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Improving the Production of *Ruta graveolens* L. Plants Cultivated under Different Compost Levels and Various Sowing Distance

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Abstract: Two field experiments were carried out during 2004/2005 and 2005/2006 seasons to study the effect of compost fertilizers at three doses of 78.54, 159.46 and 238 Kg N/hectare on growth, flower characters and active constituents of *Ruta graveolens* L. plants cultivated at three different plant distances. Compost significantly improved most vegetative growth characters as plant height, fresh and dry weight of leaves, stems and roots. The highest compost level produced highest accumulation of essential oil of leaves and flowers, rutin and coumarin percentage as well as nutrient content (N, P, K, Fe, Mn and Zn). The different sowing distance recorded various difference effects on growth characters. The narrow distance (30 cm) resulted the highest essential oil yield for both leaves and flowers, while the wider distance of 50cm produced highest accumulation of rutin, coumarin and nutrients content. Moreover, the interaction between compost doses and sowing distances indicated that the highest means values for most growth characters, rutin and coumarin were recorded with 78.54Kg N/hectare +30 cm distance between plants, while for essential oil content the applied 159.46 Kg N/hectare and sowing at 30 cm produced highest content. GC/MS analysis of rue essential oil showed that there were 32 and 31 compounds for leaves and flowers consisting about 94.54 and 96.45% of total essential oil for both organs respectively. The major constituents of rue oil were the oxygenated compounds (80.3% for leaves 83.3% for flowers). The main component was 2-undecanone which represented more the half of total essential oil. The results indicated that compost levels or sowing distances had different effects on total identified and major constituents of rue essential oil.

Key words: *Ruta graveolens* · essential oil · rutin · coumarin · compost fertilizers · sowing distances

INTRODUCTION

Ruta graveolens L. (common rue) is native to Southern Europe and Northern Africa. Rue plant is medicinal plant whose roots and aerial parts contain more than one hundred and twenty compounds of different classes of natural products such as acridone alkaloids, coumarines, essential oil, flavonoids and furoquinoline [1, 2]. Many of these compounds are physiologically active and therefore of pharmacological interest [3]. The medicinal action of common rue is abortificient, anthelmintic, antiseptic, antispasmodic, carminative, irritant and stomachic [4, 5]. The main uses of rue are to relieve gouty and rheumatic pains and to treat nervous heart problems [6, 7]. The infusion is also said to be useful in eliminating worms [8]. In addition Chiu and Fung [9] revealed that rue plants contained cardiovascular active substance that had a direct effect on the cardiovascular system. Moreover, Pathak *el al.* [10] revealed that Ruta in combination with $Co_3(Po_4)^2$ could be used for effective treatment of brain cancers, particularly glioma.

Compost fertilizer is safety for human health and environment. It is made by recycling organic material as plant and animals waste, food scraps in a controlled process.Compost used to improve soil properties, water retention capacity, drainage, pH and better availability soil micro organism [11, 12]. Several researchers reported that adding various organic compost to the soil resulted to marked promotion on different growth characters yield and chemical constituents of various medicinal and aromatic plants i.e. on peppermint [13], *Rosmarinus officinalis* [14], *Tagetes erecta* [15] and *Sideritis montana* [16].

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Otherwise, the distance between plants or plant density is the most important factors affect greatly on growth and chemical constituents by effecting on light and photosynthetic process, water and nutrients uptake. The suitable spacing and its affect on the productivity of different plants were reported by El-Gengaihi *et al.* [17] on *Dracocephalum moldavica*, Omar *et al.* [18] on *Silybum marianum*, El-Sherbeny *et al.* [16] on *Sideritis montana*.

Thus, this investigation was conducted to detect the optimum compost dose with suitable plant distance to produced highest vegetative and flowering growth with good quality of essential oil as well as rutin and coumarin content of *Ruta graveolens* plants.

