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Interaction of chemical attributes of a Regossol cultivated with beans and fertilized with biochar

Interação dos atributos químicos de um Neossolo Regolítico cultivado com feijão e adubado com biochar

R. E. de Melo[1*]; M. F. de A. T. Alves[2]; V. P. da Silva[2]; A. R. M. dos Santos[1]; M. H. L. Lopes[2]; E. D. Barbosa[1]; L. de J. Oliveira[2]; C. P. Silva Neto[3]; J. C. C. Costa[1]; J. R. de S. Lima[2]

[1]*Federal Rural University of Pernambuco (UFRPE), Dois Irmãos, Recife - PE, 52171-900*
[2]*Federal University of Agreste de Pernambuco (UFAPE), Garanhuns - PE, 55292-270*
[3]*University of the State of Bahia (UNEB), Euclides da Cunha - BA, 48500-000*

**ravi.melo@ufrpe.br*
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The world's population is predicted to reach 10 billion people by 2050, increasing the need for food and encouraging farmers to work on applying technologies to increase crop productivity. Furthermore, the increase in the cost of synthetic fertilizers makes the use of organic matter in soils viable. Therefore, the objective of this study was to evaluate the use of multivariate statistics through the analysis of the main components in the contents of chemical elements in two layers of soil in a bean cultivation cycle and to determine the possible correlations of the variables with the respective treatments. Biochar was made from sewage sludge. Cultivation was carried out under rainfed conditions. The treatments used were NPK = synthetic fertilizer; B5 = Biochar 5 t ha^{-1}; B10 = Biochar 10 t ha^{-1}; B20 = Biochar 20 t ha^{-1}; B40 = Biochar 40 t ha^{-1}; CM = chicken manure 5 t ha^{-1}; and SS = Sewage sludge 5 t ha^{-1}. In the 0-0.1 m layer, PC1 explained 71.82% of the data variability, influenced by K, P, Mg, SO42-, TOC and N, while PC2 influenced salinity and acidity. Biochar, at doses of 20 and 40 t ha^{-1}, improved nutrient availability. In the 0.1-0.2 m layer, PC1 explained 84.39% of the variability, with contributions from all variables, while PC2 influenced the Mg concentration. Therefore, the application of biochar is a sustainable and promising practice to increase productivity in the Agreste of Pernambuco.
Keywords: principal component analysis, recalcitrance, sustainability.

Prevê-se que a população mundial atinja 10 bilhões de pessoas até 2050, aumentando a necessidade de alimentos e incentivando os agricultores a trabalharem na aplicação de tecnologias para elevar a produtividade das culturas. Além disso, o aumento dos custos dos fertilizantes sintéticos viabiliza a utilização de matéria orgânica nos solos. A partir disso, o objetivo deste estudo foi avaliar o uso da estatística multivariada através da análise de componentes principais nos teores de elementos químicos em duas camadas de solo, em um ciclo de cultivo de feijão e apontar possíveis correlações das variáveis com os respectivos tratamentos. O biochar foi produzido a partir de lodo de esgoto. O cultivo foi feito em regime de sequeiro. Os tratamentos foram: NPK = fertilizante sintético; B5 = Biochar 5 t ha^{-1}; B10 = Biochar 10 t ha^{-1}; B20 = Biochar 20 t ha^{-1}; B40 = Biochar 40 t ha^{-1}; EG = Estero de Galinha 5 t ha^{-1}; LE = Lodo de Esgoto 5 t ha^{-1}. Na camada de 0-0.1 m, PC1 explicou 71.82% da variabilidade dos dados, influenciada por K, P, Mg, SO_4^{2-}, TOC e N, enquanto PC2 influenciou a salinidade e acidez. O biochar, nas doses de 20 e 40 t ha^{-1}, melhorou a disponibilidade de nutrientes. Na camada de 0.1-0.2 m, PC1 explicou 84.39% da variabilidade, com contribuição de todas as variáveis, enquanto PC2 influenciou a concentração de Mg. Com isso, a aplicação de biochar é uma prática sustentável e promissora para aumentar a produtividade no Agreste de Pernambuco.
Palavras-chave: análise de componentes principais, recalcitrância, sustentabilidade.

