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Original paper

Research on the growth and development of some varieties of Lavandula Angustifolia (Mill.) in the South-East of Romania

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Abstract The purpose of this paper was to analyze the canopy volume of lavender shrubs as a morphologic trait influenced by variety and also to evaluate the development of the root system on a Chromic Luvisol with an argic B horizon. The crop was established in 2017 at Belciugatele Didactic Station/Moara Domnească Farm (44°30′ North, 26°15′ East) using the following lavender varieties: Sevstopolis, Vera, Hidcote, and Buena Vista. During 2017-2019, plants' height and diameters were measured at harvest, and these observations were used to determine lavender shrubs' canopy volume, by applying the derived ellipsoid volume formula. Varieties (*A*) obtained different values in terms of canopy volumes, and these values also varied under the influence of the different doses and combinations of mineral and organic fertilizers (*B*). The highest canopy volume was registered by Vera, with values ranging from 0.0557 m^3 (1^{st} year, Control) and 0.0944 m^3 (3^{rd} year, organic fertilization with manure at 30 t/ha). The evaluation of the root system distribution and development was performed after carrying out a soil profile between two plants, along the row, for each researched variety. Measurements were conducted using a frame of 50/50 cm, and data sampling was performed for every 10 cm layer, by counting and measuring the roots. Based on these observations the root section area (RSA) was determined. The values of this indicator ranged between 283.06 mm^2 (Buena Vista) and 378.29 mm^2 (Vera).

Keywords *Lavandula angustifolia* (Mill.), volume, ellipsoid formula, RSA.

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Introduction

Lavandula angustifolia (Mill.) is part of the *Lavandula* genus, a genus with 47 useful plant species across the Globe. Along with other 233 genera, comprising 5500 species, they form the *Labiatae* (*Lamiaceae*) family GÜNER, 2000 [5]; KORKUNC et al, 2018 [8]; ŁYCZKO, 2020 [10].

Lavender originates in the Mediterranean area and is found in a range of ecologic and geographic areas, from the Balkan countries, North America, North Africa, and India to the Arabic area, South Asia and Australia (REID, 2000 [17]; UPSON and ANDREWS, 2004 [27]; MOJA et al, 2016 [14]; LOPES and BARATA, 2017 [9]; KORKUNC et al, 2018 [8]; ŁYCZKO et al, 2020 [10].

Fertilization is an important factor in growing *Lavandula angustifolia* (Mill.), and regardless of the fertilizers' type (organic or mineral), it has a positive impact on the species yield (MAGANGA, 2004 [11]; ȘEKEROĞLU and ÖZGÜVEN 2008 [22]; SEIDLER-LOŻYKOWSKA et al, 2014 [21]; SKOUFOGIANNI et al, 2017 [24]). Organo-mineral fertilizers contribute to a higher yield of the lavender crop due to a slow release of nutrients around the root system (SILVA et al, 2017 [23]), and also help improving soil physical and chemical properties (SAKR et al, 2015 [19]), playing an important role in restoring soil fertility (USLGA, 2019 [30]).

It is preferable to grow lavender in farming conditions rather than using and capitalizing wild lavender plants, because lavender crops have a positive effect on preserving soil water content (between 5 and 20 cm depth) and on soil erosion phenomena, reducing the mechanical impact of raindrops on soil particles, diminishing soil erosion and reducing the risk of rain washing away soil (PLEGUEZUELO et al, 2009 [16].

Results obtained by different researchers show that organic fertilization has a high impact on lavender plants, especially on young plants, or seedlings, because it assures better development of the root system, stimulating roots growing (JELAČIĆ et al, 2008 [6]; BEATOVIĆ et al, 2012 [1]; RYAN, 2016 [18]; NAJAR et al, 2019 [15]).

Irrigation is another factor that helps young plants' roots development, mainly drip irrigation is recommended, in the first two years, in areas with high risks of hydric stress (MAGANGA, 2004 [11]; KIMBROUGH and SWIFT, 2009 [4]; DAFF, 2012 [28]; ERNST, 2017 [4]; SALEHI et al., 2018 [20]); MIHALAȘCU et al, 2020 [13]. But it must be considered that, excess moisture in addition to poor soil drainage increases the risk of developing pathogens (MASON, 2014 [12]).

