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Growth Rates and Sunflower Production in Function of Fertilization with Biochar and NPK

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Abstract

The use of alternative sources such as biochar can contribute to sustainable agriculture. The objective of this study was to evaluate the effect of fertilization with biochar in combination with mineral fertilizer, growth rates and yield of sunflower cv. Embrapa 122/V2000. The experiment was carried out in a protected environment of UAEAg/CTRN/UFCG in pots with a capacity of 20 dm^3 under a completely randomized experimental design, with treatments arranged in a factorial scheme (5 × 4) and four replicates corresponding to five doses of mineral fertilization 0, 25%, 50%, 75%, and 100% of fertilization indication with NPK (100, 300, and 150 mg kg^{-1}) and four doses of biochar, 0; 5% (400 g/pot); 10% (800 g/pot) and 15% (1100 g/pot) calculated on the basis of the soil volume. Fertilization with biochar promoted an increase in sunflower growth rates in the evaluation periods. The combination of 50: 150: 75 mg kg^{-1} of NPK and 400 g/pot of biochar promotes higher production of sunflower (23.91 g/plant).

Keywords: biomass, fertilization, *Helianthus annuus* L.

1. Introduction

Sunflower (*Helianthus annuus* L.) is an important oilseed crops for Brazilian semiarid due to short duration, having ability to adapt wide range of climate and soil conditions providing a greater competitive advantage in relation to other crops such as soybean, for to yield higher yields in oil production per hectare (Zobiole et al., 2010). It is a very demanding crop from the nutritional point of view, and its response to fertilization is limited by the productive potential and by the nutrient export rate.

According to Prado and Leal (2006) the elements nitrogen (N), phosphorus (P) and potassium (K) are the most limiting growth and dry matter production of sunflower, and from this crop accumulates a total of 41 kg of N; 17.1 kg of P_2O_5 and 171 kg of K_2O to produce one ton of grain (Castro & Oliveira, 2005). However, according to Zobiole et al. (2010) about 90 to 95% of the amount of absorbed K can return to the soil with the mineralization of the cultural remains.

There are various factors responsible for obtaining the higher yield of sunflower such as fertilizing that improves the yield as well as quality of this crop. According to Campos et al. (2012), the fertilization with 60 kg ha^{-1} of N; 80 kg ha^{-1} of P_2O_5 and 80 kg ha^{-1} of K_2O provides the best quality of sunflower inflorescences cv. Embrapa 122/V2000. Among the new technologies that reduce environmental impact and improve agricultural production, the use of biochar, which according to Madari et al. (2012) is among the only available technologies that can contribute to the improvement or maintenance of soil properties and thus to the production of sustainable energy and food.

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 Lehmann (2007). Among the various sources used in the production of biochar, the use of chicken litter in Brazil is notable due to the high production generated per year; according to Corrêa and Miele (2011) is around 6.8 million m^3. Costa et al. (2009) point out that chicken litter is a viable alternative in agricultural use because it is available on rural properties at low cost.

Several studies have focused on the beneficial effects of biochar fertilization on the chemical, physical and biological properties of the soil, as well as on increasing biomass accumulation and crop productivity (Kookana et al., 2011; Thomas et al., 2013; Jien & Wang, 2013). Utomo et al. (2012) verified that the application of 15 t ha^{-1} of biochar reduced the need for application of nitrogen fertilizer by up to 43% to produce the same amount of maize dry matter; however, according to Steiner et al. (2007) greater efficiency when it is associated with mineral fertilization due to its low availability of nutrients.

In this sense, the analysis of plant growth is an essential mechanism in ecophysiological studies, because environmental factors such as water and nutrient availability affect the plant growth dynamics. Therefore, with the study of growth rates, it is possible to identify growth efficiency and the ability to adapt to environmental conditions. According to Peixoto et al. (2011), quantitative growth analysis is an accessible and accurate tool to evaluate plant development and the contribution of different physiological processes on its performance in the different soil and climatic conditions that are submitted. On the other hand, the study of production and production components becomes essential to understand the relationship between the factors limiting productivity, which are important variables, affected by nutrition and can help identify the point of maximum productive efficiency. Therefore, this study was set up to evaluate the effect of fertilization with poultry litter biochar in combination with mineral fertilizer under the rates of growth and production of sunflower cv. Embrapa 122/V2000.

