Priprioca essential oil and nutritional content in response to organic fertilization and liming

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Abstract

The native aromatic flora of Amazon has been the subject of several basic studies. One of these species is *Cyperus articulatus* L., known as priprioca, whose essential oil has great potential for exploitation due to its importance in the local pharmacopoeia. The objective of this work was to evaluate the production of essential oil and macronutrient contents of priprioca plants in response to organic fertilization and soil correction. The experimental design was completely randomized, in a 4 x 2 factorial scheme distributed in four replications. Poultry litter was more efficient than castor bean cake and cattle manure, promoting the highest yields of essential oil when applied to dosages with 330 g pot^{-1} and 440 g pot^{-1} in soil where limestone was applied. Poultry litter and liming, in interaction, or with the other treatments, were the most efficient in stimulating the absorption of macronutrients; liming did not influence the uptake of K, Ca, Mg and S when in interaction with castor bean or cattle manure.

Keywords: *Cyperus articulatus*. Medicinal plant. Aromatic plant. Mineral nutrition. Soil fertility.

Introduction

Medicinal plants should guarantee greater sustainability for agriculture as they cease to be exploited only for extractive purposes, especially if a production chain is created, connecting production, industrialization and commercialization. Like the great majority of crops, these plants must respond positively to an adequate production program, involving the correct management of the soil and the species grown in it. A proper nutrient supply, based on chemical analysis of the soil and plant tissues, associated with other cultural practices, may promote results, such as adequate productivity, profitability and environmental protection (AMARAL et al., 2010).

Essential oils are used to provide aroma and special odors to several foods and perfumery products. In addition, its use in analgesic, antiseptic, sedative, expectorant, stimulant, stomatal and

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even antifungal and antibacterial activities is also very important (SILVA, 2011; ALMEIDA et al., 2011). They are volatile products and, usually, have a complex constitution. In some cases, they contain more than a hundred components distributed in varying amounts (CASTRO et al., 2010).

The international market for essential oils moves around 1.8 billion dollars annually. However, Brazilian share in this scenario is still small, corresponding only to 0.1% (BIASI et al., 2009). In the State of Pará, priprioca *Cyperus articulatus* L. has aroused great scientific and economic interest due to the pleasant aroma of the essential oil obtained from its rhizomes.

A major challenge involving the use of medicinal and aromatic plants is achieving stable yields, in a desired quantity and quality, increasing the reliability of herbal medicine since the production of active principles in Brazilian regions oscillates immensely, thus justifying the importance of the studies related to the cultivation of those plants.

Not much is known about the mineral nutrition of priprioca, since many of the medicinal and aromatic species are still considered semi-wild, consequently, they have not undergone genetic manipulation, making it necessary to better understand the mechanism of absorption and metabolization of the mineral elements in an efficient way (SILVA, 2005).

The objective of this study was to evaluate the production of essential oil and macronutrient contents of priprioca (*Cyperus articulatus* L.) plants in response to organic fertilization and soil amendment.

Material and methods

The experiment was carried out from January to October 2011, in a greenhouse covered by 150 microns plastic, located at the Federal Rural University of the Amazon in Belém, state of Pará. This study used samples of soil classified as Dystrophic Yellow Latosol (EMBRAPA, 2006), collected in the 0-0.20 m depth layer on a farm located in the municipality of Santo Antônio do Tauá, state of Pará.

The experimental design was completely randomized in a 4 x 2 factorial scheme, distributed in four replicates. The factors were four organic fertilizations: castor bean cake, cattle manure, poultry litter and soil as control treatment; two levels of corrections, with and without the addition of limestone.

The doses of cattle manure (0, 280, 420 and 520 g pot^{-1}) and poultry litter (0, 220, 330 and 440 g pot^{-1}) were differentiated to maintain the same N content in the doses aplied with castor bean cake (0, 100, 150 and 200 g pot $^{-1}$), based on the recommendation for black pepper in the region (CRAVO et al., 2007), which will be compared in 0, 1, 2 and 3 doses. Chemical composition of the organic substrate used in the experiment is presented in Table 1.

Table 1. Chemical characterization of castor bean cake (CBC), cattle manure (CM) and poultry litter (PL), used as fertilizers in the experiment.

