BOLETIN LATINOAMERICANO Y DEL CARIBE DE PLANTAS MEDICINALES Y AROMÁTICAS
© / ISSN 0717 7917 / www.blacpma.ms-editions.cl

Articulo Original / Original Article

Production and composition of Lavender oil: nutritional management and cultivation systems

[Producción y composición de aceite de lavanda: Manejo nutricional y sistemas de cultivo]

Roberta Camargos de Oliveira[1], Jarbas dos Reis Silva[1], José Magno Queiroz Luz[1], Arie Fitzgerald Blank[2], Taís Santos Sampaio[2] & Sérgio Macedo Silva[3]

[1]Instituto de Ciências Agrárias, Universidade Federal de Uberlândia, Uberlândia, MG, Brazil
[2]Departamento de Engenharia Agronômica, Universidade Federal de Sergipe, São Cristóvão, SE, Brazil
[3]Universidade Federal dos Vales do Jequitinhonha e Mucuri, Unaí, MG, Brazil

Reviewed by:
Daniela Russo
Basilicate University
Italy

Luciana Mendes Souza
Universidade Federal de Minas Gerais
Brazil

Correspondence:
José Magno **QUEIROZ LUZ**
jmagno@ufu.br

Section Phytochemistry

Received: 5 July 2020
Accepted: 27 October 2020
Accepted corrected: 17 November 2020
Published: 30 November 2021

Citation:
de Oliveira RC, Silva JR, Luz JMQ, Blank AF, Sampaio TS, Silva SM. Production and composition of Lavender oil: nutritional management and cultivation systems
Bol Latinoam Caribe Plant Med Aromat
20 (6): 649 - 659 (2021).
https://doi.org/10.37360/blacpma.21.20.6.46

Abstract: The objective was to evaluate the production and composition of lavender essential oil, simultaneously at open field and greenhouse, in spring-summer season, under different types of fertilization. Each cultivation system was considered an experiment (field and greenhouse), and in both, the experimental design used was randomized blocks, with five treatments, being fertilization with nutrient source - 100% mineral (100% M), 100% organic (100% O), 100% organomineral (100% OM), 50% organomineral (50% OM), and without fertilization (control), and three repetitions. Better performance and productivity of *Lavandula dentata* is related to respectively 100% OM and 50% OM fertilization in the field and greenhouse. The essential oil content does not differ between cultivation systems and kind of fertilizers, and the majorities compounds were 1.8-cineol, fenchone and camphor.

Keywords: *Lavandula dentata*; Fertilization; Field cultivation; Greenhouse cultivation; Plant nutrition.

Resumen: El objetivo fue evaluar la producción y composición del aceite esencial de lavanda a campo abierto e invernadero simultáneamente, en la temporada primavera-verano, bajo diferentes tipos de fertilización. Cada sistema de cultivo fue considerado un experimento (campo e invernadero), y en ambos, el diseño experimental utilizado fue bloques al azar, con cinco tratamientos, siendo la fertilización con fuente de nutrientes 100% mineral (100% M), 100% orgánico (100% O), 100% organomineral (100% MO), 50% organomineral (50% MO), y sin fertilización (control), y tres repeticiones. Un mejor rendimiento y productividad de *Lavandula dentata* está relacionado con una fertilización de 100% OM y 50% OM en el campo y en invernadero, respectivamente. El contenido de aceite esencial no difiere entre sistemas de cultivo y tipo de fertilizante, y los compuestos mayoritarios fueron 1.8-cineol, fenchone y alcanfor.

Palabras clave: *Lavandula dentata*; Fertilización; Cultivo de campo; Cultivo en invernadero; Nutrición vegetal.

INTRODUCTION

Lavender (*Lavandula* spp.) is a perennial shrub belonging to the Lamiaceaes family, with aromatic, medicinal and ornamental functions. The species *L. angustifolia*, *L. dentata* and *L. latifolia* have the greatest commercial importance, being cultivated specially to essential oil extraction from the leaves, branches and inflorescences (Adamuchio, 2017).

The lavender essential oil composition has important pharmacological functions, including antioxidant, antibacterial, antifungal, and anxiolytic actions (Pereira *et al.*, 2016, Kivrak, 2018). Studies have shown efficacy in treatments using essential oil and a lower incidence of adverse effects compared to other widely used drugs (Costa *et al.*, 2011, Zuzarte *et al.*, 2011), even in cancer therapy (Oliveira *et al.*, 2015).

The essential oil quality needs a lot of attention from the grower to attend the industries requirements in relation to the minimum levels of the predominant elements and the absence and / or presence of certain compounds (Adamuchio, 2017). The essential oils chemical composition can be changed by several factors, the plant genotype is the most determining aspect, but factors external to plants such as nutrients availability and cultivation system have the potential to influence the essential oil production.

Adequate nutritional management guarantees a high productive response from lavender, even though it is not a very demanding crop in terms of culture and relatively resistant. Care with fertilization must be monitored by producers, since the lack or excess of certain nutrients can cause changes in the composition of the oil (Silva *et al.*, 2017).

The cost of mineral fertilizers (an increased risk of environmental contamination) makes fertilization a major bottleneck in production. The alternative fertilization sources such as organic materials from animals and vegetables have been shown positives impacts in economic, environmental and development of many crops, including lavender (Borges *et al.*, 2019).

