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RESEARCH ARTICLE

GROWTH OF SESAME IN FUNCTION FERTILIZATION WITH NPK AND POULTRY LITTER BIOCHAR

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ABSTRACT

The objective of this study was to evaluate the effect of mineral fertilizer NPK associated with poultry litter biochar on growth initial of sesame cv. BRS Seda. The experiment was carried at city Campina Grande, PB, Brazil, in greenhouse with a completely randomized experimental design, with three replications. The treatments were arranged in a factorial 5 x 4 consisted of five doses of mineral fertilization with N:P:K (D1 = 0:0:0; D2 = 13.5:50:14; D3 = 27.5:100: 27.5; D4 = 41.:150:41.5; D5 = 54.5:200:55 mg kg^{-1}) associated with four doses of poultry litter biochar (0; 20; 40; 55 g kg^{-1}) calculated based on the volume of soil. At 30 and 45 days after sowing were determined plant height, stem diameter, number of leaves by plant, leaf area and dry biomass of shoot. The mineral fertilization promoted increase in plant height, stem diameter, number of leaves, leaf area and dry sesame biomass at 45 DAS, reaching maximum growth with the N: P: K = 50: 150: 75 mg kg^{-1} of soil. The fertilization with poultry litter biochar promoted reduction of all variables in sesame at 30 and 45 DAS and raised the pH and electrical conductivity of the soil.

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INTRODUCTION

The biochar is an organic compound produced from different sources of biomass, as woody material, agricultural residues (Ioannidou and Zabaniotou, 2007), green waste (Chan *et al.*, 2008) and manure (Lima *et al.*, 2008) through the fast or slow pyrolysis process. Pyrolysis is defined as the thermal degradation of biomass in the absence or at low concentrations of O_2 to produce condensable vapors, gases and charcoal. The application of biochar for agriculture has been used to improve the physical and chemical characteristics of soils increasing their fertility, reducing the acidity and neutralizes toxic aluminum. According Andrenelli *et al.* (2016) the biochar has the potential to increase soil water and with its adsorption capacity increases soil nutrient and crop productivity. Furthermore, biochar has remediated soil contaminated with heavy metals and has reduced emissions of greenhouse gases due carbon sequestration (Lehmann *et al.*, 2006). As Petter *et al.* (2012), the application of eucalyptus biochar for two years in sandy loam soil affected in the first year, the fertility of this soil increasing the available phosphorus, calcium and magnesium exchangeable and total organic carbon (TOC); decreased soil acidity (H + Al) and consequently, increased pH. With this there was a positive effect on rice productivity. In the second year, the highest efficiency observed in this culture was the application of biochar associated with mineral fertilization because of their low nutrient availability (Steiner *et al.*, 2007). In Brazil one of the main available organic wastes is poultry litter. It is estimated that the annual Brazilian production of poultry litter is around 6.8 million m^3 (Corrêa and Miele, 2011). As Sanvong and Suppadit (2013) the poultry litter biochar can be used as fertilizer and soil conditioner, being produced simply and at a low cost system, promoting self-sustaining agriculture. Sesame (*Sesamum indicum* L.) belonging to Pedaliaceae family, is a plant with very complex leaf morphology, with sheets of various shapes, sizes and thickness, according to the position on the plant (Silva *et al.*, 2002). It is a potential crop for cultivation in arid and semi-arid areas to be drought resistant (Magalhães *et al.*, 2013). According to Oliveira *et al.* (2000), sesame requires rainfall between 400 and 600 mm. well distributed; in the first month, the plant requires 160-180 mm. Sesame has a great socio-food importance in t Brazil's Northeast region, being grown practically by small producers using simple management and hand labor familiar during periods of planting, thinning and harvesting, by rendering more expensive the incorporation of technology in all phases of its production chain. The seeds of

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Table 1. Physico-chemical attributes of soil utilized in the experiment