2. Material and Methods

2.1 Experimental Site

The experiment was carried out from September to December 2014 under greenhouse conditions at the Agricultural Engineering Department of the Federal University of Campina Grande, Paraiba State, Brazil (7º13′11″ S; 35º53′31″ W).

2.2 Design and Treatments

The experiment was set in a 5 × 4 factorial, completely randomized design under five mineral fertilizing (NPK) doses and four poultry litter biochar doses, with four repetitions, total of 80 experimental units. The treatments of mineral fertilizing corresponded to 0, 25, 50, 75, and 100% of NPK (100:300:150 mg kg^{-1}) fertilization for testing in greenhouse as Novais et al. (1991) and four poultry litter biochar doses corresponded to 0%; 5% (400 g/pot); 10% (800 g/pot) and 15% (1100 g/pot), calculated based on the soil volume. NPK sources used were, respectively, urea, monoammonium phosphate (MAP) and potassium chloride (KCl), 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); KCl was applied at 30, 45 and 60 DAS and urea was applied to 50 DAS. The biochar was incorporated into the soil and allowed to incubate for a period of 20 days. Carried out also a foliar fertilizer at 40 DAS using Ubyfol® at a ratio of 0.5 kg of leaf fertilizer for 100 liters of water.

2.3 Biochar Analysis

The biochar was produced from conventional pyrolysis process using waste as chicken litter (450 °C × 0.5 hours × atmospheric pressure) having as chemical attributes, according to the methodology proposed by the Andrade & Abreu (2006): pH (H_2O) = 10.2; N = 31.8 g kg^{-1}; P = 29.4 g kg^{-1}; K = 47.16 g kg^{-1}; Ca = 48.3 g kg^{-1}; Mg = 14.6 g kg^{-1}; Na = 7.3 g kg^{-1}; Fe = 8479 mg kg^{-1}; Cu = 607 mg kg^{-1}; Zn = 1070 mg kg^{-1}; Mn = 650 mg kg^{-1}.

The salinity of the biochar was determined with the following empirical methodology: in a polyethylene tube 12.5 grams of bio-carbon was mixed with 125 mL of distilled water; then the mixture was passed on a buchner funnel coupled to the kitassate and fitted with cotton (replacing filter paper) in order to avoid the loss of biochar; the drained liquid was chemically analyzed having the following results: pH (H_2O) = 9.39; CE (dS m^{-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}.

2.4 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}; OM = 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}.

At the end of the experiment, salinity analysis was carried out in the experimental units to verify the effects of biochar on the chemical attributes of the soil used, using a methodology proposed by EMBRAPA (2011) (Table 1).

Table 1. Mean values of chemical attributes of soil cultivated with sunflower as a function of biochar doses

Attributes Saturation extract (mmol$_c$ L^{-1})	B_1	B_2	B_3	B_4
pH_{sp}	5.98	7.07	7.90	8.28
EC_{se} (dS m^{-1})	3.31	7.28	9.50	9.32
Chloride (Cl^-)	33.32	47.73	50.44	50.43
Carbonate (CO_3^{2-})	0.00	0.00	0.00	0.00
Bicarbonate (HCO_3^-)	2.44	2.95	5.36	7.09
Sulfate (SO_4^{2-})	P	P	P	P
Calcium (Ca^{2+})	7.04	7.63	3.82	3.97
Magnesium (Mg^{2+})	28.13	35.44	26.98	22.84
Sodium (Na^+)	16.98	31.03	37.01	34.71
Potassium (K^+)	4.23	24.11	44.00	51.66
SAR	4.05	6.69	9.43	9.48

Note. B_1 = 0; B_2 400 g/pot; B_3 = 800 g/pot; B_4 = 1100g/pot; pH_{sp}: pH of saturation paste; EC_{se}: Saturation extract electric conductivity; SAR: Sodium adsorption ratio.