MATERIALS AND METHODS

Plant material: Two Field experiments were conducted at the Experimental Station of National Research Centre, Shalakan, Kalubia Government during two successive seasons of 2004/2005 and 2005/2006 to study the influence of different compost levels and various plant distances on growth and chemical constituents of rue plants. Seed of common rue plants (Ruta graveolens) were sown on 25th of October, during the two successive seasons in seedbeds. When seedling reached to 12-15 on long, they were transplanted in plots $4m^2$ area (2x2m) on rows of 60 cm apart with three distance interbetween 30, 40 and 50 cm. The experimental soil was analyzed according to Black [19]. It was clay loamy having pH.7.2; EC0.5, $CaCo_3$ 1.4% Total N 540 mg kg^{-1}, available $P(P_2O_5)$, 87mg kg^{-1}, available $K(K_2O)$ 256 mg $kg^{-1}$and available Mg 2500 mg kg^{-1}. DTPA extractable Fe, Mn, Zn and Cu were 22.1, 3.8 and 2.65 mg kg^{-1}, respectively.

Methods: The different treatments were arranged in 4 replication using a split plot design having the compost in the main plots, while the different plant distance were distributed at random in the sub plots. Each sub plot contained 10 plants. Compost levels were added during soil preparation at three levels, 78.54, 159.46 and 238.6 kg N/hect.Compost was produced by Green Valley for Organic Products Co., S.A.E. Physical-chemical properties of organic compost are shown in Table 1.

The experiment was included the following treatments:

1. Control (0 compost) + 30 cm distance between plants
2. Control (0 compost) + 40 cm distance between plants
3. Control (0 compost) + 50 cm distance between plants
4. Compost (78.54Kg N/hect.)+ 30 cm distance between plants
5. Compost (78.54Kg N/hect.)+ 40 cm distance between plants
6. Compost (78.54Kg N/hect.)+ 50 cm distance between plants
7. Compost (159.46Kg N/hect.)+ 30 cm distance between plants
8. Compost (159.46Kg N/hect.)+ 40 cm distance between plants
9. Compost (159.46Kg N/hect.)+ 50 cm distance between plants
10. Compost (238Kg N/hect.)+ 30 cm distance between plants
11. Compost (238Kg N/hect.)+ 40 cm distance between plants
12. Compost (238Kg N/hect.)+ 50 cm distance between plants

The plants were collected at full flowering stage in 15th May during the two successive seasons and the following data were recorded:

Vegetative growth characters:

a. Plant height (cm).
b. Number of branches per plant.
c. Fresh and dry weights of leaves, stems and roots (g/plant).
d. Fresh weight of flowers per plant (g/plant).

Chemical constituents:

a. Essential oil % in fresh leaves and flowers: Samples of fresh leaves and flowers for each treatment were separately subjected to water distillation for 3 h according to A.O.A.C. [20].
b. Essential oil yield, were calculated for plant and Hectare.

Table 1: Physical-chemical properties of organic compost fertilizer

Wet %	O.M %	pH	E.C mmohs/cm	C/N ratio	Organic carbon %	N %	P %	Fe ppm	Mn ppm	Cu ppm	Zn ppm
35	70	7.24	2.1	23:1	25.8	1.2	0.8	790	190	73.1	150

c. Oil components:
   The samples were dehydrated over anhydrous sodium sulphate then subjected to GC/MS. Separation of the resulting crude, fractions and volatile oil was accomplished on a Varian Gas Chromatography (Thermo Inst., USA) mass spectrometer and a 30 cm x 0.25 mm. DB^{-5} capillary column film thickness (J and W Scientific, USA). The column temperature was programmed from 50°C (constant for 3 min.) at a rat of 7°C/min to 250°C with 10 min. isothermal hold. The injector temperature was 220° and transition time temperature was 250°C. The carrier gas was helium and the column head pressure was 10-15 psi. The identification of the constituents was determined by comparing the spectrum with the other stored in Wiley Mass Spectral Library containing over 147000 volatile compounds.
d. Rutin percentage in dried leaves, determined according to method of Zhuang *et al*[21].
e. Coumarin percentage in dried leaves estimation as described by Harbone [22].
f. Mineral content in leaves, including total nitrogen content using the modified micro-Kjeldahl methods as Jackson [23]. Phosphorus and potassium (%) according to Chapman and Pratt [24] and Cottonie *et al*., [25], respectively.

Statistical methods: Comparisons among means of different treatments were performed using the least significant difference procedure (LSD) at 0.05 levels as illustrated by Snedecor and Cochran [26].

