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Wood ash as corrective of soil pH and as fertilizer in ornamental sunflower cultivation

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Wood ash, as having required nutrients by plants, can be an alternative in fertilization and soil acidity correction in agricultural crops. This study aimed to evaluate the development of the sunflower ornamental cultivar (*Helianthus annuus* L.) Sunflower F1 Sunbright Supreme when subjected to wood ash fertilization into of Cerrado Oxisol. The experiment was conducted in a greenhouse, in the municipality of Rondonópolis-MT, with six treatments (0, 4, 8, 12, 16 and 20 g dm^{-3} of wood ash) and six repetitions. The soil sample was collected from 0 to 0.20 m depth. Data were collected at 30, 37, 44 and 51 days after sowing on plant height, stem diameter, leaf number and chlorophyll index. Chapter diameter and height and disc diameter variables were assessed at 44 and 51 days after sowing, respectively. Data were subjected to analysis of variance and regression test at 5% probability through the SISVAR statistical program. Wood ash enhanced ornamental sunflower plant growth at doses between 12 and 16 g dm^{-3}, satisfying the commercial standards required by the flower market.

Key words: Oxisol, agriculture solid waste, *Helianthus annuus* L.

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is a plant from the southwestern part of Mexico. This species was introduced in Europe in the fourteenth century as cultivated plant, and after in America in the nineteenth century. Its utilization as an ornamental plant is intended for flowers production, a practice that has grown in the Central-South region of Brazil (Neves et al., 2005).

Floriculture practice generally comprises ornamental plant cultivation, as well as cuts cultivation and large-sized tree seedling production (Kiyuna et al., 2004). One of the options that add most value to the industry is potted plant sale, such as the ornamental sunflower, which has potential for confined spaces cultivation and has short cycle, without handling difficulties (Braga, 2009). As Cerrado soils usually have high acidity and natural fertility limitations, especially in relation to low pH, high exchangeable aluminum content and low nutrient content, especially phosphorus, it is necessary to correct these growth limits in order to have satisfactory productions (Santana, 2009). As an alternative to reduce fertilizer costs, agro-industrial by-products, use were found, such as wood ash, as it consequently reduces the

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Table 1. Soil chemical and particle size properties.

pH		P	K	Ca+Mg	Ca	Mg	Al	H	M.O	Sand	Silt	Clay
H_2O	$CaCl_2$	mg dm^{-3}		-------------cmol$_c$ dm^{-3}-------------					g dm^{-3}	----------g Kg^{-1}-----------		
4.7	4.0	1.7	24	0.4	0.2	0.2	0.8	4.4	20.6	507	116	377

Table 2. Wood ash chemical content.

pH(H_2O)	N	P_2O_5 Total	K_2O	Zn	Cu	Mn	B	Ca	S	Fe
	------CNA+H_2O------									
	------g Kg^{-1}------									
11.8	2.5	48.5	16.6	0.13	0.0	0.5	0.2	37.5	2.8	15.3

need for commercial fertilizer use, thereby contributing to soil acidification reduction and increasing calcium supply (Zimmermann and Frey, 2002; Souza et al., 2013).

Waste use, such as wood ash from power generation, industrial boilers burning, is a standard practice that helps minimize environmental impacts and mineral fertilizer acquisition and application costs (Bonfim-Silva et al., 2011a). Wood ash, when applied to the soil, reduces acidity and increases base saturation, which is useful as a corrective of soil pH (Maeda et al., 2008). Furthermore, when used as a fertilizer, wood ash that contains phosphorus, potassium, calcium and magnesium minerals, in addition to other nutrients that influence the development and favor plant cultivation, resulting in significant productivity gains (Moro and Gonçalves, 1995; Bonfim-Silva et al., 2014; Santos et al., 2014).

In this context, having a great potential use in agricultural, wood ash plays an important role in fertilization and management practices of low fertility soils (Bonfim-Silva et al., 2013) in order to reduce chemical fertilizers cost in flowers production (Pereira, 2014). Thus, the aim of the present study was to assess the influence of wood ash fertilization on ornamental sunflower plant development in Cerrado Oxisol.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse from April to July 2014 in the Federal University of Mato Grosso, Rondonópolis Campus, located at 16°28'15" South latitude, 54°38'08" west longitude and 290 meters altitude. The experimental design was randomized blocks, with six wood ash doses (0, 4, 8, 12, 16 and 20 g dm^{-3}) and six repetitions. The soil used in the experiment, Oxisol (Embrapa, 2013), was collected in Cerrado area vegetation in the 0 to 0.20 m depth. The soil was then sieved with a 4 mm mesh and used to fill the pots.

A sub-sample of this soil was sieved on a grid of 4 mm and the particle size and chemical content were determined according to the EMBRAPA (1997) (Table 1). The wood ash was obtained from eucalyptus wood (*Eucalyptus* spp.) used in food industry burning boiler (Table 2) and was characterized as fertilizer according to Darolt et al. (1993).

The wood ash was mixed with the soil and all was incubated for 30 days in plastic pots of 1.3 dm^3 volume and kept at 70% of soil maximum water holding capacity, according to the method described in Bonfim-Silva et al. (2011b). 20 mg dm^{-3} of nitrogen at sowing and 80 mg dm^{-3} of nitrogen 20 days after sowing was applied as urea solution. Three seeds of Sunflower F1 Sunbright Supreme cultivar ornamental sunflower (*H. annuus* L.) were sown per pot, and thinning was carried out 15 days after sowing, leaving one plant per pot.

Data were collected on plant height, stem diameter, leaf number and chlorophyll index at 30, 37, 44 and 51 days after sowing. For the chapter diameter, and height and diameter of the disc, two growth assessments were made at 44 and 51 days after sowing, respectively. The soil pH (H_2O) was determined after 30 days of incubation, with the removal of 1cm^3 of soil from each pot. Each sample was stored in plastic glasses of 100 ml. 25 ml of water was added, and it was left for 60 min, afterwards, the reading of each sample was performed.

Plant height (cm) was measured using a ruler graduated in centimeters, from soil surface to the plant apex distance, or up to inflorescence insertion point as present in Figure 1A. The stem diameter (cm) was measured with a digital caliper in the middle third of the main stem (Figure 1B). The determination of leaf number per plant was done by counting all leaves produced by the plants during the experiment.

