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Biomass and water use efficiency of chrysanthemum under organic, mineral, and organomineral fertilization[1]

Biomassa e eficiência no uso da água do crisântemo sob adubação orgânica, mineral e organomineral

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HIGHLIGHTS:
Fertilizers with wood ash increases biomass production of chrysanthemum.
Organomineral using wood ash as raw material is an alternative fertilizer for chrysanthemum cultivation.
Organic, mineral, and organomineral fertilizers increase water use efficiency.

ABSTRACT: Most soils are excessively acidic, which decreases the productive efficiency of plants. There are several ways to correct soil acidity to make nutrients available to crops. Wood ash is a residue generated by the combustion of vegetal biomass and is used to correct soil acidity for use as a fertilizer. The application of organomineral wood ash to crops is yet another alternative fertilizer that reduces the doses of wood ash and mineral fertilizer. The objective of this study was to evaluate the biomass production and water use efficiency of chrysanthemum cultivated with organic, mineral, and organomineral fertilizers associated with liming. The greenhouse experiment was conducted in a 5 × 2 factorial randomized block design with five fertilization managements (incubated wood ash, non-incubated wood ash, organomineral, mineral fertilization, and control) and two liming values (0 and 100% of the recommendation), with five replicates. Biomass production was significantly affected by fertilization alone and organomineral application resulted in higher biomass production. Incubated ash was more appropriate because resulted in higher yields.

Key words: *Dendranthema grandiflora*, wood ash, mineral fertilizer

RESUMO: A maioria dos solos tem uma acidez excessiva que diminui a eficiência produtiva das plantas. Existem diversas formas de corrigir a acidez do solo e disponibilizar nutrientes para as culturas. A cinza vegetal é um resíduo gerado pela combustão da biomassa vegetal utilizada na correção da acidez do solo e como fertilizante. O organomineral utilizando como matéria prima a cinza vegetal é uma outra alternativa de fertilizante, reduzindo o volume de cinza vegetal e adubo mineral utilizados no campo. Objetivou-se por esta pesquisa avaliar a produção de biomassa e eficiência no uso da água no cultivo de Crisântemo sob adubação orgânica, mineral e organomineral associada a calagem. O experimento foi realizado em casa de vegetação em delineamento de blocos casualizados, com esquema fatorial 5 × 2, sendo cinco manejos de adubações (cinza de madeira incubada, cinza de madeira não incubada, organomineral, adubação mineral e controle) e dois níveis de calagem (0 e 100% da recomendação), com cinco repetições. A produção de biomassa foi significativa somente para adubação de forma isolada e o organomineral demonstrou maior produção de biomassa. Cinza incubada é mais adequada, pois resultou em maiores valores de produção.

Palavras-chave: *Dendranthema grandiflora*, cinza vegetal, adubo mineral

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Introduction

Brazil has several regions, latitudes, microclimates, altitudes, and climatic conditions suiting the increased production of different ornamental plants and flowers (Oliveira et al., 2021). Chrysanthemum is one of the most popular ornamental flowers because of its varied colors and exuberant inflorescence (Carvalho et al., 2020).

Most soils have excessive acidity, which interferes with the availability of nutrients and decreases the productive efficiency of plants (Oliveira et al., 2020; Santos et al., 2020). Thus, it is necessary to correct soil acidity by introducing calcium and magnesium into the exchange complex so as to increase pH (Santos et al., 2020).

There are several ways to introduce nutrients into the soil. Organic fertilizers are suggested as a sustainable alternative to expensive chemical fertilizers which also increase environmental pollution (Araújo et al., 2020).

Wood ash (biomass ash) is a residue generated by the combustion of vegetal biomass, such as tree trunks, bark, and branches. Several studies have reported the positive effects of wood ash to correct soil acidity and its use as a fertilizer (Bonfim-Silva et al., 2020a; Reis et al., 2020; Bonfim-Silva et al., 2021).

