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Soil chemical properties, growth and production of sunflower under fertilization with biochar and NPK

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Abstract

The use of biomass can contribute to improve the soil properties. The objective of this study was to evaluate the effect of fertilization with poultry litter biochar in combination with mineral fertilizer on soil chemical attributes, growth and yield components of sunflower. For this purpose, a greenhouse experiment was carried out in pots with a capacity of 20 dm^3 under randomized design, with treatments arranged in a factorial 5 × 4 design with four replicates. The treatments consisted of five doses of mineral fertilizer (0, 25, 50, 75 and 100% fertilization recommendation) with NPK (100, 300, and 150 mg kg^{-1}) and four doses of biochar of poultry litter, 0; 5% (400 g/pot); 10% (800 g/pot) and 15% (1,100 g/pot) calculated based on the volume of the soil. The results showed that fertilization with poultry litter biochar of 400 g/pot, increased soil salinity of the experimental units. Besides, there was a reduction in the number of leaves (NL), plant height (PH), stem diameter (SD) and number of achenes for each head (NAH). Fertilization with 50% of NPK recommendation (50:150:75 mg kg^{-1}) produced the highest growth and yield components of sunflower, compared with other NPK treatments. The combination from 50:150:75 mg kg^{-1} (50%) of NPK fertilization and 1,100 g/pot of poultry litter biochar promoted larger head diameter (HD) of sunflower.

Keywords: Biomass; Poultry litter; *Helianthus annuus* L.; Mineral fertilizer.
Abbreviations: DAS_days after sowing, ECs_electrical conductivity of the saturation extract, HD_head diameter, K_ potassium, N_nitrogen, NL_number of leaves, NAH_number of achenes for each head, P_phosphorus, PH_plant height, SAR_sodium adsorption ratio, SD_stem diameter, W100A_hundred achenes weight.

Introduction

The biochar is an organic compound produced by the fast or slow pyrolysis process. It can be applied to the soil, improving its physical and chemical properties (Lehmann et al., 2006). 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. Biochar can be produced from different sources of biomass such as woody materials, agricultural waste, green waste and manure. However, according Coomer et al. (2012), the production of biochar from animal waste has higher quality nutrition regarding the biochar produced from vegetable waste, due to the higher levels of nitrogen.

The poultry litter is of special interest for the production of biochar in Brazil due to the high production around 6.8 million m^3 per year (Corrêa and Miele, 2011). According to Sanvong and Suppadit (2013), the poultry litter biochar can be effectively used as a fertilizer and soil conditioner, owing to its simple production process and low cost. However, it is noted that most biochar application efficiency is associated with the mineral fertilizer according to their low availability of nutrients (Steiner et al., 2007).

Sunflower (*Helianthus annuus* L.) is an oilseed crop that is attracting interest by farmers due to its high potential for biofuel production. It is a very important crop for the Brazilian semiarid region because of its good adaptability to high temperatures, accounting for about 13% of all vegetable oil produced in the world (Nobre et al., 2010). Sunflower has desirable characteristics, such as adaptation to different soil and climatic conditions, short cycle (100 days), good grain yield (average 1,741 kg ha^{-1}), tolerance to abiotic factors and the oil content in its seeds (38 - 50%) with high chemical quality. Apart from that, their grain, the crop residues and by-products generated in the oil extraction, can be used in animal feeding (Nobre et al., 2011). The Brazilian production of sunflower crop in 2012/2013 was 110 tons. The Mato Grosso State was the largest producer, with 84,700 tons, which corresponds to 64.9% of national production and an average productivity of 1,671 kg ha^{-1}. In the Northeastern parts of Ceará and Bahia states, the average yield of 456 and 400 kg ha^{-1} has been reported (Conab, 2013); however, the ability to reach the achenes maximum productivity is related, in part, with a suitable mineral nutrition of the plant (Aquino et al., 2013).

Due to insufficient available information on application of biochar in production systems, this study was set up to evaluate the effect of fertilization with poultry litter biochar in combination with mineral fertilizer in soil chemical properties, growth and production components of sunflower cv. Embrapa 122 / V2000.