Root, stem, leaf and chapter dry matter (g $plant^{-1}$) were determined at 51 days after sowing. The shoot was separated into stem, leaves and chapter, and roots were washed under running water. After dry matter weighing, parts were separated and placed in paper bags and taken to an oven with forced air circulation at 65°C, up to constant weight. When achieving constant mass, shoot and roots were weighed in analytical balance, in order to determine the dry weight. Chapter height (cm) was measured with the aid of a ruler graduated in centimeters, from soil surface to the plant apex distance (Figure 2B).

Disc and chapter diameter (cm) were measured with a ruler graduated in centimeters. Floral chapter diameter was obtained by measuring the inflorescences diameter when they were fully formed. Disc diameter was measured when the chapter was completely formed (Figure 2A). Leaves Falker's chlorophyll index (chlorophyll content indirect determination) was assessed using an electronic meter (ClorofiLOG - CFL 1030®). The measurement was made on three plant middle third leaves (Figure 3).

Data were subjected to analysis of variance and regression test at 5% probability with the SISVAR statistical program (Ferreira, 2011). The wood ash doses that provided the maximum values for the variables that adjusted the quadratic regression model were

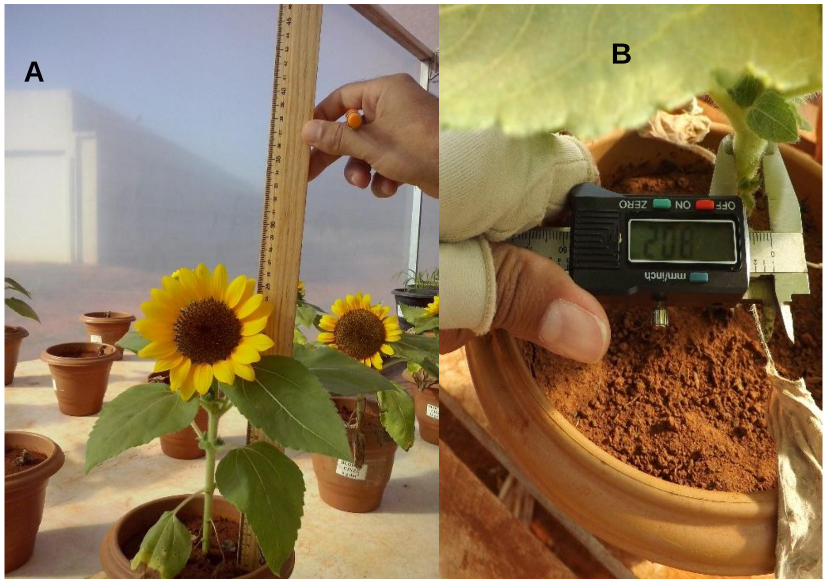

Figure 1. Ornamental sunflower plant height (A) and stem diameter measurement (B).

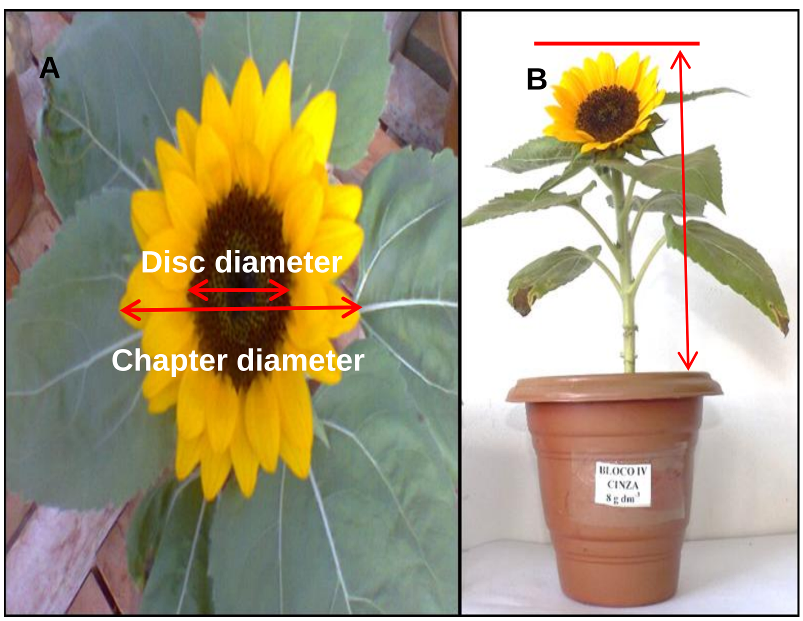

Figure 2. Ornamental sunflower disc and chapter diameter (A) and chapter height (B).

determined by the first derivative of the equations.

RESULTS AND DISCUSSION

The assessments of the Sunflower Chlorophyll index did not show a significant effect of wood ash doses. This could be occurred because all treatments received the same nitrogen fertilization (100 mg dm^{-3}). For soil pH, plant height, stem diameter, leaf number, chapter, leaf and stem dry matter and chapter height and diameter, there was a significant effect by adjusting linear and quadratic regression models (Table 3).

Soil pH after 30 days of incubation with wood ash was

Figure 3. Ornamental sunflower plants indirect chlorophyll content readings with a chlorophyll meter.

Table 3. Summary of ANOVA for the parameters: plant height and chapter diameter , stem diameter, chlorophyll index , chapter dry mass , stem and disc , leaf and root , number of leaves and soil pH.

Parameter	Evaluations	F_t	Cofficient of variation (%)
Chlorophil index	1°	0.3829^{ns}	8.91
	2°	0.4476^{ns}	5.46
	3°	0.8761^{ns}	8.01
	4°	0.2392^{ns}	7.89
Soil pH	1°	0.0000***	2.56
Plant height	1°	0.0000***	19.66
	2°	0.0000***	12.25
	3°	0.0000***	9.89
	4°	0.0000***	10.42
Stem diameter	1°	0.0000***	8.80
	2°	0.0000***	17.79
	3°	0.0000***	13.34
	4°	0.0000***	7.73
Number of leaves	1°	0.0000***	10.99
	2°	0.0000***	10.84
	3°	0.0000***	10.61
	4°	0.0000***	10.61
Chapter dry mass	4°	0.0000***	19.53
Leaves dry mass	4°	0.0000***	17.97
Stem dry mass	4°	0.0000***	23.67
Root dry mass	4°	0.0000***	53.90
Chapter height	3°	0.0078**	8.22
	4°	0.0020**	8.92
Chapter diameter	3°	0.0044**	18.86

Table 3. Contd.