2.5 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 days after sowing (DAS), seedlings were thinned to two and one plant per pot, respectively. The artificial cross-pollination was carried out when the plants reached the R5 stage (beginning of the anthesis), which consisted of using a brush with a good amount of pollen from several flowers produced by different plants, with a quick touch of form to reach all the stigmas. The plants were tutored when they reached the R6 stage (Flowering is complete and the ray flowers are wilting), which includes the end of flowering.

Irrigation was performed daily using rainwater. The applied water volume (*Wv*) was measured using the water consumption by the plants in 100% ETr, 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).

$$Wv = \frac{Pcc - Pa}{n} \quad (1)$$

With plant height and stem diameter data, evaluated at 30, 60 and 90 days after sowing the sunflower (DAS) were determined the Absolute Growth Rate and the Relative Growth Rate using the methodology proposed by Benincasa (2004), according to the equations described below:

For the absolute growth rate:

$$AGR = \frac{(A_2 - A_1)}{t_2 - t_1} \quad (\text{cm day}^{-1} \text{ or mm day}^{-1}) \quad (2)$$

For the relative growth rate:

$$RGR = \frac{(\ln A_2 - \ln A_1)}{t_2 - t_1} \quad (\text{cm cm}^{-1} \text{ day}^{-1} \text{ or mm mm}^{-1} \text{ day}^{-1}) \quad (3)$$

where, A_2 = height or diameter obtained at the end of the study period; A_1 = height or diameter obtained at the beginning of the study period; $t_2 - t_1$ = time difference between the samplings.

The production components were evaluated at the time of harvest, being: number of viable achenes (NVA); percentage of non-viable achenes (PNVA) - considering as non-viable achenes, the coarse grains; and production of achenes per plant (PROD).

2.6 Statistical Analysis

The experimental data were analyzed by ANOVA using F test. For significant data regression analysis were used with adjustment of the greatest determination coefficients ($p \le 0.05$). All analyses were performed using statistical software SISVAR (Ferreira, 2011). Due to the heterogeneity of the data, the transformation into $\sqrt{X}$ or $\sqrt{X}+1$ was necessary.

3. Results and Discussion

The biochar (B) in the experimental units significantly influenced the absolute and relative growth rates of sunflower plant height (AGR-PH and RGR-PH) in the evaluated periods from 30 to 60 DAS and 60 to 90 DAS, in addition, influenced to the absolute growth rate of stem diameter (AGR-SD) in the evaluated period from 30 to 60 DAS (Table 2). It is also observed the significant effect of fertilization with NPK (D) on the AGR-SD in the period from 30 to 60 DAS; however, there was no significant effect for interaction between the factors (D x B) for any variable analyzed. These results show that biomass increase as a function of time (growth rate) remained constant at all levels of fertilization. Ribeiro et al. (2016) did not observe a significant effect of nitrogen fertilization under sunflower growth rates. Corroborating, Furtado et al. (2014) did not find a significant effect of potassium fertilization under AGR-PH and RGR-PH in the evaluation period of 35-60 DAS.

Table 2. Summary of 'F' test for absolute and relative growth rate of plant height (AGR-PH and RGR-PH) and stem diameter (AGR-SD and RGR-SD) of sunflower in the evaluation periods performed between 30-60 and 60-90 days after sowing (DAS) as a function of doses of NPK and biochar

Growth Rate	Source of Variation	'F' Test			
		AGR-PH	AGR-SD	RGR-PH	RGR-SD
30-60 DAS	Doses (D)	ns	**	ns	ns
	Linear Regression	-	Ns	-	-
	Quadratic Regression	-	**	-	-
	Biochar (B)	**	*	*	-
	Linear Regression	**	*	*	-
	Quadratic Regression	ns	Ns	*	ns
	D × B	ns	Ns	ns	ns
	VC (%)	22.25	30.61	14.67	33.06
60-90 DAS		AGR-PH[1]	AGR-SD[1]	RGR-PH[1]	RGR-SD[1]
	Doses (D)	ns	Ns	ns	ns
	Biochar (B)	**	-	**	-
	Linear Regression	**	-	**	-
	Quadratic Regression	*	Ns	*	ns
	D × B	ns	Ns	ns	ns
	VC (%)	42.47	37.85	45.84	35.56

Note. (**), (*), (ns): ($p \leq 0.01$) and ($p \leq 0.05$) and not significant respectively; [1] Statistical analysis performed after data transformation in $\sqrt{X}$.