Materials and Methods

Researches were carried out at Belciugatele Didactic Station/Moara Domnească Farm, Ilfov county (44°3' Nord, 26°15' Est), during 2017-2019, on a Chromic Luvisol with an argic B horizon. The crop was established in 2017, under moderate drip irrigation, with the factors ***A*** – lavender varieties: Sevstopolis (a_1), Vera (a_2), Hidcote (a_3) and Buena Vista (a_4) and ***B*** – doses and combinations of mineral and organic fertilizers $N_0P_0K_0$-Ct (b_1), $N_{60}P_{60}K_{60}$ (b_2) CAN: calcium nitrate $N_{60}CaO_{15,5}Mg_{11,1}$ (b_3), $N_{30}P_{30}K_{30+}$Manure 15 t/ha^{-1} (b_4), Manure 30 t/ha^{-1} (b_5).

Upon crop establishment (March 2017) the soil was characterized by a 7.64 pH and a humus content of 1.92 in the soil layer 0-40 cm. In terms of soil's physical parameters, bulk density (BD) was 1.63 g/cm^3, total porosity (TP) had a value of 33,21% and the degree of compaction was 34.91%.

During 2017-2019, climatic conditions of the vegetation period (March – October) differed compared to the multiannual values (1961-2007), both in terms of temperatures and precipitations (Table 1). Thus, temperatures recorded higher values than the normal multiannual values of the area, by 3.7°C in 2017, 2.3°C in 2018 and 1,9°C in 2019. In terms of rainfall, except for 2018 (Table 1), the amount was slightly over the growing season average (449.5 mm).

Table 1. Climatic conditions during the research period (2017-2019)

Month	Average monthly temperature (°C)				Rainfall (mm)			
	2017	**2018**	**2019**	**1961-2007**	**2017**	**2018**	**2019**	**1961-2007**
March	15,0	3,7	9,5	4,8	44,5	0,2	31,2	40,0
April	16,5	16,4	11,3	11,1	90,0	0,0	78,4	46,9
May	18,6	19,7	17,0	16,7	47,3	0,0	148,2	66,0
June	22,4	22,5	23,1	20,4	46,8	53,2	109,4	77,0
July	26,4	23,0	22,6	22,3	105,2	107,6	76,0	67,7
August	24,2	24,1	24,3	21,4	37,1	2,0	2,4	57,4
September	19,1	19,2	19,1	16,6	37,0	28,9	4,8	52,9
October	11,5	13,8	12,6	10,7	70,9	10,4	41,1	41,6
Average / Sum	**19,2**	**17,8**	**17,4**	**15,5**	**478,8**	**202,3**	**491,5**	**449,5**

a. Canopy volume measurements (m^3)

During 2017-2019, at harvest, lavender plants' diameter and height were measured for each variant. Using these biometrical parameters, the derived ellipsoid volume formula proposed by THORNE et al, 2002 [24] was used to calculate plants canopy volume, in cubic meters (m^3), as follows:

$$CV = 2/3\pi H(A/2xB/2)$$

where: CV = canopy volume (m^3), H = plant height, A = major canopy axis, and B = minor canopy axis.

b. Root system measurements

To evaluate root system distribution and development a soil profile was carried out between two plants, along the row, for each researched variety, applying 1987 ICPA's methodology ([29]) used by other researchers for perennial species like vegetable crops and fruit trees (DUDU et al, 2015 [3]; BOLOHAN, 2018 [2]; TUDOR et al, 2019 [26]. The soil profile was conducted in the 3rd year of the crop (November 2019) for the experimental variant with the highest impact on plants' development, Manure 30 t/ha^{-1}. Root system measurements were carried out using a frame of 50/50 cm (Figure 1), and data sampling was performed for every 10 cm layer, counting and measuring the roots with the digital calliper (Figure 1). Based on the data collected, the root section area (RSA) was determined for each variety, first in each soil layer (10 cm) and then total RSA (0-50 cm).