	4°	0.0355*	11.28
Disc diameter	3°	0.0017**	17,20
	4°	0.0015**	13.71

[ns]non significant, ***, **, * significant at 0.1, 1 and 5% of probability, respectively, by the F test.

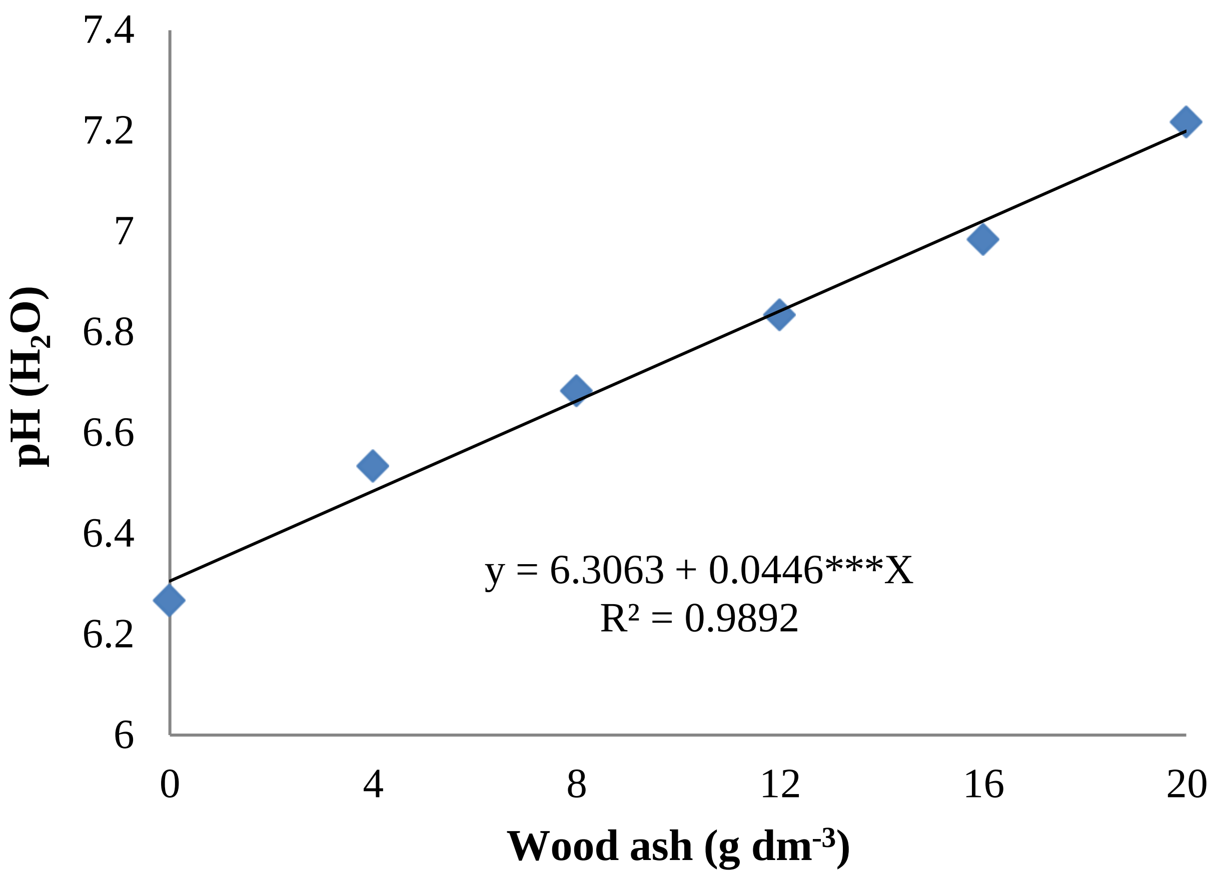

Figure 4. Soil pH after 30 days of incubation as function of wood ash doses in CerradoOxisol. *** 0.1% significance.

set to the linear regression model, where the highest pH value (7.2) was observed in the 20 g dm^{-3} wood ash dose (Figure 4). Comparing the highest pH found with the value obtained in the wood ash fertilization absence, there was an increase of 13.8%.

The pH increase increased with the wood ash doses may be related to soil acidity neutralizing capacity that wood ash has (Osaki and Darolt, 1991). Wood ash oxides, hydroxides and carbonates of Ca and Mg and basic cation significant amounts, such as calcium, magnesium and potassium reduce soil acidity and increase soil pH, improving its fertility (Haraldsen et al., 2011; Norstrom et al., 2012). Similar effect to that of the present study was observed by Ferreira et al. (2012) when wood ash was used as fertilizer in Latossol. In fact, these authors find that soil content of H + Al significantly decreased with wood ash rate increase. At 30 days after sowing, it was observed that the highest plant height (14.15 cm) was achieved with a 13.01 g dm^{-3} wood ash dose, with an increase of 88.9% compared to the treatment that had not received wood ash fertilization (Figure 5). During the second evaluation, at 37 days after sowing, a plant height increase of 75.5% was observed, with maximum height (19.79 cm) being observed in the 12.94 g dm^{-3} wood ash dose (Figure 6).