The main advantage of organic fertilizer is your gradual solubilization of nutrients. The continuous and slow availability of nutrients reduces leachate losses and guarantees a constant nutrition of plants throughout the development cycle (Silva *et al.*, 2017, Mumbach *et al.*, 2019). In the literature, there are researches with organo-mineral fertilizers in planting and leaf nutrition of crops such as potatoes (Abdel-Nabi *et al.*, 2016), beans (Rady *et al.*, 2016) and with potential expansion for species medicinal products, such as lavender (Silva *et al.*, 2017) and basil (Silva *et al.*, 2019).

The composition of essential oils is also significantly altered according to the interaction between plants and environment, especially solar radiation and temperature (Zheljazkov *et al.*, 2013, Mambrí *et al.*, 2018). Cultivation in a protected environment promotes changes in the environment for plants, compared to cultivation in the open field, due to the protection barrier of screens and plastic, which can alter the metabolism and content of key compounds in medicinal plants.

Studies on the influence of agricultural systems and fertilizer sources in lavender still scarce in the literature. So, the objective of this work was to evaluate *Lavandula dentata* production, simultaneously in open field and greenhouse, with different fertilizers sources.

MATERIAL AND METHODS

Experimental area

The experiments were conducted at Glória Experimental Farm, belonging to the Federal University of Uberlândia (18°57’S and 48°12’W). The experimental area is located on BR 050, 12 km from downtown Uberlândia, Minas Gerais State, Brazil. According to the Koppen climate classification, the region's climate is characterized as AW (megathermic), presenting well-defined seasons during the year, with dry winter and rainy summer. The soil present in the study area is Eutrophic Red Latosol (Embrapa, 1999).

The greenhouse was the high tunnel type, 8 m wide, 50 m long and 4 m high lateral with metal structure and cover with agricultural plastic film with a thickness of 150 microns. Before transplanting, a soil sample was taken.

Lavender species (*Lavandula dentata*) were used and the spacing of each plot was 80 cm between rows and 50 cm between plants. The plots, in the field and greenhouse, consisted of 3 lines of 7 plants, the useful plot being the five plants of the central line.

Initially, *Lavandula dentata* seeds (Topseed Garden Sementes) were sown in 72 cell trays with agricultural substrate for seedlings, containing coconut fiber, sand and vermiculite. At 45 days after sowing, the fully formed seedlings were transplanted to the experimental area, after soil preparation and treatments application.

Experimental arrangement and treatments

Each cultivation system (open field and greenhouse) was considered an experiment, conducted in a randomized block design (DBC), with five treatments and three repetitions. The treatments consisted of two doses of organo-mineral fertilizer (Fabrication Geocycle Biotechnology S/A): 100% and 50% of the amount determined based on the analysis of soil data (field and greenhouse) (100% OM and 50% OM), 100% of the recommended for fertilization exclusively via mineral (100% M), 100% of the fertilization exclusively via organic (100% O), having as source tanned bovine manure and absence of fertilizer (control). The 100% refers to the application of 500 kg ha^{-1} of 10-10-10 fertilizer.

The composition of the organic compost is described in the Table 1.

Table Nº1
Analysis of the bovine manure used in the experiment

Analyse	Unit	Dry base 110ºC	Natural moisture
pH $CaCl_2$ 0,01M (Ref. 1:2,5)	pH	----	6.10
Density	g cm^{-3}	----	0.42
Total moisture	%	----	10.64
Total Nitrogen	%	1.97	1.76
Total Organic Matter (Combustion)	%	85.73	76.61
Organic Matter Compostable (Titration)	%	60.01	53.62
Organic Matter Compost Resistant	%	25.72	22.99
Total Carbon (Organic and Mineral)	%	47.63	42.56
Organic Carbon	%	33.34	29.79
Total Mineral Residue	%	14.37	12.84
Insoluble Mineral Residue	%	3.81	3.40
Soluble Mineral Residue	%	10.57	9.44
C/N ratio (Total C and Total N)	----	24/1	24/1
C/N ratio (Organic C and Total N)	----	17/1	17/1
Phosphorus (Total P_2O_5)	%	0.52	0.46
Potassium (Total K_2O)	%	2.18	1.95
Calcium (Total Ca)	%	2.39	2.14
Magnesium (Total Mg)	%	0.21	0.19
Sulfur (Total S)	%	0.12	0.11
Boron (Total B)	mg kg^{-1}	40.00	36.00
Copper (Total Cu)	mg kg^{-1}	18	16
Iron (Total Fe)	mg kg^{-1}	3243	2898
Manganese (Total Mn)	mg kg^{-1}	54	48
Zinc (Total Zn)	mg kg^{-1}	48	43
Sodium (Total Na)	mg kg^{-1}	504	450

The soil mineral analysis was determined according to the method described by EMBRAPA (2011). The physical and chemical analyses of the 0-20 cm layer were as follows: pH H_2O = 6.1; P = 95 mg dm^{-3}; K = 115 mg dm^{-3}; Ca = 3.6 $cmol_c$ dm^{-3}; Mg = 1.1 $cmol_c$ dm^{-3}; Al = 0.0 $cmol_c$ dm^{-3}, CTC= 8.3 $cmol_c$ dm^{-3}; V= 62.6%; M.O. = 3.7 dag kg^{-1} and C.O. = 2.4 dag kg^{-1} in the field and pH H_2O = 6.2; P = 255 mg dm^{-3}; K = 235 mg $cmol_c$ dm^{-3}; Ca = 6.4 $cmol_c$ dm^{-3}; Mg = 2.9 $cmol_c$ dm^{-3}; Al = 0.0 $cmol_c$ dm^{-3}, CTC= 12.7 $cmol_c$ dm^{-3}; V= 72.1%; M.O. = 6.5 dag kg^{-1} and C.O. = 3.4 dag kg^{-1} in the greenhouse. The soil preparation was performed with the use of subsoiler and a rotary hoe attached to the micro tractor for both areas. The drip irrigation used was carried out every 2 days for 50 minutes.

