

1 **Application of wood ash, organomineral and mineral fertilizers to**
2 **increase the growth of Arugula (*Eruca sativa* Miller) at different**
3 **base saturation on Oxisol**

4
5 **ABSTRACT**

6 The objective of this study was evaluating the production of arugula fertilized with wood ash,
7 organomineral fertilizer (wood ash + mineral fertilizer) and mineral fertilizer in function of
8 the base saturation levels in Oxisol. The experiment was performed in a greenhouse using the
9 completely randomized experimental design with eight treatments, as follows: T1 - wood ash
10 at 50% of BS; T2 - wood ash at 80% of BS; T3 - wood ash + mineral fertilizers at 50% of BS;
11 T4 - wood ash + mineral fertilizers at 80% of BS; T5 - mineral fertilizers at 50% of BS; T6 -
12 mineral fertilizers at 80% of BS; T7 - control (limed for 50% of BS) and T8 - control (limed
13 for 80% of BS) and four replications. The experimental units consisted of a 2 dm³ soil pot. pH
14 of the soil 30 days after incubation with limestone and wood ash was evaluated for all
15 treatments. At 30 days after emergence of plants the chlorophyll index, fresh and dry mass of
16 shoot, dry mass of root and evapotranspiration of the arugula were evaluated. The highest
17 values of pH of the soil were observed in the treatments at 80% of BS. Generally, the higher
18 of shoot fresh and dry mass were obtained by application of mineral and wood ash combined
19 with mineral fertilizers (organomineral fertilizer). The higher of root dry mass was obtained
20 by minerally fertilized plots at 80% of BS. Compared to wood ash fertilized plots only, the
21 minerally fertilized plots followed by the wood ash and mineral treated plot provided the
22 highest of chlorophyll index, shoot fresh and dry mass and root dry mass of the arugula
23 plants. For the mineral or organomineral fertilizer, arugula could be grown at a base saturation
24 of 80% and 50%, respectively.

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

27

28 1.INTRODUCTION

29

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

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

40 For the good development of the plants it is necessary, among other factors, a soil with
41 good fertility. Researches affirm that for the cultivation of vegetables crops a soil with good
42 fertility and base saturation (BS) between 70 and 80% is required [3], which does not is the
43 reality of the most of soils in Brazil territory.

44 Oxisol are predominant soil class in the Cerrado, characterized by the low natural fertility,
45 high aluminum saturation, acid pH and low levels of calcium and magnesium [4], needing of
46 fertilizer complementation. Therefore, to make these soils more productive, it is essential to
47 use agricultural practices such as liming and supplementary fertilization.

48 Nutrient replenishment through mineral fertilizers is interesting, since these can be rapidly
49 absorbed by the roots of plants, due to high concentration and high solubility. However, the

50 process of leaching and acidification of the soil can be increased easily [5], make the rational
51 management and assembly of fertilization necessary, and the incorporation of alternative
52 fertilizers to the system.

53 With the necessity for new fertilization alternatives emerged the organomineral composts,
54 originating from the mixture of mineral fertilizers with solid residues of burned organic
55 compounds, such as wood ash. This fertilizer is used as a soil conditioner (ameliorant),
56 stimulating the development of plant roots and enhancing the absorption of water and
57 nutrients. Thus, increases in crop production, stimulating agricultural sustainability [6],
58 specifically by family farming, since the greenery crops are greatly exploited in organic
59 farming [7] and have increased aggregate value.

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

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

70

71 2. MATERIAL AND METHODS

72

73 The experiment was conducted at greenhouse in the Federal University of Mato Grosso,
74 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].

77

Table 1 -Chemical analyses and granulometric of the Oxisolat 0.0-0.2 layer

pH		P	S	K	Ca	Mg	Al	H	SB	CEC	V	m
H ₂ O	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 (H₂SO₄ 0,025N + HCl 0,05N); S - calcium phosphate;

B - hot water; BS - Sum of Bases; CEC - Cation Exchange Capacity; V - Base Saturation

79

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 dm³, each pot was considered as an experimental unit (plot). The treatments with mineral fertilization were applied 80 mg dm⁻³ of N, 200 mg dm⁻³ P₂O₅ and 90 mg dm⁻³ of K₂O, using as sources: urea, single superphosphate and potassium chloride, respectively [12].

In the treatments with wood ash, the 20 g dm⁻³ rate of ash was used (equivalent to 40 Mg ha⁻¹), which was established through previous experiments (pilots) with same type of soil and

Comment [Nazimah1]: dm³ for measuring volume. Calculate correct it throughout the paper.