1. INTRODUCTION

Beans (*Phaseolus vulgaris* L.) are legumes of broad economic and social importance in underdeveloped countries; in addition, their nutritional value, linked to their low cost, contributes to the food security of low-income citizens [1]. In the harvest (2021/2022), the state of Pernambuco had a production of 84.8 thousand tons, with an average productivity of 374 kg ha^{-1} [2].

Despite the prominence of this microregion, the low productivity compared to that of the Southeast and Central-West regions may be related to the soils of these municipalities, classified as Regosols, which are generally poorly developed, sandy soils with low water and nutrient retention capacity [3-4]. Therefore, it is necessary to carry out more research to provide alternatives to increase the productivity of legumes. Based on this, research indicates the use of biochar in soils [5-4].

Biochar is a carbon-rich material produced through pyrolysis by the decomposition of organic biomass [6-7]. This product has been applied with the aim of improving fertility and promoting sustainability in agriculture worldwide [8]. Furthermore, biochar can be used for carbon sequestration; unlike other readily mineralized organic matter sources, the aromatic structures of biochar make it resistant to decomposition by microorganisms, which have been present in the soil for centuries [9].

Biochar also has the potential to improve soil fertility by facilitating biochemical nitrogen cycling, providing essential nutrients such as P, K, and C to plants [10]. Biochar has beneficial effects, such as increasing soil aeration, increasing the productivity of agricultural crops and improving the biological properties of the soil [6-11]. Furthermore, the potential to retain nutrients in the soil will reduce the use of synthetic fertilizers in farming [12].

In this context, principal component analysis (PCA) is a multivariate statistical technique that linearly converts a set of data with different variables [13]. The main components symbolize a new set of artificial variables that constitute linear functions of the original variables and that have maximized variance [14]. In this way, the chemical attributes of the soil are ordered, summarizing the multidimensional variation of the analyzed data in diagrams and ordering them on the axes according to their similarities in terms of the variables used [15].

PCA can be used to generate indices and group individuals. This technique groups individuals by taking into account their variation, that is, according to their variances due to their behavior within the population, represented by the variation in the set of characteristics that define the individual. In this way, PCA contributes to the removal of superfluous data and the extraction of original data, reducing the size of the data space [16]. Although multivariate analysis techniques were initially developed to solve problems in biology and psychology, they can also be used to solve problems in different areas of knowledge, such as soil science [17].

The objective of this study was to evaluate the use of multivariate statistics through the analysis of the main components of N, P, K, Mg, Na, SO_4^{2-}, pH and TOC in two layers of soil during the bean crop cultivation cycle in Agreste de Pernambuco and to determine the possible correlations of the variables with the respective treatments.

2. MATERIALS AND METHODS

2.1 Characterization of the experimental area

The experiment was carried out under field conditions on a private property in São João, PE, Brazil, with geographic coordinates of 08° 50′ 24″ S and 36° 22′ 49″ W and a 715 m altitude (Figure 1) during the period from May to August of 2022.

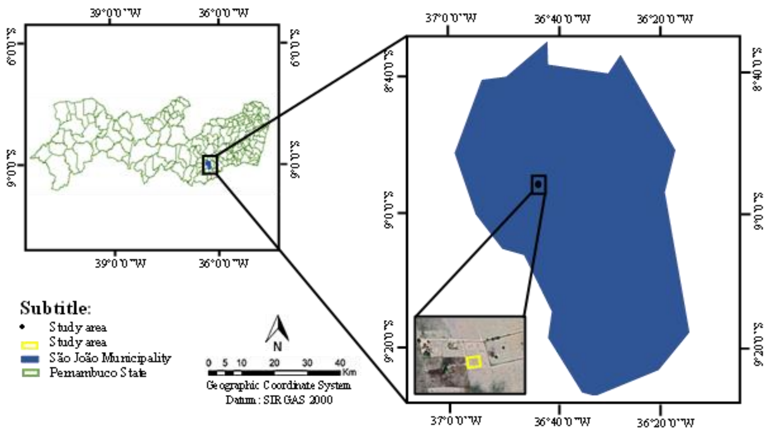

Figure 1: Location of the experimental area in São João, Pernambuco, Brazil.