Results and Discussion

Soil chemical properties after biochar treatments

The application of all poultry litter biochar doses promoted the pH and electrical conductivity of the saturation extract (ECse) in the soil of the experimental units (Table 1) (Richards, 1954), saline soils (pH ≤ 8.5; ECes > 4.0 dS m^{-1}). However, the increase in the soil pH can promote the availability of various chemicals to the plants, while the other elements become insoluble, precipitating in the soil. Liesch et al. (2010) observed increased soil pH with increasing levels of poultry litter biochar after 28 days of incubation, obtaining maximum values of 8.87 with the application of 90 t ha^{-1}. Likewise, Revell (2011) showed a linear increase of the accumulation of soluble salts in the soil with increasing doses of poultry litter biochar.

It is observed also that the chloride, bicarbonate, sodium and potassium content had the same trend as ECse, which went up by respectively 33.9%, 65.6%, 51.1% and 91.8% in relation to the soil without biochar treatments and control. However, there was a reduction of calcium and magnesium levels in the saturation extract with increasing doses of biochar, a fact that has influenced the increase of the sodium adsorption ratio (SAR). According to some researchers, SAR can promote increased nutritional imbalance, because of the difficulty of absorption of calcium, magnesium and potassium due to the increase in the proportion of soluble sodium in the soil solution. It is likely that the reaction of biochar, rich in calcium, magnesium, sodium, potassium and organic compounds (generally have a higher surface area) in the soil have caused higher cation exchange capacity, i.e., increased adsorption of calcium and magnesium, releasing the exchangeable cations sodium and potassium from the soil solution.

Number of leaves

As statistical analysis, the number of sunflower leaves was significantly influenced only by NPK doses at 60 DAS and by biochar doses at 30 and 60 days after sowing (DAS). Thus, the effect of NPK had a quadratic behavior as can be seen in Fig 1A. It is observed that up to a dose of 34.2% of fertilizer recommendation (18 leaves), there was an increase in the number of leaves of 3.9% compared to the lower dose (dose 0). Subsequently from that point, there was a reduction of 14.3% compared to the dose of 100% (N: P: K, 100: 300: 150 mg kg^{-1}) (14 leaves) of the recommendation. The nutritional status of the plant, especially after adequate supply of N, P and K, are directly related to their growth and development because these elements perform functions for energy metabolism. Chaves et al. (2014) found positive effects of NPK fertilization for this variable, getting maximum number of 16 leaves at 60 DAS with the combination of 71.2 kg ha^{-1} N, 120 kg ha^{-1} of P_2O_5 and 78.6 kg ha^{-1} K_2O. Likewise, Adebayo et al. (2010) observed an increase in the number of sunflower leaves as a function of phosphorus levels, obtaining a maximum number of leaves (35 leaves) with the application of 4.8 g/plant.

The fertilization with poultry litter biochar linearly reduced the number of sunflower leaves, at 30 and 60 DAS, of 34.5% and 20.6%, respectively, compared with plants grown without fertilizer with biochar (dose 0) and the dose of 1,100 g/pot (Fig. 1B). The highest number of leaves was obtained when the plants were grown without fertilizer with biochar (19 leaves). Such results may be related to the negative effects of salt stress caused by the fertilization with poultry litter biochar. According to Oliveira et al. (2013) the reduction of the number of leaves functions as anatomical adaptation in saline stress conditions reflecting transpiration reduction as an alternative to maintain the water absorption.

Plant height (cm)

According to the regression equation (Fig. 2A), NPK doses had quadratic effect on the plant height of the sunflower at 90 DAS, i.e., from the lowest dose (97.5 cm) up to a dose of 33.3% NPK it was increased by 3.9%. From this point there was a decrease of 15.5%, These results show that under the conditions of this research the fertilizer recommendation adopted for sunflower was far superior to the crop's needs. According to Jahangir et al. (2006) the combination of 120 kg ha^{-1} of N and 75 kg ha^{-1} of P_2O_5 promoted height of sunflower plants, reaching a maximum height of 62.1 cm. Salih (2013) evaluating the combination of different doses of N and P in Sudan and found increases in sunflower plant height with increasing doses of mineral fertilizer.

The results concerning the height of sunflower plants according to the biochar doses were adjusted to the linear model (Fig. 2B), indicating that plant height decreased as a function of increasing biochar level at 60 DAS. The lower estimated values of plant height for plants grown under 1,100 g/pot fertilizer were 61.4 cm, which corresponds to a decrease of 30.8% compared to the plants receiving no fertilization. These results may be related to increased soil salinity ECse evidenced by the high values. In addition, excess salts in the soil can reduce the nitrogen absorption of plants, while the absorbed and retained Cl levels are increased, promoting lower growth (Bosco et al., 2009). Nobre et al. (2010) and Morais et al. (2011) observed a linear reduction of sunflower plants height under salt stress conditions. According to Javid et al. (2011), increased salinity is associated with decreases in auxin, cytokinin, gibberellins and salicylic acid in the plant tissues which are involved in plant growth and developmental processes. The other treatments of NPK and biochar that have not been discussed above showed no significant effect on plant height.