Comment [Nazimah2]: Pilots

91 culture, also applied 80 mg dm⁻³ of N, using the urea as a source of N, because the low nitrogen
 92 content in wood ash. The treatments with inorganic fertilization were composed of 50% of the
 93 rate of mineral fertilization and 50% of the rate of wood ash.

94 After the liming with dolomitic limestone, the soil was incubated for 30 days, to neutralize
 95 the acidity of the soil and elevate at 50% and 80% BS, respectively. At the time of the
 96 application of the limestone, the ash rates were added, in the two treatments with wood ash
 97 (5.82 Mg ha⁻¹ at 50% BS and 10.02 Mg ha⁻¹ at 80% BS of dolomitic limestone).

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

100

101 Table 2-Chemical composition of burned wood ash

N	P ₂ O ₅	K ₂ O	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

102 Soluble in CNA + water.

103

104 ~~It was sown 10~~Ten arugula seeds (*Eruca sativa* Miller) ~~were sown~~ per pot. After the
 105 establishment, the thinning was carried out by leaving two plants per pot. For irrigation of
 106 plants it was adopted as a criterion for the replacement of evapotranspiration by means of the
 107 gravimetric method, maintaining the soil at 80% of the maximum water retention capacity
 108 [13].

109 The variables evaluated were: pH of the soil 30 days after incubation with limestone and
 110 wood ash evaluated for all treatments. At 30 days after emergence of plants the chlorophyll
 111 index (reading SPAD), shoot fresh and dry mass, root dry mass and evapotranspiration of the
 112 arugula were evaluated. The pH of the soil was obtained through the pH meter in water
 113 solution and CaCl₂[11].

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 °C 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).

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 vasepot ⁻¹		L vasepot ⁻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 $P>0.05$).

135

136 The chlorophyll index in the leaf has a positive relationship with the chlorophyll content
137 [14] that influenced the absorption of nutrients, mainly of nitrogen. The organomineral
138 fertilizer presented similar efficiency to mineral fertilizer, showing that the constituent ash of
139 the organomineral fertilizer contributed to the best utilization of the nitrogen applied,
140 providing nutrients, such as magnesium, constituent of the chlorophyll
141 molecule. Corroborating with the results of this work, another study [15] on cottons plants
142 evaluating rates of wood ash in Oxisol, observed increases in the chlorophyll content with the
143 application of vegetable ash, attributing this effect to an improvement in nitrogen absorption
144 due to the applications of wood ash.

145 Studies with wood ash rates in the culture of the radish (*Raphanussativus*), presented
146 influence in the chlorophyll index, effect provided by the availability of nutrients, which
147 participate in the synthesis of chlorophyll and photosynthetic processes [16]. Related results
148 were also observed in studies with rates of wood ash in the marandu-grass, in which there was
149 an increase in the chlorophyll content with the increase in the ash rates [17].

150 In the shoot fresh and dry masses, the mineral fertilizer (50% and 80% BS) and
151 organomineral (50% and 80% BS) have provided greater increments in mass production, in
152 relation to the application of ash and control (Table 3). In the treatment control, there was no
153 mass production because the death of the plants.

154 The use of mineral fertilizers and organomineral were more efficient in relation to wood
155 ash, due to a better nutrient availability for the arugula culture, resulting in greater production
156 of shoot fresh and dry masses. Studies with mineral fertilization have reported increases in the
157 productions of shoot dry mass and shoot fresh mass of the arugula [2] [18].

158 However, experiment on lettuce and arugula associations in different spatial arrangements,
159 under organic and mineral fertilizer, was observed better productivity of arugula performance

160 under organic fertilization [19]. Confronting,another study [20],reported that the
161 organomineral fertilization was more efficient in the increase in agricultural production which
162 was isolated from a mineral or organic fertilizer. According to the authors, the association of
163 these fertilizers can complement the lack of some nutrient of isolated fertilizer.

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

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

176 The treatments with 80% BS had pH higher than the 50% BS at 30 days after incubation,
177 regardless of the rate of wood ash (Table 3). This effect was due to the use of limestone to
178 elevate the base saturation(50% and 80% BS) and even though the ash increases the pH, such
179 effect was not observed in the present study.

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

183

184 4. CONCLUSION

185

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

191

192 **COMPETING INTERESTS**

193

194 Authors declared that no competing interests exist.

195

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