Organic sources	N	P_2O_5	K_2O	S	Ca	OM Total	C/N	pH
	(%)	-----------mg.dm^{-3}----------			$cmol_c\ dm^{-3}$	g Kg^{-1}	-	-
CBC	5.18	1.26	1.1	0.37	0.028	74.07	7.94	5.81
CM	1.85	1.16	0.65	0.2	0.026	73.16	21.97	5.16
PL	2.35	1.93	2.45	0.05	0.026	73.65	17.41	5.37

Source: Elaborated by the authors (2015).

Liming was performed using a mixture of $CaCO_3$ and $MgCO_3$ (87% PRNT), in the 3:1 ratio, on the basis of 2.5 t ha^{-1}. The soil collected was taken to the laboratory where the chemical analyzes were carried out (TABLE 2).

Table 2. Chemical characterization of soil samples used in the experiment (0-20 cm depth).

pH (H_2O)	OM	P	K^+	Ca^{+2}	Mg^{+2}	H + Al	SB	Al^{+3}	CEC pH 7
	g Kg^{-1}	mg dm^{-3}	----------	----------	---------- cmol$_c$ dm^{-3}	----------	----------	----------	
4.3	8.9	3.0	0.08	0.9	0.4	2.45	1.41	0.3	3.86

Source: Elaborated by the authors (2015).

Available phosphorus was determined by using Mehlich 1 extractor; pH was determined in water; exchangeable calcium, magnesium and aluminum were extracted with 1 mol L^{-1} KCl solution; exchangeable potassium was extracted with Mehlich1 and quantified by flame photometry; H + Al were extracted with 0.5 mol L^{-1} calcium acetate solution buffered to pH 7.0 and determined by neutralization titrations according to Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA (1997).

The soil was initially incubated for a period of thirty days. Soil-filled pots were initially saturated with distilled water and drained for approximately two hours until the field capacity was obtained, then they were incorporated into the organic sources according to the established treatments and, subsequently, a tuber of priprioca was planted per pot.

Data were collected eight months after planting. The plants were collected and separated in tubers, roots and later washed for removal of the excess of the substrate contained in them. The roots were then packed in paper bags and dried in a forced circulation oven at 60°C. The nutrient contents in the plant tissue were then determined. Total N content was determined according to the micro Kjeldahl method and the extract obtained by nitro-percloria digestion of the plant material. Phosphorus was determined by colorimetry, and K, Ca and Mg by atomic absorption spectrophotometry following the methodology of Embrapa (2005).

Regarding extraction of the essential oil from the rhizomes of the priprioca plants, the steam distillation hydrodistillation method was used with the aid of Clevenger apparatus adapted to a volumetric flask with a capacity of 1.000 mL. At each extraction, lasting approximately four hours, the 50 g rhizome samples were placed in a flask with 500 mL of distilled water. After a few minutes of rest in the obtained hydrolate (water + oil mixture), the solution was filtered and the amount of essential oil in the container was measured.

The results were submitted to the analysis of variance by comparing the treatments using F test ($P < 0.05$), test of Tukey was applied to 5 % of probability, using the statistical software Sisvar (FERREIRA, 2011).

Results and discussion

The production of priprioca essential oil and the contents of the nutrients were significantly influenced by the treatments and their interactions, except for P, which did not present any changes as treatments were applied (TABLE 3).

Table 3. Summary of the analysis of variance of the applied treatments: Organic fertilization (OF) and Soil amendments (AMD) for oil production (OP) and nutrient content in priprioca (*Cyperus articulatus* L.) plant tissue.

Source of Variation	DF	OP	N	P	K	Ca	Mg
OF	2	**	**	ns	**	**	**
AMD	1	**	**	ns	**	**	**
OF*AMD	2	**	**	ns	**	**	**
Residue	75	0.002	0.58	0.26	0.62	0.52	0.53
CV		17.94	12.79	10.17	15.55	7.49	13.36

Source: Elaborated by the authors (2015).

The highest yields of essential oil were verified by the application of poultry litter in all applied doses of organic fertilization. In general, production of priprioca oil increased as the doses of the organic sources increased, except for castor bean cake, which provided reduction from the third dose applied (TABLE 4).

Besides being a source of nutrients to the plants, organic fertilization is able to properly supply the needs of the crop and to contribute to the improvement of the physical, chemical and biological qualities of the soil. Medicinal and aromatic plants like any other crop depend on the adequate supply of nutrients for good agricultural productivity. The organic fertilizer improves soil edaphic conditions and can positively contribute to the production of biomass and active principles depending on the species, as it was observed in the experiment.