TC	Sd	TP	pH	O.M.	P	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	$H^{+}+Al^{3+}$	CEC
	g cm^{-3}	%	(H_2O)	--mg dm^{-3}-		-------------------$cmol_c$ dm^{-3}-----------------					
Sand	2.71	52.03	6.4	4.8	4.6	2.10	2.57	0.06	0.14	4.05	6.65

TC – Textural Classification; Sd. Soil density; TP – Total Porosity; O.M. - Organic matter; CEC - cation exchange capacity.

this plant have about 50% of excellent quality oil, which can be used in the food, chemical and pharmaceutical industries and also in animal feed because of the nutritional quality of your pie (Correa *et al*., 1995). Perin *et al*. (2010) mention that among the limiting factors for obtaining high yields sesame highlights the availability of nitrogen and phosphorus. Therefore, it becomes necessary better understanding of the response of this culture as the fertilizer efficiency as sesame is a rustic culture, undemanding in soil fertility and water presenting different answers when evaluating locations and seasons growing, or even cultivars (Avila and Graterol, 2005). However, it is believed that the application of biochar, organic material, along with the mineral fertilizer acts on the physico-chemical properties of soil, improving, particularly, the fertility of soils. Considering that there is little information regarding the use of biochar in production systems and none information focused to sesame culture, this study aimed to evaluate the initial growth of sesame, cv BRS Seda when subjected to doses of mineral fertilizer and poultry litter biochar.

MATERIALS AND METHODS

The experiment was carried out in the period from June to July 2014 in a greenhouse located in the Academic Unit of Agricultural Engineering at the Federal University of Campina Grande (UFCG), Brazil, situated at 7º 12' 88"S and 35º 54' 40"O, with an average altitude of 532 m. Plastic pots with 20 liter capacity, corresponding to the experimental units, were filled with 20 kg of Entisol collected surface soils (0-20 cm) from a local farm located in Campina Grande, PB, whose physical and chemical properties were determined according to the methodology proposed by Embrapa (2011) (Table 1).

The experimental design was completely randomized in a factorial 5 x 4, with four replications. Os treatments consisted of five doses of mineral fertilizer with N, P and K, as fertilizer recommendation for trials (N: P: K = 100 : 300: 150 mg kg^{-1} soil) (Novais *et al*.,1991) (Table 2) and four doses of poultry litter biochar (0; 20 g kg^{-1}; 40 g kg^{-1} and 55 g kg^{-1}) calculated based on the volume of soil.

Table 2. Values of N. P and K applied in each treatment with mineral fertilization

Dose	N	P	K
	-------------------mg kg^{-1}--------------------		
D1	0	0	0
D2	13.5	50.0	14.0
D3	27.5	100.0	27.5
D4	41.0	150.0	41.5
D5	54.5	200.0	55.0

The biochar produced from conventional pyrolytic process of poultry litter (450° C x 0.5 hours x atmospheric pressure), presents the following chemical characteristics: pH (H_2O) = 10.1; N = 42.31 g kg^{-1}; P = 32.56 g kg^{-1}; K = 48.56 g kg^{-1}; Ca = 57.75 g kg^{-1}; Mg = 12.40 g kg^{-1}; Na = 14.37 g kg^{-1}; Fe = 137 g kg^{-1}; Cu = 812 g kg^{-1}; Zn = 700 g kg^{-1}; Mn = 862 g kg^{-1}. The soil was incubated with biochar for a period of 20 days, keeping moisture of 80% of the maximum water retention. After this period was applied to each experimental unit fertilization with Mono-Ammonium Phosphate - MAP (52% P_2O_5 and 10% N) and potassium chloride - KCl (60% K_2O) according to each treatment. The MAP was applied every seven days from 25 days after sowing (DAS) and potassium was applied at 30 DAS, via solution. Each experimental unit received fifteen seeds of sesame cultivar BRS Seda, having performed thinning to maintain one plant per pot. Irrigation was performed daily, using rainwater, which was collected by the collection system of greenhouse and stored in a box with 5 m^3 capacity. The applied water volume (Wv) was measured using the water consumption of the plants in 100% ETr according to equation 1, obtained by the difference between the mean weight of the vessel with the maximum water retention (Pcc), and average weight of vessels in the non-saturation condition (current weight) (Cw) divided by the number of vessels (n).

$$Wv=\frac{Wcc - Cw}{n} \quad (1)$$

At 30 DAS was carried out chemical control of whitefly (Bemisiatabaci) with insecticide at a dose of 0.005 g i.a./planta.

