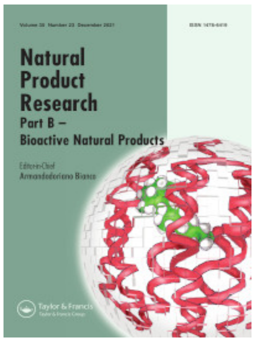

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SHORT COMMUNICATION

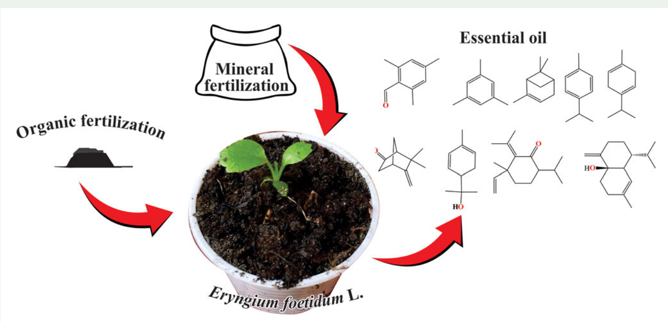
Physiological performance and chemical compositions of the *Eryngium foetidum* L. (Apiaceae) essential oil cultivated with different fertilizer sources

Thiara Luana Mamoré Rodrigues[a], Gledson Luiz Salgado Castro[b], Rafael Gomes Viana[b], Ely Simone Cajueiro Gurgel[a], Sebastião Gomes Silva[c], Mozaniel Santana de Oliveira[a] and Eloisa Helena de Aguiar Andrade[a]

[a]Postgraduate Program in Biological Sciences - Tropical Botany, Paraense Museum Emilio Goeldi, Belém, Brazil; [b]Institute of Agricultural Sciences, Federal Rural University of the Amazon, Belém, Brazil; [c]Federal University of Para, Belém, Brazil

ABSTRACT

The present work proposed an evaluation of the physiological performance, yield and chemical profile of the essential oil obtained from leaves and roots of *Eryngium foetidum* L. (Apiaceae) cultivated using different fertilizer sources. The other gas exchange and chlorophyll a fluorescence parameter was not different, suggested that the photosystem II was not affected by the different fertilizer sources. Highest essential oil yield was obtained in leaf samples cultivated with the mineral fertilizer (0.18%) and control conditions (0.22%), while it was obtained by mineral fertilization in the case of root samples (0.22%). The principal component analysis - PCA and hierarchical cluster analysis – HCA showed two groups: the first was formed by roots (OrgR, MinR and ConR), characterized by the constituents 2,3,4-Trimethylbenzaldehyde, Muurola-4,10(14)-dien-1β-ol, Isoshyobunone, para-Mint-1,5-dien-8-ol, 6-Canphenone, (*E*)-γ-Atlantone and (*E*)-β-Farnesene; and the second group formed by leaves (OrgF, MinF, ConF), related to (2*E*)-2-Dodecenal, *t*-2-Tetradecenal, 1-Dodecanal, 1-Decanal, Tetradecanal, γ-Terpinene, Mesitylene and ρ-Cymene.



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CONTACT Thiara Luana Mamoré Rodrigues thiaramamore@gmail.com; Mozaniel Santana de Oliveira mozaniel.oliveira@yahoo.com.br

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1. Introduction

Fertilization is a widely used practice in agriculture in view of its important role in crop improvement, acting on nutrient supply to promote better physiological performance of plants (Zörb et al. 2014; Elanchezhian et al. 2017). Organic fertilization is often recommended in the scientific literature for the cultivation of aromatic plants, because it allows the preservation of their active principles and the improvement of physical and biological properties of the soil (Carrubba 2015; Caplan et al. 2017). On the other hand, mineral fertilizers promote rapid physiological responses, with immediate availability of plant-absorbable nutrients (Doni et al. 2014; Rubio et al. 2017).

Overall, there is no generalized definition of doses of chemical or organic fertilizers for the cultivation of aromatic plants, considering that species may respond differently to the stimuli of agronomic practices employed in crop management (Timsina 2018). *Eryngium foetidum* L. is an example of aromatic food and medicinal plant species to which no recommendations on fertilization are offered in the literature as a spice plant cultivated in Vietnam, India, Australia outers. In Brazil is popularly known as chicória-do-Pará, *E. foetidum* is a tropical aromatic, oleraceous, herbaceous spice (8-40 cm in height), native to Central and Latin America, and found throughout the Amazon region (Morales-Payan and Stall 2005; Paul et al. 2011). The objective of this study was to evaluate the influence of different fertilizer sources on the physiological performance, yield, and chemical profile of *E. foetidum* essential oil.

2. Results and discussion

2.1. Gas exchange

The different fertilization sources did not promote or influence significantly the CO_2 assimilation rate (P_N) (Figure S1-A). It was observed that Chicória-do-Pará plants has a normal performance of their functions in this parameter; the different sources of fertilization probably provided nutrients (N, P and K) for performance in CO_2 assimilation. Stomatal conductance was significantly influenced in plants submitted to the different fertilization sources (Figure S1-B). Plants cultivated under organic fertilization presented lower averages than those cultivated under mineral fertilization and the control. The latter did not differ from each other. Stomatal conductance had higher values in plants grown with mineral fertilization and in control conditions, making it possible to infer that the plants had higher transpiration rates in relation to those receiving organic fertilization, as shown in Figure S1-D. The decrease of stomatal conductance under organic fertilization is still not completely elucidated. However, this decline may be due to several simultaneous factors, such as reduction of the concentration of potassium in leaves, an important element for the normal functioning of stomatal (Shabala and Pottosin 2014; Engineer et al. 2016). It is reported that the content of potassium (K) in organic poultry manure used as fertilizer is lower in relation to nitrogen (N) and phosphorus (P) (Eckhardt et al. 2018).

