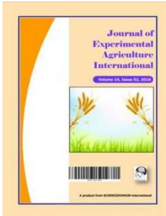

Journal of Experimental Agriculture International

17(3): 1-6, 2017; Article no.JEAI.35486
Previously known as American Journal of Experimental Agriculture
ISSN: 2231-0606

Application of Wood Ash, Organomineral and Mineral Fertilizers to Increase the Growth of Arugula (*Eruca sativa* Miller) at Different Base Saturation on Oxisol

Edna Maria Bonfim-Silva[1*], Eduardo Souto de Oliveira[1], Maria Débora Loiola Bezerra[2], Thiago Henrique Ferreira Matos Castañon[2], William Fenner[2] and Tonny José Araújo da Silva[1]

[1]Department of Agricultural and Environmental Engineering, Institute of Agricultural Sciences and Technology - ICAT, Federal University of Mato Grosso - UFMT, Brazil.
[2]Department of Tropical Agriculture, Faculty of Agronomy and Zootechnic - FAAZ, Federal University of Mato Grosso - UFMT, Brazil.

Authors' contributions

This work was carried out in collaboration between all authors. The authors EMBS and TJAS conceived the idea, designed the experiment and edited the manuscript. The authors ESO and MDLB conducted the experiment, statistical data analysis, interpretation of results and preparation of first draft of the manuscript. The authors THFMC, MDLB and WF interpretation of results and edited the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2017/35486
Editor(s):
(1) Nazimah Maqbool, Department of Botany, University of Agriculture, Pakistan.
Reviewers:
(1) Tualar Simarmata, University of Padjadjaran Bandung, Indonesia.
(2) Funda Yoldas, Ege University, Turkey.
(3) Manju Pande, Mississippi Valley State University, USA.
Complete Peer review History: http://www.sciencedomain.org/review-history/20682

Original Research Article

Received 15th July 2017
Accepted 22nd August 2017
Published 26th August 2017

ABSTRACT

The objective of this study was evaluating the production of arugula fertilized with wood ash, 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 using the completely randomized experimental design with eight treatments, as follows: T1 - wood ash at 50% of BS; T2 -

**Corresponding author: E-mail: embonfim@hotmail.com;*

wood ash at 80% of BS; T3 - wood ash + mineral fertilizers at 50% of BS; T4 - wood ash + mineral fertilizers at 80% of BS; T5 - mineral fertilizers at 50% of BS; T6 - mineral fertilizers at 80% of BS; T7 - control (limed for 50% of BS) and T8 - control (limed for 80% of BS) and four replications. The experimental units consisted of a 2 dm^3 soil pot. pH of the soil 30 days after incubation with limestone and wood ash was evaluated for all treatments. At 30 days after emergence of plants the chlorophyll index, fresh and dry mass of shoot, dry mass of root and evapotranspiration of the arugula were evaluated. The highest values of pH of the soil were observed in the treatments at 80% of BS. Generally, the higher of shoot fresh and dry mass were obtained by application of mineral and wood ash combined with mineral fertilizers (organomineral fertilizer). The higher of root dry mass was obtained by minerally fertilized plots at 80% of BS. Compared to wood ash fertilized plots only, the minerally fertilized plots followed by the wood ash and mineral treated plot provided the highest of chlorophyll index, shoot fresh and dry mass and root dry mass of the arugula plants. For the mineral or organomineral fertilizer, arugula could be grown at a base saturation of 80% and 50%, respectively.

Keywords: Eruca sativa Miller; wood ash; organomineral; alternative fertilizers; root development, waste vegetal.

1. INTRODUCTION

The arugula (*Eruca sativa* Miller), is cultivated mainly in small and medium properties throughout the Brazilian territory, in the family farming system. Presents 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. Researches affirm that for the cultivation of vegetables crops a soil with good fertility and base saturation (BS) between 70 and 80% is required [3], which does not is the reality of the most of soils in Brazil territory.