At 44 days after sowing, 12.07 g dm^{-3} of wood ash allowed the highest plant height (18.02 cm), giving an increase of 72.1%. Similarly, at 51 days after sowing, the

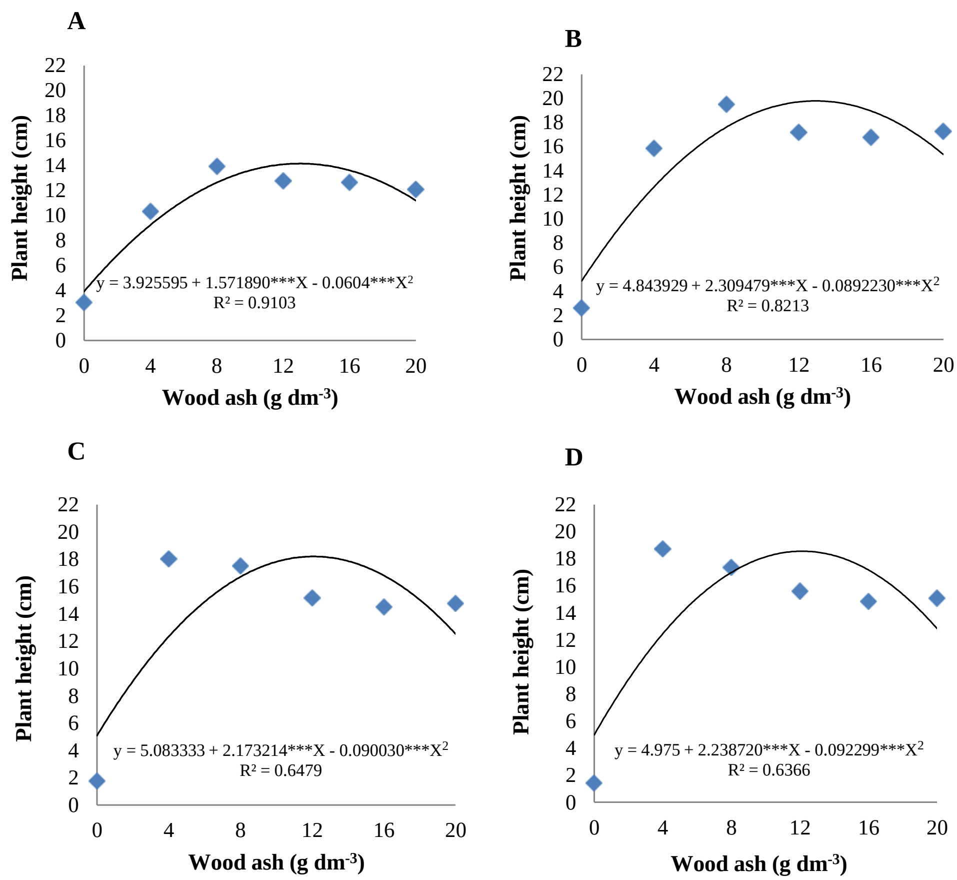

Figure 5. Ornamental sunflower plant height at 30 (A), 37 (B), 44 (C) and 51 (D) days after sowing, depending on wood ash doses. *** 0.1% significance.

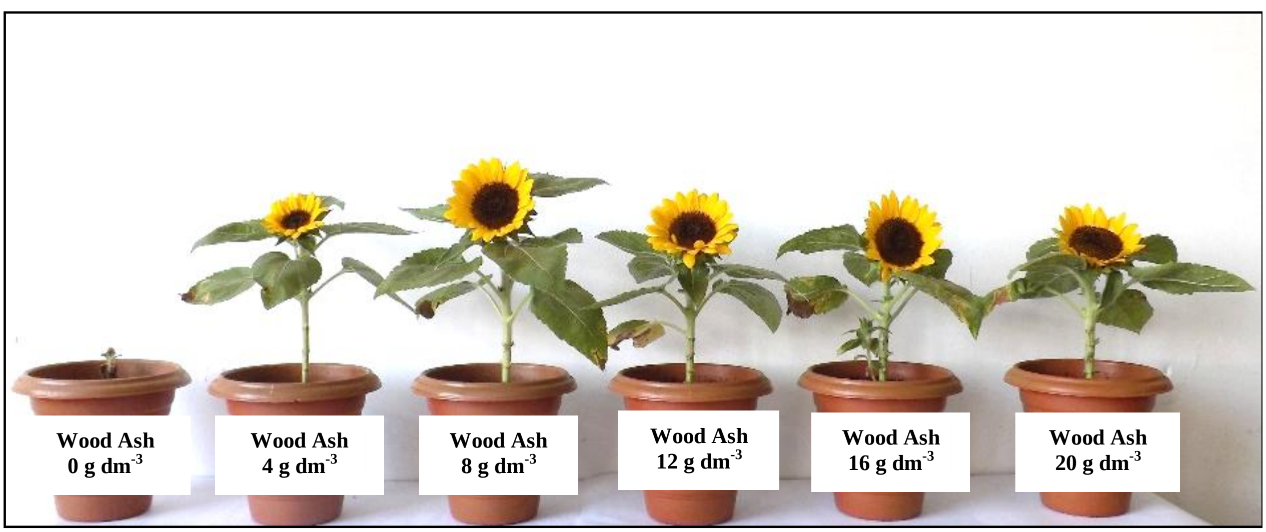

Figure 6. Growth curve of ornamental sunflower as influenced by wood ash doses at 37 days after sowing.

highest height of 18.55 cm was obtained with 12.13 g dm^{-3} wood ash dose, giving an increase of 73% (Figure 5).

The highest values for the height (18.55 and 18.20 cm) were obtained with 12.07 and 12.13 g dm^{-3} of wood ash,