An increase in oil production was observed as the higher doses of cattle manure were applied.

When evaluating the yield of essential oil of *Hyptis marrubioides* EPL. under organic fertilizer with cattle manure, Sales et al. (2009) called attention to a linear adjustment, for each kilogram of implemented organic fertilizer, there was an increase of 0.0034 g plant^{-1}. Santos (2009), when studying the height, leaf yield, content and yield of essential oil of true lemon balm (*Melissa officinalis* L.) using cattle manure, found that applying 15 t ha^{-1} per year induced the increase of total biomass yield by 10.7 % and the total yield of essential oil by 10.3 % in relation to the control treatment. In the experiment, an increase of 37.5 % was observed when the highest dose (520 g pot^{-1}) was applied in relation to the control (dose 0).

However, Assis et al. (2009) indicated cattle manure negatively influenced the essential oil content in *Lippia sidoides*. Contrary to these results, Valadares et al. (2010) verified a significant increase in the production of essential oil in *Lippia citriodora* (Lam.) with the addition of liming and cattle manure. However, in a second material collection, a small reduction was observed.

Brant et al. (2010) verified lower levels of essential oil in citrus [Aloysia triphylla (L'Hérit)] with the use of bovine manure as treatment. Nevertheless, in this study, the participation of this manure in the increase of the production of the priprioca is emphasized.

Similarly to the results for cattle manure, the application of poultry litter promoted an increase in the production of essential oil of priprioca as the doses were expanded.

Table 4. Priprioca (*Cyperus articulatus* L.) oil production at the organic fertilization doses.

ORGANIC SOURCES	ORGANIC FERTILIZATION DOSES			
	0	1	2	3
CBM	0.08 Cab	0.29 Ab	0.15 BCc	0.11BCc
CM	0.03 Cc	0.17 BCc	0.43 Ab	0.46Ab
PL	0.09 Ca	0.46 Ba	0.50 ABa	0.53 ABa

Means followed by the same uppercase letters (horizontal) and lowercase letter (vertical) do not differ from each other at 5 % level by Tukey test. Castor bean (CBM), cattle manure (CM), poultry litter (PL).

Source: Elaborated by the authors (2015).

Corrections in the soil acidity through liming increased the production of essential oil in treatments with castor bean and poultry litter. The cattle manure treatment caused a reduction in oil production (TABLE 5). Under the effect of liming, poultry litter provided a 25.71% increase in the production of priprioca essential oil that initially was from 0.35 g plant^{-1} to 0.44 g plant^{-1}. As castor bean cake was applied, the increase was more significant, providing an increase of 120 % in oil production, that is, from 0.10 g plant^{-1} to 0.22 g plant^{-1}. In contrast to other applications of organic fertilization, cattle manure promoted a reduction of 34.78% in the production of priprioca essential oil, which was 0.31 g plant^{-1}, reducing to 0.23 g plant^{-1}.

Table 5. Production of priprioca (*Cyperus articulatus* L.) essential oil as a function of the organic fertilization and liming.

OM	No limestone	With limestone
CBM	0.10 Bb	0.22 Ab
CM	0.31 Ab	0.23 Bb
PL	0.35 Ba	0.44 Aa

Means followed by the same uppercase letters (horizontal) and lowercase letter (vertical) do not differ from each other at 5 % level by the Tukey test. Castor bean (CBM), cattle manure (CM), Poultry Litter.

Source: Elaborated by the authors (2015).

By means of the averages found in the study, with an adequate significance in the application of liming, a great tolerance to acid soils cannot be attributed to the crop. Sales et al. (2009), when studying *Hyptis marrubioide*s EPL, demonstrated there was no interaction of organic fertilizer doses with the presence or absence of liming. However, Corrêa et al. (2010) observed the doses of mineral and organic (poultry) fertilization had a significant influence on plant growth, yield and chemical composition of oregano essential oil.

Oliveira Júnior (2005) evaluated the effect of the application of limestone and mineral and organic fertilizer (coat manure) on the concentration and yield of arnica (*Lychonophora ericoides*) essential oil and observed that the studied variables were influenced by the interaction between liming and fertilization. Moreover, the author still points out the treatments of mineral and mixed fertilization with liming and mineral fertilization without liming were those that presented the lowest levels of essential oil. In addition, organic treatment without liming presented lower yield of essential oil, whereas the higher yields were obtained from the mineral and mixed treatments without liming.

