Growth and Development of Bell Peppers Submitted to Fertilization with Biochar and Nitrogen

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Abstract

The experiment was carried out in the greenhouse of the DEAg/UFCG, Campina Grande (PB), Brazil, to evaluate the growth and development of the bell pepper subjected to fertilization with biochar and nitrogen. The experiment was conducted in pots under greenhouse conditions. Treatments were arranged in a completely randomized design, in 4 × 4 factorial scheme, relative to four doses of biochar (0; 7; 14 and 21 $m^3 \cdot ha^{-1}$) and four doses of nitrogen (0; 40; 80 and 120 $kg \cdot ha^{-1}$), with three replicates. Considering the analysis of growth of bell pepper plants during the first 45 DAS, is recommended the average dose of biochar of 19 $m^3 \cdot ha^{-1}$ on vegetable behavior. Under the conditions of the experiment, nitrogen favored only the absolute growth rate of plant height and the stem diameter.

Keywords

Capsicum annuum L., Mineral Fertilizer, Poultry Litter

1. Introduction

Biochar, a carbon rich product, is obtained by heating an organic biomass in a closed system with limited oxygen supply, *i.e.* obtained by pyrolysis, a thermal decomposition process, between 400˚C and 800˚C. Its structural and chemical composition depends on a combination of the type of raw material and the pyrolysis conditions used.

The presence of the mixed biochar with soil influences the physical properties of the same; increases the cation exchange capacity by adsorbing metal ions nutrients from plants, such as calcium, iron, copper, or toxic to them; influence on soil reaction; provides nutrients to the soil and, consequently, influences nutrient uptake by plants [1], among several functions.

Studying the influence of biochar produced from wood residues [2], eucalyptus [3], olive trees and wheat straw [4], rice straw [5], wood chips [6], papermill waste [7] and poultry litter [8] for soil fertility, these authors observed, in general, an increase in the availability of calcium, magnesium, potassium and phosphorus; increased pH and the total organic carbon of the soils [9], reducing the exchangeable acidity of the soils.

Some authors have reported that the use of biochar in agriculture has a significant result in productivity gains. According to Peter *et al.* (2012) [3] [4] [7] and [10], the eucalyptus biochar, wheat straw and olive pruning residues biochar, papermill waste biochar, and wheat straw biochar had a significant effect on rice; wheat grain; wheat, soybean and horseradish; and corn yield, respectively. In spite of all the benefits associated with the addition of biochar in the soil, studies on the effect of poultry litter biochar in bell pepper crop development are scarce.

Bell pepper (*Capsicum annuum* L.), belonging to the solanaceous family, is considered one of the most cultivated vegetables in Brazil [11] occupying among the ten most important vegetables on the market, both in value and volume sold. This vegetable can be consumed in the form of green fruits, mature and industrialized in powder form [12]. It is a very demanding plant with respect to the chemical and physical characteristics of the soil, with a good response to organic fertilization. The highest yields are obtained through the combination of organic fertilizers and minerals [13].

According to Marcussi *et al.* (2004) [14], mineral nutrition is essential to increase productivity and improve the quality of the harvested bell peppers, and play important roles in plant metabolism. Among the macronutrients, nitrogen is the second most demanded by vegetables [15] and is considered one of the most limiting nutrients for the bell pepper crop, because it influences the physiological processes that occur in plants and fruit production.

According to the above, the present study had as objective to evaluate the growth and development of the bell pepper submitted to the fertilization with poultry litter biochar and nitrogen.

2. Materials and Methods

The experiment was carried out in the period from August to November 2018, in greenhouse (a structure covered and sheltered artificially with transparent materials to protect the plants against the external meteorological agents) at the Agricultural Engineering Department of the Federal University of Campina Grande, Campina Grande, PB, Brazil (7˚12'52"S; 35˚54'24"W and mean altitude of 550 m), using soil samples collected in the 0 - 20 cm layer in the municipality of LagoaSeca-PB. After collection, the composite sample was air-dried, passed through a 2-mm-mesh sieve and characterized according to [16] for the following physical attributes: clay = 158.5 $g \cdot kg^{-1}$, silt = 120.7 $g \cdot kg^{-1}$ and sand = 720.8 $g \cdot kg^{-1}$, and chemical attributes: pH = 5.75; EC = 0.16 $dS \cdot m^{-1}$; Ca = 1.56 $cmol_c \cdot kg^{-1}$; Mg = 1.18 $cmol_c \cdot kg^{-1}$; Na = 0.06 $cmol_c \cdot kg^{-1}$; K = 0.26 $cmol_c \cdot kg^{-1}$; H = 1.27 $cmol_c \cdot kg^{-1}$; P = 4.9 $mg \cdot kg^{-1}$; OM = 14.8 $g \cdot kg^{-1}$.