Figure 1. Soil profile and root systems measurement with metrical frame in *Lavandula* varieties, 2019.

c. Statistical analysis

A two-way analysis of variance (ANOVA), followed by Fisher's LSD test, when ANOVA resulted in $p<0.05$, was used to determine and compare the differences of means between the factors (*A* and *B*).

Pearson correlation was conducted to analyse to which extent canopy volume and root system development are related.

Results and Discussions

a. Canopy growth and development

Each year, the influence of the variety (A) on lavender plants' canopy volume is noticeable. For the experimental factor B, varieties obtained uniform statistical differences compared to the mean of the four varieties, starting with the second year of the crop (Table 2).

Every year, the highest canopy volume (m^3) was obtained by plants of Vera variety, while plants belonging to Buena Vista variety had the smallest canopy volume.

After the first year (1st crop year), the canopy volume of Vera plants had values ranging from 0.0557 m^3 to 0.0682 m^3 (Table 1), and very significant differences ($p<0.001$) compared to the average of the four varieties (Table 2). For Sevstopolis, the canopy volume was also higher than Control, with differences between 0.0037 m^3 and 0.0041 m^3, during the first year, but only for the mineral fertilization $N_{60}P_{60}K_{60}$ the difference was statistically assured. Buena Vista and Hidcote obtained lower values of the canopy volume compared to the average of the four varieties, with differences statistically significant, ranging from -0.0076 (Hidcote, Control) and -0.0196 (Buena Vista, $N_{60}P_{60}K_{60}$).

In the second year of the crop (2nd year), the average canopy volume of lavender varieties had values from 0.0489 m^3 to 0.0587 m^3 (Table 2), and varieties Vera and Sevstopolis obtained higher volumes than average, with statistically assured differences, while Hidcote and Buena Vista had lower values than Control, with very significant negative differences. The pattern and significance of canopy volume differences of each variety compared to the average volume maintained in the third year of the crop (3rd year), having higher values for Vera and Sevstopolis and lower values for Buena Vista and Hidcote.

Considering that canopy volume as a morphological trait in lavender plants is influenced by variety is supported by the differences obtained among each of the four lavender varieties (Tabel 3). Volume differences distribution highlights their emphasis based on crop maturity. Pronounced differences were obtained after the third year of the crop (3rd year).

Table 2. Variety influence on canopy volume (m^3) of lavender varieties for each year of crop development

Crop year	Fertilization rate	Sevstopolis (a_1)		Vera (a_2)		Hidcote (a_3)		Buena Vista (a_4)		Avg. varieties (Ct)
		Volume (m^3)	Diff. (m^3)	Volume (m^3)	Diff. (m^3)	Volume (m^3)	Diff. (m^3)	Volume (m^3)	Diff. (m^3)	Volume (m^3)
	$N_0P_0K_0$	0.0396	0.0037 ^{ns}	0.0557	0.0199***	0.0283	-0.0076^{oo}	0.0199	-0.0160^{ooo}	**0.0359**
1st year	$N_{60}P_{60}K_{60}$	0.0465	0.0033 ^{ns}	0.0682	0.0250***	0.0346	-0.0086^{ooo}	0.0236	-0.0196^{ooo}	**0.0432**
	CAN	0.0418	0.0041*	0.0580	0.0203***	0.0298	-0.0079^{ooo}	0.0211	-0.0166^{ooo}	**0.0377**
(2017)	$N_{30}P_{30}K_{30+}$**M15**	0.0440	0.0038 ^{ns}	0.0624	0.0223***	0.0322	-0.0080^{ooo}	0.0220	-0.0181^{ooo}	**0.0402**
	Manure30	0.0410	0.0036 ^{ns}	0.0588	0.0214***	0.0293	-0.0081^{ooo}	0.0205	-0.0169^{ooo}	**0.0374**
LSD 5%: 0.0040 m^3; LSD 1%: 0.0056 m^3; LSD 0.1%: 0.0078 m^3										
	$N_0P_0K_0$	0.0580	0.0091***	0.0711	0.0221***	0.0403	-0.0086^{ooo}	0.0264	-0.0226^{ooo}	**0.0489**
2nd year	$N_{60}P_{60}K_{60}$	0.0651	0.0096***	0.0801	0.0246***	0.0472	-0.0084^{ooo}	0.0298	-0.0258^{ooo}	**0.0555**
	CAN	0.0634	0.0107***	0.0742	0.0216***	0.0443	-0.0084^{ooo}	0.0288	-0.0239^{ooo}	**0.0527**
(2018)	$N_{30}P_{30}K_{30+}$**M15**	0.0668	0.0107***	0.0781	0.0221***	0.0479	-0.0081^{ooo}	0.0312	-0.0248^{ooo}	**0.0560**
	Manure30	0.0687	0.0100***	0.0820	0.0233***	0.0502	-0.0085^{ooo}	0.0339	-0.0248^{ooo}	**0.0587**
LSD 5%: 0.0031 m^3; LSD 1%: 0.0044 m^3; LSD 0.1%: 0.0063 m^3										
	$N_0P_0K_0$	0.0653	0.0109***	0.0802	0.0258***	0.0431	-0.0113^{ooo}	0.0291	-0.0253^{ooo}	**0.0544**
3rd year	$N_{60}P_{60}K_{60}$	0.0722	0.0123***	0.0866	0.0267***	0.0477	-0.0121^{ooo}	0.0330	-0.0269^{ooo}	**0.0599**
	CAN	0.0706	0.0128***	0.0834	0.0257***	0.0459	-0.0119^{ooo}	0.0311	-0.0266^{ooo}	**0.0577**
(2019)	$N_{30}P_{30}K_{30+}$**M15**	0.0786	0.0149***	0.0899	0.0262***	0.0512	-0.0125^{ooo}	0.0351	-0.0286^{ooo}	**0.0637**
	Manure30	0.0822	0.0149***	0.0944	0.0271***	0.0554	-0.0119^{ooo}	0.0372	-0.0301^{ooo}	**0.0673**
LSD 5%: 0.0037 m^3; LSD 1%: 0.0052 m^3; LSD 0.1%: 0.0075 m^3										