Organic fertilizers, having both organic and mineral composition, reduce the use of mineral fertilizers and their environmental impact and volume of wood ash presently recommended (Bonfim-Silva et al., 2020b).

The objective of this study was to evaluate the biomass production and water-use efficiency of chrysanthemum cultivation under organic, mineral, and organomineral fertilization along with liming.

Materials and Methods

The experiment was carried out in a greenhouse between June and October 2021, at the Federal University of Rondonópolis (Rondonópolis-MT), at the geographical coordinates 16° 27’ 49” S, 54° 34’ 46” W and altitude of 290 m. This region is characterized by Tropical Climate (Aw) according to Köppen & Geiger (1928) classification. This climate is tropical with rainy summer, and dry winter (Aparecido et al., 2020).

During the experiment, the maximum and minimum temperatures were measured by using a digital thermometer installed inside the greenhouse (Figure 1).

The soil collected at a depth of 0-0.20 m in an area under native Cerrado vegetation, classified as dystrophic Red Latosol (Oxisol) (United States, 2014; EMBRAPA, 2018) was sieved with 2.0 mm mesh for chemical and particle-size characterization (Teixeira et al., 2017) (Table 1) and 4.0 mm mesh for use in the experimental pots.

The experimental units consisted of pots with a capacity of 2 dm³ grown with chrysanthemum cv. Singelo. Sowing was done on June 8, 2021 with each experimental unit having one plant. Wood ash (biomass ash) was obtained from the food industry in the region of Rondonópolis-MT characterized as a corrective agent (Alcarde & Rodella, 1996) and as fertilizer (Alcarde, 2009) (Table 2).

The experiment consisted of randomized blocks in a 5 × 2 factorial design, corresponding to five types of fertilizers (incubated wood ash, non-incubated wood ash, organomineral fertilizer, mineral fertilizer, and control) and two liming values (0 and 100% of the recommendation) with five replicates totaling 50 experimental units, each having 2 dm³ pots.

For treatments with 100% liming, the base recommended saturation of 1.88 g dm^{-3} was raised to V = 70%. The liming was mixed into the soil, and the moisture adjusted to 60% of the maximum water holding capacity, after which it was incubated for 30 days according to the methodology of Bonfim-Silva et al. (2020b).

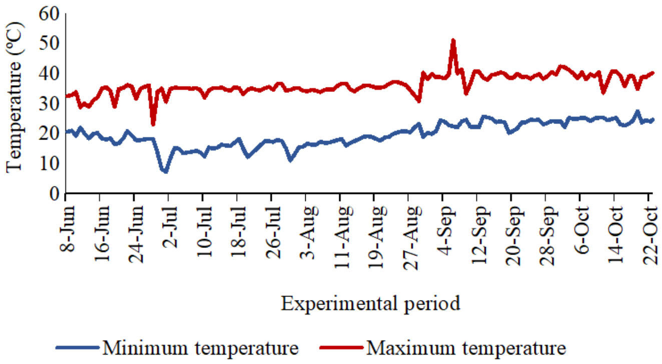


Figure 1. Maximum and minimum daily air temperature during the greenhouse experiment

Table 1. Chemical and particle-size characterization of dystrophic Red Latosol (Oxisol) collected from 0–0.20 m layer under Cerrado vegetation

pH	P	K	S	Ca	Mg	Al	H+Al	CEC	SB	V	m
$CaCl_2$	(mg dm^{-3})			(cmol$_c$ dm^{-3})						(%)	
4.3	1.5	18	2	0.5	0.2	0.6	4.8	5.6	0.8	13.5	44.4

Zn	Mn	Cu	Fe	B	OM	Clay	Silt	Sand
(mg dm^{-3})					(g kg^{-1})			
0.7	21.8	0.2	64	0.15	21.3	455	100	445

OM - Organic matter; CEC - Cation exchange capacity; SB - Sum of bases; V - Base saturation; m - Aluminum saturation