The evaluations were performed at 30 and 45 DAS, determining the plant height (PH) in cm; stem diameter (SD) in mm; number of leaves per plant (NL) determined by counting; leaf area (LA) in cm^2 measured by non-destructive method, using the methodology proposed by Silva *et al*. (2002) according to equation 2:

"LA = L x W x F" (2)

Where: LA = leaf area (cm^2); L = length of the midrib of the leaves of each plant (cm); W = leaf width (cm); F = correction factor (0.7).

At the end of the experiment, the plants were cut close to the ground, dried in air circulation oven forced to 65ºC to constant weight and determined the dry matter of the aerial part (shoot) (DMS). Likewise, soil samples were collected from each experimental unit, air-dried, sieved (2 mm opening) and determined Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{-}, HCO_3^{-}, SO_4^{-}, Cl^{-} levels, CEes and pHse saturation extract, according to the methodology proposed by Embrapa. Data were evaluated by analysis of variance and, when significant, the polynomial regression analysis was performed using the SISVAR 5.0 statistical software (Ferreira, 2011).

Table 3. Test 'F' result for plant height (PH), stem diameter (SD), number leaves per plant (NL) and leaf area (LA) at 30 and 45 days after sowing (DAS) of sesame in function of doses NPK and biochar of chicken litter

Source of variation	Test F							
	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
Mineral fert. (MF)	ns	**	ns	*	ns	**	ns	*
Biochar (B)	**	**	**	**	**	**	**	**
MF x B	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	23.9	21.1	17.2	18.6	33.2	30.7	30.9	31.1

ns, * and ** = no significative and signficative to 5% and 1% of probability, respectively. [1]Statistical analysis realized with data transformation in √X.

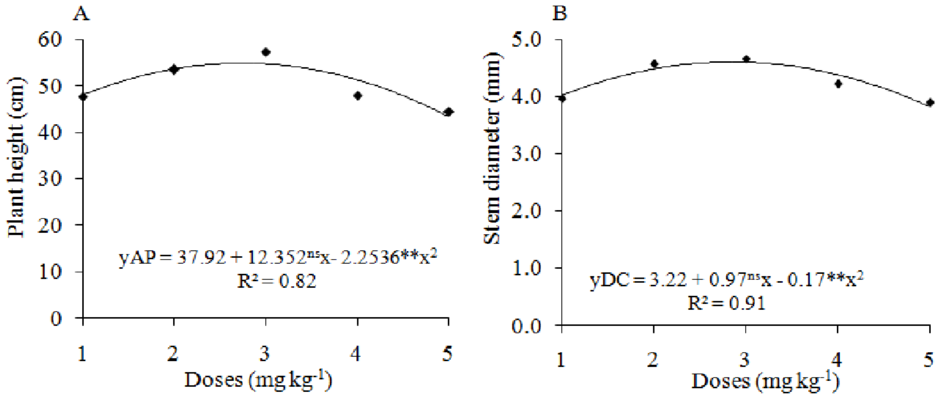

Figure 1. Plant height (A) and stem diameter (B) of sesame at 45 DAS in function of NPK doses (mg kg^{-1}); ns, * and ** = no significative and signficative to 5% and 1% of probability, respectively