Harvesting and evaluations

Harvesting was realized when the plants were in full bloom. In both cultivation systems, the plants were sectioned at a height of 20 cm from the ground level, packed in plastic bags and destined to the Laboratory for plants processing.

The variables analyzed were fresh and dry mass of the aerial part, content (% per plant), yield (L ha^{-1}) and chemical composition of the essential oil. Weed control was done by manual weeding every 15 days, or as needed. It was not necessary to realize phytosanitary treatments.

To assess the fresh mass of the aerial part, the plants were weighed on a precision scale. To determine the dry mass, the samples were placed in a drying oven at 105°C for 72 hours.

The essential oil was extracted via hydrodistillation, using samples of 110 grams of fresh leaves and flowers with Clevenger apparatus. The distillation was carried out in approximately 45 minutes.

The chemical composition of the essential oil was analyzed at the Photochemistry Laboratory of the Federal University of Sergipe, using a chromatograph coupled to a mass spectrometer (Shimadzu QP5050A). The identification of the constituents was carried out by comparing their mass spectra with those in the equipment database (spectroteca NIST 107 and NIST 21) and by comparing the retention indices calculated through co-injection, using a homologous series of linear hydrocarbons (n- C8-n-C19) with standards.

Data analysis

A joint analysis was carried out between the studied cultivation systems. The means of the variables were subjected to analysis of variance and, when significant, compared by the Tukey test at 5% probability. All the analysis were performed in the SPSS and SISVAR Software.

RESULTS

Fresh and dry mass

The interaction between fertilizer sources and cultivation systems was significant for the parameters fresh and dry mass, and biomass productivity (Figures No. 1 and No. 2). The accumulation of fresh and dry mass was higher in open field cultivation when the plants received fertilization 100% OM and 100% O. Nutrient supplementation with 100% OM revealed an increase in fresh and dry mass of 117.6 and 125.1% in relation to the greenhouse cultivation. In the case of fertilization with 100% O, the increase observed in the field was 61.4 and 59.6% in relation to greenhouse cultivation (Figure No. 1).

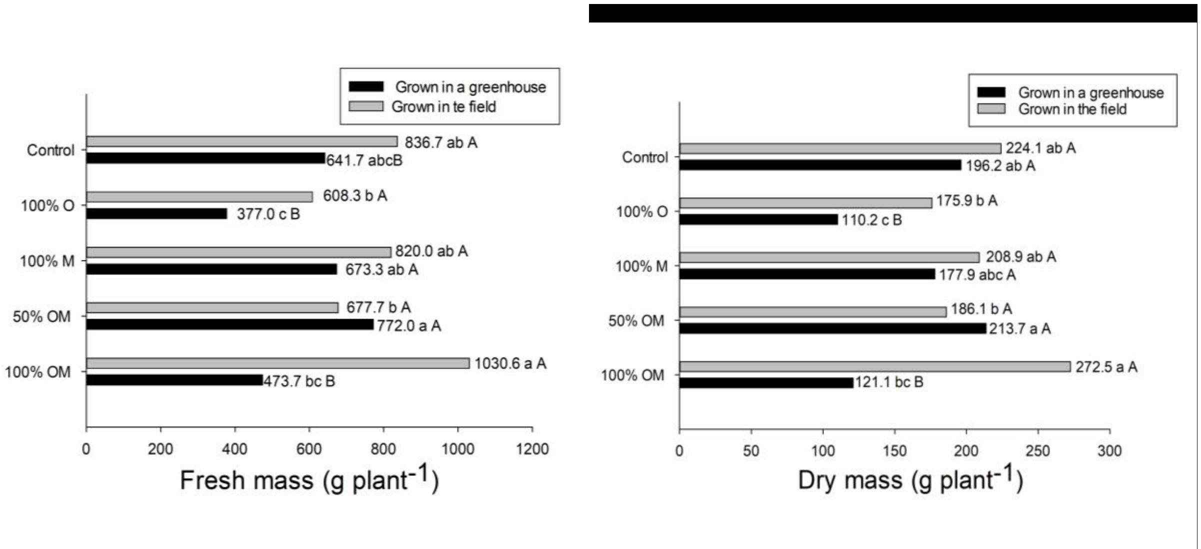
Regarding fertilization in each cultivation system, in greenhouse cultivation the fresh and dry mass were stimulated with 50% OM, compared to 100% O, not differing from 100% M and control. In this environment, the absence of supplementation with nutrients was 78% higher than fertilization with 100% O source. In the open field, the plots fertilized with 100% OM presented better performance compared to fertilization with 50% OM and 100% O, about fresh and dry mass of the aerial part of lavender.

Plants that received supplementation with 100% M, 100% O and no fertilization showed biomass productivity per hectare 120; 61.4 and 30.4% higher in the open field, compared to the greenhouse (Figure No. 2).

Essential oil content and yield

The essential oil content did not differ significantly between cultivation systems and fertilizers (Figure 3). There were significant differences between the sources of fertilization in greenhouse cultivation for essential oil yield, ranging from 6.1 to 10.5 L ha^{-1}. The highest essential oil yield was significantly obtained with 50% OM, being 81.4 and 85.3% higher than fertilization with 100% OM and 100% O, respectively. The other sources showed income intermediate. For this evaluated variable, there was also no difference between the cultivation systems.

