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Organo-mineral fertilization effects on biomass and essential oil of lavender (*Lavandula dentata* L.)

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ABSTRACT

Large-scale production of aromatic plants is subject to phytotechnical challenges, such as management, irrigation, nutrition, and soil fertility, as well as exogenous issues that may affect the chemical composition of secondary metabolites. The aim of this study was to evaluate the effect of organo-mineral fertilizer on the biomass and essential oil of lavender (*Lavandula dentata* L.). A randomized block experimental design was used in a split-plot arrangement, consisting of five rates of organo-mineral fertilizer, and an additional treatment with only mineral fertilizer. The organo-mineral fertilizer was used at the same recommended rate as the mineral fertilizer. The organo-mineral fertilizer was formulated with 10% total nitrogen, 10% P_2O_5, 10% total potassium, and 8% organic carbon, and was applied at the following rates: 100%, 80%, 60%, 40%, and 20%. Flowers, leaves, and stems were harvested three times. Plant biomass, and the concentration, yield, and chemical composition of the essential oils were evaluated. Results showed that the highest flower yield was obtained at 145 days after planting through use of the 100% rate of the organo-mineral fertilizer. The 60% rate of the organo-mineral fertilizer produced more than 320 g $plant^{-1}$ of fresh biomass. The major compounds were 1,8-cineole, camphor, and fenchone, and these compounds together represented more than 80% of the chemical composition. The organo-mineral fertilizer can ensure greater yield through slow release of nutrients around the root system, especially at the flowering stage. We conclude that associating organo-mineral fertilization with the appropriate harvest season has a noticeable impact on the chemical composition of lavender essential oil.

1. Introduction

Lavender (*Lavandula dentata* L.) belongs to the Lamiaceae family and is native to the Mediterranean region. It is cultivated worldwide because of its therapeutic and economic value, as well as for ornamental and decorative purposes; it is also a meliferous plant (González-Coloma et al., 2011; Touati et al., 2011). It is produced mainly to obtain large quantities of high quality essential oil for the perfumery, cosmetics, and pharmaceutical industries (Verma et al., 2010).

The natural hybrid "lavandin" (*L. x intermedia*) and lavender (*L. angustifolia*) are the most productive species, yielding from 1.0% to 1.5% essential oil extracted from fresh flowers, and from 5.0% to 6.0% extracted from dried flowers (Kara and Baydar, 2013).

These essential oils are composed of monoterpenes. Each botanical species has a typical chemical profile, and a few prominent molecules determine the aroma and properties of the essential oils (Demissie et al., 2011). One of the lavender types (*Lavandula dentata*) has a high quantity of 1,8-cineole and camphor.

The composition of the essential oil is determined mainly by the plant genotype; however, environmental and growing conditions can also have a significant impact on the production of these compounds (Demissie et al., 2011). Sellami et al. (2009) reported that soil characteristics and growing conditions can affect biomass production and the composition of the essential oils.

The association of organic fertilizers with mineral fertilizers has had positive effects on essential oil yield in *Ocimum basilicum* L. (El-Naggar et al., 2015), *Pelargonium graveolens* (Ram et al., 2003), *Plectranthus barbatus* (Rosal et al., 2009), *Cymbopogon citratus* (Blank et al., 2007), *Camomila recutita* (Amaral et al., 2008), and *Rosmarinus officinallis* L. (Singh and Guleria, 2013), and on different vegetable crops (Luz et al., 2010) and sugarcane (Sousa, 2014).

The organo-mineral fertilizers allow better retention of nutrients in

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the soil due to the presence of organic matter. This characteristic limits leaching of nutrients in the soil and increases availability of nutrients for the root system since organo-mineral fertilizers release nutrients to the soil solution more slowly (Cerri, 2011).

For aromatic crops, such as lavender, the main advantage of long-term maintenance of organo-mineral fertilizers in the field is their lower solubility. Thus, their content is released during plant development throughout the crop cycle. This can reduce the rate required and make a difference in biomass and essential oil yield.

Specifically for lavender, there is a need for further clarification regarding the advantages and disadvantages of the use of mineral, organic, or combined fertilizers, in order to improve the scale of production and the quality of the compounds (Shekofteh et al., 2013). Therefore, the aim of this study was to evaluate the effect of different rates of organo-mineral fertilizers on both field and greenhouse production of lavender (*Lavandula dentata* L.).

2. Materials and methods

2.1. Plant material and experimental design

The experiments were carried out in two experimental areas (field and greenhouse) at the "Glória" Research Farm in the municipality of Uberlândia, Minas Gerais, Brazil. Data on temperature, humidity, photoperiod, and accumulated rainfall are shown in Table 1. The experiments were performed simultaneously in both environments from march to december of 2013.

Seedlings of *Lavandula dentata* L. were obtained by vegetative propagation, and they were transplanted when they had a height of 15 cm. No pesticides were applied in the study area throughout the experimental period.

Each experiment was carried out in a randomized block design using a split-plot arrangement with four replications. In the plots, five rates of the organo-mineral fertilizer and an additional treatment with mineral fertilizer (control) were tested. The following rates of organo-mineral fertilizer were used: 100% (T1), 80% (T2), 60% (T3), 40% (T4), and 20% (T5). Mineral fertilizer was used as a control by applying 500 kg ha^{-1} NPK 10-10-10. Harvest times were tested in the split-plots (at 100, 145, and 180 days after planting). Plants were spaced at 80 cm between rows, and 50 cm between plants.

