nitrogen suitable for decomposition, which contributes to the deposition of dead material and C/N cycling (SILVA et al, 2009; GARCIA, 2021). They favor the availability and chemical increase of parameters such as organic matter, pH, Ca, K and P (BRESSAN et al, 2013; LACERDA et al, 20015; SILVA et al, 2017).

There are several uses for the soil, protecting it from processes that intensify surface erosion and nutrient leaching, reducing impacts on the physical attribute where the use of some cultivars mitigates water erosion by dissipating the kinetic energy of the impact of raindrops, reducing the disintegration of primary particles in the silt and clay area and surface sealing, as well as increasing porosity and reducing soil density (SILVA et al, 2017), promoting increased infiltration and water storage capacity.

Some grass species, such as millet and brachiaria, have the capacity to cycle essential nutrients to successive crops and, in the case of most legumes, to fix nitrogen. These characteristics of cover crops can help reduce production costs, especially with chemical fertilizers, which in addition to impacting on the cost of production of crops grown for grain, fibre and energy, are non-renewable natural resources (LAMAS, 2017).

Many species of legumes and grasses have shown results in terms of the physical and chemical attributes of the soil, as well as positive results expressed by high green mass productivity. Some factors and the performance of some grasses and legumes have been able to identify that they maintain a certain significant moisture content in the soil compared to when without cover (PEREIRA et al, 2017).

Phytomass production from aerial part production data is higher in grasses compared to legumes in relation to production total (BRAZ et al, 2007). On the other hand, the production of this mass evaluated in some species such as millet, forage sorghum and crotalaria planted in rainy seasons is up to twice as high when compared to dry seasons (VAZQUEZ et al, 2011).

It is significant that this technique demonstrates the effect of different cover crops on the cycling of C and N in different systems as well as on the reduction of greenhouse gases and grain production (FRASIER et al, 2016; KAUFMAN et al, 2013; KUO S et al, 2001; ABDALLA et al, 2019; RUSCH et al, 2020; WITTWER et al, 2017).

The use of cover crops after cultivation or crop rotation allows some cultivars used to regulate agricultural nitrogen (N) as they reduce leaching through soils and then supply N to subsequent commercial crops (KAYE J et al, 2019; LIMA et al, 2015).

The use of legumes before the cultivation of plants of economic interest such as corn has high rates of N increase in the soil, and the plant's N absorption reflects on grain yield (OHLAND et al, 2005). Grasses, on the other hand, regulate weed suppression, as in the case of sorghum and brachiaria (BORGES et al, 2014).

CROTALARIA, SORGHUM, MILLET, GUANDU BEANS, BRACHIARIA, ARUANA GRASS

CROTALARIA

Crotalaria juncea L is native to India and tropical Asia. It is an annual, sub-shrubby species that grows well and is very well adapted to sandy soils. It is used in green manure to produce fibrous raw material (AZZINI, et al 1981). It has adaptive characteristics in medium fertility, sandy loam and aerated soils and does not tolerate flooded areas (BURLE et al., 2006; WUTKE et al., 2014).

Nitrogen fixation in *Crotalaria juncea L* averages between 150 and 165 kg/ha/year (and can reach 450 kg/ha/year). Of the total nitrogen observed in *Crotalaria juncea*, 60% remains in the soil, 30% goes to the plants sown after the green manure and 10% is lost from the soil-plant system.

In Brazil, this species is commonly used for green manure, as it stands out for its potential to produce biomass in a short space of time, guaranteeing an efficient supply of nitrogen to the soil. It also helps to combat erosion and controls spontaneous plants (CARVALHO et al. 2022).

SORGHUM

Sorghum bicolor is a species native to the African continent and part of Asia. It is an erect plant, with high phytomass production, slower decomposition, interesting for maintaining straw on the soil surface, tolerates mild to high temperatures, between 17 and 37° C, its nutritional requirements in soils are on average low to high fertility and it has a biomass production of 30 to 50 t/ha. Its potential for chemical increase in the soil through cycling averages 125 kg/ha of N, 17 kg/ha of P, 132 kg/ha of K, 29 kg/ha of Ca and 11 kg/ha of Mg in 10.5 t/ha of DM (CARVALHO et al. 2022).