Ct = control

Analysing the differences among varieties every year (Table 3), for each level of the experimental factor *B*, it is observed that the highest values were obtained between Buena Vista (a_4) and Vera (a_2), ranging from -0.0359 m^3 (1st year) to -0.0573 m^3 (3rd year). The smallest differences among varieties were obtained between Buena Vista and Hidcote (a_3), after the first crop year (2017) and between Sevstopolis (a_2) and Vera in the following years (2018 and 2019). All volume differences among varieties were statistically assured.

The average canopy volume of the four lavender varieties ranged in the first year (1st year) between 0.0359 m^3 (Control) and 0.0432 m^3 ($N_{60}P_{60}K_{60}$) (Figure 2).

Mineral fertilization with $N_{60}P_{60}K_{60}$ and organo-mineral treatment $N_{60}P_{60}K_{60}$+ Manure15 t/ha^{-1} generated statistically assured volume growths, compared to the unfertilized variant (Ct). Ammonium nitrate (CAN) and organic fertilization (Manure 30 t/ha^{-1}) also brought canopy volume increases, but the differences were not significant in statistical terms ($p>0.05$) (Figure 2).

Table 3. Canopy volume (m^3) differences among varieties

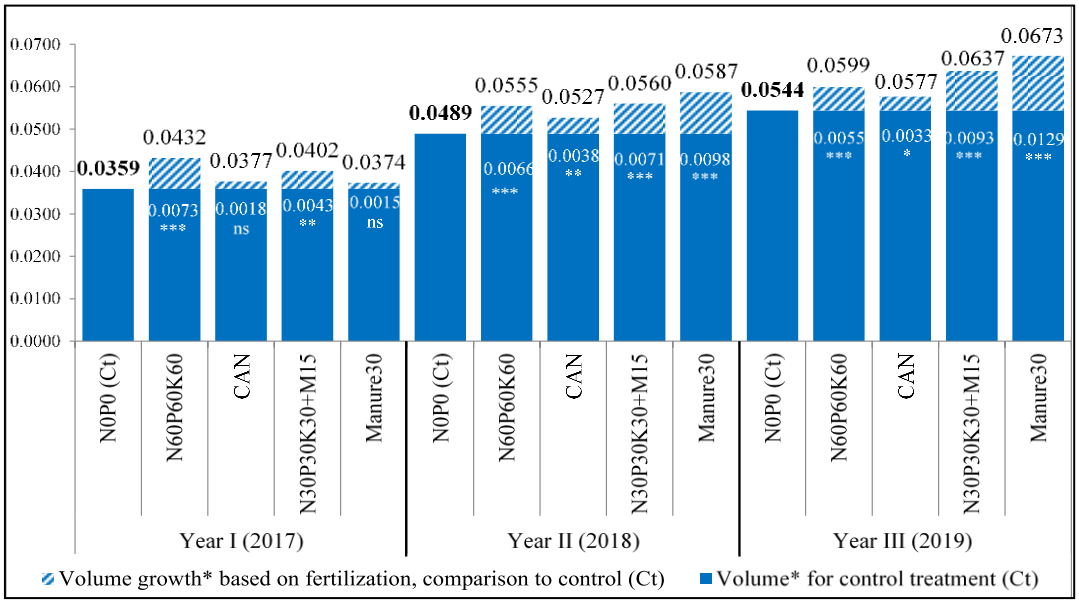
Crop year	Fertilization	Differences (m^3) among varieties*					
		a_2-a_1	a_3-a_1	a_4-a_1	a_3-a_2	a_4-a_2	a_4-a_3
	$N_0P_0K_0$	0.0162	-0.0113	-0.0197	-0.0275	-0.0359	-0.0084
1st year	$N_{60}P_{60}K_{60}$	0.0217	-0.0119	-0.0229	-0.0336	-0.0446	-0.0110
	CAN	0.0161	-0.0120	-0.0207	-0.0281	-0.0368	-0.0087