The predominant climate in the region is As', which is equivalent to a hot and humid climate, according to the Köppen classification [18]. The soil in the area was classified as a Regossol [19]. The climatic data recorded during the field experiment period at the meteorological station installed in the area can be found in Figure 2.

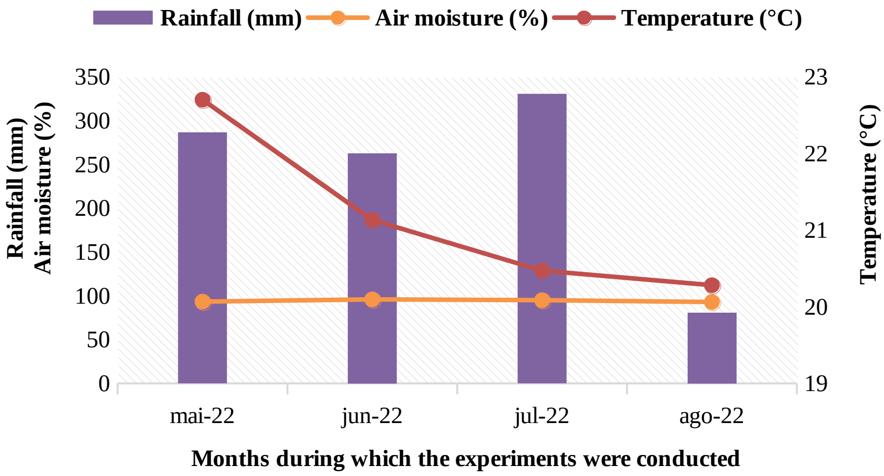

Figure 2: Climatic data collected during the experiment.

Before the experiment, soil samples were collected from 0.0-0.1 and 0.1-0.2 m deep layers, and soil analyses of chemical attributes were carried out (Table 1) following the standard methodologies of EMBRAPA and IAC. Available phosphorus (P) was determined by the Olsen method described by Irving and McLaughlin (1990) [20] and analyzed according to Teixeira et al. (2017) [21]. The exchangeable sodium and potassium contents (Na^+ and K^+) were determined according to Teixeira et al. (2017) [22]; the exchangeable magnesium (Mg^{2+}) content was determined by atomic absorption according to Teixeira et al. (2017) [23]; and the available sulfate (SO_4^{2-}) content was determined according to Williams and Steinbergs (1959) [24] and analyzed according to the methodology of Camargo et al. (2009) [25]. The pH of the water at a ratio of 1:2.5 was obtained according to Teixeira et al. (2017) [26], and the total nitrogen (N) content was obtained according to Camargo et al. (2009) [27]. OM (M.O.) content was determined according to Fontana (2017) [28] by dividing by the van Bemmelen factor (1.724) to determine the TOC content, considering that the M.O. content accounts for 58% of the total organic carbon (TOC) content according to Fageria et al. (1999) [29].

Table 1: Chemical attributes of the soil in the 0 to 0.1 m and 0.1 to 0.2 m layers of the experimental area.

Layer (m)	Chemical attributes								
	P	**Na**	**K**	**Mg**	**S**	**pH**	**N**	**OM**	**TOC**
	mg kg^{-1}	cmol$_c$ kg^{-1}			hg g^{-1}	H_2O	___ % ___		
0-0.1	14.39	0.20	0.11	0.21	0.35	6.23	0.048	1.28	0.74
0.1-0.2	10.22	0.24	0.13	0.21	0.40	6.49	0.059	0.71	0.41

P: phosphorus. Na: sodium. K: potassium. Mg: magnesium. S: sulfate. pH: hydrogen potential. N: nitrogen. OM: organic matter. TOC: total organic carbon.