MILLET (*Pennisetum glaucum*)

This is an annual tropical fodder crop that grows erect and is between 1.5 and 2.0 m tall. It is considered a rustic species whose main characteristic is its low water demand. It has low nutritional requirements and adapts very well to low-fertility soils. In addition to its high potential for extracting nutrients from the soil, it produces biomass in the range of 50 - 60 t/ha, providing the soil with 113 kg/ha of N, 13.9 kg/ha of P, 93 kg/ha of K, 32 kg/ha of Ca and 16 kg/ha of Mg (CARVALHO et al. 2022). It has low soil fertility requirements and medium tolerance to aluminum (CALEGARI et al. 2016).

GUANDU BEAN (*Cajanus cajan*)

A semi-evergreen, shrubby plant with determinate and indeterminate growth, adapted to latitudes varying between 30°N and 30°S. Its initial development is slow, and a temperature range of 18 to 30 °C is more suitable. Its plants have many possible uses: in green manure, in human and animal food and in making handicrafts. A plant found in soils of medium fertility, it makes a mechanical contribution to the soil's physical properties, acting as a biological subsoiler (breaking up compacted layers) and chemically it has allelopathic effects on invasive plants. Its chemical contribution is rapid compared to crotalaria (ALCÂNTARA et al. 2000). It can also increase quantities of up to 29 kg/ha of P, 74 kg/ha of K, 209 kg/ha of Ca and 4.50 kg/ha of Mg in the soil (CALEGARI et al. 2016; AMABILE et al. 2000).

BRACHIARIA DECUMBENS

Brachiarinha, or decumbens, is a grass that originated in Uganda, Africa and was introduced to Brazil in the 1950s. Its characteristics are that it is a highly acclimatized plant, especially in the cerrados. It is an aggressive plant and helps to contain erosion. It has good digestibility for feeding some animals. It grows in a decumbent form and has a perennial vegetative cycle. The choice of forage grasses for forming a pasture or recovering an area without cover follows criteria and targets points such as productivity and, in the case of animal feed, the significant value in relation to crude protein (CRISPIM; BRANCO, 2002). This grass can provide the soil with 197 kg/ha of N, 13 kg/ha of P, 273 kg/ha of K, 57 kg/ha of Ca and 43 kg/ha of Mg (CALEGARI et al. 2016).

ARUANA GRASS

The genus *Panicum* can be described as a perennial grass that grows in a cespitose manner, forming very dense clumps that are around 1 meter wide and can reach heights of 2.5 to 3.0 meters. Its leaves have a bluish-green color. The tropical Brazilian climate provides good growth for the genus, as it is demanding of light. Another factor that favors its high fodder production in the country is the fertility of the soil and the sandy texture found in some regions (RASQUINHO, 2012).

Among its most interesting characteristics, the following can be highlighted: medium size; high tillering capacity and speed; good capacity to occupy the pasture area; propagation by seeds (easier, quicker and less expensive); good seed production, guaranteeing rapid re-establishment of the pasture in the event of need for recovery; excellent acceptability by animals (SILVA; BORTOLINI, 2012).

MATERIALS AND METHODS

The experiment was conducted in the Forage Sector, at the Center for Agricultural, Environmental and Biological Sciences (CCAAB/UFRB), on the Campus of the Federal University of Recôncavo da Bahia, at coordinates 12°39'52"S and 39°4'45"W, located in the municipality of Cruz das Almas, state of Bahia, between the months of May (fall) to September (winter) 2021.

The region is part of the Tabuleiros Costeiros of northeastern Brazil, with an Af-type climate, classified as tropical rainy forest, with an average annual temperature of 24.2°C, average monthly rainfall of over 60 mm and annual rainfall of 1500 mm, with no defined dry season and relative humidity of approximately 82% (KÖPPEN, 1948). The predominant soil in the area is classified as distrocohesive Yellow Latosol (SANTOS et al, 2018).

The experimental area had been fallow for two years prior to the study, having previously been used for grazing in two consecutive years. Prior to setting up the experiment, the area was cleared using a brush cutter, followed by the application of herbicide Roundup® to avoid competition between the invasive species and the crops of interest. In addition, to control ants, the insecticide Regent® 800 WG was applied using a knapsack sprayer, in a localized manner, only on the banks where the anthills enter.

When setting up the experiment, similar to the no-till system, a randomized block design (RBL) was used, with six treatments and four replications per treatment (blocks): C- Crotalária; Brac-Brachiaria decumbens; S- Sorghum; Aru- Aruana; G- Feijão Guandú; M- Milheto), which were laid out in rows, similar to the no-till method. Table 01 below shows a sketch of the area.

