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Organic fertilizers, minerals and base saturations in the cultivar of arugula in Oxisol

Abstract

The objective of this study was to evaluate the production of arugula fertilized with wood ash, with organomineral fertilizer (wood ash + mineral fertilizer) and mineral fertilizer in function of the base saturation levels in Oxisol. The experiment was performed in a greenhouse in a completely randomized experimental design with eight treatments (organomineral fertilization and soil base saturation at 50 %, organomineral and base saturation of 80 %, mineral fertilization and base saturation at 50 %, fertilization (without fertilization) with 50 % base saturation, control (without fertilization), with an increase in the percentage of the soil and the percentage of the soil 80 % base saturation and four replicates. The experimental units consisted of a 2 dm^3 soil pot. The pH of the soil was evaluated at 30 days after the incubation of the limestone and wood ash, according to the treatments, and at 30 days after emergence of plants the chlorophyll index, fresh and dry matter of shoot, dry matter of root and evapotranspiration of the arugula were evaluated. The highest values of pH of the soil were observed in the treatments with base saturation of 80 %. The fresh and dry matter shoot were higher with the application of mineral and organomineral fertilizers, independent of the saturation. The dry matter of root was higher in the mineral fertilization with base saturation of 80 %. The mineral fertilization followed by the organomineral provided the highest of chlorophyll index, fresh and dry matter of shoot and dry matter root of the arugula plants in comparison to the fertilization with only wood ash. It is possible to use base saturation of 80 % for mineral fertilizer and 50 % for organomineral fertilizer.

Keywords: *Eruca sativa* Miller, wood ash, organomineral, alternative fertilizers, root development.

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1. Introduction

The arugula (*Eruca sativa* Miller), is cultivated mainly in small and medium properties throughout the Brazilian territory, in the system we know as family farming. It is a short cycle crop, herbaceous hardwood and fast growing vegetative, originating from southern Europe and the western part of Asia. The leaves are very appreciated in the form of salad, mainly in São Paulo and in the South region of Brazil [1].

Throughout the years, this culture has been highlighting itself in the national market. Due to this appreciation in the scale of production, arugula obtains advantages over other crops, due to its nutritional value in relation to the low cost per unit of production [1]. This bitter and spicy vegetable is rich in iron, potassium and sulfur also contains elevated levels of proteins and vitamins A and C [2].

For the good development of the plants it is necessary, among other factors, a soil with good fertility. Reference [3] states that for the cultivation of vegetables crops a soil with good fertility and base saturation between 70 and 80 % is required. The predominant soil class in the Cerrado is Oxisol, characterized by low natural fertility, high aluminum saturation, acid pH and low levels of calcium and magnesium [4]. Therefore, to make these soils productive, it is essential to use agricultural practices such as liming and fertilization.

Nutrient replenishment through mineral fertilizers is interesting, since these can be rapidly absorbed by the roots of plants, due to high concentration and high solubility. However, the process of leaching and acidification of the soil can be increased easily [5], make the rational management and assembly of fertilization necessary, and the incorporation of alternative fertilizers to the system.

With the need for new fertilization alternatives emerged the organomineral compost, originating from the mixture of mineral fertilizers with solid residues of organic compounds,

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such as wood ash. This fertilizer is used as a soil conditioner, stimulating the development of plant roots and enhancing the absorption of water and nutrients. Thus, increases in crop production, stimulating agricultural sustainability [6], specifically by family farming, since the greenery crops are greatly exploited in organic farming [7] and have increased aggregate value.

The importance of organic fertilizers is due to the maintenance and improvement of the soil's physical, chemical and biological properties, reflecting on the performance of crops [8]. Nutrient releases by organic fertilizers occur by the contact of soil micro-organisms with organic matrix that will reduce size and gradually releasing nutrients to the plant, effect known as controlled release [9].