Stem diameter (mm)

At 60 DAS, the stem diameter of sunflower plants subjected to fertilization with 0 and 400 g/pot of biochar was exponentially related according to regression equations (Table 2), (Fig. 3A). In this case, the stem diameter increased up to 55.7% dose of biochar (11.68 mm) and 46.8% (10.05 mm) of the NPK recommendation, respectively. The lowest values of stem diameter were observed in plants fertilized with 100% of NPK recommendation. However, it is observed that the stem diameter of the plants subjected to fertilization with 800 and 1,100 g/pot of biochar decreased linearly according the regression equations, showing reduction of 19.38% and 27.5%, respectively, when compared to the smaller and higher dose of NPK fertilization.

The stem diameter at 90 DAS was found to be the best fit data to the quadratic model, when plants did not receive fertilizer with biochar (dose 0) (Fig. 3B), where dose of 57.6% (12.47 mm) NPK recommendation increased the trait by 34.5%, compared to the smallest dose. From this point, there was a reduction of 18.7% compared to 100% dose of NPK recommendation. Doses of 800 and 1,100 g/pot of biochar affected the linear regression equations. They reduced

Table 1. Average values of the chemical properties of soil cultivated with sunflower in terms of doses of poultry litter biochar (B).

Chemical properties in saturation extract	Biochar Dose (g/ pot)			
	B1	B2	B3	B4
	0	400	800	1100
pH_{se}	5.98	7.07	7.90	8.28
EC_{se}(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
SAR	4.05	6.69	9.43	9.48

pH_{se} - pH of saturation extract; ECse- Electrical Conductivity of saturation extract; SAR- Sodium adsorption ratio.

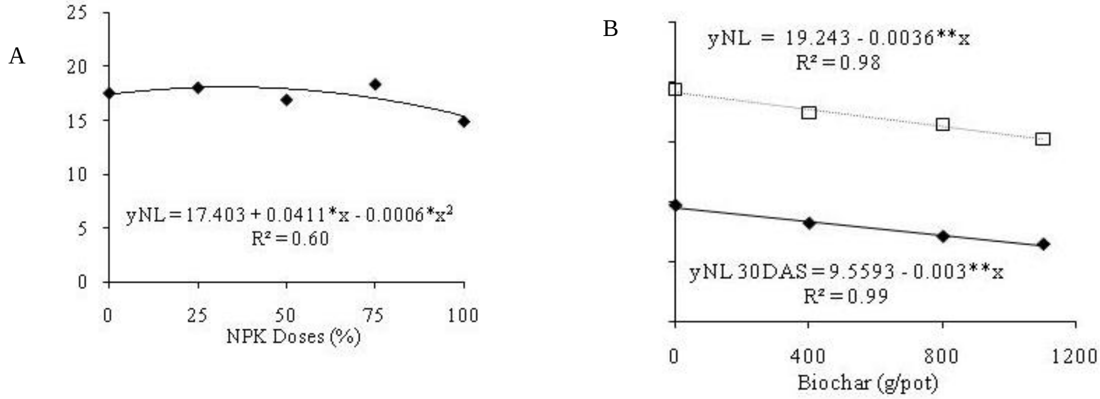

Fig 1. Number of leaves at 60 DAS in NPK doses function - % (A) and at 30 and 60 DAS due to doses of poultry litter biochar - g/pot (B).

Table 2. Regression equations of sunflower stem diameter at 60 and 90 days after sowing (DAS) and sunflower head diameter (HD) due to NPK doses and poultry litter biochar.