2.2 Experimental design

The experimental design used was a randomized block design (RBD) with 7 treatments and 4 blocks. The treatments were NPK = synthetic fertilizer; B5 = biochar 5 t ha^{-1}; B10 = biochar 10 t ha^{-1}; B20 = biochar 20 t ha^{-1}; B40 = biochar 40 t ha^{-1}; EG = chicken manure 5 t ha^{-1}; and LE = sewage sludge 5 t ha^{-1}, totaling 28 experimental plots.

2.3 Characterization of biochar, chicken manure and sewage sludge

Biochar was produced from sewage sludge through slow pyrolysis in a traditional oven at temperatures varying between 400 and 500 °C for approximately 10 hours. The sewage sludge biochar (SSB) was passed through a 2.0 mm sieve, homogenized and sent to Plant Soil Laboratories, located in Petrolina, PE, for assessment of chemical attributes. The chicken manure was obtained from poultry farms located in the municipality of São João – PE and was donated by local farmers. The chemical attributes of the materials are shown in Table 2.

Table 2: Chemical attributes of the materials used.

Material	**N**	**OC**	**P**	**K**	**Ca**	**Mg**	**Na**	**S**	**EC**	**pH**
	g kg^{-1}				g kg^{-1}				dS m^{-1}	
Sewage sludge	10.6	124.2	11.5	3.1	20.1	2.9	1.0	20.5	3.38	3.59
Biochar	9.7	121.1	7.2	1.2	10.2	1.6	1.8	88.6	2.20	7.92
Chicken manure	24.0	230.7	20.9	35.7	15.0	10.0	-	-	-	8.90

N: nitrogen. OC: organic carbon. P: phosphorus. K: potassium. Ca: calcium. Mg: magnesium. Na: sodium. S: sulfate. EC: electric conductivity. pH: hydrogen potential.

2.4 Grow crops

The experimental area was measured and staked into 4 blocks, measuring 540 m^2 (18x30 m), composed of 28 plots measuring 9 m^2 (3 x 3 m). Between experimental plots and between blocks the spacing was 1 m. The experiment was carried out with the common bean cultivar IAC Netuno under rainfed conditions, during the winter season crop. Sowing was carried out using a manual planter on May 6, 2022, with a spacing of 0.30 m between holes and 0.30 m between rows, corresponding to a population of 240,000 plants ha^{-1}. To guarantee germination, five grains were used per pit at a depth of 5 cm. Seedling emergence started 6 days after sowing (DAS), and thinning was carried out at 15 DAS, leaving three plants per hole.

2.5 Determination of chemical characteristics of the soil

After harvesting, deformed samples were removed from the 0-0.1 and 0.1-0.2 m layers in all the experimental plots with the aid of a 0.2 m graduated pipe of known volume and an octagonal mallet. As they were collected, the samples were packaged in plastic bags and identified. At the Soil and Geology Laboratory of the Federal Rural University of Pernambuco, the samples were air-dried and sieved through a 2.0 mm mesh sieve to obtain air-dried fine earth (ADFE). The pH and P, Na^+, K^+, Mg^{2+}, N, SO_4^{2-}, and TOC contents were determined according to previously described methodologies.

2.6 Principal component analysis

Principal component analysis (PCA) was performed with the aim of highlighting the main soil variables influenced by the different dosage levels of biochar and other treatments. Statistical procedures for PCA were carried out using PAST® software, version 4.03 [30]. The raw data were not entered into PAST®, as they were on different scales, and a transformation was carried out to balance the weights of the selected variables. To achieve this, the following equation was used, according to Petersen et al. (1989) [31]:

$$Score-z=\frac{Ci-x}{\sigma} \quad (1)$$

where Score-z is the standard score for each variable; Ci is the corresponding value of each standardized variable; x is the arithmetic mean of the variable; and σ is the sample standard deviation of the variable.