The challenge is to elaborate practices that can demonstrate that solid residues of organic compounds, applied in the soil, improve the availability of nutrients for plants and at the same time reduce impacts to natural resources. In this context, it was aimed at evaluating the effect of fertilizers with wood ash, organomineral fertilizers, in function the bases saturations in the culture of the arugula in Oxisol.

2. Material and Methods

The experiment was conducted at greenhouse in the Federal University of Mato Grosso, *Campus* of Rondonópolis. The Oxisol [10] it was collected at the layer of 0.0 - 0.2 m deep in area under Cerrado vegetation. The chemical and particle size characteristics of the soil (Table 1) followed the methodology of [11].

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Table 1 - Chemical analyses and granulometric of the Oxisol collected at the layer of 0.0 - 0.2 m in area under Cerrado vegetation, Rondonópolis, MT, Brazil

pH		P	S	K	Ca	Mg	Al	H	SB	CTC	V	m
H_2O	$CaCl_2$											
		-mg dm^{-3}-		----------cmol$_c$ dm^{-3}----------							------%------	
4.7	4.0	1.7	6.8	0.06	0.2	0.2	0.8	4.4	0.46	5.66	8.13	63.49

Zn	Cu	Fe	Mn	B	O. M.	Sand	Silt	Clay
----------mg dm^{-3}----------					----------g kg^{-1}----------			
0.9	0.5	194	13.4	0.26	20.6	507	116	337

Extraction Zn, Cu, Fe, Mn - Mehlich - 1 (H_2SO_4 0,025N + HCl 0,05N); S - calcium phosphate; B - hot water.

The experimental design used was entirely randomized with eight treatments and four repetitions. The treatments were the following: i - wood ash and base saturation at 50 %; ii - wood ash and base saturation at 80 %; iii - fertilization with organomineral (wood ash + mineral fertilizer) and base saturation to 50 %; iv - organomineral (wood ash + mineral fertilizer) and base saturation 80 %; v - mineral fertilization and base saturation 50 %; vi - mineral fertilization and base saturation 80 %; vii - control (no fertilization) and base saturation 50 % and viii - control (no fertilization) and base saturation 80 %.

The culture used was the arugula, being cultivated in pots with a capacity of 2 dm^3, each pot being an experimental unit. The treatments with mineral fertilization were applied 80 mg dm^{-3} of N, 200 mg dm^{-3} P_2O_5 and 90 mg dm^{-3} of K_2O, using as sources: urea, single superphosphate and potassium chloride, respectively, according to [12].

In the treatments with wood ash, the 20 g dm^{-3} rate of ash was used, being that the rate was established through previous experiments (pilots) with same type of soil and culture, also

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applied 80 mg dm^{-3} of N, using as a source to urea, due low nitrogen content in wood ash. The treatments with organomineral fertilization were composed of 50 % of the rate of mineral fertilization and 50 % of the rate of wood ash.

After the liming with limestone dolomitic, the soil was incubated for 30 days, to neutralize the acidity of the soil and elevate the base saturation 50 and 80 %, respectively. At the time of the application of the limestone, the ash rates were added, in the two treatments with wood ash (base saturation 50 % and 80 %).

The wood ash used, from wood burning in food industries boilers, was analyzed as fertilizer and the composition is presented in Table 2.

Table 2 - Chemical composition of burned wood ash in boiler

N	P_2O_5	K_2O	Ca	S	Zn	Cu	Mn	B	pH ($CaCl_2$)
----------g kg^{-1}----------									-
5.6	16.7	27.2	27.0	14.9	0.1	0.1	0.0	0.2	10.9

Soluble in CNA + water.

It was sown 10 arugula seeds (*Eruca sativa* Miller) per pot. After the establishment, the thinning was carried out by leaving two plants per pot. For irrigation of plants it was adopted as a criterion for the replacement of evapotranspiration by means of the gravimetric method, maintaining the soil at 80 % of the maximum water retention capacity [13].