According to regression studies for AGR-SD as a function of NPK doses (Figure 1), the data were adjusted for the quadratic model; the highest value being obtained at a dose of 60% of the recommendation (0.1902 mm day^{-1}) and from that point there was a reduction of 8.41%. It is also seen that the increase provided with increasing NPK levels between 0 and 60% of the recommendation was 18.93%. According to Furtado et al. (2014), potassium fertilization promotes an increase in sunflower AGR-SD up to the dose of 100 mg kg^{-1} of soil in the evaluation period from 35 to 60 DAS. Maia Junior et al. (2013) verified, for the same cultivar, a mean AGR-SD of 0.0974 mm day^{-1} in the evaluation period of 20 to 80 DAS.

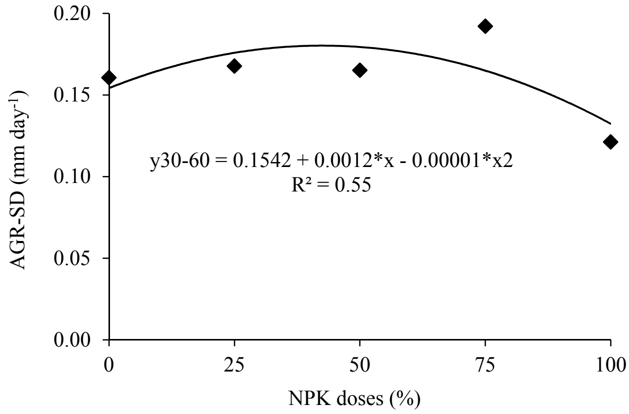

Figure 1. Absolute growth rate of stem diameter (AGR-SD) in the evaluation period performed between 30-60 days after sowing of sunflower (DAS) as a function of NPK doses (%)

The increase of the bichar doses promoted linear reduction of the AGR-PH of sunflower in the period from 30 to 60 DAS (Figure 2A). The lowest value of AGR-PH was 1.48 cm day^{-1} when the plants received fertilization with 1100 g/pot of biochar, corresponding to a decrease of 34.25% in relation to plants that were not fertilized with biochar (2.25 cm day^{-1}). These results are related to the effect of saline stress due to the application of biochar in the soil as verified in Table 1. Ribeiro et al. (2016) found a reduction on the sunflower growth rate in the period 31-45 DAS under conditions of salt stress. Maia Junior et al. (2013) working with cv. Embrapa 122/V2000, observed, on average, AGR-PH of 1.31 cm day^{-1} in the evaluation period of 20-80 DAS. The inhibition of the growth of plants under conditions of salt stress is due to the reduction of the osmotic potential of the soil solution to levels that make it impossible to absorb water and nutrients, together with the ionic toxicity due to the excess accumulation of certain ions in the tissues vegetables (Flowers, 2004).

The vegetative growth rates are variables used to determine plant growth at different stages of development and are dependent on the amount material of previously accumulated. These variables represent increase in height or mass, as a function of time (absolute growth) or growth per unit of time, expressed in a mass, area and length initial (relative growth) (Taiz & Zeiger, 2013). Because of this, through these variables, it is possible to determine the intensity of biotic or abiotic stress on plant growth.