The seeds were sown in five rows per plot, with a spacing of 0.7 m between rows. Each experimental unit (plot) is five meters long by four meters wide, comprising 20m² with streets one meter apart (Figure 1). Samples were then taken for chemical analysis at two depths: 0.0 to 0.20 m and 0.20 m to 0.40 m.

Treatment	Repetitions					
$Block_A$	C	Brac	S	Aru	G	M
$Block_B$	M	C	Aru	G	Brac	S
$Block_C$	Brac	G	M	C	S	Aru
$Block_D$	S	Aru	G	Brac	M	C

Treatments: (C- Crotalaria; Brac-Brachiaria decumbens; S- Sorghum; Aru- Aruana; G- Guandú Beans; M- Millet)

Chart 01. Sketch of the experimental unit in a randomized block design

Figure 1. Procedures for setting up the experiment - A) Demarcation of planting lines; B) Furrows in lines; C) planting seeds between furrows; D) soil collection; E) seed germination.

Source: Personal archive, 2021

Deformed soil samples were collected at depths of 0-0.20m and 0.20-0.40m using a Dutch hand auger in the fall before and after the cover crops were planted. After collection, the samples were air-dried, sieved through a 2 mm mesh and left in the shade to dry, in order to characterize the chemical parameters. After processing, the samples were sent to the laboratory of LAFSMA - Laboratório DE Análise De Fertilizantes, Solo E Monitoramento Ambiental in the city center of Cruz das Almas.

CHEMICAL SOIL ANALYSIS:

For the chemical characterization of the soil, the following analyses were carried out: pH in water, available phosphorus and Cation Exchange Capacity (CEC), potential acidity (H+AL), were carried out as follows using Ca(OAc)2 0.5 mol/L, pH 7 (H + Al, in cmolc/dm^3. The extraction of H + Al was carried out with Ca(OAc)2 0.5 mol/L, pH 7, in the ratio 5 cm^{3}TFSA: 75 mL extractant, 10 min of agitation and decantation for 16 h. The Aluminum (Al) content was measured using the KCl 1 mol/L method (Al$^{(3)+}$, in cmolc/dm^3, in which extraction was carried out with KCl 1 mol/L at a ratio of 10 cm^{3}TFSA: 100 mL extractor, 5 min of stirring and decanting during the night (16 h). Base saturation (V%) was calculated by solving the equation (V = 100 SB/T, in %). Potassium (K) was quantified by the Mehlich-1 method (K, in mg/dm3 = ppm (m/v)) using the Mehlich-1 extractant (HCl 0.05 mol/L + H_2SO4 0.0125 mol/L), in the ratio 10 cm^{3}TFSA: 100 mL extractant, 5 min of stirring and decanting for 16 h. Magnesium (Mg) was quantified using the KCl 1 mol/L method (Mg^{2+}, in cmolc/dm^3, and extraction was carried out with KCl 1 mol/L at a ratio of 10 cm^{3}TFSA: 100 mL extractor, 5 min of stirring and decanting during the night (16 h). Calcium (Ca), by the KCl 1 mol/L method (Ca$^{(2+)(}$$_{,)}$in cmolc/dm^{3}and extraction was done with KCl 1 mol/L in the ratio 10 cm^{3}TFSA: 100 mL extractor, 5 min of stirring and decanting overnight (16 h). Sulphur (S) was quantified using the Hoeft et al. method and extracted with Ca(H2PO4)2, 500 mg/L of P, in HOAc 2 mol/L. To 10 cm^{3}TFSA add 0.5 g of activated carbon and 25 mL of extractant. Stir for 45 min, decant for 5 min and filter through slow filtration paper. Sodium (Na) was quantified using the Mehlich-1 extractant method (HCl 0.05 mol L-1 and H2SO4 0.0125 mol L-1) and the Mehlich-1 extractant (HCl 0.05 mol/L + H2SO4 0.0125 mol/L) was used, in the ratio 10 cm^{3}TFSA: 100 mL extractant, 5 min of stirring and decanting for 16 h. All these procedures were carried out according to the CFSEMG Manual (1999). CEC was measured using the soil sorptive complex method (effective CEC, total CEC). The organic matter content of the soil (OM) was determined according to Walkley and Black 1(984) and Bremner (1988). The results obtained from the previous assessment of the area can be seen in Table 1.