The biochar used in the experiment was produced using poultry litter, a solid waste resulting from chicken rearing, under slow pyrolysis, and had the following composition: Nitrogen = 3.45%; P_2O_5 = 7.78%; K_2O = 4.90%; Calcium = 6.83%; Magnesium = 1.34%; Sulfur = 0.76%; Iron = 0.46%; Manganese = 0.09%; Copper = 0.04%; Zinc = 0.08%; Boron = 0.01%; pH = 9.45; Carbon/nitrogen ratio = 11.53%; Organic carbon = 39.77%; Organic matter = 68.56% and CEC = 388.90 $mmol_c/kg$.

The experimental design was completely randomized in a 4 × 4 factorial scheme, composed of four doses of nitrogen (N) (0, 40, 80 and 120 $kg \cdot ha^{-1}$) and four doses of biochar (0, 7, 14 and 21 $m^3 \cdot ha^{-1}$), with three replicates, totaling 48 experimental units. These doses were defined based on the recommendations of N fertilization and organic matter (bovine manure, 20 $m^3 \cdot ha^{-1}$) for the bell pepper crop [17].

Each experimental unit consisted of one 8 dm^3 polyethylene pot, covered with 6.0 kg of soil material. After filling, biochar was incorporated in each experimental unit in the upper part of the soil material and the mixture was irrigated until reaching moisture content corresponding to 80% field capacity, for the experimental units to remain incubated for 8 days.

Bell pepper seedlings, IKEDA cultivar, were prepared on a plastic tray, using a commercial substrate, where 3 seeds were planted in each tray cell; at 28 days after sowing (DAS), the seedlings were transplanted to the pots and thinning was carried out 8 days after transplanting, leaving only one plant per pot. Plants were daily irrigated with the water volumes required to reach 80% soil field capacity. Bell pepper plants were staked until the end of the cycle to assist in their support.

After thinning, the experimental units were fertilized with 120 $kg \cdot ha^{-1}$ of phosphorus (46 mg/pot), 70 $kg \cdot ha^{-1}$ of potassium (26.8 mg/pot), 40, 80 and 120 $kg \cdot ha^{-1}$ of nitrogen (16.7; 33.3 and 50 mg/pot, respectively), using monoammonium phosphate, potassium chloride and urea as sources. In order to meet the requirements of micronutrients, plants were sprayed at 30, 45 and 60 DAS, with a solution (2.5 $g \cdot L^{-1}$) with the following composition: N (15%); P_2O_5 (15%); K_2O (15%); Ca (1%); Mg (1.4%); S (2.7%); Zn (0.5%); B (0.05%); Fe (0.5%); Mn (0.05%); Cu (0.5%); Mo (0.02%).

At 30 and 45 days after transplanting (DAT) the heights (cm) and shoot diameter (mm) of the plants were measured from the lap of the plant to the insertion of the apical meristem (AP), and the mediation at 2 cm from the lap of the plant (DC), respectively.

The number of leaves (NF) was obtained by counting totally expanded leaves with a minimum length of 3 cm in each plant and the leaf area (AF) (cm^2) was determined, according to [18], using Equation (1):

$$LA = 0.60 \times W \times L \quad (1)$$

where: LA—leaf area (cm^2); 0.60 = Correlation coefficient; W = Sheet width (cm); L—Sheet length (cm).

With the growth data, absolute growth rates (AGR) were calculated for all variables analyzed, following the methodology proposed by [19]. The collected data were subjected to analysis of variance by F test at 0.05 and 0.01 probability levels. When significant, linear and quadratic polynomial regression analysis was carried out using the statistical program SISVAR [20]. Growth rate values were transformed (√ (X + 1)).

3. Results and Discussion

Biochar doses significantly influenced all variables studied, while N doses significantly affected ($p < 0.01$) only the absolute growth rate of plant height (AGRPH) and stem diameter (SD). However, the interaction between these factors did not significantly influence ($p < 0.01$) any of the variables (**Table 1**) disagreeing with [21]. These authors observed that the application of nitrogen associated with biochar, produced from agricultural residues (pruning, grass and cotton), increased productivity in radish (*Raphanussativus*) dry mass of 266% compared to the control treatment (application only with biochar).