Table 2. Chemical characterization of wood ash (biomass ash) as fertilizer

pH	N	P_2O_5	K_2O	Ca	Mg	MgO	SO_4	CaO	Fe	Cu	Mn	B	Zn
$CaCl_2$	(%)												
10.97	0.49	0.79	3.25	4.96	4.20	6.50	0.60	9.10	0.72	0.01	0.04	0.04	0.02

N: total nitrogen; P_2O_5 - Phosphorus; K_2O - Potassium; Ca - Calcium; Mg - Magnesium; MgO - Magnesium oxide; SO_4 - Sulfur; CaO - Calcium oxide; Fe - Iron; Cu - Copper; Mn - Manganese; B - Boron; Zn - Zinc

The wood ash recommendation was 32 g dm^{-3} for the incubated and non-incubated ash treatments (Bär et al., 2018). These two treatments differed in the form of application of the ash. The incubated ash was mixed with the soil and the moisture adjusted to 60% of the maximum water holding capacity, and subsequently incubated for 30 days in a greenhouse in plastic bags. The non-incubated wood ash treatment was mixed with soil at the time of sowing.

The wood ash recommended for gerbera was used for chrysanthemum since both belong to Asteraceae family and have morphological similarities (Bär et al., 2018).

The recommended concentrations of phosphorus (P_2O_5), potassium (K_2O), and micronutrients at 360, 240, and 50 mg dm^{-3}, respectively, were applied as mineral fertilizers (Ribeiro et al., 1999). Simple superphosphate was used as a source of phosphorus, potassium chloride as a source of potassium, and FTE (Fritted Trace Elements) consisting of Boron 1.8%, copper 0.8%, iron 3.0%, manganese 2.0%, molybdenum 0.1%, and zinc 9.0%, as a source of micronutrients.

Urea as a nitrogen (N) source was applied in all treatments, except for the control, at the recommended dose of 120 mg dm^{-3} N (Teixeira, 2004). The fertilizer was applied in two splits of 60 mg dm^{-3} each at 30 and 45 d after sowing.

The organomineral treatment consisted of 50% each of wood ash and minerals, except for N, which received 100% of the recommendation. According to Bonfim-Silva et al. (2015), N is lost in the burning process of wood ash. Hence, organomineral was mixed with the soil at the time of sowing, except for N applied at 30 and 45 d after sowing. No fertilizer was added to the soil in the control.

Irrigation was managed using the subsurface self-irrigating system proposed by Bonfim-Silva et al. (2007). This system maintained a controlled tension of 3.0 kPa and allowed the continuous replacement of water to the plant according to its need.

Thirty days after sowing, the soil was collected from the first 10 cm depth of the pot for pH analysis using $CaCl_2$ solution (concentration 0.01 mol L^{-1}) and pH meter. The productive variables were analyzed when chrysanthemum was cut at 145 d after sowing.

The root volume was determined using a 1000 mL graduated beaker with root from each pot immersed in a beaker containing known volume of water. The excess volume difference after the addition of the root was equal to its observed volume. After determining the volume, the roots were placed in a forced-air circulation oven at 65 °C for 72 hours drying and then weighed on a semi-analytical balance to determine the dry mass.

Fresh shoot dry mass was determined by placing the shoot of each plot in a forced-air circulation oven at 65 °C for 72 hours for drying and weighed on a semi-analytical scale.

Water use efficiency (WUE) was determined by the ratio of the shoot dry mass to the total water consumption in each of the treatments (Eq. 1).

$$\mathrm{WUE} = \frac{\mathrm{SDR}}{\mathrm{TWC}} \tag{1}$$

where:

WUE - water use efficiency (g L^{-1})
SDR - shoot dry mass (g per pot), and
TWC - total water consumption (L per pot).

The total water consumption was determined by totaling the water consumed in each plot during the entire period of the experiment. The volume of water consumed was quantified by measuring the level using a Mariotte bottle to the irrigation system.