(2017)	$N_{30}P_{30}K_{30+}$**M15**	0.0184	-0.0118	-0.0220	-0.0302	-0.0404	-0.0102
	Manure30	0.0148	-0.0147	-0.0235	-0.0295	-0.0383	-0.0088
LSD 5%: 0.0040 m^3; LSD 1%: 0.0056 m^3; LSD 0.1%: 0.0078 m^3							
	$N_0P_0K_0$	0.0131	-0.0177	-0.0316	-0.0308	-0.0447	-0.0139
2nd year	$N_{60}P_{60}K_{60}$	0.0150	-0.0179	-0.0353	-0.0329	-0.0503	-0.0174
	CAN	0.0109	-0.0191	-0.0346	-0.0299	-0.0455	-0.0155
(2018)	$N_{30}P_{30}K_{30+}$**M15**	0.0114	-0.0189	-0.0355	-0.0302	-0.0469	-0.0167
	Manure30	0.0153	-0.0166	-0.0329	-0.0318	-0.0482	-0.0163
LSD 5%: 0.0031 m^3; LSD 1%: 0.0044 m^3; LSD 0.1%: 0.0063 m^3							
	$N_0P_0K_0$	0.0148	-0.0222	-0.0363	-0.0371	-0.0511	-0.0140
3rd year	$N_{60}P_{60}K_{60}$	0.0143	-0.0245	-0.0393	-0.0388	-0.0536	-0.0148
	CAN	0.0128	-0.0247	-0.0394	-0.0376	-0.0523	-0.0147
(2019)	$N_{30}P_{30}K_{30+}$**M15**	0.0113	-0.0274	-0.0435	-0.0387	-0.0548	-0.0161
	Manure30	0.0158	-0.0232	-0.0414	-0.0390	-0.0573	-0.0183
LSD 5%: 0.0037 m^3; LSD 1%: 0.0052 m^3; LSD 0.1%: 0.0075 m^3							

a_1 – Sevstopolis, a_2 – Vera, a_3 – Hidcote, a_4 – Buena Vista

Influenced by fertilization (Figure 2), plants canopy volume had statistically assured increases between 0.0033 m^3 (CAN) and 0.0098 m^3 (Manure30 t/ha^{-1}) (2nd year), and between 0.0544 m^3 (Ct) to 0.0673 m^3 (Manure30 t/ha^{-1}) (3rd year).

b. Root system distribution and development

Analysing data in Figure 3 and Table 4 it is shown that, with the highest RSA (mm^2) values for all four researched lavender varieties, the root mass was mainly distributed at 0-10 cm depth in the soil profile.