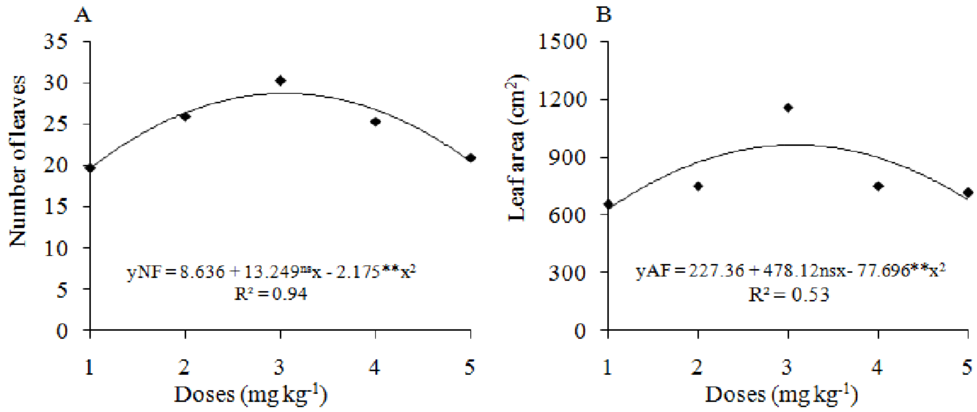

Figure 2. Number of leaves (A) and leaf area of sesame at 45 DAS to 45 DAS in function of NPK doses (mg kg^{-1}). ns, * and ** = no significative and signficative to 5% and 1% of probability, respectively

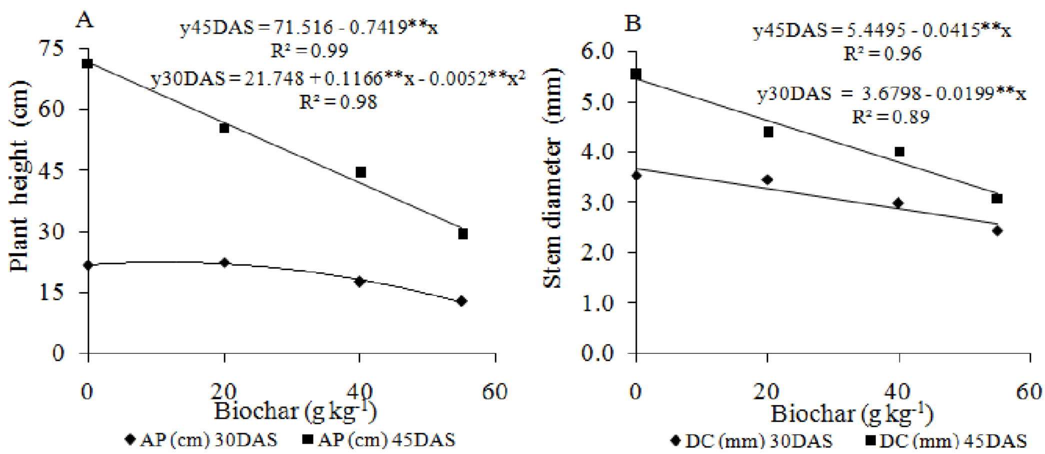

Figure 3. Plant height (A) and stem diameter (B) of sesame at 30 and 45 DAS in function of biochar doses (g kg^{-1}); ns, * and ** = no significative and signficative to 5% and 1% of probability, respectively