2.2. Chlorophyll a fluorescence

The different sources of fertilization did not affect the photosystem II because there were no statistical differences in the analyzed variables. The species performed its functions normally in its metabolism. However, trends in the type of fertilization can be observed in the graphs shown in Figure S2. There was no significant difference between fertilization sources in terms of electron transport rate (ETR) (A) and quantum yield of PSII (ΦPSII) (B) of the plants. The ETR, which measures the transport of electrons between PSII and PSI, remained stable, without significant differences, and values of 172.22, 172.93 and 157.52. This indicates that when the energy from the photons get in contact with the chlorophyll, it stimulates this molecule to an excited state, taken it to a higher level of energy, and prompting a continuous flow of electrons between the two systems (Bezerra et al. 2019).

Quantum yield of PSII (ΦPSII) is the variable that measures the photosynthetic efficiency of plants after dark-adaptation. In this study, the different sources of fertilization did not significantly affect *E. foetidum* plants. However, a reduction of 0.359 was observed in the quantum yield of plants grown in the control treatment. Initial fluorescence (F_0) was not significantly affected by the different fertilization sources. The treatments used in F_0 in *E. foetidum* showed that all reaction centers were open. However, there was a slight trend towards better responses to the mineral fertilizer in relation to T1 and T2.

As for maximum fluorescence (Fm), there was linearity between the values for each type of fertilizer; probably all the quinone was reduced to the photochemical reaction centers, indicating the maximum fluorescence intensity. The maximum photochemical efficiency (Fv/Fm) was 0.7432, 0.7348, and 0.7500 in the different fertilizer sources. *Eryngium foetidum* plants were intact. The photochemical quenching coefficient (qP) did not show significant differences, indicating that the reaction centers remained open, avoiding light saturation of photosynthesis. The species showed normal performance of its photochemical dissipation functions, with values of 0.696595, 0.64313 and 0.62076. Photochemical quenching (qP) may be related to photoinhibition and photoprotection processes, as it measures the dissipation efficiency of excess heat energy in the dark-adaptation of plants. In the experiment, the different sources of fertilization did not interfere significantly with this variable, resulting in values of 0.303405, 0.35687 and 0.377924.

2.3. Yield of essential oil

The yields of essential oils from *E. foetidum* leaves and roots of individuals grown with organic and mineral fertilizers and in control conditions were 0.11%, 0.18% and 0.22% and $<$ 0.11%, 0.22% and 0.10%, respectively (Table S2). The Student-Newman-Keuls test was applied only to leaf samples, as explained in the methods section. Statistical significance ($P \leq 0.05$) was found only between the average essential oil yield from leaves of plants cultivated with mineral fertilization and those cultivated in control conditions. Samples of *E. foetidum* leaves and roots cultivated with mineral fertilization and in control conditions obtained comparatively higher yields than those reported in other studies for example, in the study by, oil yields by hydrodistillation of *E. foetidum* leaves 0.17% and 0.18%, respectively results similar to other literatures (Martins et al. 2003; Chandrika et al. 2015).

2.4. Chemical profile

The predominant classes found in the chemical profile of the essential oil of *E. foetidum* were aldehydes (leaves: 71.38%, 81.35% 74.45%; roots: 70.06%, 74.19% and 68.99%) and sesquiterpenes (leaves: 11.96%, 10.03% and 11.78%; roots: 24.37%, 14.7% and 21.58%) (Table S3).

Multivariate analyses (PCA and HCA) were run with the chemical constituents of the essential oils of leaves and roots of individuals cultivated with different fertilizer sources (organic, mineral and control) that had a content $\geq$ 1.0% to verify possible clusters between the plant organs and fertilizer sources. The first two principal components (PC1 and PC2) presented a proportional variance of 69.4% and 15.0%, respectively. The sum of PC1 and PC2 explained 84.4% of the total variance of the analyzed oil samples. The PCA showed the separation of two groups among the chemical constituents analyzed (Figure S3). The HCA confirmed the formation of these groups (Figure S4). The first was formed by the roots (OrgR, MinR and ConR) and was characterized by the constituents 2,3,4-Trimethylbenzaldehyde, Muurola-4,10(14)-dien-1β-ol, Isoshyobunone, sesq. Oxygenated (MM = 222), *p*-Mint-1,5-dien-8-ol, 6-Camphene, (*E*)-γ-Atlantone, (*E*)-β-Farnesene, and (*Z*)-γ-Atlantone. The second group comprised the leaves (OrgF, MinF, ConF), this one related to the components (2*E*)-2-Dodecenal, *trans*-2-Tetradecenal, 1-Dodecanal, 1-Decanal, Tetradecanal, γ-Terpinene, Mesitylene, ρ-Cymene, α-Pinene, 1-Undecanal, Carotol, Tetradec-1-ene. Literatures report that (*E*)-2-Dodecenal is the highest concentration compound in *E. foetidum* essential oil (Darriet et al. 2014; Thomas et al. 2017). Figure S5 shows the chemical structures of the compounds identified in the *E. foetidum* essential oil.

3. Conclusions

According to gas exchange and chlorophyll a fluorescence analyses, the species responded well in terms of performance of its functions in cultivation with the different fertilizer sources. The results provided evidence of a strong effect of the mineral fertilizer, particularly on the volume of essential oil in leaves and roots. On the other hand, higher leaf biomass was obtained with the organic fertilizer, indicating that this is the best treatment for the purpose of production of greater quantities of raw material. The chemical profile among the studied organs was marked by aldehydes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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