	Stem Diameter at 60 DAS (mm)		
Biochar (g/pot)	Equations	R^2	Mean
0	$Y = 7.3487+ 0.1559^*x – 0.0014^{**}x^2$	0.8763	10.08
400	$Y = 8.7411+ 0.562x – 0.0006^*x^2$	0.6252	9.28
800	$Y = 9.2338 – 0.0179^*x$	0.6711	8.34
1,100	$Y = 9.085 – 0.025^*x$	0.4099	7.83
	Stem Diameter at 90 DAS (mm)		
Biochar (g/pot)	Equations	R^2	Mean
0	$Y = 8.1634+ 0.1497x – 0.0013^{**}x^2$	0.8830	10.81
800	$Y = 11.461 – 0.0263^{**}x$	0.7565	10.14
1,100	$Y = 10.939 – 0.0352^{**}x$	1.0000	9.18
	Head diameter (cm)		
Biochar (g/pot)	Equations	R^2	Mean
0	$Y = 6.3268+ 0.1139^{**}x – 0.0009^{**}x^2$	0.816	8.54
1,100	$Y = 7.2476+ 0.0721^{**}x – 0.001^{**}x^2$	0.799	7.28

(**), (*) significant to ($p \leq 0.01$) and ($p \leq 0.05$); Y = head diameter (cm); x = NPK doses (%).

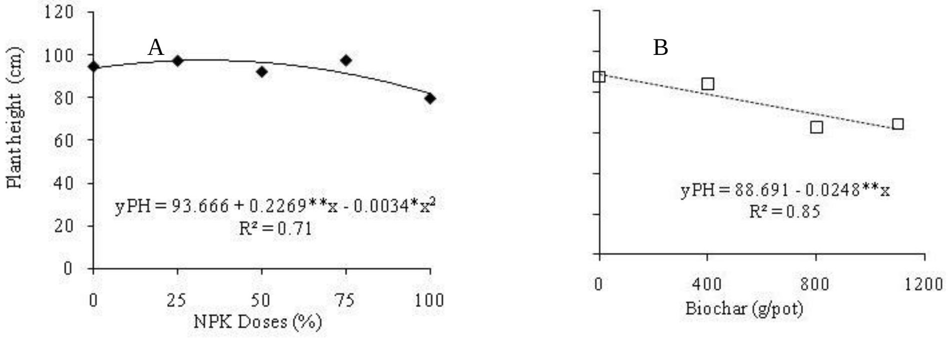

Fig 2. Sunflower plant height at 90 DAS in fertilizer doses function (%) (A) and poultry litter biochar (g/pot) at 60 DAS (B).

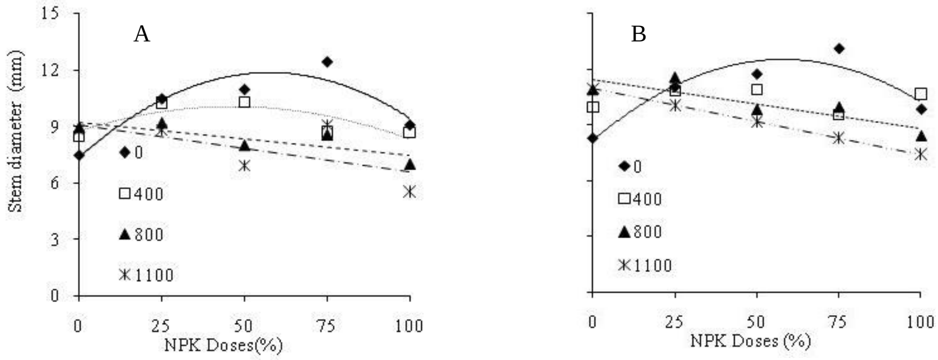

Fig 3. Stem diameter at 60 (A) and 90 DAS (B) in function of NPK doses (%) and biochar (g/pot).

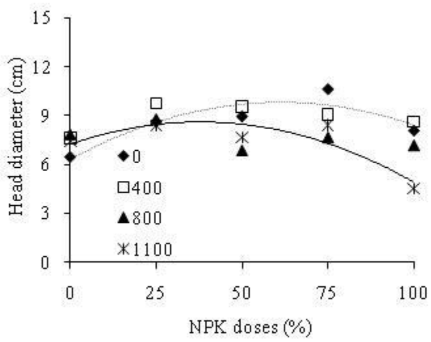

Fig 4. Sunflower head diameter depending on NPK doses (%) and poultry litter biochar (g/pot).