RESULTS AND DISCUSSION

The growth variables were significantly affected by NPK doses only at 45 DAS and by biochar in both evaluation periods, 30 and 45 DAS (Table 3). However there was no significant interaction between the mineral fertilization x biochar factors for any variable analyzed. Before 30 DAS, NPK doses did not influence significantly these variables due to the fact of not have been applied these nutrients in the experimental units. According to Arriel *et al*. (2006), potassium (K) and nitrogen (N) absorption peaks at sesame occur between 35 days after emergence and the end of the cycle and between 30 and 74 days after emergence, respectively. The larger plant height values (57.27 cm) and sesame stem diameter (4.66 mm) were observed with the dose 3 of NPK (N: P: K = 27.5; 100.0; 27.5 mg kg^{-1}), which corresponded to an increase, respectively, 20.09% and 17.38% over the lower dose (47.69 cm; 3.97 mm). As the mineral fertilizer had a quadratic effect on these variables, from dose 3 (N: P: K = 27.5; 100.0; 27.5 mg kg^{-1}) up to dose 5 (54.5; 200.0; 55.0 mg kg^{-1} NPK) there was a reduction of 22.24% in plant height and 16.52% in stem diameter (Figure 1A and B). These results concerning the plants height are larger than those reported by Perin *et al*. (2010), who observed greater height of sesame plants (48.5 cm) at 43 days after emergence with the application of 800 kg ha^{-1} of NPK 04-14-08 formulation. However, Grilo Junior and Azevedo (2013), evaluating sesame cv. BRS Seda, observed height and stem diameter of plants to 45 DAS at around 95.6 cm and 11.6 mm, respectively, ie, larger than the present experiment data. The behavior of the number of leaves per plant, and sesame leaf area due NPK doses adjusted to the quadratic model (Figure 2 A and B), which shows that the highest values of these variables, 30 sheets and 1159.87 cm2, were obtained with the dose 3 (27.5; 100.0; 27.5 mg kg^{-1} NPK) and the lowest with dose 5 (54.5; 200.0; 55.0 mg kg^{-1} NPK ; 21 leaves per plant and leaf area 714.23 cm^2) with a reduction of 30.53% and 38.42%, respectively. The value of the leaf area was lower in this experiment than 2,500 cm^2 found by Grilo Junior and Azevedo (2013). According to these authors, the leaf area is an important indicator of productivity of sesame culture. The quadratic effect of biochar doses on plant height at 30 DAS (Figure 3A), showed that the greatest height reached, 22.40 cm, corresponded to the amount of 11.21 g kg^{-1} which provided an increase of 2.99% in relation to treatment was not applied biochar (21.74 cm); from that point (greatest height) was reduced by 44.50% compared to a dose of 55 g kg^{-1} biochar (12.43 cm). However, at 45 DAS, the application of increasing doses of biochar promoted linear reduction in plant height reaching the lowest value, with the dose of 55 g kg^{-1} (30.71 cm) corresponding to a decrease of 57.05 % in relation to plant height not received biochar (71.51 cm).

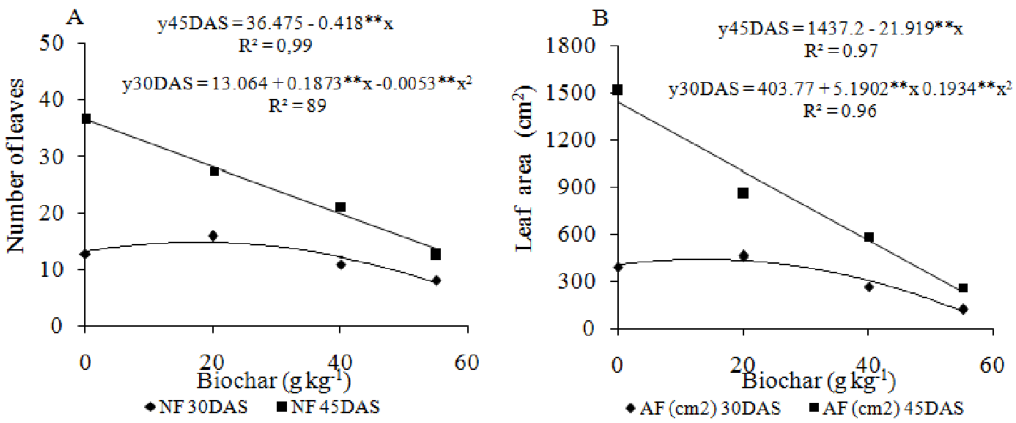

Figure 4. Number of leaves (A) and leaf area-cm^2 (B) of sesame at 30 and 45 DAS in function of biochar doses (g kg^{-1}); ns, * and ** = no significative and signficative to 5% and 1% of probability, respectively