The plant height data as a function of the biochar doses (**Figure 1(a)**) were adjusted to the quadratic equation, reaching the maximum height of 33.62 cm with the 11.68 m^3·ha^{-1} dose of biochar. This result may be related to the increase of the macronutrients liberated by biochar to the soil, favoring the growth of the plants corroborating [22]. These authors, analyzing the effects of the biochar in the soil, observed a significant increase in the levels of phosphorus, potassium and magnesium.

It is interesting to observe that the increasing doses of the biochar increased the pH of the soil samples from 5.5 to 6.5, probably by providing the chemical elements of the soil, thus favoring plant nutrition.

The absolute growth rate (**Figure 1(b)**) for plant height showed a linear decreasing effect, that is, the increase of the biochar doses caused a reduction of 0.1057 cm^{-1} for each increment of 7 m^3·ha^{-1} of biochar. This behavior may be directly associated with the increase in the electrical conductivity of the soil, which varied from 5.5 to 6.5, since, according to [23], the application of biochar elevates the soil EC and, according to [24], the bell pepper culture is sensitive to salinity.

Similar to the behavior of plant height data, the stem diameter data were adjusted to the quadratic equation (**Figure 1(c)**) with the largest stem diameter of 7.6 mm in 18.32 m^3·ha^{-1} dose of biochar at 45 DAS.

In relation to the absolute growth rate of stem diameter (**Figure 1(d)**), there was an increasing linear behavior, with a standard rate of 0.0035 mm·dia^{-1} for each 7 m^3·ha^{-1} of biochar increment, reaching a total in an average value of 0.0394 mm·dia^{-1} in the highest biochar dose, that is, 21 m^3·ha^{-1}.

Table 1. Summary of P value for plant height (PH), stem diameter (SD), number of leaves (NL), leaf area (LA), absolute growth rates of plant height (AGR_{PH}), stem diameter (AGR_{SD}), number of leaves (AGR_{NL}) and leaf area (AGR_{LA}) of bell pepper subjected to increasing levels of fertilization with biochar and nitrogen.

Source of variation	P value							
	PH	$AGR^*_{PH30-45}$	SD	$AGR^*_{SD30-45}$	NL	$AGR^*_{NL30-45}$	LA	$AGR^*_{LA\ 30-45}$
Biochar (B)	0.0178	0.011	0.00	0.0009	0.000	0.0008	0.000	0.0005
Linear Regression	0.272	0.003	0.00	0.001	0.000	0.000	0.000	0.000
Quadratic Regression	0.006	0.732	0.001	0.820	0.060	0.189	0.032	0.314
Nitrogen (N)	0.5471	0.021	0.004	0.3147	0.4693	0.1590	0.439	0.474
Linear Regression	0.496	0.089	0.000	0.111	0.145	0.028	0.131	0.131
Quadratic Regression	0.458	0.015	0.640	0.471	0.607	0.708	0.670	0.965
Interaction (B × N)	0.5206	0.315	0.869	0.8631	0.5559	0.3052	0.786	0.664
CV (%)	11.20	8.78	7.54	1.72	18.18	9.50	18.64	16.00

*Growth rate values were transformed (√ (X + 1)).