The data obtained after cultivation was subjected to analysis of variance, and when significant the Tukey test was compared using SAS® statistical software (version 9.1), adopting $P<0.05$ as the critical level for decision-making. The statistical model used is shown below:

$$\hat{Y} = Ti + Bj\ Eij +$$

$\hat{Y}$ = result obtained;

T = Treatment effect, with i ranging from 1 to 6

B = Block effect, with j ranging from 1 to 4

Eij = mean square error

RESULTS

The results of the soil analysis in the post-cultivation period and at depths of 0-20 and 20-40 can be seen in Tables 2 and 3, respectively.

	pH_{H2O}	P	K	Ca+Mg	Ca	Mg	Al	H+Al	Na	S	CTC	V	M.O
		mg/dm^3- Mehlich		Cmol$_c$/dm^3								%	g/ dm^3
BL1 0-20	**4.34**	**9**	**43**	**1,2**	**0,7**	**0,5**	**0,5**	**3,6**	**0,04**	**1,35**	**4,95**	**27,28**	**12,4**
BL1 20-40	**4.56**	**8**	**40**	**1,0**	**0,5**	**0,5**	**0,4**	**3,4**	**0,04**	**1,14**	**4,54**	**25,15**	**10,2**
BL2 0-20	**4.26**	**13**	**56**	**1,4**	**1,9**	**0,5**	**0,4**	**3,34**	**0,024**	**1,57**	**4,91**	**31,94**	**11,4**
BL2 20-40	**4.10**	**10**	**47**	**1,0**	**0,5**	**0,5**	**0,3**	**3,56**	**0,04**	**1,16**	**4,72**	**24,58**	**9,6**
BL3 0-20	**4.37**	**8**	**40**	**1,0**	**0,5**	**0,5**	**0,3**	**3,67**	**0,056**	**1,16**	**4,83**	**23,99**	**10,1**
BL3 20-40	**4.26**	**6**	**37**	**0,8**	**0,5**	**0,3**	**0,3**	**3,86**	**0,04**	**0,93**	**4,79**	**19,50**	**8,7**
BL4 0-20	**4.20**	**9**	**44**	**0,9**	**0,5**	**0,4**	**0,4**	**3,7**	**0,024**	**1,04**	**4,74**	**21,89**	**12,7**
BL4 20-40	**4.10**	**6**	**36**	**0,7**	**0,4**	**0,3**	**0,5**	**3,8**	**0,024**	**0,82**	**4,62**	**17,68**	**10,9**

pH H_2O- pH in water; P-available phosphorus; K-Potassium Ca+Mg-Calcium and Magnesium; Ca-Calcium; Mg- Magnesium; Al-Aluminum; H+Al-Aluminum acidity; Na-Sodium; S-Sulfur; CTC-Cation Exchange Capacity; V-Base Saturation; M.O-Organic Matter/BL1-Block 1; BL2-Block 2; BL3-Block 3; BL4-Block 4

Table 01 Chemical analysis of the soil in the experimental area at depths of 0-20 and 20-40m before the cultivars were planted.

Variables	Treatments						CV	EPM	P - Value
	Andu	Arua.	Brach.	Crotolaria	Millet	Sorghum			
pH	4,12	4,20	4,22	4,19	4,18	4,23	2,17	0,060	0,5824
P	10,00	14,00	17,00	14,25	14,25	11,00	69,42	0,586	0,9089
K	39,00	44,75	54,00	48,50	47,50	41,25	31,51	0,741	0,7308
Ca	1,05	1,23	1,18	1,05	1,28	1,15	18,18	0,090	0,5908
Mg	0,68	0,78	0,70	0,70	0,85	0,68	23,14	0,081	0,6430
Ca+Mg	0.43 ABC	0,50 A	0.48 AB	0,35 C	0.38 BC	0.45 ABC	15,77	0,057	0,0418
Al	0,35	0,28	0,33	0,30	0,30	0,30	31,05	0,059	0,9118
Al+H	3,37	3,19	3,37	3,44	3,10	3,28	10,99	0,117	0,7732
Na	0,08	0,07	0,06	0,10	0,07	0,07	65,48	0,042	0,9429
S	1,23	1,42	1,37	1,27	1,47	1,32	18,50	0,097	0,7552
CTC	4,60	4,60	4,74	4,71	4,56	4,61	6,95	0,108	0,9641
V	26,79	30,71	29,09	27,10	32,17	28,67	18,15	0,450	0,6876
MO	10,75	10,20	9,80	11,00	10,63	10,48	12,50	0,221	0,8273

*Means followed by different letters on the same line differ ($p<0.05$) statistically by Tukey's test; [1]CV: coefficient of variation; [2]EPM: standard error CV %-Coefficient of Variation; pH H_2O- pH in water; P-Available Phosphorus; K-Potassium Ca+Mg-Calcium and Magnesium; Ca-Calcium; Mg- Magnesium; Al-Aluminum; H+Al-Aluminum Acidity; Na-Sodium; S-Sulfur; CEC-Cation Exchange Capacity; V-Base Saturation; M. O-Organic Matter.O-Organic Matter.