For the plants that received treatment with castor bean cake, liming did not show significant results.

Cattle manure and poultry litter were influenced by liming, and soil correction provided the highest N uptake by plants. The contents of phosphorus were not affected by soil correction. The levels of K were significantly affected by soil correction only in the application of the poultry litter, at which liming provided higher levels of this element.

The Ca contents, similar to those of K, were higher with the poultry litter after soil correction. Liming promoted a reduction in the Mg contents after liming, except for fertilization with the poultry litter. For S contents, liming also showed higher values with the chicken litter (TABLE 6).

By evaluating the effect of N content on the roots, no interaction was observed between the use of liming and the addition of castor bean cake. However, the use of poultry litter and cattle manure with the addition of limestone showed the highest levels of N. The practice of soil management with organic fertilization produces several benefits when used correctly. In this aspect, the contribution of organic fertilization becomes a fundamental tool, considering the benefits such as nitrogen supply to the system, increase in the content of organic matter and other elements.

Amaral (2010), when evaluating the concentration of nutrients in the aerial part of *Baccharis trimera*, highlights the source of poultry since over 60 % of nitrogen and phosphorus amounts are also present in the mineral form. Therefore, they do not need to be decomposed by the microorganisms to become available to the plants.

For most organic fertilizers, N is the most abundant nutrient, presenting itself as a constituent of organic molecules that, with the process of mineralization, releases these nutrients as minerals that are absorbed by plants. Smith and Hadley (1989) reported that part of N, present in organic fertilizers, is resistant to fast mineralization and becomes available only to the subsequent crops, and the use of compounds do not only supplies plants with a considerable amount of nutrients, but contributes to maintaining the natural fertility, which involves the biological cycles of the nutrients in the cultivated soils.

Table 6: Contents of N, P, K, Ca, Mg and S in priprioca (*Cyperus articulatus* L.) roots as a function of the organic fertilization and liming.

	N		P		K		Ca		Mg	
	(%)		mg dm^{-3}		-------------------------- cmol$_c$ dm^{-3} -------------------------------					
OM	**WL**	**NL**	**WL**	**NL**	**WL**	**NL**	**WL**	**NL**	**WL**	**NL**
CBM	5.59 Ab	5.98 Aa	1.55 Aa	1.52 Aa	4.43 Ba	5.22 Ab	3.20 Aab	3.06 Aa	1.69 Bb	2.08 Aa
CM	5.70 Ab	5.10 Bb	1.65 Aa	1.63 Aa	4.48 Ba	7.28 Aa	3.03 Bb	3.22 Aab	1.28 Bc	2.24 Aa
PL	7.52 Aa	5.93 Ba	1.56 Aa	1.54 Aa	5.09 Aa	3.99 Bc	3.25 Aab	2.56 Bb	1.99 Aa	1.06 Bb

Means followed by the same uppercase letters (horizontal) and lowercase letter (vertical) do not differ from each other at 5 % level by Tukey test. Castor bean (CBM), cattle manure (CM), poultry litter (PL), with liming (WL), no liming (NL)

Source: Elaborated by the authors (2015).

The contents of phosphorus were not influenced by liming in the different evaluated organic fertilizations. The application of organic residues reduces the fixation of phosphorus in the soil and increases the efficiency of the use of applied phosphate fertilizers. In addition, the organic residues, when interacting with the soil, may present similar effects to those of the limestone (calcium and magnesium carbonates) from the precipitation of iron and aluminum (HUE, 1990). Andrade, Fernandes and Faquin (2003), working in flooded low lands soils, verified the application of organic residue, limestone and gypsum reduces phosphorus fixation.

The greatest levels of K found in the dry matter of the priprioca were observed with the absence of liming, with the application of castor bean cake and cattle manure. In the poultry litter treatment, the effect of liming was significant, promoting a large increase in the contents of K. This lack of limestone response in castor bean and cattle manure can be explained, in part, by the short reaction period, as the application was carried out 30 days before planting. On the other hand, although the soil presented high acidity, the exchangeable Al content was low; therefore, it did not constitute an impediment to root development. The significant values verified with the avian bed can be related to the high concentration of macronutrients in their composition (ZHANG et al., 1998), providing increase in the total carbon, in the content of organic matter (SINGH et al., 2009) and consequently increase of soil pH.