The data were subjected to analysis of variance and Tukey's test ($P \leq 0.05$). Statistical analysis was performed using SISVAR software (Ferreira, 2019).

Results and Discussion

The pH of the soil collected from the Cerrado vegetation (Table 1) and at 30 days after sowing, as a function of fertilization and liming, showed that the treatments with non-incubated wood ash with and without liming had a high pH at 30 days after sowing (Table 3); and hence the seeds did not germinate in some replicates warranting transplanting of already raised seedling to fill up mortality.

As shown in Table 3, wood ash (biomass ash) is an alkaline residue used to correct soil acidity, increase pH, and decrease aluminum toxicity. Treatments with mineral fertilization and control without liming had the lowest pH averages. Liming is used to correct soil acidity, increase pH, and promote greater absorption of nutrients from the soil by the crop (Oliveira et al., 2020). This reveals that liming is necessary when fertilizers without wood ash are not used.

The pH of soil is important for crop development and influences seed germination (Li et al., 2020). According to Teixeira (2004), the ideal pH for chrysanthemum cultivation is between 5.5 and 6.5. The Organomineral without liming came closest to the ideal pH for chrysanthemum development (Table 3).

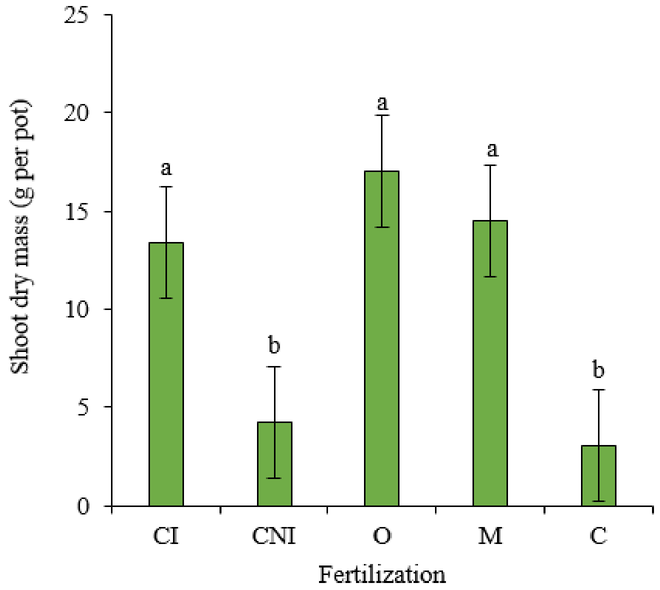
The control and mineral treatments, when liming was not used, had pH values below the ideal for chrysanthemum (Table 3). Thus, liming is necessary when these forms of fertilizers are used.

Shoot dry mass was influenced by the type of fertilization. The highest values of dry mass were observed in the treatments with incubated wood ash, organomineral, and mineral, at 13.385, 17.05 and 14.5 g per pot, respectively (Figure 2).

Table 3. pH of dystrophic Red Latosol (Oxisol) at 30 days after chrysanthemum sowing

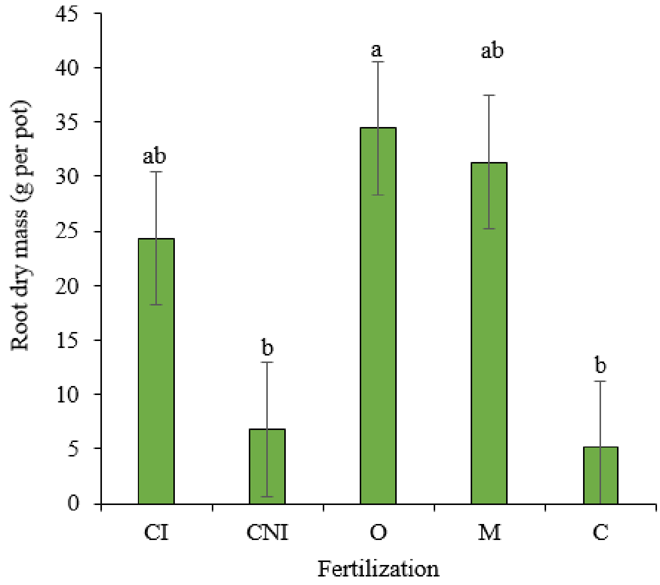
	Fertilization				
	Incubated wood ash	Non-incubated wood ash	Organomineral	Mineral	Control
With liming	7.61aA	9.22 aA	8.36 aA	5.29 aA	5.21 aA
Without liming	7.52 aA	9.23 aA	6.39 aA	4.93 aA	4.71 aA