Table 02. Chemical analysis of the soil in the experimental area, after cultivation and at a depth of 0.0-0.20m

Variables	Treatments						CV	EPM	P - Value
	Andu	Aruana	Brachiaria	Crotolaria	Millet	Sorghum			
pH	4,15	4,22	4,18	4,24	4,20	4,20	2,48	0,062	0,8536
P	6,50	5,25	11,50	11,00	7,00	6,00	70,62	0,470	0,4845
K	36,50	36,00	43,75	42,00	38,00	33,75	26,67	0,624	0,7320
Ca	0,78	0,95	1,10	1,08	0,88	1,08	25,81	0,101	0,3996
Mg	0,45	0,48	0,60	0,70	0,48	0,63	29,84	0,084	0,2349
Ca+Mg	0,33	0,48	0,48	0,43	0,40	0,45	28,27	0,069	0,5023
Al	0,40	0,30	0,38	0,30	0,35	0,30	41,75	0,072	0,8490
Al+H	3,63	3,25	3,44	3,18	3,45	3,17	12,47	0,128	0,5811
Na	0,06	0,07	0,11	0,09	0,06	0,06	44,35	0,037	0,2375
S	0,93	1,12	1,32	1,27	1,03	1,22	21,74	0,102	0,2645
CTC	4,56	4,37	4,75	4,44	4,47	4,38	8,63	0,121	0,7449
V	20,47	25,85	27,98	28,27	23,10	27,75	22,09	0,482	0,3254
MO	10,08	11,05	10,85	11,28	11,25	10,43	11,67	0,220	0,7154

*Means followed by different letters on the same line differ ($p<0.05$) statistically by Tukey's test; [1]CV: coefficient of variation; [2]EPM: standard error of the mean.

Table 03. Chemical analysis of the soil in the experimental area, after cultivation and at a depth of 0.20-0.40m

PH IN WATER

For the pH in Water variable analyzing the treatment and block factors, the results showed no significant interaction. Thus, pH in Water had little interaction and expressed a significant result depending on the treatments in relation to the depths. The results expressed here under these conditions show that the values in the research environment did not change. The test proved that there was no variation over the period studied, which justifies the fact that these values are references and can later be compared to a future study.

According to Wolschick et al, (2018) evaluating the effects of cover crops on the soil found results and concluded that some soil chemical parameters were little influenced by the cover crop species under study. The means of the treatments differed little according to the F test at 5% significance, which is justified by the uncontrolled conditions in the field. It is noteworthy that, for the evaluation of the first year of recovery of a degraded area, there was still no positive effect from the cover plants used, and this behavior has already been recorded in other specialized literature. It should be noted that given that the soil was not corrected by liming and the predominant characteristics of the soil class in which the study area is located, possible results for the pH variable were to be expected.

PHOSPHORUS

For the Phosphorus variable, analyzing the treatment and block factors and according to the depths studied, the results showed no significant interaction. Likewise, the evaluation of the individual factors also showed no significant difference.

Phosphorus is an element whose concentration varies greatly in relation to the pH range and soil class, thus affecting its availability to the plant. Once it is in the soil in concentrations, its availability varies according to its mobility in relation to certain factors, the main one being the soil class . Acidic soils make it unavailable on the surface and subsurface. Its availability and mobility depends on the pH factor.

The results shown in the tables for

both depths indicate the need to combine phosphate fertilizer with cover crops in order to raise the levels of this nutrient in the soil and improve its mobility and consequently its availability. However, it is worth noting that before phosphate correction, the soil's pH must be corrected in order to avoid the immobility of this nutrient in the soil.

In studies by Silva et al, (2017) analyzing the influence of cover crops on the soil, the authors found that some millet cultivars significantly increased P and Ca levels, as well as MO, K and Mg values.