Jamovi® software version 2.4.11 (https://www.jamovi.org/download.html) was used for calculations relating to eigenvalues.

3. RESULTS AND DISCUSSION

3.1 Soil layer 0-0.1 m

In Table 3, the eigenvalues, the variance in percentage and the accumulated variance of each main component of the chemical attributes belonging to the 0-0.1 m soil layer are presented.

Table 3: Characteristics of the main components of the 0-0.1 m layer.

Components	Eigenvalue	% variance	% variance accumulated
1	5.746	71.82	71.82
2	1.651	20.64	92.46
3	0.310	3.87	96.33
4	0.184	2.30	98.63
5	0.083	1.04	99.67
6	0.026	0.33	100
7	1.08e-16	1.34e-15	100
8	-1.39e-16	1.73e-15	100

Based on Table 3, the percentage variances explained by the main components are verified, with the first component explaining 71.82% of the total data variability, followed by the second main component explaining 20.64% of the unexplained variance by the first component. Both components explained 92.46% of the total variability of the data. In this way, the main components with eigenvalues greater than 1 (> 1.0) were retained, being the first and second components, in accordance with the criterion established by Kaiser (1960) [32] and Cattell (1966) [33].

In Table 4, the correlation coefficients between the main components and the variables used for the 0-0.1 m layer (loadings/loads) are presented. For each component, the most significant correlation coefficients were highlighted, with the aim of analyzing the most relevant variable in the formation of the components. Therefore, loads above 0.3 reach the established minimum, loads of 0.4 are more relevant, and loads above 0.5 are statistically significant [34].

Table 4: Loadings of the main components by variables.

Variables	PC1	PC2	PC3	PC4	PC5	PC6
K	0.95398	0.20492	0.026303	-0.014441	-0.19689	0.090906
Na	0.53136	-0.77319	0.2079	0.27438	-0.034049	-0.013194
P	0.9764	-0.046513	0.13792	-0.14654	0.062001	-0.011881
Mg	0.97442	0.13249	-0.18095	-0.0027581	0.012665	0.0064387
SO_4^{2-}	0.9325	0.068303	-0.32622	0.10189	-0.040507	-0.085694
pH	0.27035	0.91758	0.14441	0.23736	0.087107	0.012989
TOC	0.91247	-0.34999	-0.097511	-0.014202	0.1724	0.073962
N	0.93565	0.14883	0.27813	-0.14158	-0.01073	-0.06998

K: potassium. Na: sodium. P: phosphorus. Mg: magnesium. So_4^{2-}: sulfate. pH: hydrogen potential. TOC: total organic carbon. N: nitrogen. PC1: principal component 1. PC2: principal component 2. PC3: principal component 3. PC4: principal component 4. PC5: principal component 5. PC6: principal component 6.

PC1 is defined by most of the variables, namely, K, P, Mg, SO_4^{2-}, TOC and N, with load values (correlations) of 0.95398, 0.9764, 0.97442, 0.9325, 0.91247, and 0.93565, respectively. PC2 is defined by two variables, Na and pH, with correlation values of 0.77319 and 0.91758, respectively. The variables Na, TOC and P are inversely proportional to the pH.

From the data presented above, it is possible to state that PC1 is highly influenced by most soil chemical variables, reflecting the high heat loadings. These correlations prove that this component was responsible for most of the variation occurring through the nutrients evaluated. Therefore, PC1 encompasses soil fertility and nutrition. Biochar acts in this component by improving the availability of these nutrients in the soil, confirmed by the high loading values. In this scope, the application of biochar improves the chemical attributes of the soil, favoring the cultivation of beans. These results reflect the efficiency of fertilization with biochar. PC2 is defined by two variables, that is, it can be associated with soil salinity and acidity, these high correlations with Na and pH infer that this component has a high correlation with the ion balance. This correlation indicates that the soil has a higher pH and a greater quantity of sodium, significantly influencing the availability and absorption of nutrients by the bean plant.