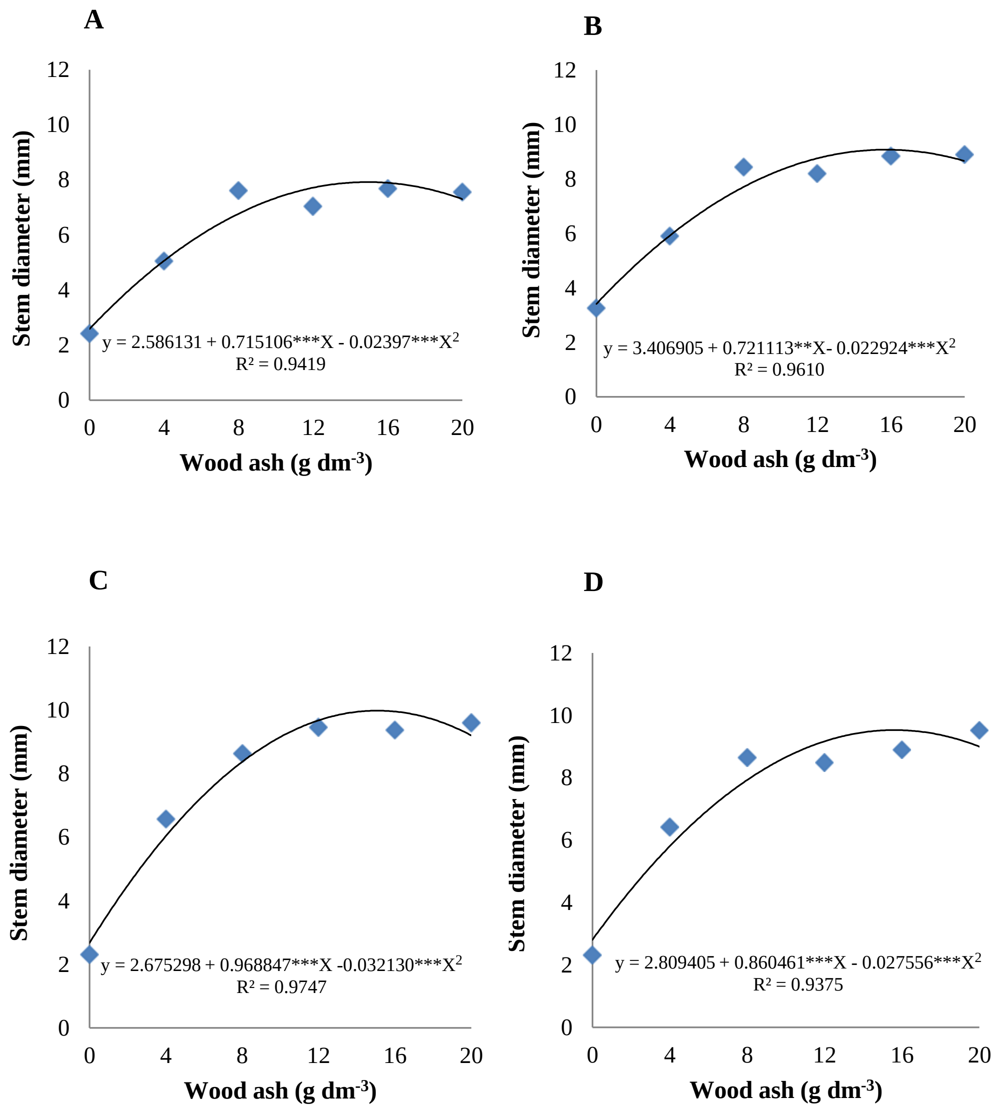

Figure 7. Ornamental sunflower stem diameter at 30 (A), 37 (B), 44 (C) and 51 (D) days after sowing as influenced by wood ash doses. *** = 0.1% significance.

which were observed in 44 and 51 days after sowing, respectively (Figure 5). However, curves adjusted to plant height in the third (Figure 5C) and fourth (Figure 5D) assessments had lower determination coefficients (R^2) when compared with the first two assessments.

It was observed during the experiment that plants fertilized with the wood ash dose of 8 g dm^{-3} showed, on average, the highest heights, until the 37th day after sowing. From the third assessment, plants fertilized with 4 g dm^{-3} of wood ash had higher plant height than others. This occurred was due to long vegetative stage observed in plants subjected to 4 g dm^{-3} of wood ash when compared to other plants that have reached the beginning of the reproductive stage (chapter formation) at around 30 days after sowing. According to Castiglioni et al. (1997), when reaching the reproductive stage, sunflowers have already grown around 95% of their total.

Setting a standard height for the ornamental sunflower potted in the flower market is a difficult task, and is a subjective characteristic that depend on consumer preference. However, are found in the flower market, plants with an average of 25 cm (Neves et al., 2005). In the present study, the plants showed sizes that are more compact what is feasible and facilitates transport, without damaging the plants. In addition, the appropriate transport does not compromise the quality of flowers, where the aesthetics of the product determines the market value of the plant (Mcmahon and Kelly, 1999; Curti et al., 2012).

As for stem diameter, for the four assessments, it can be observed adjust of the data for the quadratic regression model (Figure 7). In the first assessment, the highest diameter (7.92 mm) was observed in the 14.92 g dm^{-3} wood ash dose, and in the second, it was found that