The variables evaluated were: pH of the soil at 30 days after incubation; chlorophyll index on the leaf (reading SPAD); Fresh and dry matter of shoot; dry matter of root and evapotranspiration of the arugula, at 30 days after the emergence of plants. The pH of the soil was obtained through the pH meter in water solution and $CaCl_2$, according to methodology proposed by the [11].

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The chlorophyll index in the leaf (reading SPAD - Soil plant analysis development) was obtained by the average reading in five sheets using the indirect reading method of chlorophyll with the Chlorophyll meter SPAD - 502. The fresh mass of the air and the roots were determined in a semi-analytic and subsequently, packed in an air forced circulation kiln to obtain dry mass at 65 °C until constant mass. The evapotranspiration was determined by the sum of the water repositions in each pot.

The results were submitted to the ANOVA and Scott-Knott test up to 5 % probability, in the statistical program SISVAR.

3. Results and Discussion

There was significant difference of treatments in all variables analyzed (P = .05).

The largest values of the chlorophyll index in the leaf were with the use of mineral fertilizer (V50 % and V80 %) and organomineral (V50 % and V80 %), not differing statistically among themselves, but presenting greater values in relation to the treatments with wood ash and control (Table 3).

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Table 3 - Chlorophyll index (CI), Fresh Matter of Shoot (FMS), Dry Matter of Shoot (DMS), Dry Matter of Root (DMR), Evapotranspiration of culture (ETc) and pH of the soil ($CaCl_2$), in the culture of arugula according to the application of sources of fertilizers in Oxisol, Rondonópolis - MT

Fertilizers	CI	FMS	DMS	DMR	ETc	pH
	SPAD	---------g vaso^{-1}---------			L vaso^{-1}	
Wood Ash V50 %	10.53 b	0.38 b	0.06 b	0.07 b	2.78 a	5.84 b
Wood Ash V80 %	17.65 b	0.83 b	0.12 b	0.02 b	2.31 b	6.44 a
Mineral V50 %	45.93 a	3.80 a	0.51 a	0.06 b	2.20 b	5.48 b
Mineral V80 %	41.20 a	6.88 a	1.31 a	1.45 a	2.65 a	6.38 a
Organomineral V50 %	50.80 a	3.80 a	0.89 a	0.51 b	2.57 a	5.78 b
Organomineral V80 %	29.55 a	5.00 a	0.74 a	0.37 b	2.52 a	6.38 a
Control V50 %	-	-	-	-	-	5.90 b
Control V80 %	-	-	-	-	-	6.36 a
CV %	53.90	75.86	109.04	105.79	12.35	4.51

Averages followed by the same letter, in the column, do not differ from each other by the Scott-Knott test to 5% probability.

The chlorophyll index in the leaf has a positive relationship with the chlorophyll content [14] being influenced by the absorption of nutrients, mainly of nitrogen. The organomineral fertilizer presented similar efficiency to mineral fertilizer, showing that the constituent ash of the organomineral fertilizer contributed to the best utilization of the nitrogen applied, providing nutrients, such as magnesium, constituent of the chlorophyll molecule. Corroborating with the results of this work, [illegible] evaluating rates of wood ash in cotton plants in Oxisol, observed increase in the chlorophyll content with the application of vegetable ash, attributing this effect to an improvement in nitrogen absorption due to the applications of wood ash.

Studies with wood ash rates in the culture of the radish, presented influence in the chlorophyll index, effect provided by the availability of nutrients, which participate in the synthesis of chlorophyll and photosynthetic processes [16]. Related results were also observed

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by reference [17] in studies with rates of wood ash in the marandu-grass, in which there was an increase in the chlorophyll content with the increase in the ash rates.

In the fresh and dry matter of shoot the mineral fertilizer (V50 % and V80 %) and organomineral (V50 % and V80 %) have provided greater increments in mass production, in relation to the application of ash and control (Table 3). In the treatment control, there was no mass production due to the death of the plants.

The use of mineral fertilizers and organomineral were more efficient in relation to wood ash, due to a better nutrient availability for the arugula culture, resulting in greater production of fresh and dry matters. Surveys with mineral fertilization have presented increases in the productions of fresh and dry matters shoot of the arugula [2] [18].