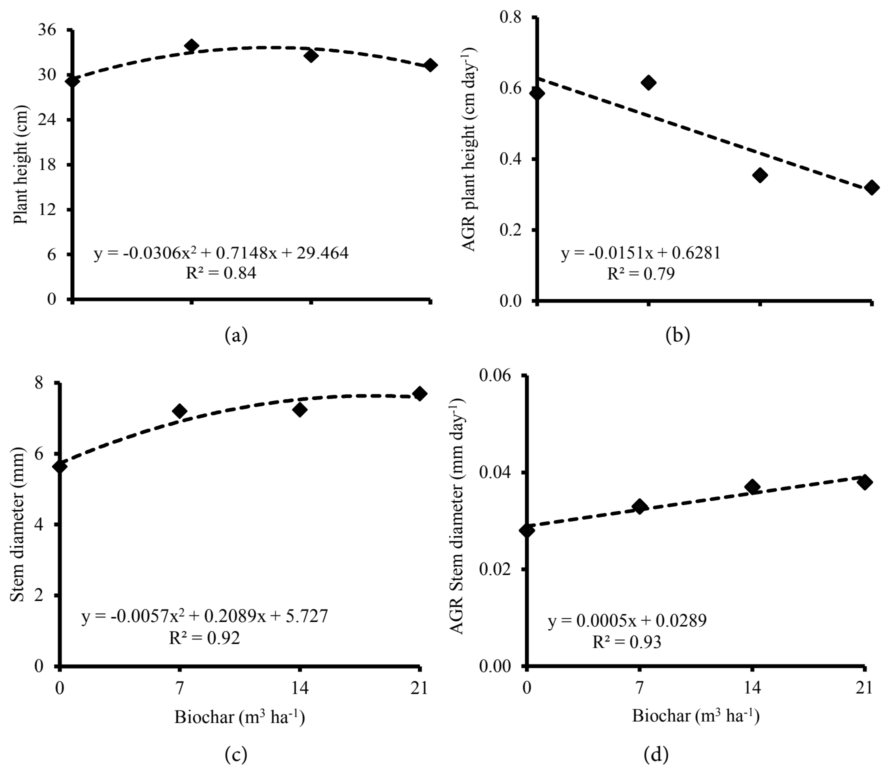

Figure 1. Plant height (a), absolute growth rates of plant height (AGR_{PH}) (b), stem diameter (c) and absolute growth rates of stem diameter (AGR_{SD}) (d) of bell pepper as a function of the biochar.

When analyzing the number of leaves (Figure 2(a)) regarding the influence of biochar, a behavior with quadratic regression, with a maximum of 38.04 leaves, was observed at a dose of 19.48 $m^3 \cdot ha^{-1}$. These results were lower than those

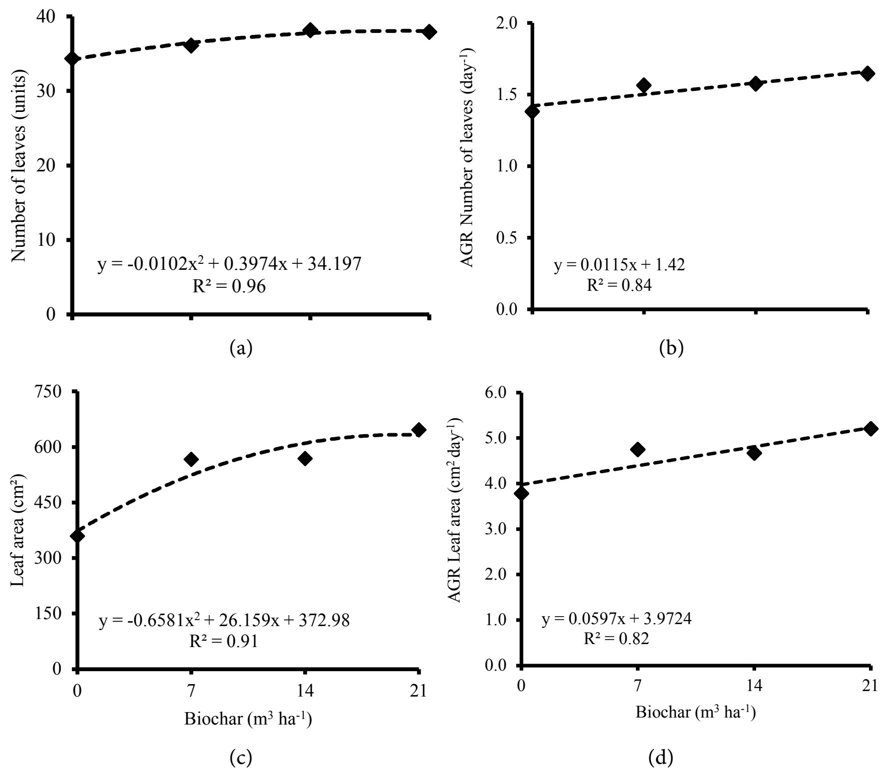

Figure 2. Number of leaves (a), absolute growth of number rates of leaves (AGR_{NL}) (b), leaf area (c) and absolute growth rates of leaf area (AGR_{LA}) (d) of bell pepper as a function of biochar.

found by [25] that, working with different soils and saline levels of irrigation water, found values of 41.67 leaves per plant for the lowest salt level (0.5 $dS \cdot m^{-1}$). However, with the highest saline level (5.0 $dS \cdot m^{-1}$), these authors found 31.08 leaves per plant, that is, lower values than those observed in the present study.

Similarly, with increasing doses of biochar, the TCA for the number of leaves (**Figure 2(b)**) also increased, however, in an increasing linear fashion with the highest value of 1.66 leaves per·day^{-1} at the dose of 21 $m^3 \cdot ha^{-1}$.

The mean values of leaf area as a function of the increasing doses of biochar were presented in **Figure 2(c)**. It was verified that the data were adjusted to quadratic regression, being possible to find the maximum point in the dose of 19.87 $m^3 \cdot ha^{-1}$ of biochar, with an area of 632.1 cm^2. This result, similarly to the previous results, that is, increase of the studied variables as a function of increasing doses of biochar, may be associated to the increase of the macronutrient content released by the biochar in the soil, and/or these nutrients are available from the soil increasing the pH, favoring the growth of the plants. The soil pH ranged from 5.46 to 6.47 according to increasing biochar doses corroborating [8] who observed that pH of the soils Argisol, Oxisol and Entisol increased significantly with the increase of rates of application of biochar in these soils.