Based on the regression studies for AGR-PH in the period from 60 to 90 DAS (Figure 2B), the model that best fit was the quadratic one indicating that the increase of the biochar dose up to 785.7 g/pot promoted an increase in the AGR-PH of 67.00% in relation to the plants that were not fertilized and from this point there was a decrease of 10.71% in relation to the highest dose; these results can be justified by the greater adaptation of the culture after 60 DAS. Corroborating, Ribeiro et al. (2016) found no significant effect of salt stress on sunflower growth rates in the 46-60 and 61-75 DAS assessment periods; these authors also point out that these results are related to permanent osmotic adjustment, which is a mechanism that allows halophyte plants to live in saline stress conditions.

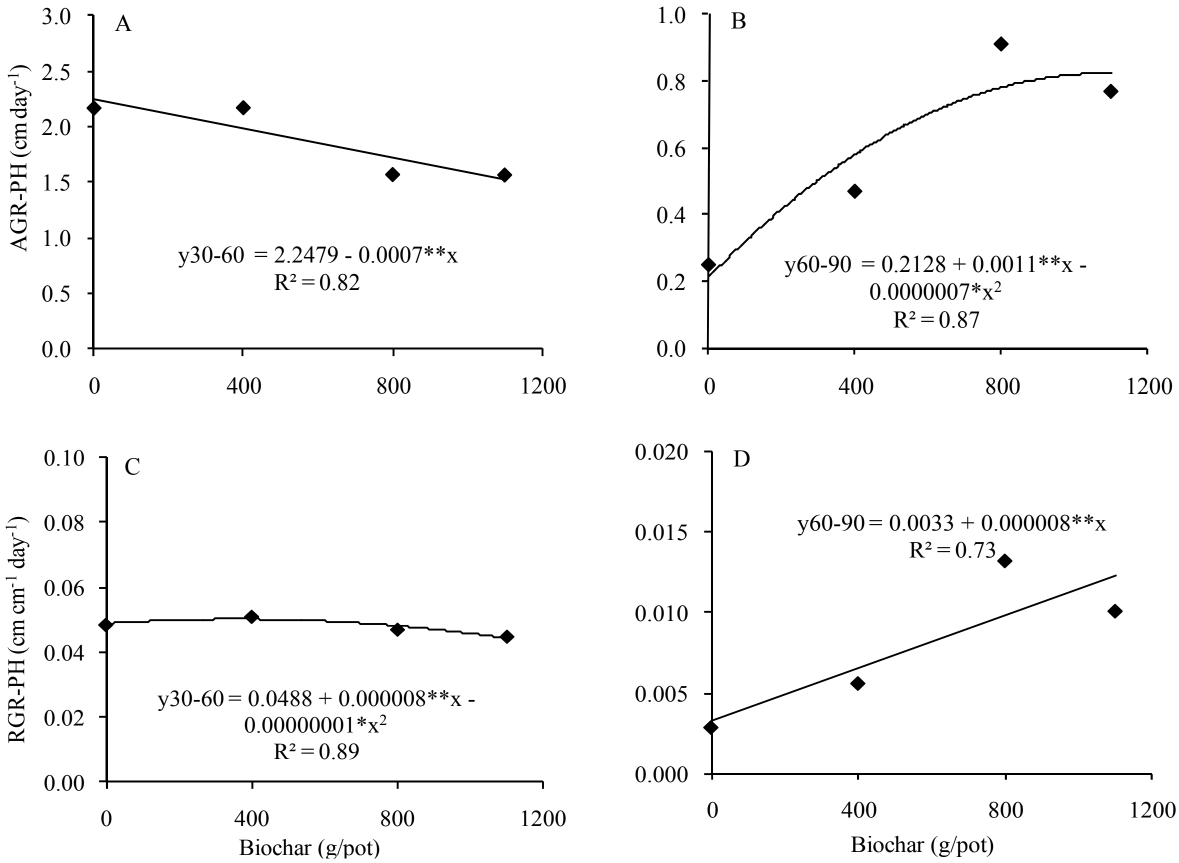

Figure 2. Absolute growth rate of plant height (AGR-PH) in the evaluation period between 30-60 (A) and 60-90 (B) days after sunflower seeding and relative growth rate of plant height (RGR-PH) at 30-60 (C) and 60-90 (D) days after sunflower seeding as a function of doses of biochar