In the studies carried out by some authors, there was significant evidence of the cover plant test and the availability of minerals in the soil, as well as a reduction in weed infestation (Adami et al, 2020), nitrogen accumulation and an increase in the agronomic performance of other varieties and legumes such as common beans (OLIVEIRA et al, 2017), improvements in soil fertility with an increase in nutrient levels (P, K, Mg and Ca) and soil organic matter (NASCENTE et al, 2015). Therefore, the introduction of the technique of using cover crops in the soil for succession or implantation of a crop presents significant gains and enhances soil management from a productive point of view, reducing costs and conserving the area (PEREIRA et al, 2017).

POTASSIUM

For the Potassium variable, analyzing the treatment and block factors in relation to the depth factor, the results showed no significant interaction.

Due to the predominant soil class with marked characteristics such as acidic pH and low availability of cations and low levels of organic matter, it is characteristic to observe in the table (02 and 03) that the potassium values for both depths do not represent values expressed with significant levels. It is worth noting that the results expressed according to the soil class and levels of other variables were already expected. It should also be noted that this element is essential for crops and is desirable in greater quantities than micronutrients. Although there was no difference between treatments, corrections would not be necessary, just bear in mind that subsequent crops can minimize the existing values of this mineral in the soil. Therefore, as it is a mineral required in higher concentrations by crops, it should be noted that its supply in soils is mostly carried out through chemical fertilization, and on the other hand, the use of cover crops such as guandu beans and crotalaria which release macro nutrients into the soil totals significant results in terms of supply and cost reduction in the long term (BERTOLONI, et al 2019).

CALCIUM

The Calcium results shown in tables 02 and 03 at both depths showed no significant interaction. Thus, the variable factors showed a coefficient of variation of medium dispersion, although they did not vary between the depth and treatment mean levels. Calcium is an important element in soil fertility, required by crops in lower concentrations than essential levels. The concentration in the current range is justified by the fact that soils with low pH and $Al^{3+}$and CTC values consequently have these results. Lime can be an alternative corrective associated with cover crops for soil correction, and Ca is directly related to soil pH, so correcting it would have a positive effect on pH and its concentration.

MAGNESIUM

For the Magnesium variable, when analyzing the relationship between the variable factor and treatment, the results did not show a significant interaction when looking at the depths, as shown in Tables 02 and 03, where there was a medium dispersion

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coefficient and low significance values in the 5% test of means. The magnesium content in the soil is influenced primarily by the source material, which has low concentrations of the nutrient, and by the intense pedogenetic processes during the formation of the soils in which Mg and other bases are easily leached. The acidification process as a characteristic factor negatively influences Mg due to the low concentrations of carbonates, sulphates, silicates and aluminosilicates (CASTRO et al, 2020). Considering the soil class in which the experiment was carried out, it is known that acidity and consequently low levels of bases in the soil solution are characteristic. In addition to calcium and potassium, magnesium is lower than the desired levels. The supply of this element in isolation is not an indicator of nutrient availability in the soil. It is therefore considered that its supply is due to its close relationship with the other cations in the soil, its mobility and retention by colloids and also the processes inherent in the absorption of the cation by plants (CASTRO et al, 2020). The fact that liming was not carried out in the area of the experiment means that, in addition to the low levels, it was not possible to quantify significant post-treatment levels in this study.

CALCIUM + MAGNESIUM

The variable under analysis had a difference between the treatments, even so in general, the range of their sum is still low, which may explain the low pH value of the soil and its relationship with the values of the cation exchange capacity. The values expressed justify the point that acidic soils have a low availability of exchangeable cations and are also undoubtedly reflected in the organic matter values.

Analyzing the variables together, as shown in Tables 02 and 03, the average values are lower for each treatment in relation to the single variable, but the coefficients are the same at both depths and the average results vary according to each treatment.

ALUMINUM

The Aluminum variable in relation to the treatment results did not show a significant interaction. Thus, the forage under study in relation to the interacting variable showed a highly dispersed coefficient of variation for the 0.20 to 0.40 m layer and the results were not significant for both depths in the analysis of means test. For good fertility, it is desirable that Al^{3+}levels in the soil are reduced, due to its toxicity to plants. The presence of this element demonstrates the need for correction and neutralization, since possibly the use of cover crops alone would not be enough to reduce it. Its presence in the soil is strongly related to the acidity range of the soil class, where the presence of hydrogen ions and alumina in the colloids is higher than the bases, potassium, calcium and magnesium.