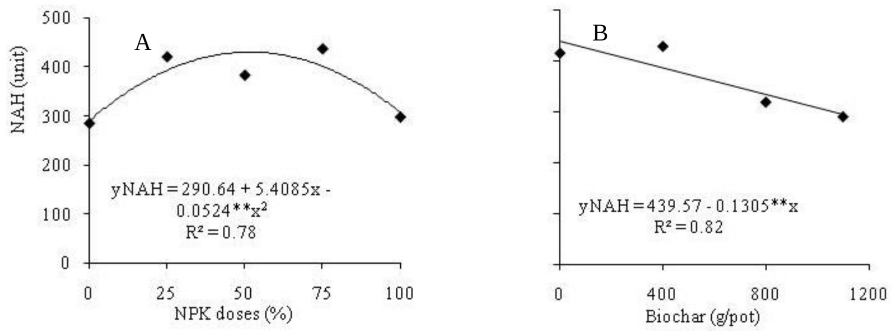

Fig 5. Number of achenes per head (NAH) in NPK doses function -% (A) and poultry litter biochar - g/pot (B).

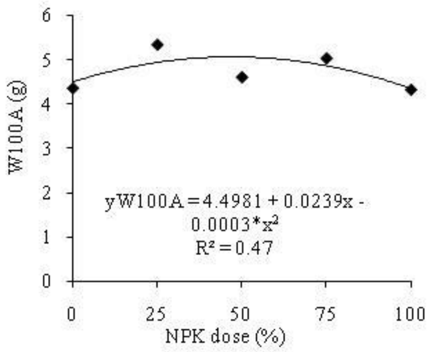

Fig 6. Hundred achenes weight (W100A) as a function NPK dose (%).

The stem diameter by 22.9% and 32.2%, respectively, when compared to lower and higher dose of NPK recommendation. Regarding the plants that received the dosage of 400 g/pot of biochar, as regression studies showed, there was no significant effect on stem diameter being reached an average value of 10.4 mm, a fact related to the effects of salt stress, such as those mentioning earlier.

Head diameter (cm)

There is an apparent significant interaction between the NPK doses (factors) × Biochar doses on head diameter (HD) (Fig 4), according to the regression equations (Table 2). We observed increase in the head diameter up to the dose of 63.3% (9.9 cm) and 36.0% (8.55 cm) of the NPK recommendation with 0 and 1,100 g/pot of biochar dose respectively. The smallest estimated value was observed in plants fertilized with 100% of NPK recommendation.

Plants that received the dosage of 400 and 800 g/pot of biochar (according to regression studies), showed no significant effect on head diameter being reached average values of 8.9 and 7.7 cm, respectively. As for the growth variables, sunflower head diameter was also significantly reduced with the application of biochar mainly due to increased soil salinity. According to Nobre et al. (2010), increased salinity causes a reduction in water availability to the plants and consequently the reduction of sunflower head diameter.

Number of achenes for head

As the regression equation shows (Fig. 5A), there is a quadratic effect on the number of achenes for each head (NAH) on the basis of NPK doses. The highest value was observed at a dose of 51.6% (430 achenes) of the recommendation dose, which promoted an increase of 32.4% compared to the lower doses. It is also noted that from this point, there is a reduction of 28.5% in the number of seeds per head, compared to the plants receiving 100% of NPK recommendation. Such results are related to the larger sunflower head diameter (HD) obtained near 50% of the NPK dose recommendation. The major sunflower head diameter favors the increased formation of flowers and, in turn, also more achenes. Pivetta et al. (2012) found a significant positive correlation between number of achenes in head and sunflower head diameter, showing that an increase of a variable will result in increasing the others. According to Jahangir et al. (2006) the combination of 120 kg ha^{-1} of N and 75 kg ha^{-1} of P_2O_5 promoted greater number of achenes per head obtaining an average of 341 achenes. Centeno et al. (2014) found a linear increase of the total number of achenes with increasing nitrogen rates, obtaining the greatest results with the dose of 150 mg kg^{-1}.

The results of the number of sunflower achenes per head, as function of biochar doses, were better adjusted to the linear model (Fig. 5B). As the regression equation shows, there is 35.7% reduction in the number achenes per head, when compared to the doses 0 and 1,100 g/pot. The number of achenes per head varied 296-440 units. The increase in soil salinity due higher doses of biochar also affected the number of achenes per sunflower head. Accordingly, Rhoades et al. (2000) reported that the effects of salt stress manifest both the development and production of crops, mainly reducing the development of the fruit, like symptoms of water stress. Centeno et al. (2014) found linear reduction in the number of sunflower achenes with the increase of the EC of irrigation water.