No significant effects were observed in the Ca contents, with the application of limestone in relation to castor bean cake. As limestone was added in the cattle manure treatment, there was a reduction in Ca contents in the plant tissue of priprioca. The addition of limestone in the poultry caused an increase in Ca contents, with highly significant effects.

In a work carried out with different organic fertilization, with and without limestone application, Janegitz et al. (2011) observed the cattle manure presented better results than the castor bean cake. In the treatments without limestone, the castor bean cake was superior because it presented a fast decomposition, taking into account its efficiency according to the amount of the fertilizer used in the study. These results are similar to those of this experiment, evidencing the importance of castor bean cake as an organic fertilizer, even without liming.

Contents of Mg in the plant tissue of priprioca were reduced by liming, with application of castor bean and cattle manure. Regarding poultry litter, an increase in the contents of this nutrient was observed with liming. Excess of calcium in relation to magnesium in the soil solution may impair the absorption of magnesium as well as the excess magnesium may impair the absorption of calcium, similar to that occurring for potassium (MALAVOLTA et al., 1997). When evaluating the lack of macronutrients in basil (Ocimum sp.), Amaral et al. (1999) observed a marked increase in the concentration of Ca in the roots in the treatment with no Mg, probably due to the antagonism between these elements.

Conclusion

The greater production of essential oil of the priprioca occurs with the application of the avian bed in soil with the addition of limestone.

In the priprioca plant tissue the N content is higher with the application of the aviary bed and with the addition of limestone.

The nutrients P, Ca and Mg presented the highest levels when adding bovine manure without liming.

Óleo essencial e teores de nutrientes da priprioca em resposta à adubação orgânica e à calagem

Resumo

A flora aromática nativa da Amazônia vem sendo alvo de vários estudos básicos. Uma dessas espécies é a *Cyperus articulatus L.*, conhecida como priprioca, cujo óleo essencial tem grande potencial de exploração devido a sua importância na farmacopeia local. O objetivo do trabalho foi avaliar a produção de óleo essencial e os teores de macronutrientes de plantas de priprioca (*Cyperus articulatus L.*), em resposta à adubação orgânica e à correção do solo. O delineamento experimental foi inteiramente casualizado, em esquema fatorial 4 x 2 distribuídos em quatro repetições. A cama de aviário foi mais eficiente que a torta de mamona e o esterco de gado promoveu as maiores produções de óleo essencial quando aplicadas às dosagens com 330 g vaso^{-1} e 440 g vaso^{-1} em solo que recebeu calcário. A cama aviária e a calagem em interação ou com os outros tratamentos foram as mais eficientes no estímulo à absorção dos macronutrientes; a calagem não influenciou a absorção de K, Ca, Mg e S quando em interação com a torta de mamona ou com o esterco de gado.

Palavras-chave: *Cyperus articulatus*. Planta medicinal. Planta aromática. Nutrição mineral. Fertilidade do solo.

References

ALMEIDA, L. F. D.; CAVALCANTI, I. W.; VIANA, W. P.; LIMA, E. O. Screening da Atividade Antifúngica de Óleos Essenciais sobre Candida Albicans. **Revista Brasileira de Ciências da Saúde**, João Pessoa, v. 14, n. 4, p. 51-56, 2011. Disponível em: http://periodicos.ufpb.br/index.php/rbcs/article/viewFile/9818/5686. Acesso em: 28 set. 2015.

AMARAL, A. S.; RADÜNZ, L. L.; MOSSI, A. J.; SANTI, A.; ROSA, N. M. F. F.; FEITEN, F. Rendimento de matéria seca e de óleo essencial de *Baccharis trimera* com adubação química e orgânica. **Revista de Ciências Agroveterinárias**, Lages, v. 9, n. 1, p. 20-28, 2010. Disponível em: http://revistas.bvs-vet.org.br/rca/article/download/35145/39516. Acesso em: 30 set. 2015.