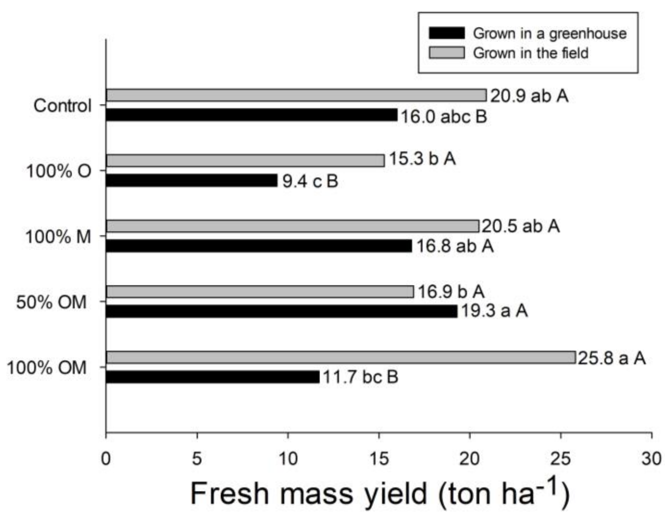
Regarding the composition of the essential oil of *Lavandula dentata* in the field and in the greenhouse (Table No. 2), it was identified 38 compounds, being the majorities 1.8-cineol, fenchone and camphor.



***Values followed by the same lower case letters between fertilizer sources and upper case letters between cultivation systems do not differ statistically according to Tukey test (0.05)**

Figure Nº1

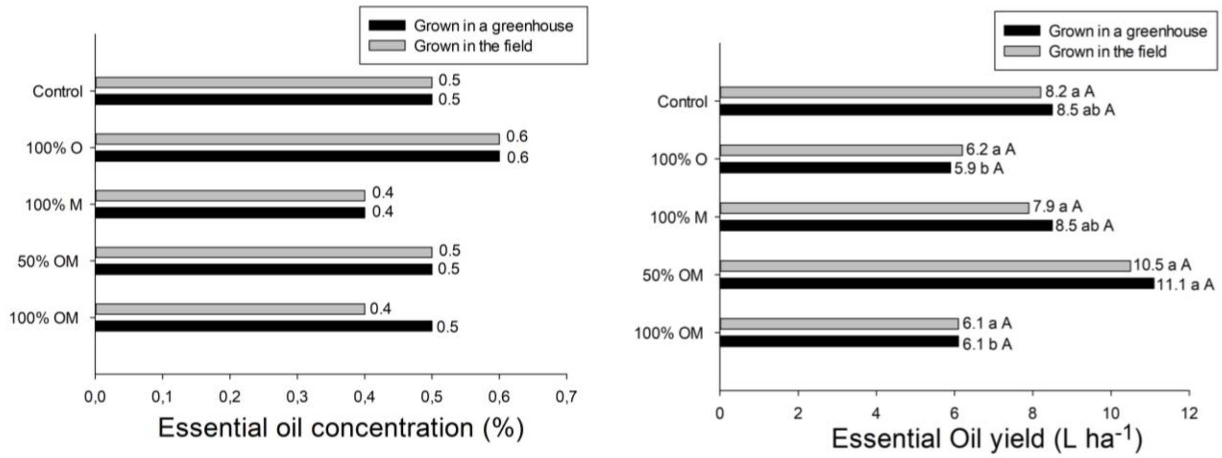
Fresh and dry mass (g) of *Lavandula dentata* plants under cultivation systems (field and greenhouse) and fertilization sources (OM- organo-mineral, O- organic, M- mineral and control)



***Values followed by the same lower case letters between fertilizer sources and upper case letters between cultivation systems do not differ statistically according to Tukey test (0.05)**

Figure Nº2

Biomass productivity (kg ha^{-1}) of *Lavandula dentata* under cultivation systems (field and greenhouse) and sources of fertilization (OM- organo-mineral, O- organic, M- mineral and control)



***Values followed by the same lower case letters between fertilizer sources and upper case letters between cultivation systems do not differ statistically according to Tukey test (0.05)**

Figure Nº3

Essential oil concentration (%) and yield (L ha^{-1}) of *Lavandula dentata* under cultivation systems (field and greenhouse) and fertilizer sources (OM- organo-mineral, O- organic, M- mineral and control)

Table Nº2

Average percentage (%) of the chemical compounds found in the essential oil of *Lavandula dentata* in the field and in the greenhouse