However, [19] in experiment on lettuce and arugula associations in different spatial arrangements, under organic and mineral fertilizer observed better productivity of arugula performance under organic fertilization. Confronting, [20] reported that the organomineral fertilization was more efficient in the increase in agricultural production which was isolated from a mineral or organic fertilizer. According to the authors, the association of these fertilizers can complement the lack of some nutrient of isolated fertilizer.

There was significant difference between the fertilization used for the dry matter root of the arugula plants (Table 3). The largest dry matter root was obtained with mineral fertilization V80 %, since fertilization and soil correction contributed to the best development of the root system. Also, it was found that this same treatment provided the largest dry matter of shoot, indicating that there is a positive relationship in the productivity of the aerial part with the root development of the plant.

The largest water consumption by the arugula plants was observed in the V50 % wood ash treatments, mineral fertilization V80 %, organomineral V50% and organomineral V80 %, respectively (Table 3). The increase in water consumption is associated with mineral

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fertilization treatments and organomineral, which produced greater dry matter of shoot, as the largest nutrient intake in the soil resulted in greater vegetative development and consequently raised water consumption by the arugula.

The treatments with V80 % had pH higher than the V50 % at 30 days after incubation, regardless of the rate of wood ash (Table 3). This effect was due to the use of limestone to elevate the base saturation (V50 % and V80 %) and even though the ash provides a pH increase in the soil, it was not observed that effect.

However, several works showed the increase in the pH of the soil with the addition of wood ash [21] [22] [15] [23] [24]. This effect is due to the reaction of ash on the soil, releasing potassium carbonate (K_2CO_3) and reacting with the soil H^+ [25].

4. Conclusions

The mineral fertilization followed by the organomineral provided the largest chlorophyll index, fresh and dry matters of shoot and root in the arugula plants in comparison to fertilization with only wood ash.

It is recommended to use the base saturation of 80 % for mineral fertilizer and 50 % when applied to the organomineral fertilizer.

5. Competing interests

Authors declared that no competing interests exist.

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6. References

[1] Filgueira FAR. New manual of olericultura: Modern agro-technology in the production and commercialization of vegetables. 3th. Ed. Publisher UFV: Viçosa; 2008.

[2] Porto RA, Bonfim-Silva EM, Souza DSM, Cordova NRM, Polizel AC, Silva TJA. Potassium fertilization in arugula plants: production and efficiency in water use. Rev. Agroamb. Online. 2013; 7 (1): 28-35. Portuguese http://dx.doi.org/10.18227/1982-8470ragro.v7i1.760

[3] Souza RB. Mineral nutrition of vegetables. 1st ed. EMBRAPA. Goiânia; 2009.

[4] Resende M, Curi N, Rezende S, Corrêa GF. Pedology: basis for distinguishing environments. 6th. Ed. Publisher UFLA: Lavras; 2014.

[5] Ronquim CC. Soil fertility concepts and proper management for tropical regions. 1 st ed. Embrapa Satellite Monitoring: Campinas; 2010.

[6] Kiehl EJ. Organomineral fertilizers. 1st ed. Publisher Degaspari: Piracicaba; 2008.

[7] Pelá A, Silva Júnior GS, Silva RCD, Silva CS, Pelá GM. Production and nitrate content in arugula under organic fertilization with litter of bovine manure. Rev. Green. 2017; 12 (1): 48-54.

[8] Trani PE, Purquério LFV, Figueiredo GJB, Tivelli SW, Blat SF. Liming and fertilization of lettuce, almeirão, watercress, chicory, coriander, spinach and arugula. 1st ed. Instituto Agronômico de Campinas: Campinas; 2014.

[9] Costa JC, Braz CH, Souza CHE. Coffee production (New World) in production of 4th and 5th harvests due to fertilization with organomineral fertilizers. Rev. Perquirere. 2015; 12 (2): 221-229. English

[10] Brazilian Agricultural Research Corporation - EMBRAPA. Brazilian system of soil classification. 3rd ed. Embrapa: Brasília; 2013.