Hundred achenes weight (g)(W100A)

For the hundred achenes weight (W100A) (Fig. 6), best fit of the data to the quadratic model can be observed; thus reaching the maximum point at the dose of 39.8% of NPK recommendation, corresponding to an increment of 9.5% compared to the lower dose. The hundred achenes weight varied from 3.9 to 4.9 g; however, these values are lower than those reported by Jahangir et al. (2006) who observed variation from 5.0 to 5.7 g, and maximum values obtained with combination of 120 kg ha^{-1} of N and 75 kg ha^{-1} of P_2O_5. Nobre et al. (2011) found linear effect of nitrogen fertilization on this variable, and the plants subjected to a dose of 125 mg kg^{-1} obtained hundred achenes weight of 4.9 g. Banerjee et al. (2014) reported that the combination of 50 kg ha^{-1} 100:50: NPK promotes the hundred achenes weight (5.6 g). According to Amorim et al. (2008) there are significant effect between seed yield, head diameter, percentage of normal seed and thousand grains weight.

Materials and Methods

Plant material and location of the experiment

The experiment was carried out under greenhouse conditions at the Agricultural Engineering Department of the Federal University of Campina Grande, Paraiba State, Brazil (35º 53’ 31” W, 07º 13’ 11” S; 547 m asl) from September to December 2014. The climate is the Csa type according to the climate classification Köeppen, which is mesothermal climate, sub-humid, with hot and dry period (4-5 months) and rainy season autumn to winter. In the period from September to December 2014 the temperature ranged from 18.9 °C to 28.5 °C and the relative humidity ranged from 82% to 77.5% (Aesa, 2014). The sunflower cultivar used was Embrapa 122 / V2000 bred by Embrapa.

Experimental design and treatments

The treatments were carried out in a completely randomized design, in a 5 × 4 factorial experiment (five mineral fertilizing (NPK) doses and four poultry litter (biochar doses) with four repetitions, comprised of 80 experimental units. The treatments of mineral fertilizing corresponded to 0; 25; 50, 75 and 100% of NPK (100:300 and 150 mg kg^{-1}) fertilization for testing in greenhouse according to Novais et al. (1991) and four poultry litter biochar doses corresponded to 0%; 5% (400 g/pot); 10% (800 g/pot) and 15% (1,100 g/pot), calculated based on the soil volume (Jien and Wang, 2013). The NPK sources used were urea (salt index=75), monoammonium phosphate (MAP) (salt index=30) and potassium chloride (KCl) (salt index=115) respectively, being applied in the treatment with 100% recommendation 1.41 g of urea, 13.64 g of MAP and 5 g KCl. The MAP was applied every seven days from 25 days after sowing (DAS). The KCl was applied at 30; 45 and 60 DAS and urea was applied at 50 DAS. The biochar was incorporated into the soil and allowed to incubate for a period of 20 days. A foliar fertilizer was also applied at 40 DAS, using Ubyfol® (micronutrients) at a ratio of 0.5 kg of leaf fertilizer for 100 liters of water.

Soil analysis

Each experimental unit consisted of a plastic vase filled with 20 kg of soil with the following chemical characteristics according to the methodology of Embrapa (2011): pH (H_2O)

= 6.4; Ca = 2.10 $cmol_c$ kg^{-1}; Mg = 2.57 $cmol_c$ kg^{-1}; Na = 0.06 $cmol_c$ kg^{-1}; K = 0.14 $cmol_c$ kg^{-1}; H + Al = 4.05 $cmol_c$ kg^{-1}; O.M. = 4.8 g kg^{-1}; P = 4.6 mg kg^{-1}; pH_{se} (saturation extract) = 5.8; EC_{se} = 0.22 dS m^{-1}; SAR (sodium adsorption ratio) = 0.75; Cl^-_{se}= 1.0 $mmol_c$ L^{-1}; $CO_3^{2-}{}_{se}$= 0.0; $HCO_3^-{}_{se}$= 1.2 $mmol_c$ L^{-1}; $Ca^{2+}{}_{se}$= 0.25 $mmol_c$ L^{-1}; $Mg^{2+}{}_{se}$= 1.50 $mmol_c$ L^{-1}; $Na^+{}_{se}$ = 0.70 $mmol_c$ L^{-1}; $K^+{}_{se}$= 0.19 $mmol_c$ L^{-1}.

Biochar analysis

The biochar was produced from conventional pyrolysis process using chicken litter waste (450°C × 0.5 hours × atmospheric pressure) having as chemical attributes, according to the methodology proposed by the Embrapa (2009): 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}. In order to analyze the salinity of biochar, the following empirical methodology was adopted: 12.5 grams of biochar was mixed in 125 mL of distilled water in polyethylene tube with a drain partially closed by cotton to prevent the loss of biochar. The drained liquid was chemically analyzed. The results were: pH (H_2O) = 9.39; E.C. (dSm^{-1}) = 8.87; P = 56.9 mg L^{-1}; K = 9.6 mg L^{-1}; Ca = 3020.2 mg L^{-1}; Mg = 88.4 mg L^{-1}; Na = 465.1 mg L^{-1}.