Compounds				100% OM		50% OM		100% M		100% O		Control	
	Iret	RRLI	RORI	Field	Green house	Field	Green house	Field	Green house	Field	Green house	Field	Green house
α-pinene	7.9	932	916	4.82	4.00	4.22	3.64	4.30	3.93	4.03	4.14	3.67	4.06
Camphene	8.4	946	930	1.49	1.19	1.24	1.21	1.24	1.21	1.15	1.17	1.08	1.23
Sabinene	9.1	969	955	1.32	1.17	1.24	0.95	1.35	1.17	1.23	1.18	1.12	1.18
Octen-3-ol <1>	9.2	974	959	6.64	5.56	5.91	5.17	6.26	5.94	5.87	6.16	5.49	5.70
Myrcene	9.5	988	970	1.47	1.07	1.05	0.84	1.24	1.14	1.19	1.24	1.08	1.07
1,8-cineol	11.1	1026	1020	41.91	56.60	42.53	46.08	42.73	41.81	41.40	41.24	43.49	44.01
NI	12.1		1051	0.33	0.58	0.22	0.23	0.00	0.29	0.22	0.26	0.27	0.00
Fenchone	12.9	1083	1073	12.17	11.43	13.28	13.70	12.68	13.42	13.18	13.07	13.46	12.98
Linalol	13.1	1095	1083	2.61	5.55	2.05	1.93	2.17	2.81	2.36	2.73	2.44	2.01
Endo-fechol	13.6	1114	1097	1.78	0.29	1.17	1.42	1.09	2.15	1.15	2.10	1.78	0.93
Exo-fenchol	13.8	1118	1101	5.52	5.57	4.94	5.79	5.01	6.13	4.96	5.91	6.05	4.59
allo-ocimene	13.9	1128	1107	0.27	0.35	0.25	0.24	0.25	0.26	0.26	0.26	0.25	0.24
Camphor	14.8	1141	1133	11.87	11.57	14.74	14.02	14.63	13.72	15.87	13.57	13.76	15.14
pinocarvone	15.1	1160	1146	0.37	0.32	0.35	0.31	0.29	0.27	0.31	0.27	0.29	0.29
Isoborneol	15.3	1155	1150	1.89	0.43	1.63	1.49	1.62	1.59	1.65	1.65	1.58	1.53
Terpinen-4-ol	15.5	1174	1159	0.29	1.07	0.32	0.25	0.32	0.26	0.30	0.25	0.25	0.30
iso-pinocampheol	15.9	1176	1169	0.40	0.74	0.44	0.32	0.40	0.32	0.45	0.36	0.34	0.42
α-terpineol	16.0	1186	1173	1.08	0.23	1.09	0.75	1.13	0.91	1.17	0.99	0.94	1.01
myrtenal	16.2	1195	1179	0.72	0.21	0.73	0.59	0.68	0.57	0.69	0.58	0.56	0.70
Carvone	17.5	1239	1223	0.27	0.38	0.22	0.00	0.00	0.00	0.22	0.00	0.00	0.21
Caryophyllene oxide	27.1	1582	1566	0.63	0.40	0.47	0.35	0.41	0.36	0.40	0.63	0.00	0.38
β-eudesmol	28.7	1646	1632	0.38	0.29	0.35	0.21	0.42	0.50	0.27	0.31	0.53	0.00
α-epi-bisabol	29.3	1683	1657	0.36	0.22	0.26	0.00	0.33	0.26	0.25	0.33	0.26	0.29
z-lanceol	30.8	1760	1721	1.42	0.79	0.76	0.47	0.96	0.81	0.76	1.28	0.84	0.88

Tret: retention time; RLLI: Relative-Literature Retention Index; RORI: Relative-observed Retention Index;

The sum of the percentages of the predominant compounds in the essential oil of *Lavandula dentata* represented approximately 80%. The statistical analysis of the average percentages of 1.8-cineol, fenchone and camphor did not present significant interaction between planting systems and fertilizers, as shown in Table No. 3. Only a significant difference was observed between field and greenhouse for the 1.8-cineole compound.

Table Nº3
Average percentage (%) of the majorities compounds found in the essential oil of *Lavandula dentata* in function of system of planting and fertilizers

			1.8-cineol			
System of planting	Mineral	Organic	100% OM	50% OM	Control	Means*
Greenhouse	42.74	44.26	42.58	42.61	43.28	43.10b
Field	46.45	46.63	45.63	44.29	46.33	45.86a
C.V.(%)	5.96					
			Fenchone			
Greenhouse	14.25	14.23	14.52	13.57	14.25	14.16a
Field	13.79	13.81	13.85	13.30	13.58	13.66a
C.V.(%)	8.25					
			Camphor			
Greenhouse	21.86	21.60	22.66	22.96	21.02	22.02a
Field	22.57	22.63	22.17	21.38	23.02	22.35a
C.V.(%)	7.97					

***Values followed by the same lower case letters do not differ statistically according to Tukey test (0.05)**

DISCUSSION

The response of lavender to dosage and source of fertilizer is dependent on the cultivation system. Correa *et al.* (2010), highlighted that the recommendation for organic fertilizers must be in accordance with the dosage and genotype of the species. In addition to these factors, we can observe that the cultivation environment also has a marked effect on the yield of biomass and lavender essential oil. According to Wang *et al.* (2019) successive applications of organic material inputs in acidic soils can increase the abiotic and biotic immobilization capacity of N, which disadvantages production.

The organic portion of fertilization provides many benefits to the soil; its presence contributes to the maintenance of biota and better use of nutrients. In addition, organic matter tends to protect the soil from erosion and compaction generated by intense winds and rains. As a result, the fertilizer segment that combines organic and mineral fertilization reflects great opportunities for innovation (Dias *et al.*, 2018) and improves performance and environmental sustainability (Keshavarz *et al.*, 2018).

According to Yang *et al.* (2018), organic fertilizer helps to retain water in the soil, increasing the efficiency of water use. Associated with the presence of nutrients from the mineral fraction, the contribution of the elements readily available for plant growth is obtained. Thus, the OM provide the soil with the physical and chemical conditions necessary for an optimal development of the root system and, consequently, growth of the aerial part, as evidenced in the present study (100% OM in field cultivation, which can be reduced by half - 50%, in greenhouse cultivation).