Figure 3 shows a representation of the correlation coefficient graph (biplot) showing the first two main components (PC1 and PC2) of the 0-0.1 m layer. The variables K, N, Mg, P, SO_4^{2-} and TOC present a slope on the abscissa axis (PC1), which indicates a correlation between these variables and PC1. In contrast, the pH and Na variables are located on the PC2 ordinate axis, indicating a correlation with PC2.

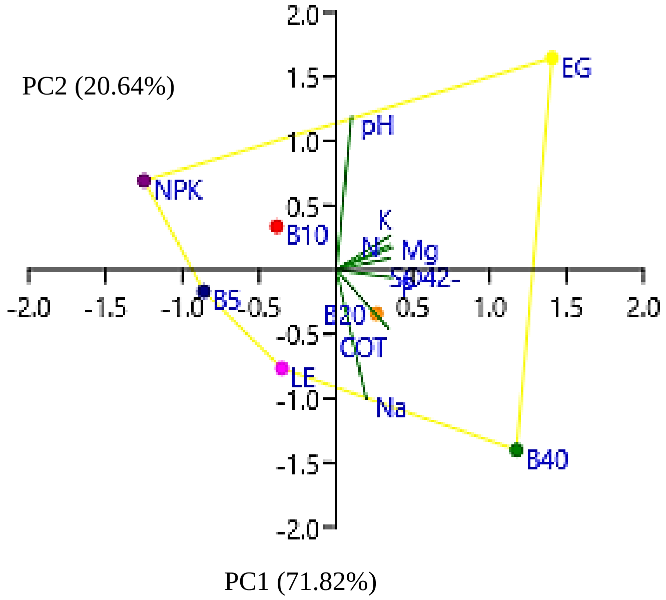

Figure 3: Biplot graph of PC1 and PC2 with correlation coefficients.

Regarding the correlations with the treatments, an increase in the dosage of biochar (B20 and B40) promoted increases in the chemical attributes of the soil in the 0-0.1 m layer (Figure 6), where the maximum biochar dose resembled the use of chicken manure (CM), while sewage sludge (SS) resulted in responses similar to those observed with synthetic fertilizer (NPK) and the lowest dosages of biochar (B5 and B10).

The influence of biochar on soil carbon is due to its interference in several biological processes, such as changing the chemical attributes of the soil [6]. The chemical attributes of the soil are stimulated by the addition of biochar due to the greater absorption of nutrients due to the reactive surfaces at the edges of the aromatic structures of the porous surface of the biochar, which acts as a soil conditioner [35]. The results corroborated those obtained by [36], who, working with inoculation of *Trichoderma aureoviride* in biochar made from coffee grounds, bean husks and coffee husks, reported an increase in TOC.

In general, the addition of higher doses of biochar, represented in treatments B20 and B40, influenced the change in total organic carbon (TOC) content, as well as chemical attributes, such as P and SO_4^{2-} and Na content. For the other variables, such as K, N, Mg and pH, the addition of chicken manure (CM) had a greater effect, especially on the N content, which is directly correlated with this input.

The influence of CM on N levels is due to the levels of this element in its composition, with this nutrient being made available quickly as a result of accelerated decomposition in tropical soils. Furthermore, this material constitutes an excellent organic fertilizer containing essential nutrients and trace elements and is widely used to improve soil quality, helping to improve numerous vital processes for plants and culminating in increasing crop productivity [37]. These results corroborate those reported by several authors who reported increases in the nutrient content and productivity of agricultural crops [37-40].

3.2 Soil layer 0.1-0.2 m

For the variables in the 0.1-0.2 m layer, the eigenvalues, the variance in percentage and the accumulated variance of each main component of the chemical attributes are presented in Table 5.

Table 5: Characteristics of the main components of the 0.1-0.2 m layer.