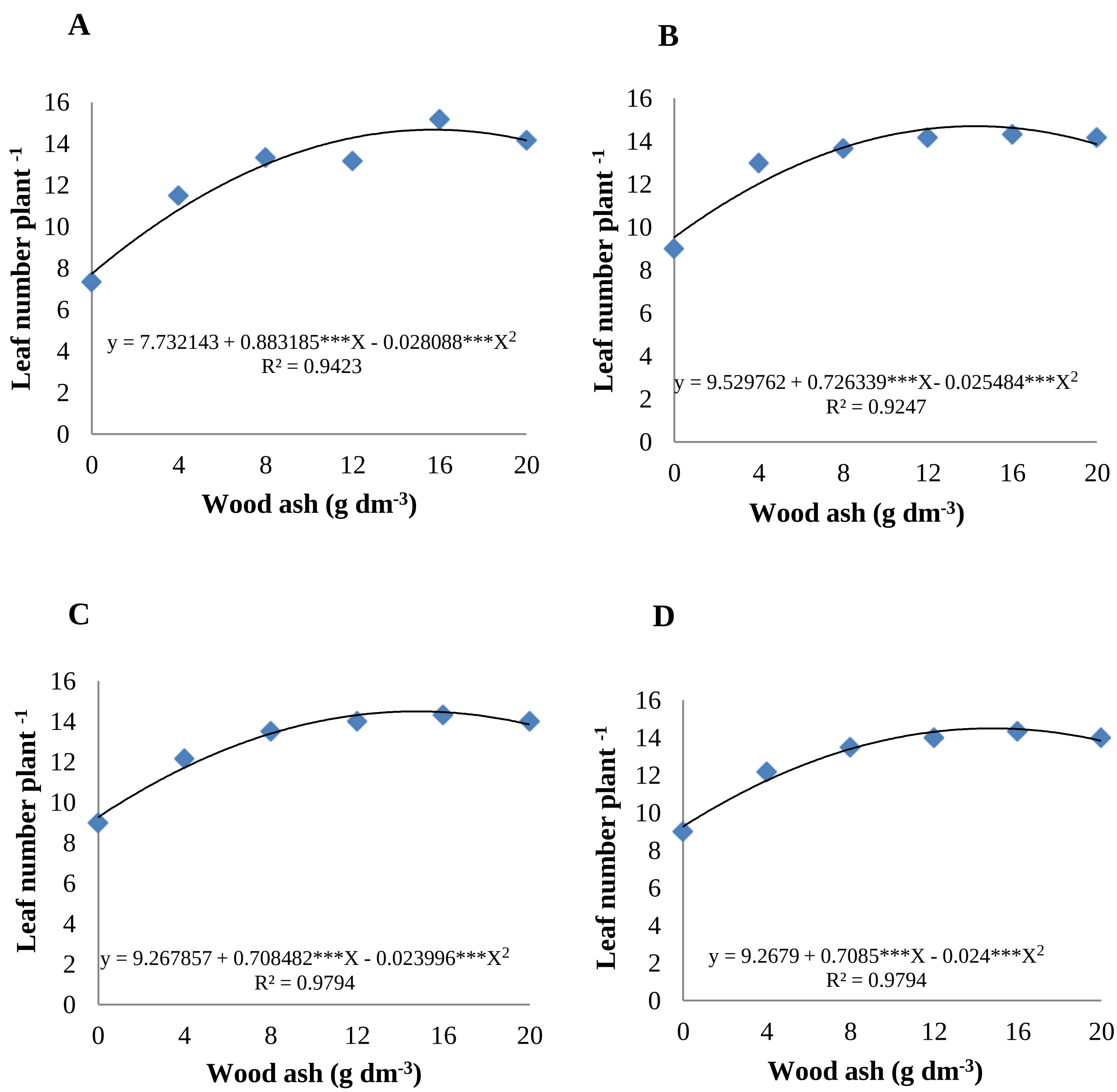

Figure 8.Leaf number at 30 (A), 37 (B), 44 (C) and 51 (D) days after sowing influenced by wood ash doses. *** 0.1% significance.

15.72 g dm^{-3} wood ash dose provided higher plant stem diameter of 9.08 mm.

In the third assessment, it was observed that the 17.08 g dm^{-3} wood ash dose favored plants to develop stem with higher diameters (9.85 mm). According to the fourth assessment results, it appears that the largest diameter (9.53 mm) was found in the 15.62 g dm^{-3} wood ash dose. Stem diameter increases measured at 30, 37, 44 and 51 days after sowing were 67.3, 62.4, 72.8 and 70.5%, respectively..

This study results corroborate the observation of Braga (2009) on ornamental sunflower development in relation to nitrogen doses, at 40 days after sowing, that noted that the largest stem diameter was 9.70 mm. According to Sabach (2008), stem diameter lower than 6 mm is not favorable, since stems with lower diameter are flexible, compromising inflorescence sustainability. In the present study, at 30 and 37 days after sowing, plants fertilized with the lowest wood ash dose (4 g dm^{-3}) had, on average, lower than 6 mm stem diameters. However, it has not compromised ornamental sunflower inflorescence support. For leaf number, it was observed that during the experiment, plants subjected to wood ash treatments produced approximately 7 to 15 leaves (Figure 8).

At 30 days after sowing, the largest leaf number (14.67)

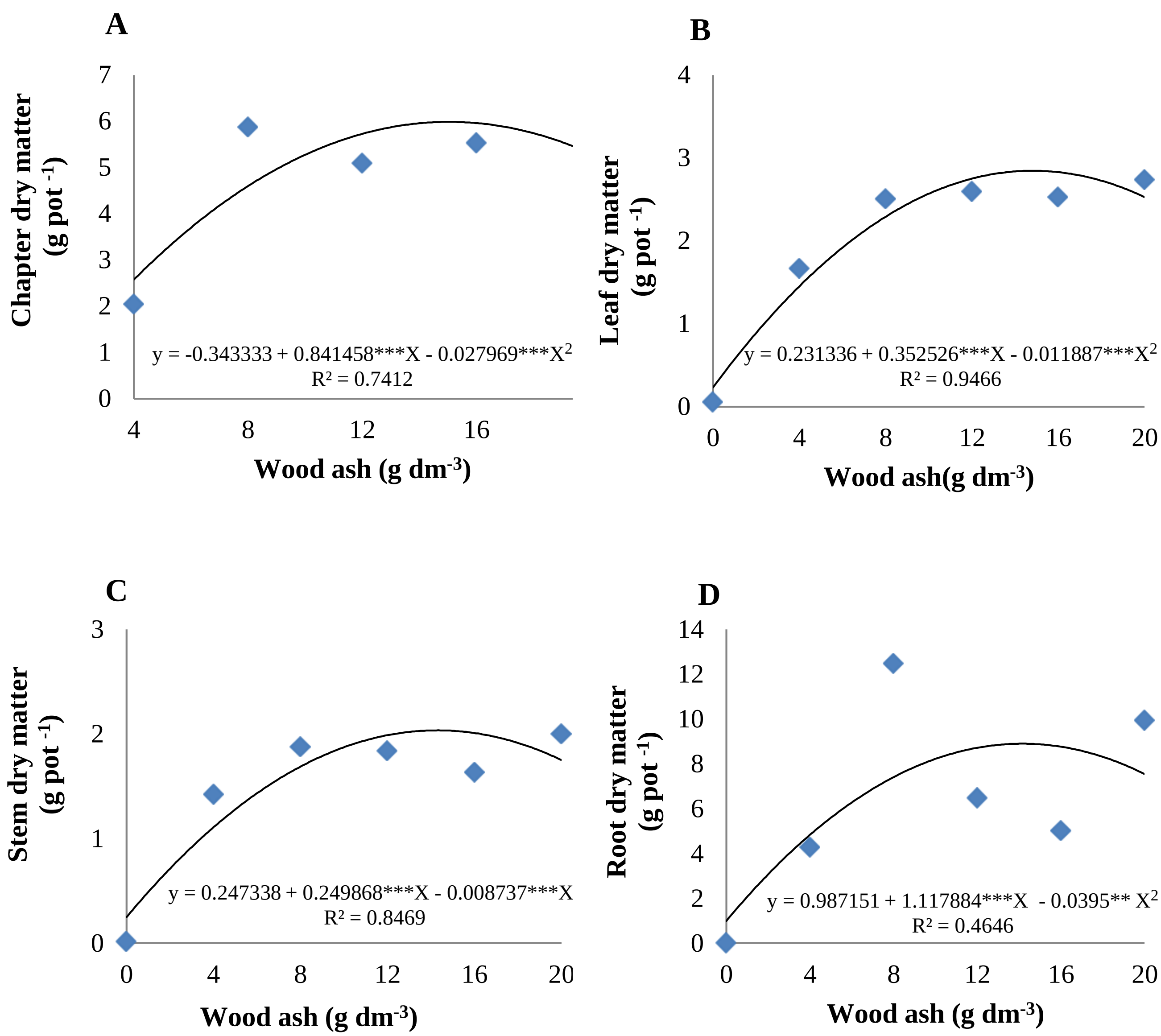

Figure 9. Ornamental sunflower chapter (A), Leaf (B), stem (C) and root (D) dry matter at 51 days after sowing influenced by wood ash doses. ***, ** 0.1 and 1% significance.