Conduct of the study

Three sunflower seeds (cultivar Embrapa 122 / V2000) were sown on October 19, 2014 directly in the pots at a 5 cm depth. Ten and twenty DAS, seedlings were thinned to two and one plant per pot, respectively. During the experimental period, the cross-pollination, cultural treatments and phytosanitary control were made.

Irrigation was performed daily using rainwater. The applied water volume (Va) was measured using the water consumption by the plants in 100% ETr, according to Eq.1, being obtained from the difference between the mean weight of the container in conditions of maximum retention of water (Pcc) and the average weight of the containers in the non-saturation condition (current weight) (Pa) divided by the number of containers (n).

$$Va = \frac{Pcc - Pa}{n} \qquad (1)$$

After the experiment, in the extract saturation the chemical elements contents and CEse and pH values were determined according to the methodology proposed by Embrapa (2011). At 60 and 90 DAS, the plant height (PH) and stem diameter (SD) were evaluated. The number of fully expanded leaves (NL) with minimal length of 3 cm was evaluated at 30 and 60 DAS.

When the plants reached the harvest stage the following production components were evaluated: head diameter (HD number of achenes per head (NAH), hundred achenes weight (W100A), considering only viable achenes according to the methodology proposed by Brasil (2009).

Statistical analysis

The experimental data was analyzed by ANOVA using F test. In case of significance of the interaction between factors, affected polynomial regression analysis was carried out. In cases of no significant interaction, the isolated effect of factors was done through regression analysis, when it had a significant effect. The F-test was adopted at 5% of probability for all analyzes. All analyses were performed using statistical software SISVAR (Ferreira, 2011).

Conclusions

The fertilization with poultry litter biochar from 400 g/pot and higher triggered soil salinity of the experimental units and reduced the growth and production components of sunflower, in which the reductions in the number of leaves (NL), plant height (PH), stem diameter (SD) and number of achenes for each head (NAH) were observed. Fertilization with 50% of NPK recommendation (50:150:75 mg kg^{-1}) was the best treatment and promoted the growth values and production components, when compared with other NPK treatments. The combination of 50:150:75 mg kg^{-1} (50%) of NPK fertilization and 1,100 g/vaso of poultry litter biochar produced larger head diameter (HD) of sunflower.

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References

Adebayo AG, Akintoye HA, Olatunji MT, Shokalu AO, Aina OO (2010) Growth response and flower yield of sunflower to phosphorus fertilization in Ibadan, Southwestern Nigeria. Rep and Opi. 2: 29-33.

AESA - Agência Executiva de Gestão das Águas do Estado da Paraíba (2014) Available at: <http://www.aesa.pb.gov.br>

Aquino LA, Silva FDB, Berger PG (2013) Agronomic characteristics and nutritional status of irrigated sunflower cultivars. R Bras Eng Agr Amb. 17: 551-557.

Amorim EP, Ramos NP, Ungaro MRG, Kiihl TA (2008) Correlations and path analysis in sunflower. Bragantia. 67: 307-316.

Banerjee H, Dutta SK, Pramanik SJ, Ray K, Phonglosa A, Bhattacharyya K (2014) Productivity and profitability of spring planted sunflower hybrid with nitrogen, phosphorus and potassium fertilizer. An Plant Soil Res. 16: 250-256.

Bosco MRO, Oliveira AB, Hernandez FFF, Lacerda CF (2009) Influence of salt stress on the mineral composition of eggplant seedlings. R Ci Agr. 40: 157-164.

Brasil. Regras para análise de sementes (2009) Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Mapa/ACS, Brasília.

Centeno CRM, Santos JB, Xavier DA, Azevedo CAV, Gheyi HR (2014) Components of production of sunflower Embrapa 122-V2000 under water salinity and nitrogen fertilization. R Bras Eng Agr Amb. 18: 539-545.

Chaves LHG, Guerra HOC, Campos VB, Pereira WE, Ribeiro PHP (2014) Biometry and water consumption of sunflower as affected by NPK fertilizer and available soil water content under semiarid Brazilian conditions. Agr Sci. 5: 668-676.