Components	Eigenvalue	% variance	% variance accumulated
1	6,751	84,39	84,39
2	0,949	11,86	96,25
3	0,210	2,63	98,88
4	0,065	0,81	99,69
5	0,022	0,27	99,96
6	0,003	0,04	100
7	3.92e-16	4.90e-15	100
8	-2.07e-16	2.59e-15	100

Table 5 shows the percentage of variance explained by the components. The first component explained 84.39% of the total data variability, and the second principal component explained 11.86% of the variance not explained by the first component. The second component was considered to have an eigenvalue of 0.95, which is close to 1. In this way, the two components alone explain 96.25% of the data variance. In Table 6, the loads between the main components and the variables used for the 10-20 cm layer are shown. The most significant loads were highlighted in the components. Therefore, loads greater than 0.5 were highlighted [34].

Table 6: Loadings of the main components by variables.

Variables	PC1	PC2	PC3	PC4	PC5	PC6
K	0.91952	0.37609	-0.065538	0.087228	0.010667	-0.031967
Na	0.82186	-0.4698	0.31462	0.064973	0.020205	-0.014803
P	0.99013	-0.025815	-0.12999	0.043265	0.01327	0.0050979
Mg	0.82128	0.55014	0.12751	0.070127	0.027821	0.029846
SO_4^{2-}	0.94405	-0.27414	-0.13104	0.074676	-0.10384	0.0095012
pH	0.94927	-0.21205	-0.20862	-0.06527	0.078284	-0.0041299
COT	0.9652	-0.23673	0.057955	-0.091593	0.013106	0.020631
N	0.92272	0.32795	0.099142	-0.16709	-0.055636	-0.014048

K: potassium. Na: sodium. P: phosphorus. Mg: magnesium. So_4^{2-}: sulfate. pH: hydrogen potential. TOC: total organic carbon. N: nitrogen. PC1: principal component 1. PC2: principal component 2. PC3: principal component 3. PC4: principal component 4. PC5: principal component 5. PC6: principal component 6.

Table 6 shows that PC1 is defined by all the variable loads, namely, K, Na, P, Mg, SO_4^{2-}, pH, TOC and N, with loads of 0.91952, 0.82186, 0.99013, 0.82128, 0.94405, 0.94927, 0.9652, and 0.92272, respectively. PC2 is defined by a variable, Mg, with a correlation value of 0.55014. The variables Na, P, SO_4^{2-}, pH and TOC are inversely proportional to the variable Mg.

From the data presented above, it is possible to state that PC1 is highly influenced by most soil chemical variables, reflecting the high loading values. Component 1 of the 0.1-0.2 m layer reflects the chemical quality and fertility of the soil, taking into account the association of all chemical variables with high loading values. These loads infer that PC1 retains much of the variation related to chemical elements and soil ph. Biochar acts to improve this availability and stabilize pH, reflecting the high PC1 loads. Therefore, fertilization with biochar promotes significant improvements in the chemical attributes of the soil in that layer, positively influencing bean cultivation. PC2 is defined by a variable, namely mg, this component being related to the variation of mg in the soil independently of the other variables. The remaining variables are inversely proportional to mg, therefore, in PC2 when mg is present in greater quantities, other variables tend to be present in lower concentrations, indicating an interaction between the availability of mg and other elements in the soil characteristics. In general, PC2 reinforces that there is a significant variation in the concentration of mg in the 0.1-0.2 m layer that is not explained by other variables, which influences the availability of nutrients in that layer.

Figure 4 shows a graph of the correlation coefficients (biplot) for the first two main components (PC1 and PC2) of the 0.1-0.2 m layer. The variables P, pH, SO_4^{2-} and TOC present a slope on the abscissa axis (PC1), which indicates a correlation between these variables and PC1. In contrast, the variables Mg, K, N and Na are located on the PC2 ordinate axis, indicating a correlation with PC2.