According to regression equations, a quadratic effect is observed for RGR-PH of sunflower in the period from 30 to 60 DAS (Figure 2C), in which the dose of biochar from 400 g/pot led to a decrease of 9.72% in the RGR-PH; however, the RGR-PH in the period from 60 to 90 DAS increased linearly with the increment of the doses of biochar being the highest values obtained with the dose of 1100 g/pot (0.0121cm cm^{-1} day^{-1}), which promoted an increase of 72.73% in relation to the plants that did not receive fertilization with biochar (Figure 2D). Based on these results, it was observed that the RGR-PH followed the same trend observed for the AGR-PH (Figures 2A and 2B), noting that after 60 DAS there was possibly a greater adaptation of the culture to the stress conditions.

The application of increasing doses of NPK in the experimental units had a significant effect on the components of sunflower production (Table 3) corroborating Jahangir et al. (2006), which verified a significant effect of fertilization with N and P on the yield of sunflower grains. Biochar significantly affected the number of viable achenes (NVA) and production of achenes per plant (PROD). According to Suppadit et al. (2012) biochar had a significant effect on soy production components. There is also a significant effect of the interaction between the factors D × B for PROD (Table 3).

Table 3. Summary of the 'F' test for number of viable achenes (NVA), percentage of non-viable achenes (PNVA) and production of achenes per plant (PROD) as a function of NPK doses and biochar

Source of Variation	'F' Test		
	NVA	PNVA[1]	PROD
Doses (D)	**	**	**
Linear Regression	ns	**	ns
Quadratic Regression	**	Ns	**
Biochar (B)	**	Ns	**
Linear Regression	**	-	**
Quadratic Regression	*	-	**
D × B	ns	Ns	*
VC (%)	16.74	36.75	28.79

Note. (**), (*), (ns): ($p \leq 0.01$) and ($p \leq 0.05$) and not significant respectively; [1] Statistical analysis performed after data transformation in $\sqrt{X} + 1$.

According to the regression equation (Figure 3A), NPK doses had a quadratic effect on the number of viable achenes of the sunflower (NVA), indicating that the dose increase up to 54.48% (374 units) of the NPK recommendation promoted an increase of 41.95% in relation to the lowest dose. It is also observed that from this point, there was a reduction of 29.25% in relation to the plants that received 100% (N: P: K, 100: 300: 150 g/pot) of the recommendation. The fertilization around 50% of the NPK recommendation promoted higher NVA, which is justified by the adequate availability of nutrients, especially in the flowering stage (Stage R1).