aA Means followed by the same lowercase letter in the columns and uppercase letter in the line have no statistical difference according to the Tukey test ($p \leq 0.05$)



CI - incubated wood ash; CNI - Non-incubated wood ash; O - Organomineral; M - Mineral fertilizer; C - Control. Vertical bars represent the confidence intervals for the mean ($p \leq 0.05$). Means followed by the same letters are not statistically different according to Tukey's test ($p \leq 0.05$)

Figure 2. Shoot dry mass (g per pot) as a function of fertilization types in chrysanthemum



CI - incubated wood ash; CNI - Non-incubated wood ash; O - Organomineral; M - Mineral fertilizer; C - Control. The vertical bars represent confidence intervals for the mean ($\alpha = 0.05$). Means followed by the same letters are not statistically different according to Tukey's test ($p \leq 0.05$)

Figure 3. Root dry mass (g per pot) as a function of fertilization types in chrysanthemum

The treatment with non-incubated wood ash presented the lowest values of shoot dry mass (Figure 2). It was observed that this form of application of wood ash presented high pH values, with and without liming, and above the ideal for chrysanthemum development (Table 3). This justifies the low values of dry mass because chrysanthemum did not develop adequately under alkaline conditions.

In addition to the treatment with non-incubated wood ash, the control without fertilization, showed low shoot dry mass (Figure 2). However, it was observed that this treatment had a pH below the ideal for chrysanthemum development (Table 3), and since no fertilizer was applied, nutrients were not available for its growth.

Chang et al. (2010) studied mineral and organic fertilization in the cultivation of the anthurium flower (*Anthurium andreanum*), and observed that organic fertilization produced the same results as mineral fertilization as found in our study.

Bonfim-Silva et al. (2020b) observed that the highest values of radish shoot dry mass were found in treatments with wood ash and organomineral fertilizers. Albuquerque et al. (2010) observed in Golden Torch Heliconia (*Heliconia psittacorum* x *Heliconia spathocircinata*) that under the combined influence of mineral and organic fertilization, organic fertilization optimized mineral utilization, providing greater productivity of the crop.

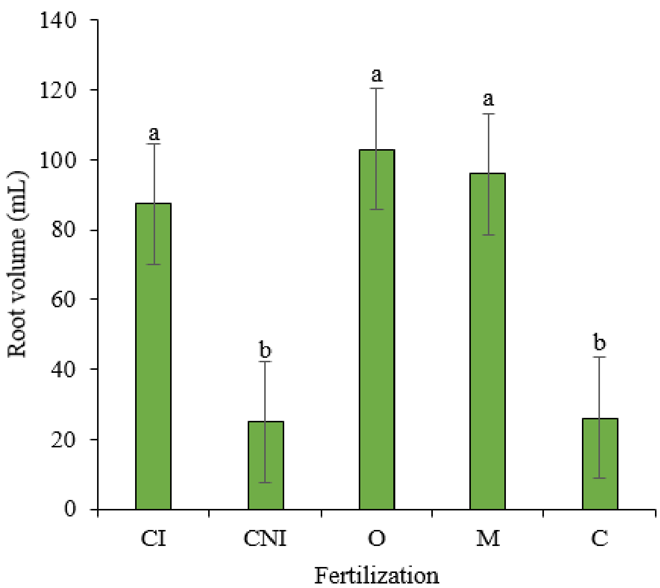
The association of wood ash with mineral fertilizer provided good results for shoot dry mass, which is a viable alternative for chrysanthemum biomass production (Figure 2).