LSD 5%: 0.0024 m^3; LSD 1%: 0.0034 m^3; LSD 0.1%: 0.0047 m^3

Figure 2. Canopy volume (m^3) as influenced by fertilization.

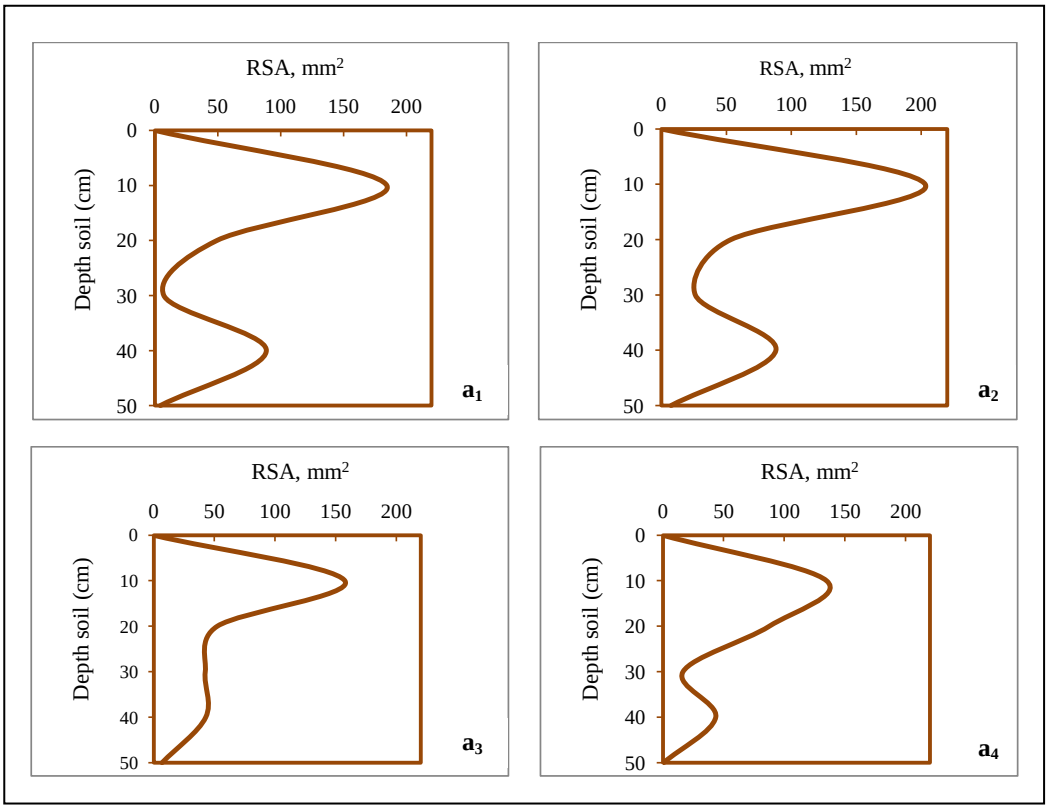


Figure 3. Root Section Area (RSA) from *Lavandula* variety:
a_1 - Sevstopolis; a_2 - Vera; a_3 - Hidcote; a_4 - Buena Vista.

The average RSA of the lavender varieties in this soil layer (Table 4) was 169.99 mm^2, with Vera obtaining the highest value (203.10 mm^2), and Buena Vista having the lowest value (134.97 mm^2). At 30-40 cm depth, Sevstopolis (88.56 mm^2) and Vera (88.16 mm^2) had an increase in RSA compared to the previous soil layer (20-30 cm), correlated to better development of the canopy volume. Hidcote (42.81 mm^2) and Buena Vista (43.51 mm^2) had lower RSA values and moderate canopy development.