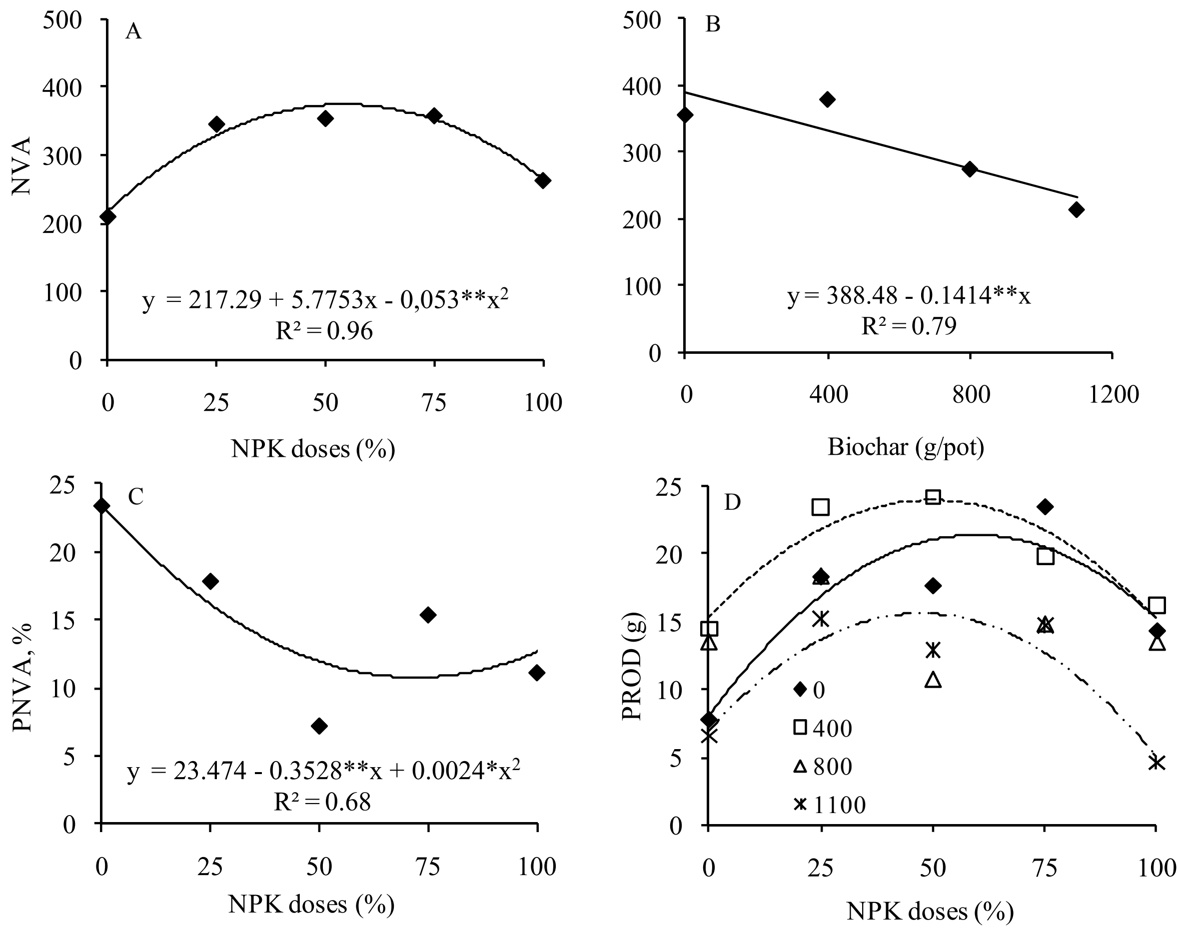

Figure 3. Number of viable achenes - NVA as a function of doses of NPK -% (A) and biochar - g/pot (B); percentage of non-viable achenes - PNVA as a function of NPK doses -% (C); split of the interaction between the factors for production of achenes per plant - PROD (D)

Biochar fertilization reduced linearly the NVA of the sunflower (Figure 3B); the lowest value was observed with the dose of 1100 g/pot (233 units), which corresponded to a reduction of 40.03% with reference to the plants that were not fertilized with biochar (388 units). Again, the effect of increasing soil salinity from fertilization with biochar is observed. The increase of the excess soluble salts in the soil promotes an increase in the osmotic potential and a reduction of the water potential, reducing the photosynthetic rate and, consequently, the production of photoassimilates to the reproductive organs. Santos Junior et al. (2011a) verified a linear reduction of the NVA with the increase of the electric conductivity (EC) of the irrigation water and obtained, on average, 300 units at the level of 4.3 dS m^{-1}. Corroborating Centeno et al. (2014) verified a linear reduction of the percentage of viable achenes with the increment of the EC of the irrigation water.

The results of the PNVA as a function of the NPK doses were better adjusted to the decreasing quadratic model, indicating that the increase of the fertilization up to the 73.5% dose of the recommendation promoted reduction of the PNVA of 55.23% in relation to the lowest dose and from this point there is an increase of 13.78% in relation to the dose of 100% of the recommendation (Figure 3C). These results are justified by the greater nutritional availability close to the 50% dose of the recommendation. The PNVA ranged from 10.51% to 23.47%, however, these values are lower than those reported by Santos Júnior et al. (2011b) which obtained a change from 21.70% to 35.81%. According to Garcia et al. (2010), progressive saline stress may induce ionic toxicity and/or nutritional imbalance due to the excessive accumulation of ions in the cellular protoplasm, and may cause cellular injury through oxidative stress, which may result in a decrease in the number of achenes, mass of achenes and, consequently, greater number of pimples. It is also verified that the PNVA presented an opposite tendency to the behavior of the NVA (Figure 3A), which shows consistency between the results, that is, as there is an increase in NVA there is reduction of the PNVA, a fact that is justified seen that the estimated maximum doses were close.