was observed with the 15.72 g dm^{-3} wood ash dose, obtaining 47.3% increase compared to the treatment without wood ash fertilization. At 37 days after sowing, Sunflower plant that received 14.25 g dm^{-3} of wood ash dose obtained the highest leaf number, giving an increase of 35.3%. From 44 days after sowing, it was observed that the number of leaves did no increase until the end of the experiment. With 14.76 g dm^{-3} being the wood ash dose that had the highest leaf number, with observed increase of 36.1%.

Leaf number is directly related to the plant leaf area, that is, the higher the leaf number, the higher will be the leaf area, thus being an important index in nutrition and plant growth studies, determining dry matter accumulation, plant metabolism, potential photosynthetic capacity, yield and crop quality (Jorge and González, 1997; Oliveira et al., 2013).

In this study, leaves maximum number of 15 leaves in relation to wood ash doses is similar to the results observed by Sato et al. (2010) who found an average of 14 leaves per plant while assessing organic waste in substrate composition and ornamental sunflower development. For root, stem, leaf and the chapter dry matter was observed adjustment for the quadratic regression model. However, root dry matter showed a low determination coefficient (Figure 9D). As for chapter dry matter accumulation, there was a 57% increase in plants grown with a 15.04 g dm^{-3} wood ash dose when

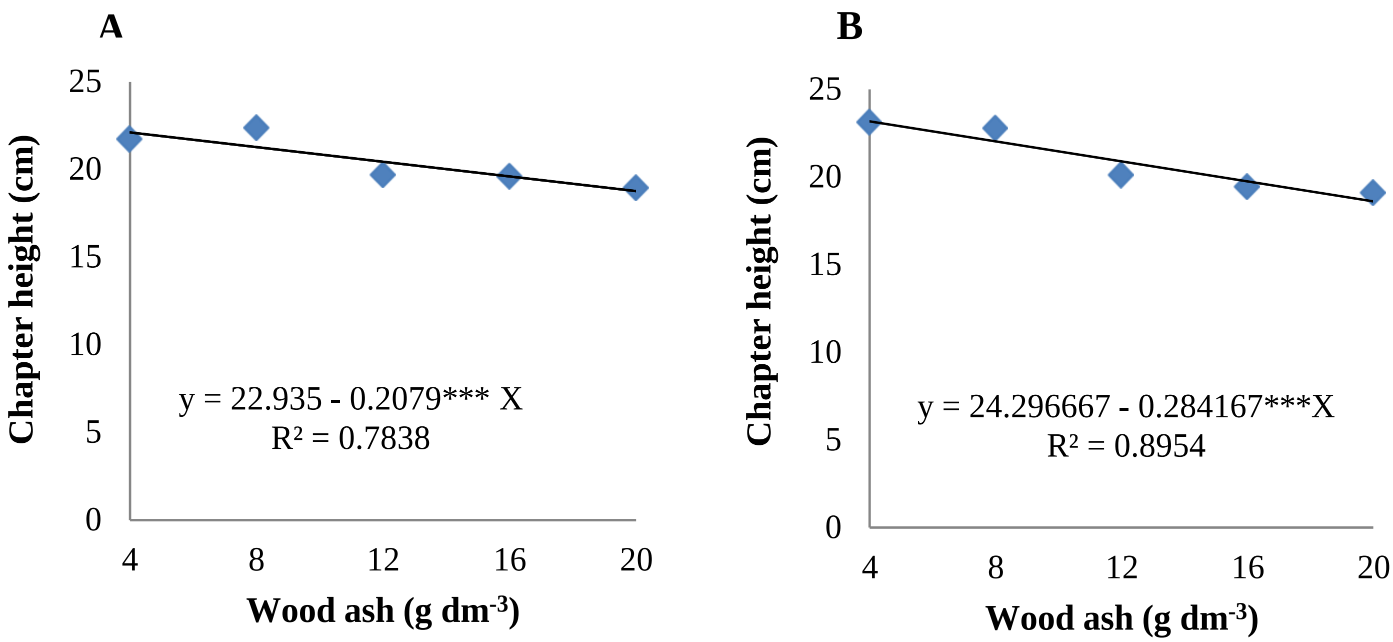

Figure 10. Ornamental sunflower chapter height at 44 (A) and 51 (B) days after sowing influenced by wood ash doses.***0.1% significant.

compared to dry matter production of plants fertilized with 4 g dm^{-3} wood ash (Figure 9A). For leaf dry matter, it was observed that the highest production of 2.85 g $plant^{-1}$ was obtained with the 14.83 g dm^{-3} wood ash dose (Figure 9B), having an 91.9% dry matter production increase when compared to the treatment with no wood ash fertilization. Stem dry matter of plant that received 14.3 g dm^{-3} wood ash dose was higher than other doses, with an increase of 84.69% compared to the treatment that had not received wood ash fertilization (Figure 9C). Root dry matter (Figure 9D) highest production (8.90 g $plant^{-1}$) was obtained with the 14.15 g dm^{-3} wood ash dose, which had an increase of 88.9% when compared to the production of plant that did not receive wood ash fertilization.

Dry matter accumulation is a parameter that allows discussing plants organic translocation process (Benincasa, 2003). Thus, higher investment for root dry matter production was observed, followed by chapter, leaves and stems dry matter production, respectively (Figure 10). For ornamental sunflower chapter height at 44 and 51 days, results were fitted to a linear regression model. The highest values were observed in plant that received 4 g dm^{-3} wood ash dose, with 22.1 and 23.16 cm, respectively, for the two assessments.