AMARAL, J. F. T. do; FONSECA, A. F. A da; MARTINEZ, H. E. P.; PEREIRA, P. R.; FONTES, P. C. R. Deficiências de macronutrientes Fe e B em manjericão (*Ocimum sp*.), em cultivo hidropônico. **Revista Ceres**, Viçosa (MG, Brasil), 1999. Disponível em: http://www.ceres.ufv.br/ojs/index.php/ceres/article/view/2540/533. Acesso em: 28 set. 2015.

ANDRADE, A. T.; FERNANDES, L. A.; FAQUIN, V. Organic residue, limestone, gypsum, and phosphorus adsorption by lowland soils. **Scientia Agrícola**, Piracicaba, v. 59, n. 2, p. 349-355, abr/jun., 2003. Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-90162002000200022. Acesso em: 30 set. 2015.

ASSIS, B. F. S.; MARTINS, E. R.; SOUZA, M. F.; MELO, M. T. P.; CARVALHO JUNIOR, W. G. O. Produção de Fitomassa e de Óleo Essencial de Alecrim-Pimenta em Função da Adubação Orgânica.

Revista Brasileira de Agroecologia, v. 4, n. 2, 2009. Disponível em: http://aba-agroecologia.org.br/revistas/index.php/rbagroecologia/article/view/9625. Acesso em: 16 set. 2015.

BIASI, L. A. **Plantas aromáticas do cultivo à produção de óleo essencial**. Curitiba, PR: Layer Studio Gráfico e Editora Ltda., 2009.

BRANT, R. S.; PINTO, J. E. B. P.; BERTOLUCCI, S. K. V.; ALBUQUERQUE, C. J. B. Produção de Biomassa e teor de óleo essencial de cidrão em função da adubação orgânica. **Revista Horticultura Brasileira**, v. 28, n. 1, 2010. Disponível em: http://www.scielo.br/scielo.php?script=sci_abstract&pid=S0102053620100001000021&lng=en&nrm=iso&tlng=pt . Acesso em: 11 set. 2015.

CASTRO, H. G.; PERINI, V. B. M.; SANTOS, G. R.; LEAL, T. C. A. B. Avaliação do teor e composição do óleo essencial de Cymbopogon nardus (L.) em diferentes épocas de colheita. **Revista Ciência Agronômica**, Fortaleza, v. 41, n. 2, p. 308-314, 2010. Disponível em: http://ccarevista.ufc.br/seer/index.php/ccarevista/article/view/287. Acesso em: 10 set. 2015.

CORRÊA, R. M.; PINTO, J. E. B. P.; REIS, E. S.; COSTA, L. C. B.; ALVES, P. B.; NICULAN, E. S.; BRANT, R. S. Adubação orgânica na produção de biomassa de plantas, teor e qualidade de óleo essencial de orégano (Origanum vulgare L.) em cultivo protegido. **Revista Brasileira de Plantas Medicinais**, Botucatu, v. 12, n. 1, p. 80-89, 2010. Disponível em: http://www.scielo.br/scielo.php?pid=S1516-05722010000100012&script=sci_abstract&tlng=pt. Acesso em: 10 set. 2015.

CRAVO, M. S.; VIÉGAS, I. J. M.; BRASIL, E. C. **Recomendação de Adubação e Calagem para o Estado do Pará**. Belém: EMBRAPA, 2007.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, Lavras, v. 35, n. 6, p. 1039-1042, 2011.

HUE, N. V. Interaction of Ca $(H_2 PO_4)_2$ applied to an Oxisol and previous sludge amendment: soil and crop response. **Communications Soil Science Plant Analysis**, New York, n. 1-2, v. 20, p. 61-73, 1990. Disponível em: http://www.tandfonline.com/doi/abs/10.1080/00103629009368215?journalCode=lcss20. Acesso em: 14 out. 2015.

JANEGITZ, B. C.; FIGUEIREDO-FILHO, L. C. S.; MARCOLINO-JUNIOR, L. H.; SOUZA, S. P. N.; PEREIRA-FILHO, E. R.; FATIBELLO-FILHO, O. Development of a carbon nanotubes paste electrode modified with crosslinked chitosan for cadmium(II) and mercury(II) determination. **Journal of Electroanalytical Chemistry**, v. 660, n. 1, p. 209-216, 2011. Disponível em: http://www.bv.fapesp.br/pt/publicacao/26575/development-of-a-carbon-nanotubes-paste-electrode-modified-w/. Acesso em: 30 out. 2015.