The production of achenes per plant (PROD) as a function of increasing doses of NPK, submitted to fertilization with 0, 400, and 1100 g/pot of biochar, increased up to the dose of 59.17% (21.29 g/plant), 49.60% (23.91 g/plant) and 48.06% (15.68 g/plant) of the recommendation respectively, that is, the highest yields were close to the 50% dose of the NPK recommendation. The lowest values were estimated for the 100% (100:300:150 mg kg^{-1}) of the NPK recommendation and the dosage of 800 g/pot of biochar there is no significant effect on the PROD, reaching an average value of 14.21 g/plant (Figure 3D and Table 4). According to Yasin et al. (2013) the mass of achenes expresses the degree of development of the grain and plays a fundamental role in the evaluation of the potential yield of a crop. According to Banerjee et al. (2014) the combination of 100: 50: 50 kg ha^{-1} of NPK promoted higher yield of sunflower achenes (1465.15 kg ha^{-1}). For Jahangir et al. (2006) the combination of 120 kg ha^{-1} of N and 75 kg ha^{-1} of P_2O_5 promoted higher yields of achenes (2,001 kg ha^{-1}); however, Ali & Noorka (2013) observed better yield of sunflower with the combination of 135 and 75 kg ha^{-1} of N and P (2,584 kg ha^{-1}).

Table 4. Regression equations for the production of achenes by sunflower plant as a function of doses of NPK and Biochar

	Production per Plant (g)		
Biochar (g/pot)	Equation	R^2	Mean
0	$Y = 7.9742 + 0.4497^{*}x - 0.0038^{**}x^2$	0.82	16.34
400	$Y = 15.308 + 0.3472x - 0.0035^{**}x^2$	0.89	19.62
1100	$Y = 6.9056 + 0.3653x - 0.0038^{**}x^2$	0.86	10.80

Note. (**), (*) significant at ($p \leq 0.01$) and ($p \leq 0.05$); Y = production of achenes per plant (g/plant); x = doses of NPK (%).

It is observed that, although the fertilization with biochar reduced NVA values (Figure 3B), the dose of 400 g/pot (19.62 g/plant) promoted an increase in the PROD of 16.72% in relation to the plants which were not fertilized with biochar (16.34 g/plant). According to Suppadit et al. (2012) the application of 98.6 g/pot of biochar promoted a higher yield of soybean seeds. According to Tagoe et al. (2008) the combination of 11.4 g/pot of biochar with 410 mg kg^{-1} of K increased the yield of soybeans and cowpea, respectively, of 53 and 185% in relation to the control (without fertilization). It was also observed that the dose of 1100 g/pot (10.80 g/plant) promoted a reduction of 44.95% in the PROD in relation to the dose of 400 g/pot, probably due to excess salts in the soil.

Saline stress promotes metabolic disturbances in plants, affecting their physiology, promoting a reduction in the absorption of water and soil nutrients, mainly due to the reduction of the leaf area, implying a lower photosynthetic surface and, consequently, lower crop yield (Lima et al., 2014). Nobre et al. (2011) observed a linear reduction of the PROD with the increment of the EC of the irrigation water, obtaining 17.4 g/plant when the plants were irrigated with higher levels of EC. Centeno et al. (2014) also observed similar results.

4. Conclusions

Biochar fertilization promoted an increase in sunflower growth rates in the evaluation periods.

The fertilization with 400 g/pot of biochar promoted a 16.72% increase in the production of achenes per plant.

The combination of 50: 150: 75 mg kg^{-1} of NPK and 400 g/pot of biochar promoted higher sunflower yield (23.91 g/plant).

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