Plants under protected cultivation generally thrive under controlled climatic conditions and less pressure from biotic agents, which generally favors the vigor and growth of plants, due to the interactions between plant metabolism and external factors. In the present study, however, the field plants showed more exuberant growth, with greater biomass response. It can be assumed that the greenhouse effect, due to the higher concentration of heat inside the structure, may have led to a photoinhibition and reduction in the photosynthetic capacity of the culture, pointing to a deleterious effect of excess heat (Pinto *et al.*, 2007; Meira *et al.*, 2012).

Variations in biomass and oil yield of medicinal plants are found in the literature and correlated with the climatic conditions of the different environments or even climatic variations between the seasons of the same cultivation site (Zaouali *et al.,* 2010, Lopez *et al*., 2015, Silva-Flores *et al.,* 2019). According to Tounkara *et al.* (2020), the different answers to the application of fertilizers are also related to the interaction with the various components of the cultivation systems and their environment, which can also be changed between fields and years.

To obtain valuable lavender essential oil, Hassiotis *et al.* (2014), suggest to harvest when flowering reaches at 60%, ambient temperature is over 26ºC and no precipitations were occurred ten days before harvesting.

Field productivity of plants that received 100% OM stood out with 25.8 t ha^{-1}. Sönmez *et al.* (2018), reported lavender yield of 14.99 t ha^{-1}, in Mediterranean conditions. It was observed that productivity in the conditions of Minas Gerais is favorable and potential for the production and extraction of lavender oils, which was also highlighted by Martins *et al.* (2019).

With respect to the greenhouse, the moisture present in the soil, in a more stable way and with less gas exchange, compared to the reality of the field, allows the soil solution to be in better balance with the root system, which optimizes the use of nutrients. This fact reflected a better response to the 50% reduction to the recommended dose in the greenhouse.

The essential oil content did not vary between cultivation and fertilization systems. In literature there is variation between the oil concentration found according to the region, climatic conditions and management. Silva *et al.* (2017) found levels between 0.4 to 0.5%, within what was observed in the present study. In general, higher values are found in *L. angustifolia*, between 0.6 - 2.6% (Rashed *et al.,* 2017, Chrysargyris *et al.,* 2016, Kirimer *et al.,* 2017).

In this present study L. *dentata* produced 38 components, being 1.8-cineol, fenchone and camphor the majority. Giannoulis *et al.* (2020) in lavender evaluation under supplementation with biostimulants reported the presence of 48 compounds, with great variation between the tested biostimulants, the expressive difference in this study referred to the difference in the composition of the biostimulants. Therefore, the difference is related to the components that may be present in the organic fractions of the different associated organic products, both those applied and those present in the soil of the cultivation site.

At the same region of study of the present work, Silva *et al.* (2017), also found the same majorities compounds of *L. dentata* essential oil. And 1.8-cineol and camphor presented higher quantities at open field in relation to the greenhouse.

The beginning of spring increases the photoperiod, and thus plants are exposed to light for a longer period. Since lavender plants respond to this longer photoperiod by the flowering, chemically speaking, the amount of 1,8-cineol increases with the increase in solar radiation. The increase of camphor in the field is also a result of the increased activity of plants in the secondary metabolism (Silva *et al.*, 2017).

Similar results were found by Bousmaha *et al.* (2005), in L. *dentata*, the authors observed higher levels of 1.8-cineol (36.4%), b-pinene (8.1%), limonene (3.9%) in essential oil extracted from the aerial part, while the composition of the essential oil of the flowers, presented low levels of these constituents, being 21.5% of 1.8-cineol, 6% of β-pinene and 2.5% limonene.

Prins *et al.* (2010) reported that 1.8-cineole components, camphor, and L-fenchone accounted for 80% of all chemicals in essential oil of L. *dentata*. Touati *et al.* (2011) also observed 1.8-cineole, camphor, and L-phenone as major compounds, accounting for 33.54, 18.89, and 8.36% in the leaf oils and for 19.85, 23.33, and 7.13% in the flower oils, respectively.

Oils with a high concentration of camphor are generally intended for the pharmaceutical industry that needs higher concentrations of this component. The constituents 1.8-cineol and camphor give the essential oil of L. *dentata* antifungal and bactericidal properties, respectively (Khan and Abourashed, 2009).

CONCLUSIONS

The organo-mineral fertilizer provided better performance to lavender cultivation. In a greenhouse the amount of fertilizer can be cut in half of the recommendation dose. The essential oil content does not differ between the cultivation systems and fertilizers for *Lavandula dentata* and its majorities compounds are 1.8-cineol, fenchone and camphor.

ACKNOWLEDGEMENTSThis study was financed in part by the Conselho Nacional de Desenvolvimento Científico e Tecnológico – Brasil (CNPq), the Fundação de Apoio à Pesquisa e a Inovação Tecnológica do Estado de Sergipe (FAPITEC/SE) - Brasil, the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG/MG) - Brasil, the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES - Finance Code 001) and the Financiadora de Estudos e Projetos (FINEP) – Brasil.

REFERENCES

Abdel-Nabi HME, Nahla EG, Keshta AR. 2016. Response of potato plants to organic, bio and mineral fertilization. **J Plant Prod** 7: 861 - 867. **https://doi.org/10.21608/jpp.2016.46198**

Adamuchio LG. 2017. Aspectos gerais sobre a cultura da Lavanda (*Lavandula* spp.). **Rev Bras Plant Med** 19: 483 - 490.