Conab - Companhia Nacional de Abastecimento (2013) Acompanhamento da safra brasileira de grãos 2012/2013 – Décimo Segundo Levantamento. Brasília: Conab. Available at: <http://www.conab.gov.br/conteudos.php?a=1252&>

Coomer TD, Oosterhuis DM, Longer DE, Loka DA (2012) Effect of Poultry Litter Biochar on Early-Season Cotton Growth. Summaries of Arkansas Cotton Research 2012. AAES Research Series 610.

Corrêa JC, Miele M (2011) A cama de aves e os aspectos agronômicos, ambientais e econômicos. In: Palhares JCP, Kunz A (ed) Manejo ambiental na avicultura. Embrapa Suínos e Aves, Concórdia (Documentos, 149).

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2009) Manual de análises químicas de solos, plantas e fertilizantes. Embrapa, Brasília.

Embrapa - Empresa Brasileira de Pesquisa Agropecuária (2011) Manual e métodos de análise de solo. Embrapa Solos, Rio de Janeiro.

Ferreira DF (2011) Sisvar: a computer statistical analysis system. Ci e Agr. 35: 1039-1042.

Jahangir AA, Mondal RK, Nada K, Afroze SR, Hakim MA (2006) Response of nitrogen and phosphorus fertilizer and plant spacing on growth and yield contributing character of sunflower. Bangladesh J Sci Ind Res. 41: 33-40.

Javid MG, Sorooshzadeh A, Moradi F, Sanavy SAMM, Allahdadi I (2011) The role of phytohormones in alleviating salt stress in crop plants. Aust J Crop Sci. 5: 726-734.

Jien SH, Wang CS (2013) Effects of biochar on soil properties and erosion potential in a highly weathered soil. Catena. 110: 225-233.

Lehmann J, Gaunt J, Rondon M (2006) Bio-char sequestration in terrestrial ecosystems - a review. Mit Adap Str Glo Change. 11: 403-427.

Liesch AM, Weyers SL, Gaskin JW, Das KC (2010) Impact of two different biochars on earth worm growth and survival. An Env Sci. 4: 1-9.

Morais FA, Gurgel MT, Oliveira FHT, Mota AF (2011) Influence of irrigation with saline water on sunflower. R Ci Agr. 42: 327-336.

Nobre RG, Gheyi HR, Correia KG, Soares FAL, Andrade LO (2010) Growth and flowering of sunflower under saline stress and nitrogen fertilization. R Ci Agr. 41: 358-365.

Nobre RG, Gheyi HR, Soares FAL, Cardoso JAF (2011) Sunflower production under saline stress and nitrogen fertilization. R Bras Ci Solo. 35: 929-937.

Novais RF, Neves JCL, Barros NF (1991) Ensaio Em Ambiente Controlado. In: Oliveira AJ (ed) Métodos de pesquisa em fertilidade do solo. Embrapa-SEA, Brasília.

Oliveira FA, Medeiros JF, Oliveira MKT, Souza AAT, Ferreira JA, Souza MS (2013) Interaction between water salinity and biostimulant in the cowpea plants. R Bras Eng Agr Amb. 17: 465-471.

Pivetta LG, Guimarães VF, Fioreze SL, Pivetta LA, Castoldi G (2012) Evaluation of sunflower hybrids and the relationship between productive and qualitative parameters. R Ci Agr. 43: 561-568.

Revell KT (2011) The Effect of fast pyrolysis biochar made from poultry litter on soil properties and plant growth. 2011. 83p. Thesis másters (Doctorate) - Virginia Tech, Blacksburg.

Rhoades JD, Kandiah A, Mashali AM (2000) Uso de águas salinas para produção agrícola. UFPB, Campina Grande.

Richards LA (1954) Diagnoses and improvement of saline and alkali soils. United States Salinity Laboratory, Washington.

Salih MNT (2013) Response of sunflower (*Helianthus annuus* L.) to phosphorus and nitrogen fertilization under rainfed conditions, Blue Nile State-Sudan. Helia. 36:101-110.

Sanvong C, Suppadit T (2013) The Characteristic of pelleted broiler litter biochar derived from pilot scale pyrolysis reactor and 200-liter-oil-drum kiln. J En Tech Pol. 3: 34-38.

Steiner C, Teixeira WG, Lehmann J, Nehls T, Macêdo JLV, Blum WEH, Zech W (2007) Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. Plant Soil. 291: 275-290.