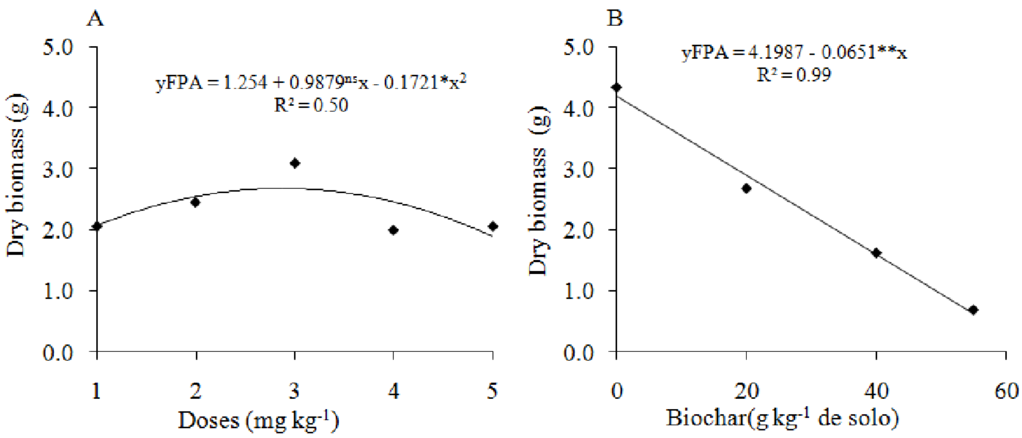

Figure 5. Dry biomass shoot - DBS of sesame at 45 DAS NPK doses function (mg kg^{-1}) (A) and biochar (g kg^{-1} de solo) (B); ns, * and ** = no significative and signficative to 5% and 1% of probability, respectively

The application of increasing doses of biochar afforded linear reduction of stem diameter at 30 and 45 DAS (Figure 3B). The lowest values of this variable, 2.58 and 3.16 mm, respectively at 30 and 45 DAS, were observed at a dose of 55 g kg^{-1}, corresponding to a reduction, respectively, 29.74% and 41.88% relative to the absence of biochar in the soil. The number of leaves and leaf area of the sesame plants at 30 DAS, varied quadratically due to biochar doses reaching 15 leaves and 438.59 cm^2 with doses, respectively, of 17.67 g kg^{-1} and 13.42 g kg^{-1}. These values correspond to an increase, respectively, of 12.66% and 8.62% relative to the absence of biochar (Figure 4 A and B). From these values to the higher dose of 55 g kg^{-1}, there was a reduction in leaf number and leaf area, respectively, of 50.17% and 76.24%. However, at 45 DAS, there was linear reduction in leaf number and leaf area as a function of increasing doses of biochar (Figure 4A and B) observing the lowest values around 13 leaves and leaf area 231.65 cm^2 compared the higher dose of biochar, which corresponded to a decrease of 63.03% and 83.88% compared to the absence of biochar. Based on the regression equation there is a quadratic effect for the dry biomass of the aerial part (DBS) according to the NPK doses (Figure 5A). It is observed increase of DBS (2.67 g) to Dose 3 (27.5; 100.0; 27.5 mg kg^{-1} NPK), which corresponded to an increase of 53.01% compared to dose 1 (without fertilizer); from this point was reduced from 29.14% to Dose 5 (54.5; 200.0; 55.0 mg kg^{-1} NPK). These results are in agreement with those reported by Perin *et al.* (2010), which also found a quadratic effect for this variable using increasing doses of NPK. However, the doses of biochar linearly reduced the DBS (Figure 5B). The lowest value of DBS was 0.61 g in a dose of 55 g kg^{-1}, which corresponded to a reduction of 85.28% compared to the absence of biochar.