MALAVOLTA, E.; VITTI, G. C.; OLIVEIRA, S. A. **Avaliação do estado nutricional das plantas: princípios e aplicações**. 2. ed. Rev. atual. Piracicaba: POTAFOS, 1997.

OLIVEIRA JÚNIOR, A.; FAQUIN, V.; PINTO, J. E. B. P.; LIMA SOBRINHO, R. R.; BERTOLUCCI, S. K. V. Teor e rendimento de óleo essencial no peso fresco da arnica, em função da calagem e adubação. **Horticultura Brasileira**, v. 23, n. 3, jul./set. 2005. Disponível em: http://www.scielo.br/pdf/hb/v23n3/a09v23n3. Acesso em: 14 out. 2015.

ROSINI, F.; DONATI, G. L.; NASCENTES, C. C.; ARRUDA, M. A. Z.; NOGUEIRA, A. R. A.; NÓBREGA, J. A. Espectrometria de absorção atômica com forno tubular na chama e aerossol térmico (TS_FF_AAS): comportamento dos elementos selênio e cobalto. São Carlos (SP, Brasil): Embrapa, 2005.

SALES, J. F.; PINTO, J. E. B. P.; BOTREL, P. P.; SILVA, F. G.; CORREA, R. M. Acúmulo de Massa, teor foliar de nutrientes e rendimento de óleo essencial de hortelã do campo (*Hyptis marrubiodes* EPL.) cultivados sob adubação orgânica. **Bioscience Journal**, Uberlândia, v. 25, n. 1, p. 60-68, 2009. Disponível em: http://www.seer.ufu.br/index.php/biosciencejournal/article/view/6785. Acesso em: 05 out. 2015.

SANTOS, M. F.; MENDONÇA, M. C.; CARVALHO FILHO, J. L. S.; DANTAS, I. B.; SILVA, M, R.; BLANK, A. F. Esterco bovino e biofertilizante no cultivo de erva-cidreira-verdadeira (Melissa officinalis L.). **Revista Brasileira de Plantas Medicinais**, Botucatu, v. 11, n. 4, p. 355-359, 2009. Disponível em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-05722009000400001. Acesso em: 05 out. 2015.

SILVA, A. B. **Estudo Integrado da Priprioca (Cyperus sp.) no Estado do Pará**. 2005. 65 f. Dissertação (Mestrado) -Universidade Federal Rural da Amazônia, Belém, 2005.

SILVA, S. M. **Sistemas e épocas de cultivo na produção agronômica e de óleo essencial de *Melissa officinalis* L.** 2011. 48 f. Dissertação (Mestrado)- Universidade Federal de Uberlândia, Uberlândia, 2011.

SINGH, Y.; GUPTA, R. K.; THIND, H. S. Poultrylitter as a nitrogen and phosphorus source for the rice–wheat cropping system. **Biology Fertilidad Soils**, v. 45, p. 701-710, 2009. Disponível em: https://link.springer.com/article/10.1007%2Fs00374-009-0373-z . Acesso em: 05 out. 2015.

SMITH, S. R.; HADLEY, P. A. Comparison of organic and inorganic nitrogen fertilizers their nitrate-N and ammonium-N release characteristics and effects on the growth response of lettuce (Lactuca sativa L. cv. Fortune). **Plant and soil**, v. 115, n. 1, p. 135-144, 1989. Disponível em: https://link.springer.com/article/10.1007/BF02220704. Acesso em: 05 out. 2015.

VALADARES, R. V.; SOUZA M. F.; VALADARES S. V.; DUARTE R. F.; FERNANDES L. A.; MARTINS E. R. Calagem e adubação orgânica na produção de biomassa e óleo essencial em Lippia citriodora (Lam.). **Horticultura Brasileira,** v. 28, p. 3591-3597. 2010. Disponível em: http://www.abhorticultura.com.br/eventosx/trabalhos/ev_4/a2527_t4576_comp.pdf. Acesso em: 05 out. 2015.

ZHANG, H. Animal Manure Can Raise Soil pH. Production technology, **Department of Plant and Soil Sciences**, v. 10. n. 7, 1998. Disponível em: http://animalwaste.okstate.edu/welcome-folder/pt98-7manureraisessoilph.pdf. Acesso em: 05 out. 2015.

Received: October 05, 2017
Accepted: February 08, 2018