Root dry mass was influenced only by the fertilization type. The highest values of root dry mass were obtained in the treatments with incubated wood ash, organomineral and mineral at 24.32, 34.43 and 31.30 g per pot, respectively (Figure 3).

In Leucaena (*Leucaena leucocephala*) seedlings fertilized with mineral and organominerals, Sousa et al. (2021) found that the root dry mass from organomineral fertilizer provided greater root dry mass compared to the mineral fertilizer. This is in agreement with our findings on chrysanthemum.

It was observed in our study that the wood ash could partially replace mineral fertilizer for root dry mass production as observed by Sousa et al. (2021). Wood ash when applied at sowing inhibited seed germination resulting in some plots left without plants, and for those that survived, the roots did not develop well due to soil alkalinity.

Root volume was influenced only by fertilization type. The highest values were found in fertilization with incubated wood ash, organomineral, and mineral, at, 87.5, 103 and 96 mL, respectively (Figure 4).



CI - incubated wood ash; CNI - Non-incubated wood ash; O - Organomineral; M - Mineral fertilizer; C - Control. The vertical bars represent confidence intervals for the mean ($\alpha = 0.05$). Means followed by the same letters are not statistically different according to Tukey's test ($p \leq 0.05$)

Figure 4. Root volume (mL) as a function of fertilization types in chrysanthemum

Non-incubated wood ash and the control showed the lowest root volume values (Figure 4). The application of non-incubated wood ash at sowing made the soil alkaline, affecting the development of chrysanthemum roots (Table 3) and the control without fertilization was devoid of nutrients resulting in inadequate root growth. Both these explain low root volumes (Figure 4).

The data corroborates with findings in wheat, that using of organominerals yielded better results for root volume than application of different other fertilizers (Ferro et al., 2018).

Oliveira et al. (2001) explained that the addition of organic matter has positive effects on crop productivity because it promotes increased cation exchange capacity and the release of nutrients to the plants. The differences in chrysanthemum root volume between the treatments can also be visually observed (Figure 5).

Total water consumption was influenced only by the fertilization type. The highest water consumption was observed in the treatment with mineral fertilizer at 26.58 L per pot (Figure 6).

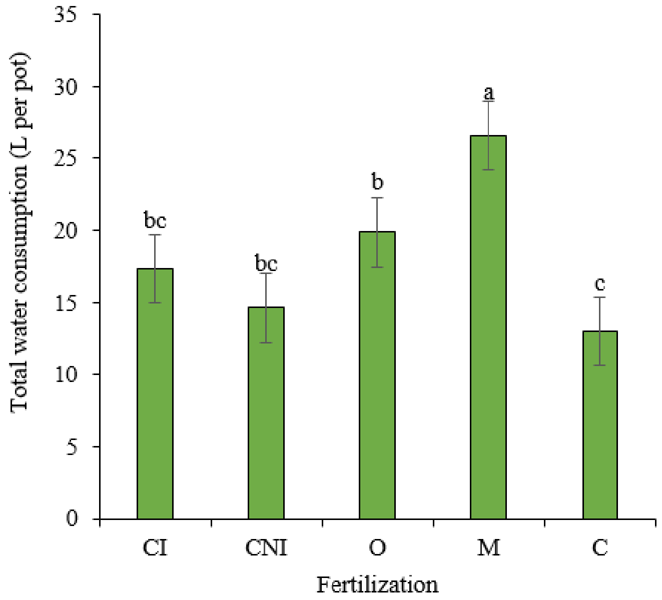
The control and non-incubated wood ash treatments exhibited the lowest water consumption. This can be explained by the size of the crops in these treatments; both treatments had plants with the lowest development. Observation for the average pH values (Table 3) showed that inadequate development of chrysanthemum in the treatment with non-incubated wood ash was due to the alkaline soil and in the control due to soil acidity, since pH is a determining factor for the availability of nutrients.