Chapter height decreased inversely with wood ash doses. In the absence of wood ash application, sunflower did not produce a chapter (Figure 10). As noted in the plant height variable, commercially, the lower the plant height, better their commercial value is, providing a more pleasing aesthetics and portability. Therefore, values found in this study are meeting commercial standards for ornamental sunflower plants.

According to Dallago (2000), wood ash fertilization significantly influence sunflower growth days after plants sowing, causing an increase reduction both in the lack or excess of nutrients. This result proves nutrients balance and soil pH importance in plant metabolism. Chapter diameter results at 44 and 51 days after sowing were set to the quadratic regression model. Wood ash doses that showed higher chapter diameter (10.48 and 10.95 cm) for the two assessments, respectively, were 13.2 and 13.7 g dm^{-3}. Increases at 44 and 51 days after sowing were of 73.9 and 23.6%, respectively (Figure 11).

Chapter diameter, along with plant height, has great influence on ornamental sunflower commercial value (Neves et al., 2005). For Sakata Seed Corporation (2003), inflorescence diameter values must be, on average, between 10.0 and 15.0 cm. These values can be obtained with wood ash use as corrective and fertilizer. According to Anefalos and Guilhoto (2003) and Dasoju et al. (1998), for potted ornamentation, sunflower plant chapter length is of utmost importance, as it should be proportional to the pot in which it is produced and marketed size. That is why stem final height reduction cannot drastically reduce chapter length, as it would lose commercial value. For sunflower disc diameter at 44 and 51 days after sowing, there was quadratic regression model adjustment (Figure 12). In these assessments, 5.25 and 6.51 cm values for disc diameter were obtained with 14.31 and 14.79 g dm^{-3} doses, respectively. At 44 days after sowing, there was a 60.4% disc diameter increase compared to the lowest assessed dose (4 g dm^{-3}),

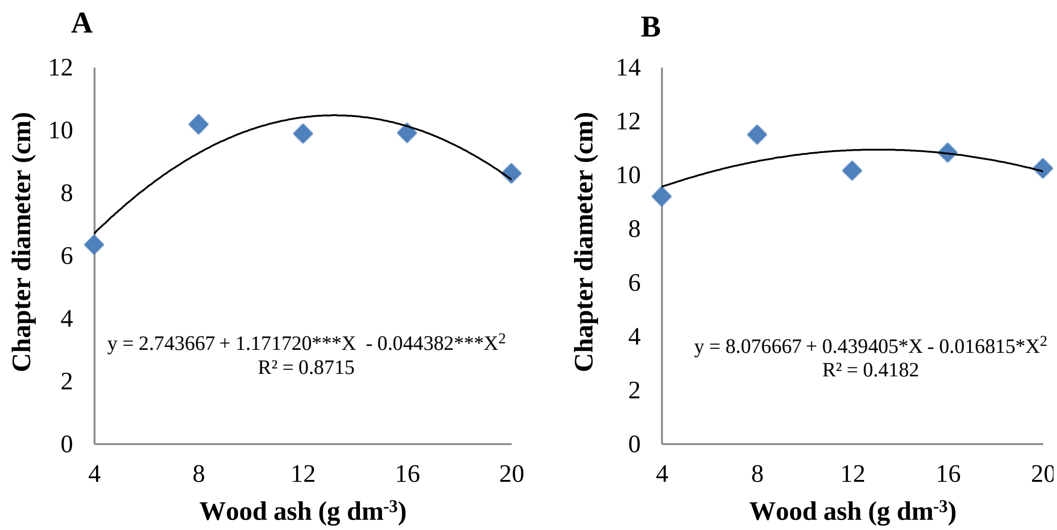

Figure 11. Ornamental sunflower chapter diameter at 44 (A) and 51 (B) days after sowing in relation to wood ash doses.***, * 0.1 and 5% significance.

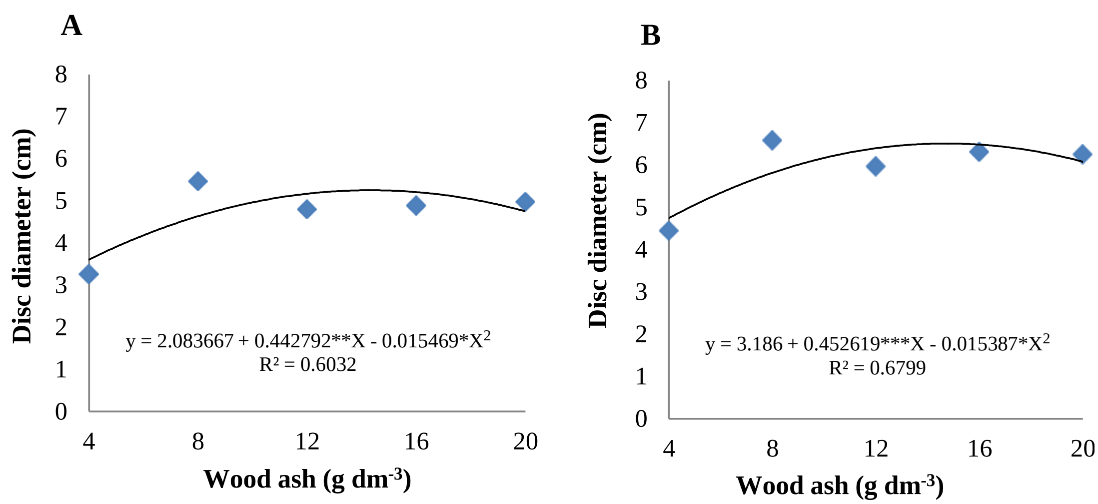

Figure 12. Wood ash effect on disc diameter at 44 (A) and 51 (B) days after sowing in. ** 1% significance level.

and at 51 days after sowing there was an increase of 51% (Figure 12). Comparing the tendency of disc diameter and chapter diameter curves at 44 and 51 days after sowing the respective periods, it was observed that there was similarity between them. Wood ash doses that provided higher chapter and disc diameters have close values. Thus, plants with larger chapter diameter, consequently, have larger disc diameter.

Conclusions

Doses of wood ashes between 12 and 16 g dm^{-3} may be used to improve the development of ornamental sunflower plants, proving their effects as corrective and fertilizer for growing flowers.

Conflict of Interest

The authors have not declared any conflict of interest.

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