According to the effect of the NPK in the characteristics of the growth and development of sesame can be seen that the dose 3 (27.5; 100.0; 27.5 mg kg^{-1} NPK) promoted the greatest results. Probably, this dose was sufficient for the development sesame or above this may have potentiated the negative effects of soil salinity. Excessive increase in the concentration of nutrients in the soil may increase the salt level, mainly due to the potassium and nitrogen, which may cause nutritional disorders plants (Epstein and Bloom, 2006). The application of biochar had a negative effect on the growth and development of sesame. This was probably due to the increase in soil salinity as a function of fertilization with biochar, which can be verified by the increase of pH_{se} and electrical conductivity of the saturation extract (ECse) in the experimental units (Table 4). The highest values were observed at doses of 40 and 55 g kg^{-1} biochar, ie $pH_{se} \leq 8,5$; ECse > 4.0 dS m^{-1} (Richards, 1954), which are characteristic of saline soils. These results may be related to the alkaline nature of biochar. The excess soluble salts in the soil promotes increased osmotic potential and reduction in absorption of water and nutrients, resulting in metabolic and physiological disorders in plants, reducing photosynthetic rates and hence the production of assimilates to the reproductive organs (Dias and Blanco 2010). According to Larcher (2000) increasing NaCl content causes a reduction in the absorption of mineral nutrients, especially NO_3^-, K^+ and Ca^{2+}. However, Vieira *et al.* (2009) and Carvalho *et al.* (2011) found positive effects of poultry litter on the growth and yield of chamomile and soybean, respectively. Likewise, Lima *et al.* (2007) and Silva *et al.* (2011) observed positive effects of fertilization with poultry litter in the growth components of *Brachiaria brizantha* cv. Marandu and corn. This suggests that the pyrolysis process in the production of biochar potentiates the effects of salinity of this material.

Table 4. Chemical attributes of soil cultivated with sunflower in function of biochar doses

Chemical attributes in saturation extract	Biochar doses (g kg^{-1})			
	0	20	40	55
pH_{se}	5.98	7.07	7.90	8.28
EC_{es} (dS m^{-1})	3.31	7.28	9.50	9.32
Chloride ($mmol_c$ L^{-1})	33.32	47.73	50.44	50.43
Carbonate ($mmol_c$ L^{-1})	0.00	0.00	0.00	0.00
Bicarbonate ($mmol_c$ L^{-1})	2.44	2.95	5.36	7.09
Sulfate ($mmol_c$ L^{-1})	P	P	P	P
Calcium ($mmol_c$ L^{-1})	7.04	7.63	3.82	3.97
Magnesium ($mmol_c$ L^{-1})	28.13	35.44	26.98	22.84
Sodium ($mmol_c$ L^{-1})	16.98	31.03	37.01	34.71
Potassium ($mmol_c$ L^{-1})	4.23	24.11	44.00	51.66
RAS	4.05	6.69	9.43	9.48

pH_{se} - pH of saturation extract; ECse- Elétrical condutivity of saturation extract; SAR – Sodium adsorption ratio.

It was also observed, an increase in chloride (Cl^-), bicarbonate (HCO_3^-), sodium (Na^+) and potassium (K^+) content of respectively 33.94%, 65.58%, 51.08% and 91.81% compared to treatments without fertilizer with biochar; the levels of Ca (Ca^{2+}) and magnesium (Mg^{2+}), however, decreased with increasing doses of biochar, promoting increased sodium adsorption ratio (SAR). As Freire *et al.* (2003), increasing the RAS occurs due to the increase in the content of Na^+ relative to other cations in the soil solution promoting nutritional imbalance by the difficulty of absorption of Ca^{2+}, Mg^{2+} and K^+ due to the increased proportion of sodium soluble in the solution soil (Pessoa *et al.*, 2010). Due to limited information on the use of poultry litter biochar as fertilizer, especially for sesame cultivation, new research in this regard stand out in importance, including using different doses of biochar, retention and nutrient release of this material, presence or no toxic components, among other issues involved in the use of biochar in agriculture.

Conclusion

Mineral fertilizer favored the development of sesame plants reaching maximum growth with the dose of 27.5; 100.0; 27.5 mg kg^{-1} NPK. The doses used of poultry litter biochar in this research harmed the development of plants.

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