Farias et al. (2004) studied irrigation management and explained that the water consumption of ornamental crops in greenhouses has not been studied in detail and for plants grown in protected environment at different locations, the water consumption is lower as compared to field raised crops

A higher water consumption does not mean that the plant has better development. It was observed in the shoot dry mass that the organomineral and incubated wood ash treatments registered values not significantly different from the mineral fertilization (Figure 2).

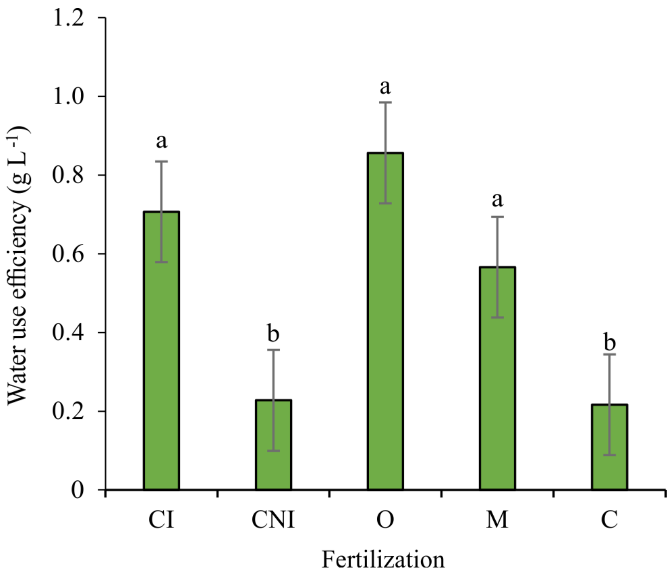
The water use efficiency was influenced by the fertilization types, in which higher efficiencies were observed for incubated wood ash, organomineral and mineral, with 0.70, 0.85 and 0.56 g L^{-1}, respectively (Figure 7).

Use of wood ash as an alternative fertilizer increases the water use efficiency in chrysanthemum cultivation. It was



CI - incubated wood ash; CNI - Non-incubated wood ash; O - Organomineral; M - Mineral fertilizer; C - Control. The vertical bars represent confidence intervals for the mean (α = 0.05). Means followed by the same letters are not statistically different according to Tukey's test (p ≤ 0.05)

Figure 6. Total water consumption (L per pot) as a function of fertilization types in chrysanthemum



CI - Incubated wood ash; CNI - Non-incubated wood ash; O - Organomineral; M - Mineral fertilizer; C - Control. The vertical bars represent confidence intervals for the mean (α = 0.05). Means followed by the same letters are not statistically different according to Tukey's test (p ≤ 0.05)

Figure 7. Water use efficiency (g L^{-1}) as a function of fertilization types in chrysanthemum

Figure 5. Root volume as a function of fertilization types in chrysanthemum

noted that the plants treated with wood ash consumed less water than those treated with mineral fertilizer (Figure 6). Ash has a greater capacity to retain water because it is hygroscopic, which justifies better water use efficiency. Furthermore, the results corroborate with those of Bonfim-Silva et al. (2020b), who found greater efficiency in water use using wood ash and organominerals.

Rego et al. (2009) evaluated chrysanthemum productivity as a function of irrigation levels and observed water use efficiency decreased with increasing irrigation levels. This is justifiable since wood ash has higher water use efficiency and consumes less water than those treated with mineral fertilizer.

Conclusions

1. The organomineral provided higher biomass production of chrysanthemum.

2. Application of wood ash, incubated wood ash was more suitable.

3. Liming did not influence chrysanthemum biomass production and water use efficiency.

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