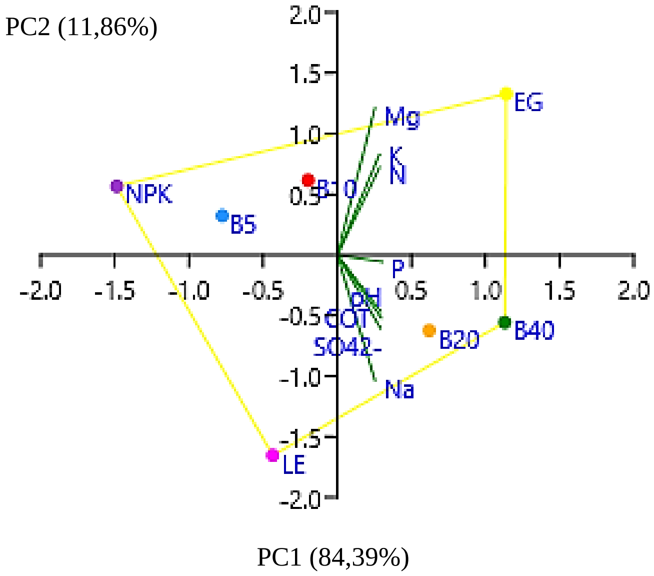

Figure 4: Biplot graph of PC1 and PC2 with correlation coefficients.

Regarding the correlations with the treatments, a similar behavior was observed in the 0-0.1 m layer, where an increase in biochar dosage (B20 and B40) promoted increases in the chemical attributes of the soil; in the 0.1-0.2 m layer, where the maximum dose of biochar resembled the use of CM, while SS resulted in responses similar to those observed in NPK and the lowest doses of biochar (B5 and B10).

In general, the addition of higher doses of biochar, represented in treatments B20 and B40, influenced the change in TOC content, as well as chemical attributes, such as P, SO_4^{2-}, pH and Na. For the other variables, such as K, N, and Mg, the addition of CM had a greater effect. The NPK treatments, B5, B10 and SS, had a negative correlation with the variables.

Soil chemical attributes, which include pH, are also affected by biochar addition [41]. These attributes are related to the raw material used to manufacture biochar, as well as the production conditions. The biochar raw material made from rice straw or sugarcane bagasse contains elements such as C, H, O_2, Ca, Mg, and S, as well as N, P and K [10]. Biochar produced from sewage sludge contains elements such as N and K and high levels of P, which has sparked interest in its use as a phosphate fertilizer [42].

Several studies have reported consistent and positive results for the chemical attributes of soil after biochar incorporation [43-46]. These effects are a result of the chemical properties of biochar, such as its porous structure [47].

4. CONCLUSIONS

PCA demonstrated a strong association between soil chemical attributes and higher doses of biochar (B20 and B40) and CM. In the 0-0.1 m layer, PC1 explained 71.82% of the total data variability, being influenced by the variables K, P, Mg, SO_4^{2-}, TOC and N, inducing greater soil fertility and nutrition. The application of biochar at doses of 20 and 40 t ha^{-1} was effective in improving the availability of nutrients in the soil, proving the effectiveness of fertilization with biochar in improving the chemical attributes of the soil, favoring bean cultivation. PC2 correlated with soil salinity and acidity, influenced by the variables Na and pH, influencing nutrient absorption by the plant.

In the 0.1-0.2 m layer, PC1 explained 84.39% of the total data variability, being defined by all soil chemical variables. The application of biochar positively affected this layer, improving the chemical attributes of the soil and stabilizing the pH, benefiting bean cultivation. PC2 correlated with the Mg variable, indicating that in this layer, the Mg concentration influences the availability of other elements.

PCA was important for understanding the dynamics between chemical attributes and sources of organic matter used in bean cultivation in the Agreste of Pernambuco, helping to identify correlations that will serve as a basis for better management of the cultivation of this legume, increasing the productive potential of rainfed agriculture in the region.

5. ACKNOWLEDGMENTS

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