Borges BMMN, Abdala DB, Souza MF, Viglio LM, Coelho MJA, Pavinato OS, Franco HCJ. 2019. Organomineral phosphate fertilizer from sugarcane byproduct and its effects on soil phosphorus availability and sugarcane yield. **Geo** 339: 20 - 30. **https://doi.org/10.1016/j.geoderma.2018.12.036**

Bousmaha L, Bekkara FA, Tomi F, Casanova J. 2005. Advances in the chemical composition of *Lavandula dentata* L. essential oil from Algeria. **J Essent Oil Res** 17: 292 - 295. **https://doi.org/10.1080/10412905.2005.9698907**

Chrysargyris A, Panayiotou C, Tzortzakis N. 2016. Nitrogen and phosphorus levels affected plant growth, essential oil composition and antioxidant status of lavender plant (*Lavandula angustifolia* Mill.). **Ind Crop Prod** 83: 577 - 586. **https://doi.org/10.1016/j.indcrop.2015.12.067**

Correa RM, Pinto JEBP, Reis ES, Costa LCB, Alves PB, Niculan ES, Brant RS. 2010. Adubação orgânica na produção de biomassa de plantas, teor e qualidade de óleo essencial de orégano (*Origanum vulgare* L.) em cultivo protegido. **Rev Bras Plant Med** 12: 80 - 89. **https://doi.org/10.1590/s1516-05722010000100012**

Costa P, Gonçalves S, Andrade PB, Valentão P, Romano A. 2011. Inhibitory effect of *Lavandula viridis* on Fe^{2+}-induced lipid peroxidation, antioxidant and anti-cholinesterase properties. **Food Chem** 126: 1779 - 1786. **https://doi.org/10.1016/j.foodchem.2010.12.085**

Dias AS, Nobre RG, Lima GS, Gheyi HR, Pinheiro FWA. 2018. Crescimento e produção de algodoeiro de fibra colorida cultivado em solo salino-sódico e adubação orgânica. **Braz J Irrigat Drainage - Irriga** 1: 260 - 273. **https://doi.org/10.15809/irriga.2016v1n1p260-273**

EMBRAPA. 1999. [Empresa Brasileira de Pecuária e Abastecimento]. Centro Nacional de Pesquisa de Solos. **Manual de análise química dos solos, plantas e fertilizantes**. Embrapa Solos, Río de Janeiro, Brasil.

Giannoulis KD, Evangelopoulos V, Gougoulias N, Wogiatzi E. 2020. Could bio-stimulators affect flower, essential oil yield, and its composition in organic lavender (*Lavandula angustifolia*) cultivation. **Ind Crop Prod** 154: 112611. **https://doi.org/10.1016/j.indcrop.2020.112611**

Hassiotis CN, Ntana F, Lazari DM, Poulios S, Vlachonasios KE. 2014. Environmental and developmental factors affect essential oil production and quality of *Lavandula angustifolia* during flowering period. **Ind Crop Prod** 62: 359 - 366. **https://doi.org/10.1016/j.indcrop.2014.08.048**

Khan I, Abourashed E. 2009. **Leung's encyclopedia of common natural ingredients: used in food, drugs and cosmetics.** Ed.III John Wiley & Sons, Hoboken, NJ, USA.

Keshavarz H, Modarres-Sanavy SAM. 2018. Original article yield and oil content of mint under different nitrogen fertilizer treatments. **Not Sci Biol** 10: 92 - 96. **https://doi.org/10.15835/nsb10110221**

Kirimer N, Mokhtarzadeh S, Demirci B, Goger F, Khawar KM, Demirci F. 2017. Phytochemical profiling of volatile components of *Lavandula angustifolia* Miller propagated under in vitro conditions. **Ind Crop Prod** 96: 120 - 125. **https://doi.org/10.1016/j.indcrop.2016.11.061**

Kivrak S. 2018. Essential oil composition and antioxidant activities of eight cultivars of Lavender and Lavandin from western Anatolia. **Ind Crop Prod** 117: 88 - 96. **https://doi.org/10.1016/j.indcrop.2018.02.089**

López LAP, de la Torre YC, Torres NW, Suárez AEF, Aranda RA. 2015. Essential oils from *Zanthoxylum fagara* wild lime, *Ruta chalepensis* L. and *Fymus vulgaris* L.: composition and activity against Aedes aegypti larvae. **Pak J Pharm Sci** 28: 1911 - 1915.

Mambri APS, Andriolo JL, Manfron MP, Pinheiro SMG, Cardoso FL, Neves MG. 2018. Yield and composition of lavender essential oil grown in substrate. **Hortic Bras** 36: 259 - 264. **https://doi.org/10.1590/s0102-053620180219**

Martins RP, Gomes RAS, Malpass ACG, Okura MH. 2019. Chemical characterization of *Lavandula dentata* L. essential oils grown in Uberaba-MG. **Ciência Rural** 49: 1 - 7. **https://doi.org/10.1590/0103-8478cr20180964**

Meira MR, Martins ER, Manganotti SA. 2012. Crescimento, produção de fitomassa e teor de óleo essencial de melissa (*Melissa officinalis* L.) sob diferentes níveis de sombreamento. **Rev Bras Plant Med** 14: 352 - 357. **https://doi.org/10.1590/s1516-05722012000200015**

Mumbach GL. Gatiboni LC, Bona FD, Schmitt DE, Dall'orsoletta DJ, Gabriel CA, Bonfada EB. 2019. Organic, mineral and organomineral fertilizer in the growth of wheat and chemical changes of the soil. **Braz J Agric Sci** 14: 1 - 7. **https://doi.org/10.5039/agraria.v14i1a5618**