Soil samples were collected before tillage. The field and greenhouse environments had the following characteristics in soil analysis: 1) field: pH 6.1, P = 133 mg dm^{-3}, K = 169 mg dm^{-3}, Ca^{2+} = 4.4 $cmol_c$ dm^{-3}, Mg^{2+} = 1.1 $cmol_c$ dm^{-3}, Al^{3+} = 0 $cmol_c$ dm^{-3}, H + Al = 3.2 $cmol_c$ dm^{-3}, sum of bases (SB) = 5.93 $cmol_c$ dm^{-3}, cation exchange capacity (T) = 9.13 $cmol_c$ dm^{-3}, base saturation (V) = 65%; organic matter (OM) = 4.3 dag kg^{-1}, and organic carbon (OC) = 2.5 dag kg^{-1} and 2) greenhouse: pH 6.0, P = 220.9 mg dm^{-3}, K = 194 mg dm^{-3}, Ca^{2+} = 7.1 $cmol_c$ dm^{-3}, Mg^{2+} = 2.5 $cmol_c$ dm^{-3}, Al^{3+} = 0 $cmol_c$ dm^{-3}, H + Al = 3.0 $cmol_c$ dm^{-3}, SB = 10.1 $cmol_c$ dm^{-3}, T = 13.1 $cmol_c$ dm^{-3}, V = 77%, OM = 8.0 dag kg^{-1}, and OC = 4.6 dag kg^{-1}.

Table 1
Climatic conditions of the "Glória" Research Farm over the months when the experiment was carried out.

Month of 2013	Maximum temp. (°C)	Minimum temp. (°C)	Solar radiation (Mj day^{-1})	Relative Humidity (%)	Rainfall (mm)
March	29	18	16.74	84	254.40
April	27	16	16.80	81	92.20
May	27	13	16.70	74	113.20
June	26	14	14.52	78	6.00
July	26	12	16.70	66	0.00
August	28	12	20.80	54	4.00
September	30	15	21.20	58	22.40
October	29	16	21.61	69	146.60
November	29	18	24.00	77	87.00
December	30	18	19.14	84	210.60

A drip irrigation system was installed with a flow rate of 2.3 L h^{-1} and was spaced at 0.75 × 0.75 m between rows. Irrigation was applied daily for 90 min in the first days after transplanting for establishment of seedlings. Irrigation was applied every two days for 60 min during crop growth.

2.2. Fertilizer characteristics and application

Mineral fertilizer was used as a control at an application rate of 500 kg ha^{-1} of NPK 10-10-10 formulated fertilizer, with 10% total nitrogen (urea), 10% P_2O_5 (phosphate monoammonium), and 10% total potassium (potassium chloride), as recommended by McNaughton (2006). An additional 100 kg ha^{-1} of urea was used in topdressing during crop growth and between harvests.

The pelletized organo-mineral fertilizer was manufactured by the Geociclo Biotecnologia S/A company, in Brazil. The compound was enhanced with mineral nutrients, such as urea, monoammonium phosphate (MAP), and potassium chloride (KCl). This was transformed into an organo-mineral fertilizer through an industrial process. The organo-mineral fertilizers were produced using a biodegradable water-soluble organic polymer for gradual release of the nutrients.

In the experiment, 500 kg ha^{-1} of the formulated organo-mineral fertilizer was used, with the following characteristics: 10% total nitrogen, 10% P_2O_5, 10% total potassium (NPK 10-10-10), 8% organic carbon, 10% moisture, pH 6, density of 0.9 g cm^{-3}, and cation exchange capacity of 175.5 mmol kg^{-1}.

For topdressing, 100 kg ha^{-1} of the formulated organo-mineral fertilizer was applied, with the following characteristics: 26% total nitrogen (NPK 26-0-0), 8% organic carbon, pH 5.5, 8% moisture, density of 0.8 g cm^{-3}, and cation exchange capacity of 145.9 mmol kg^{-1}. The topdressing fertilizations were carried out at 45 and 90 days after planting and between harvests.

2.3. Harvests and evaluations

Three flower harvests and one leaf and branch harvest were carried out. Samples were collected immediately after flowering of the plants. Initial harvests consisted of only inflorescences, as recommended for the first year of commercial production of lavender (McNaughton, 2006), by cutting the plants at about 30 cm above the ground, at the base of the inflorescences, without cutting branches and leaves. For post-harvest analyses, only the central rows of the plots were harvested.

Plants were harvested at 100 (August 15, 2013), 145 (September 30, 2013), and 180 (November 2, 2013) days after planting (DAP) and only when more than 50% of the plants had open flowers. The last harvest consisted of only leaves and branches, at 225 days after planting, to verify leaf and branch yield.

The following characteristics were evaluated in both experiments: fresh weight of flowers and leaves, and concentration, yield, and chemical composition of the essential oil.

2.4. Extraction and chemical analysis of essential oils

Essential oils were obtained by the hydrodistillation technique, using a modified Clevenger apparatus, as recommended by Blank et al. (2007). Each sample consisted of 100 g of fresh biomass distilled for 140 min. The essential oils were collected, dried with anhydrous sodium sulfate (Na_2SO_4), and stored in amber vials at −20 °C until analysis of their chemical composition.

The essential oils were analyzed using gas chromatography (GC) coupled with mass spectrometry (MS) and flame ionization detection (FID) (GC–MS/FID; QP2010 Ultra, Shimadzu Corporation, Kyoto, Japan); the instrument was equipped with an AOC-20i (Shimadzu)