Table 4. Root section area (RSA) of lavender varieties at different soil depth (0-50 cm)

Variety	RSA (mm^2) - Soil Depth (cm)					Total RSA (mm^2) 0-50 cm	Diff.
	0-10	10-20	20-30	30-40	40-50		%
Sevstopolis	184,33	49,29	3,94	88,56	4,34	330,46	102,2
Vera	203,10	53,43	26,12	88,16	7,48	378,29	117,0
Hidcote	157,55	52,26	42,41	42,81	6,78	301,81	93,3
Buena Vista	134,97	87,62	16,46	43,51	0,50	283,06	87,5
Average	169,99	60,65	22,23	65,76	4,78	**323,41**	**100 %**

The total root section area (0-50 cm) ranged as influenced by variety between 283.06 mm^2 for Buena Vista and 378.29 mm^2 for Vera. The average root section area of the four lavender varieties had a value of 323.41 mm^2 (Table 4). Vera and Sevstopolis varieties obtained positive differences compared to the average of 17.0% and 2.2%, respectively. Hidcote and Buena Vista had smaller values compared to the average RSA (0-50 cm) by -6.7% and -12.5%, respectively.

c. Canopy volume correlation to root system area

Lavender plants canopy volume is closely related to the root section area (Figure 4). Pearson correlation coefficient of 0.9851 highlights a strong dependency between the two variables, and the value of the regression coefficient indicates that plants' canopy volume is strongly influenced (97.32%) by the root section area (RSA).

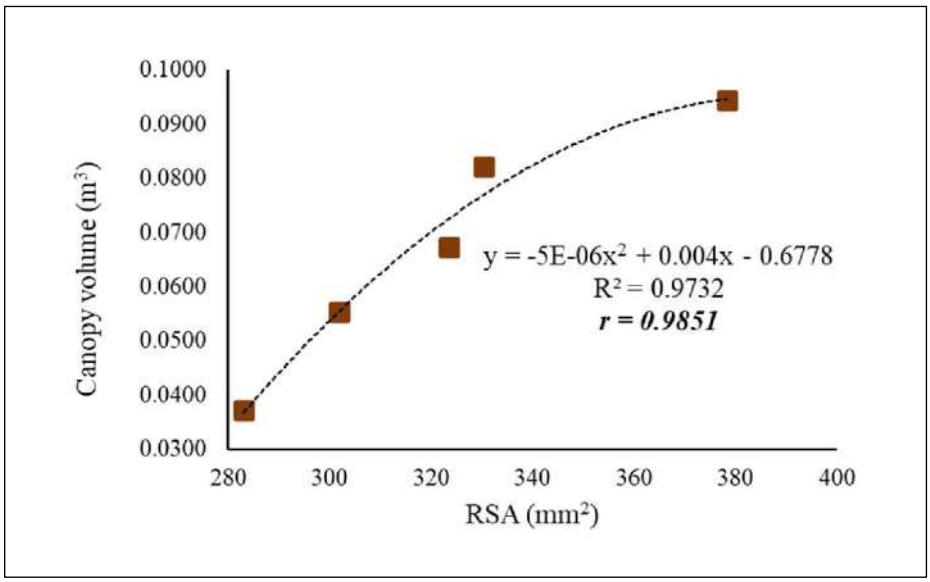


Figure 4. Scatterplot between lavender canopy volume and root section area (RSA), Manure30 t/ha^{-1}, 3rd year (polynomial regression equation).

Conclusions

Vera variety had the highest canopy volume for all doses and combinations of mineral and organic fertilizers (*B*), ranging from 0.0557 m^3 for control (unfertilized variant), in the 1st year, and 0.0944 m^3 for Manure30 t/ha^{-1} (organic fertilizer), in the 3rd year. Volume differences obtained by this variety compared to the average value and the differences it had compared to the other varieties were statistically significant.

Beyond the variety, fertilization also influenced the canopy volume. In the 1st year, mineral and organo-mineral fertilization treatments generated statistically assured volume growths, and in the following years (2nd and 3rd year), volume differences compared to Control (unfertilized variant) were also statistically significant for all doses and combinations of mineral and organic fertilizers (*B*).

Lavender plants' canopy volume is closely related to the development of the root system, varieties with a better vigour (higher canopy volume) have higher values of the root system mass.

Varieties rooting was normal. RSA was distributed mainly within 0-10 cm depth (mean value of 169.99 mm^2). Variety influenced the roots section area within 0-50 cm depth. Thus, Vera had the highest values (378.29 mm^2) and Buena Vista had the lowest values (283.06 mm^2).

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