Oliveira, PF, Alves JM, Damasceno JL, Oliveira RAM, Dias HJ, Crotti AEM, Tavares DC. 2015. Cytotoxicity screening of essential oils in cancer cell lines. **Rev Bras Farmacogn** 25: 183 - 188. **https://doi.org/10.1016/j.bjp.2015.02.009**

Pereira SIA, Monteiro C, Vega AL, Castro PML. 2016. Endophytic culturable bacteria colonizing *Lavandula dentata* L. plants: isolation, characterization and evaluation of their plant growth-promoting activities. **Eco Eng** 87: 91 - 97. **https://doi.org/10.1016/j.ecoleng.2015.11.033**

Pinto JEBP. Cardoso JCW, Castro EM, Bertolucci SKV, Melo LA, Dousseau S. 2007. Aspectos morfofisiológicos e conteúdo de óleo essencial de plantas de alfazema-do Brasil em função de níveis de sombreamento. **Hortic Bras** 25: 210 - 214. **https://doi.org/10.1590/s0102-05362007000200016**

Prins CL, Vieira IJC, Freitas SP. 2010. Growth regulators and essential oil production. **Braz J Plant Physiol** 22: 91 - 102. **https://doi.org/10.1590/s1677-04202010000200003**

Rady MM, Semida WM, Hemida KA, Abdelhamid MT. 2016. The effect of compost on growth and yield of *Phaseolus vulgaris* plants grown under saline soil. **Int J Recycl Org Waste Agric** 5: 311 - 321. **https://doi.org/10.1007/s40093-016-0141-7**

Rashed MMA, Tong Q, Rotailc A, Al-Fargad A, Aboshora W, Al-Hajj NQM. 2017. Extraction of essential oil from *Lavandula angustifolia* flowers preceded by enzymatic pre-treatment and investigate its activity against free radicals. **Int J Res Agric Sci** 4: 2348 - 3997.

Silva AS, Oliveira RC, Luz JMQ, Silva SM, Blank, Alves MF, Lana RMQ. 2019. Fertilization and cropping systems: performance and oil content of basil varieties. **Biol J** 35: 89 - 100. **https://doi.org/10.14393/bj-v35n1a2019-41451**

Silva-Flores PG, Perez-Lopez LA, Rivas-Galindo VM, Paniagua-Vega D, Galindo-Rodrıguez SA, Alvarez-Roman R. 2019. Simultaneous GC-FID quantification of main components of *Rosmarinus officinalis* L. and *Lavandula dentata* essential oils in polymeric nanocapsules for antioxidant application. **J Anal Methods Chem** Article ID 2837406, 1 - 9. **https://doi.org/10.1155/2019/2837406**

Silva SM, Luz MQ, PAM Nogueira, Blank AF, Sampaio TS, Pinto JAO, Wisniewski Junior A. 2017. Organo-mineral fertilization effects on biomass and essential oil of lavender (*Lavandula dentata* L.). **Ind Crop Prod** 103: 133 - 140. **https://doi.org/10.1016/j.indcrop.2017.04.004**

Sönmez Ç, Soysal AÖŞ, Okkaoğlu H, Karik Ü, Taghiloofar AH, Bayram E. 2018. Determination of some yield and quality characteristics αmong individual plants of lavender (*Lavandula angustifolia* Mill.) populations grown under Mediterranean conditions in Turkey. **Pak J Bot** 50: 2285 - 2290.

Touati B, Chograni H, Hassen I, Boussaïd M, Toumi L, Brahim NB. 2011. Chemical composition of the leaf and flower essential oils of Tunisian *Lavandula dentata* L. (Lamiaceae). **Chem Biol** 8: 1560 - 1569. **https://doi.org/10.1002/cbdv.201000357**

Tounkara A, Clermont-Dauphin C, Affholder F, Ndiaye S, Masse D, Cournac L. 2020. Inorganic fertilizer use efficiency of millet crop increased with organic fertilizer application in rainfed agriculture on small holdings in central Senegal. **Agric Ecol Env** 294: 106878. **https://doi.org/10.1016/j.agee.2020.106878**

Wang J, Sun N, Xu M, Wang S, Zhang J, Cai Z, Cheng Y. 2019. The influence of long-term animal manure and crop residue application on abiotic and biotic N immobilization in an acidified agricultural soil. **Geo** 337:

710 - 717. **https://doi.org/10.1016/j.geoderma.2018.10.022**

Yang S, Xiao Y, Xu J. 2018. Organic fertilizer application increases the soil respiration and net ecosystem carbon dioxide absorption of paddy fields under water-saving irrigation. **Environm Sci Poll Res** 25: 9958 - 9968. **https://doi.org/10.1007/s11356-018-1285-y**

Zaouali Y, Bouzaine T, Boussaid M. 2010. Essential oils composition in two *Rosmarinus officinalis* L. varieties and incidence for antimicrobial and antioxidant activities**. Food Chem Toxicol** 48: 3144 - 3152. **https://doi.org/10.1016/j.fct.2010.08.010**

Zheljazkov VD, Cantrell CL, Astatkie T, Jeliazkova E. 2013. Distillation time effect on lavender essential oil yield and composition. **J Oleo Sci** 62: 195 - 199. **https://doi.org/10.5650/jos.62.195**

Zuzarte M, Vale-Silva L, Gonçalves M J, Cavaleiro C, Vaz S, Canhoto J, Pinto E, Salgueiro L. 2011. Antifungal activity of phenolic-rich *Lavandula multifida* L. essential oil. **Eur J Clin Micro Inf Dis** 31: 1359 - 1366. **https://doi.org/10.1007/s10096-011-1450-4**