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[11] Brazilian Agricultural Research Corporation - EMBRAPA. Manual of methods of soil analysis. 2nd. Ed. EMBRAPA CNPS: Rio de Janeiro; 1997.

[12] Van Raij B, Cantarela H, Quaggio JA, Furlani AMC. Recommendation of fertilization and liming for the State of São Paulo. 1st ed. Instituto Agronômico de Campinas: Campinas; 1997.

[13] Bonfim-Silva EM, Silva TJA, Santos CC, Cabral CEA, Santos IB. Productive characteristics and efficiency in the use of water in arugula fertilized with vegetal ash. Enc. Biosphere. 2011; 7 (13): 178-186. English

[14] Leonardo FAP, Pereira WE, Silva SM, Costa JP. Chlorophyll content and SPAD index in pineapple cv. Vitoria due to nitrogen fertilization. Rev. Br. De Frut. 2013; 35 (2) 377-383. Portuguese http://dx.doi.org/10.1590/S0100-29452013000200006

[15] Bonfim-Silva EM, Carvalho JMG, Pereira MTJ, Silva TJA. Ash in the fertilization of cotton plants in Red Latosol of the cerrado. Enc. Biosphere. 2015; 11 (21): 523-533. English

[16] Bonfim-Silva EM, Cláudio AA, Vanessa VM, Silvério AT. Productive characteristics of radish subjected to doses of vegetable ash. Enc. Biosphere. 2015; 11 (21): 421-432. English

[17] Bonfim-Silva EM, Cabral CEA, Silva TJA, Moreira JCF, Carvalho JCS. Vegetative ash: productive characteristics and chlorophyll content of marandu grass. Biosc. J. 2013; 29 (5): 1215-1225. English

[18] Koetz M, Carvalho KS, Bonfim-Silva EM, Rezende CG, Silva JC. Arugula submitted to doses of phosphorus in Red Latosol of Cerrado. Enc. Biosphere. 2012; 8 (15): 1554-1562. English

[19] Oliveira EQ, Souza RJ, Cruz MCM, Marques VB, France AC. Productivity of lettuce and arugula, in a consortium system, under organic and mineral fertilization. Hort. Br. 2010; 28: 36-40. English

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[20] Andrade EMG, Silva HS, Silva NS, Sousa Júnior JR, Furtado GF. Organomineral fertilization in leafy vegetables, fruits and roots. Rev. Verde Mossoró. 2012; 7 (3): 07-11. English

[21] Ferreira EPB, Fageria NK, Didonet AD. Chemical properties of an Oxisol under organic management as influenced by application of sugarcane bagasse ash. Rev. Ciênc. Agro. 2012;43(2):228-236. http://dx.doi.org/10.1590/S1806-66902012000200004

[22] Souza RABMC, Monção OP, Souza HB, Oliveira JS, Reis TC. Effect of boiler ash on the chemical characteristics of a soil in the Cerrado of Bahia and yield of lettuce. Cultiv. the knowledge. 2013; 6 (4): 60-73 English

[23] Bonfim-Silva EM, Cláudio AA, Bär CSLL, Santo ESSE, Pacheco AB. Nitrogen in the production, chlorophyll index and water use in arugula cultivation. Enc. Biosphere. 2015; 11 (21): 1386-1396. English

[24] Pereira MTJ, Silva TJA, Bonfim-Silva EM, Mazzini-Guedes RB. Applying wood ash and soil moisture on gladiolus (Gladiolus grandiflorus) cultivation. Austr. J. of Crop Sci. 2016;10(3):393-401. DOI: 10.21475/ajcs.2016.10.03.p7236

[25] Darolt MR, Blanco Neto V, Zambon FRA. Vegetable ash as a nutrient source and soil corrective in the lettuce crop. Hort. Br. 1993; 11 (1): 38-40.