ALUMINUM ACIDITY

For the Aluminum Acidity variable, the results showed no significant interaction at both depths. The variable showed a low coefficient of variation, so there was little dispersion between the means. The relationship between this variable and the characteristics of the soil class in which the study was carried out is inseparable, as acidic soils have high concentrations of Al^{3+}, lower organic matter values and low exchangeable base values in relation to the desirable pH range. The value of acidity due to aluminium is directly related to the pH range, and the reduction and neutralization is via a correction process and the supply of elements that increase the CEC. Another point in relation to the variable in question refers to the organic matter content and the non-correction of the soil, as it was not possible to neutralize this element after the treatments.

SODIUM

Analyzing the two block/treatment factors in relation to the depth factor, the results showed no significant interaction. Na did not show a significant result for treatment in relation to depth, as shown in tables 02 and 03 for the 5% test. The soil in question does not present any problems in terms of sodicity, i.e. salinity due to sodium. It is important to monitor this nutrient so that salinization does not occur in the future. This element has a strong relationship with forms of land use, fertilization and irrigation processes, and high levels can inhibit the availability of other elements such as potassium and calcium, making it a toxic element (DIAS et al, 2016).

SULPHUR

For the Sulphur variable, the block/treatment factors in relation to the depth factor, the results of the averages highlight that they did not show a significant interaction. S deficiency in the soil occurs all over the world, more precisely in soils with low fertility characteristics. The supply of this mineral is directly related to the soil class, and consequently to pH levels, low levels of organic matter, high export of S caused by grains due to high production, leaching of sulphate, which are accentuated by the large application of lime and phosphorus (P). The supply of this mineral enables significant gains (MENDONÇA et al, 2023).

CATION EXCHANGE CAPACITY (CEC)

For the CTC variable, analyzing the block/treatment factors in relation to the average depths measured by the test presented in table 03 shows that the results did not show a significant interaction. The CTC interacted and expressed a significant result of the treatment in relation to the depth for the variable studied when tested in the anova for the 5% test. CEC values are expressed by the amount of elements available in the soil solution. Once these elements are in low quantities, they lead to a reduction in CTC values. This variable is directly associated with the soil class, pH values, MO content and sum of bases, and soils rich in nutrients will therefore have significant results in terms of CEC content. Soils with low fertility and high acidity have low mineral availability. Correcting the soil class would increase CEC levels, as the correction would make nutrients such as calcium and magnesium available to the soil.

BASE SATURATION-V%

The Bases Saturation in analysis of the factors treatment in relation to depth, showed no significant interaction based on table 02 and 03. For this variable, it is worth noting that its values refer to the fact that its fertility varies according to fertility levels, since fertile soils have a V%≥50% and poorly fertile soils have a V%<50%. It is worth noting that V% varies according to calcium and magnesium levels and is proportional to the sum of bases and soil class, which directly indicates the supply of these minerals.

ORGANIC MATTER

For the Organic Matter variable analyzing the block/treatment factors in relation to depth, the results showed no significant interaction over the period studied. Cunha et al, (2011) determined the influence of cover crops over four consecutive years and came to the conclusion that some cover crops such as crotalaria, guandu beans and sorghum did not show significant differences in the chemical parameters studied, but only increased the organic matter content in relation to the initial condition. Thus, the interacting variable factors had a low dispersion coefficient of variation. Therefore, the OM variable analyzed in relation to the action of the treatment on the factors observed did not express a significant result when tested in the anova for the F test at 5% significance, as shown in tables 02 and 03. The MO levels are in what is considered a low range, which suggests that cover crops can improve this soil parameter over time.

The MO did not differ between the depths, which indicates that the soil really does have low MO and needs cover crops to incorporate it. This class of soil is already characterized by its MO content as a result of pedogenetic processes, so the use of cover plants could provide important results in the medium and long term for the recovery of the area.

CONCLUSIONS

With the experiment carried out under these conditions, it can be concluded that the chemical variables analyzed did not show significant results in relation to the treatments, corroborating the hypothesis that the chemical variables analyzed were not altered.

Further studies are needed to better understand and monitor the area, as it is a site with signs of degradation. In this first year of study, the treatment carried out to provide better conditions for land use showed no change. This does not mean that cover crops do not lead to improvements and recovery of degraded areas, but it is a practice that requires more time to be applied and the results will be evaluated over the long term.

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