The same was observed in the absolute growth rate of the leaf area, which showed an increase of 0.42 $cm^2 \cdot day^{-1}$ with the increase of 7 $m^3 \cdot ha^{-1}$ of biochar, reaching, with 21 $m^3 \cdot ha^{-1}$, the highest absolute growth rate of the leaf area corresponding to 5.23 $cm^2 \cdot day^{-1}$.

The results observed in this research evidenced a good development of the culture in the presence of biochar, contrary to [23]. These authors evaluated the bean crop fertilized with biochar with and without NPK, observed that the biochar was ineffective in supplying the missing macronutrients and, consequently, did not favor the development of the plants.

According to **Table 1**, the application of nitrogen to the soil significantly influenced only the absolute growth rate of plant height and stem diameter. The other analyzed variables were not influenced by the increasing doses of nitrogen, for example, the leaf area, contrary to the results found by [26]. These authors, using cow urine as a source of nitrogen, observed a growing leaf area as a function of increasing doses, evidencing a positive effect of this nutrient on the bell pepper crop.

Nitrogen is the most important nutrient for the bell pepper crop, because influencing the cellular differentiation, besides other physiological processes, stimulates the vegetative growth of the plants [27]. This fact can be verified in the present study, since N influenced positively the absolute growth rate of plant height from 48.33 $kg \cdot ha^{-1}$ of N (**Figure 3(a)**). These data were adjusted to quadratic regression, with maximum point of 0.65 $cm \cdot day^{-1}$ using 120 $kg \cdot ha^{-1}$ of N. In general, the use of the absolute growth rate becomes a precise measure between two successive samplings and may be an indicator of the average growth rate ($g \cdot day^{-1}$ or $g \cdot week^{-1}$) over the period evaluated [19].

When analyzing the diameter of the stem (**Figure 3(b)**) fertilized with increasing doses of N, an increasing linear behavior was observed, increasing 0.0476 mm between the dosages, reaching 7.34 mm with 120 $kg \cdot ha^{-1}$ of N. When compared to the zero dose, there was a growth of 12.5% in stem diameter. However, Lorenzoni *et al.* (2015) [28] observed quadratic behavior of stem diameter as a function of increasing doses of nitrogen, with 120 $kg \cdot ha^{-1}$ of N providing a diameter of around 11.78 mm.

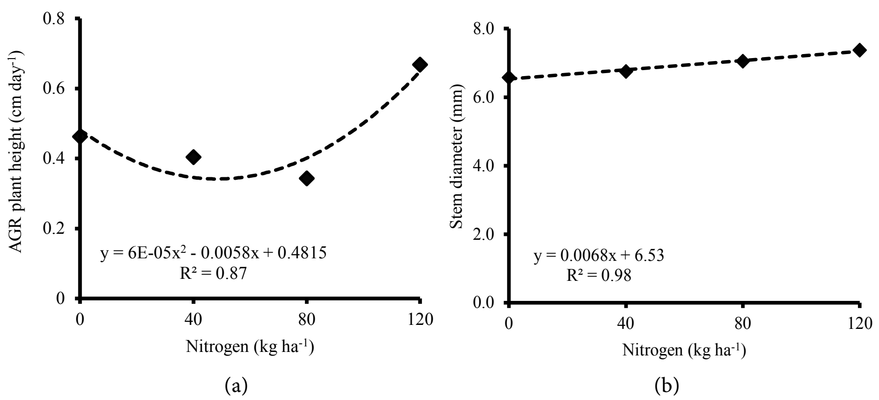

Figure 3. Absolute growth rate of plant height (AGR_{PH}) (a) and stem diameter (SD) (b) of bell pepper as a function of increasing doses of nitrogen.

4. Conclusions

The results showed that the addition of poultry litter biochar alone had a positive effect on some growth parameters.

Considering the analysis of growth of bell pepper plants during the first 45 DAS, is recommended the average dose of biochar of 19 $m^3 \cdot ha^{-1}$ on vegetable behavior.

Under the conditions of the experiment, there was not a significant poultry litter biochar × nitrogen fertilization interaction; thus, nitrogen favored only the absolute growth rate of plant height and the stem diameter.

The biochar produced by poultry litter pyrolysis is important, because it is a management option for waste materials, guaranteeing agricultural benefits.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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