Oxisol are predominant soil class in the Cerrado, characterized by the low natural fertility, high aluminum saturation, acid pH and low levels of calcium and magnesium [4], needing of fertilizer complementation. Therefore, to make these soils more productive, it is essential to use agricultural practices such as liming and supplementary 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 necessity for new fertilization alternatives emerged the organomineral composts, originating from the mixture of mineral fertilizers with solid residues of burned organic compounds, such as wood ash. This fertilizer is used as a soil conditioner (ameliorant), 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 ameliorant 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 wood ash, organomineral fertilizers, in function the base saturations in the culture of arugula in Oxisol.

2. MATERIALS AND METHODS

The experiment was conducted at greenhouse in the Federal University of Mato Grosso, *Campus* of Rondonópolis between February and April of 2014. The Oxisol [10] it was collected at the layer of 0.0 - 0.2 m deep in area under Cerrado vegetation. The chemical and granulometric characteristics of the soil (Table 1) [11].

The entirely randomized design experimental was used, with eight treatments and four repetitions. The treatments were the following: T1 - wood ash at 50% of BS; T2 - wood ash at 80% of BS; T3 - wood ash + mineral fertilizers at 50% of BS; T4 - wood ash + mineral fertilizers at 80% of BS; T5 - mineral fertilizers at 50% of BS; T6 - mineral fertilizers at 80% of BS; T7 - control (limed for 50% of BS) and T8 - control (limed for 80% of BS).

The culture used was the arugula, cultivated in pots with a capacity of 2 dm^3, each pot was considered as experimental unit (plot). The treatments with mineral fertilization were applied 80 mg L^{-1} of N, 200 mg L^{-1}, P_2O_5 and 90 mg L^{-1} of K_2O, using as fonts: urea, single superphosphate and potassium chloride, respectively [12].

In the treatments with wood ash, the 20 g L^{-1} rate of ash was used (equivalent to 40 Mg ha^{-1}), which was established through pilot's experiments (previous experiments) with same type of soil and culture, also applied 80 mg L^{-1} of N, using the urea as font of N, because the low nitrogen content in wood ash. The treatments with inorganic fertilization were composed of 50% of the rate of mineral fertilization and 50% of the rate of wood ash.

After the liming with dolomitic limestone, the soil was incubated for 30 days, to neutralize the acidity of the soil and elevate at 50% and 80% BS, respectively. At the time of the application of the limestone, the ash rates were added, in the two treatments with wood ash (5.82 Mg ha^{-1} at 50% SB and 10.02 Mg ha^{-1} at 80% SB of dolomitic limestone).

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

Ten arugula seeds (*Eruca sativa* Miller) were sown 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 30 days after incubation with limestone and wood ash evaluated for all treatments. At 30 days after emergence of plants the chlorophyll index (reading SPAD), shoot fresh and dry mass, root dry mass and evapotranspiration of the arugula were evaluated. The pH of the soil was obtained through the pH meter in water solution and $CaCl_2$ [11].

Table 1. Chemical analyses and granulometric of the oxisol at 0.0 - 0.2 layer

pH		P	S	K	Ca	Mg	Al	H	SB	CEC	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; BS - Sum of Bases; CEC - Cation Exchange Capacity; V - Base Saturation

Table 2. Chemical composition of burned wood ash

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.

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 shoot fresh mass and the roots were determined in a semi-analytic balance and subsequently, packed in an air forced circulation kiln to obtain dry mass at 65℃ until constant mass. The evapotranspiration was determined by the sum of the water repositions in each pot during the experiment.

The results were submitted to the ANOVA and Scott-Knott test (P = 0.05), in the statistical program SISVAR.

3. RESULTS AND DISCUSSION

There was significant difference between treatments in all variables analyzed (P = 0.05).

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).

The chlorophyll index in the leaf has a positive relationship with the chlorophyll content [14] that influenced 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, another study [15] on cottons plants evaluating rates of wood ash in Oxisol, observed increases 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 (*Raphanus sativus*), 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 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 [17].

In the shoot fresh and dry masses, the mineral fertilizer (50% and 80% BS) and organomineral (50% and 80% BS) 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 because 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 shoot fresh and dry masses. Studies with mineral fertilization have reported increases in the productions of shoot dry mass and shoot fresh mass of the arugula [2,18].

Table 3. Chlorophyll Index (CI), Shoot Fresh Mass (SFM), Shoot Dry Mass (SDM), Root Dry Mass (RDM), Evapotranspiration of culture (ETc) and pH of the soil ($CaCl_2$), of arugula culture in function of rates fertilizers in Oxisol

Fertilizers	CI	SFM	SDM	RDM	ETc	pH
	SPAD	**-----------------g pot^{-1}-----------------**			**L pot^{-1}**	**-**
Wood Ash 50% BS	10.53 b	0.38 b	0.06 b	0.07 b	2.78 a	5.84 b
Wood Ash 80 BS	17.65 b	0.83 b	0.12 b	0.02 b	2.31 b	6.44 a
Mineral 50 BS	45.93 a	3.80 a	0.51 a	0.06 b	2.20 b	5.48 b
Mineral 80 BS	41.20 a	6.88 a	1.31 a	1.45 a	2.65 a	6.38 a
Organomineral 50% BS	50.80 a	3.80 a	0.89 a	0.51 b	2.57 a	5.78 b
Organomineral 80% BS	29.55 a	5.00 a	0.74 a	0.37 b	2.52 a	6.38 a
Control 50% BS	-	-	-	-	-	5.90 b
Control 80% BS	-	-	-	-	-	6.36 a
CV %	53.90	75.86	109.04	105.79	12.35	4.51

Mean values followed by the same letter within the column are not different significantly (Scott-Knott test P > 0.05).

However, experiment on lettuce and arugula associations in different spatial arrangements, under organic and mineral fertilizer, was observed better productivity of arugula performance under organic fertilization [19]. Confronting, another study [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 to root dry mass of the arugula plants (Table 3). The largest root dry mass 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 shoot dry mass, indicating that there is a positive relationship in the productivity of the aerial part with the root development of the plant.

The largest ETc by the arugula plants was observed in the 50% BS wood ash treatments, mineral fertilization 80% BS, organomineral 50% BS and organomineral 80% BS, respectively (Table 3). The increase in water consumption is associated with mineral fertilization treatments and organomineral, which produced greater shoot dry mass. The largest nutrient intake in the soil resulted in greater vegetative development and consequently raised water consumption by the arugula.

The treatments with 80% BS had pH higher than the 50% BS 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 (50% and 80% BS) and even though the ash increases the pH, such effect was not observed in the present study.

However, many researches showed the increases 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. CONCLUSION

Application of mineral fertilizers or combination of wood ash with mineral fertilizers (organomineral) give the significant and positive effect on the development of chlorophyll index, shoot fresh and dry mass and root dry mass in the arugula culture. For the mineral or organomineral fertilizer, arugula could be grown at a base saturation of 80% and 50%, respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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 Available: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 Verde. 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.

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. Encicl Biosfera. 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 Bras Frut. 2013;35(2)377-383. Portuguese Available: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 Oxisol of the Cerrado. Encicl Biosfera. 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. Encicl Biosfera. 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 Oxisol of Cerrado. Encicl Biosfera. 2012;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 Bras. 2010;28:36-40. English
20. Andrade EMG, Silva HS, Silva NS, Sousa Júnior JR, Furtado GF. Organomineral fertilization in leafy vegetables, fruits and roots. Rev Verde. 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 Agron. 2012;43(2):228-236. Available: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 o Saber. 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. Encicl Bisofera. 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. Austral J of Crop Sc. 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 Bras. 1993;11:38-40.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20682