RESULTS

Growth characters

Effect of compost fertilizer on growth characters: Data presented in Table 2 showed a pronounced increment in plant height due to applied highest compost level, while the lower level (78.54 Kg N/hectare) caused insignificant decrement for these criteria. Moreover, the difference between plant height of plants treated with the maximum and the minimum level of compost reached to 6.7%. From the same table, it is noticed clearly that the

Table 2: Influence of compost fertilizer and sowing distance on vegetative characters of *Ruta graveolens* L. (means value of two seasons)

Treatments	Plant height cm	Branches No/plant	Fresh weight (g/plant) Leaves	Stem	Root	Total	Dry weight (g/plant) Leaves	Stem	Root	Total
A) Effect of compost:										
Comp 0	39.3	13.8	17.4	28.9	5.1	51.4	7.4	11.4	2.9	21.7
Comp 1	38.5	13.6	14.0	25.5	5.4	44.9	8.7	12.5	3.3	24.3
Comp 2	37.6	13.9	18.6	35.8	6.4	60.8	8.4	13.7	3.7	27.8
Comp 3	41.1	13.2	25.9	46.9	6.5	79.2	9.0	18.5	3.5	31.4
LSD %5	1.4	N.S	1.26	1.64	0.56	0.69	0.60	0.80	0.34	1.17
B) Effect of sowing distances:										
30 cm	37.4	13.6	17.5	29.9	5.2	52.6	9.0	12.1	3.1	11.1
40 cm	40.5	13.2	20.4	31.4	5.9	57.7	8.1	14.9	4.3	27.3
50 cm	39.5	14.2	19.1	40.8	6.5	66.2	8.0	15.2	4.4	27.7
LSD %5	1.21	0.48	1.09	1.42	0.49	0.60	0.54	0.69	0.29	1.01
C) Effect of the interaction between compost and sowing distances:										
Comp 0										
30cm	39.9	14.1	20.4	35.3	5.0	60.7	8.9	14.6	3.0	26.5
40cm	40.1	12.5	16.6	25.0	4.9	46.5	6.7	9.6	2.9	19.2
50cm	37.8	14.9	15.2	23.3	5.3	43.8	6.5	10.0	2.7	19.2
Comp1										
30cm	36.6	13.8	10.9	15.7	4.2	30.8	10.9	9.2	3.5	23.6
40cm	39.9	14.5	15.7	31.5	6.2	53.4	8.2	14.9	3.4	26.5
50cm	39.1	13.0	15.4	29.2	5.9	50.5	7.1	13.5	3.0	23.6
Comp2										
30cm	34.1	15.1	17.4	28.9	6.4	52.7	8.3	11.4	3.5	23.2
40cm	38.9	11.8	20.9	37.2	6.3	64.4	8.8	17.6	3.7	33.1
50cm	39.8	14.9	17.6	41.2	6.4	65.2	8.0	12.2	3.9	27.1
Comp3										
30cm	39.1	12.0	21.4	39.6	5.0	66.0	7.8	13.2	2.5	23.5
40cm	43.0	13.9	28.2	31.8	6.3	66.3	8.8	17.4	4.3	30.5
50cm	41.3	13.8	28.0	69.4	8.4	105.4	10.5	25.0	4.8	40.3
LSD%5	2.42	0.96	2.19	2.84	0.97	1.20	1.09	1.39	0.58	2.02

Comp1: 78.54 Kg N/hect. Comp2: 159.46 Kg N/hect. Comp3: 238 Kg N/hect

application various of compost levels had insignificant effect on number of branches/plant.

Concerning the effect of compost levels on fresh and dry weight of various plant organs, it could be observed that the highest compost levels caused a marked improved effected on fresh weights of leaves, stems, roots and total plant. The increment percentages for these characters over the control reached to 48.9, 62.3, 27.5 and 54.1% respectively. Similarly, the stimulation effect on dry weight of the same organs as a result of higher compost level reached to 21.6, 62.3, 34.5 and 44.7%, respectively compared with control plants.

Effect of plant distances on growth characters: The results presented in Table 2 indicated that different plant distances markedly effect on vegetative growth characters. The medium distance (40 cm) resulted in tallest plant height which reached to 40.5 cm, while the narrow distance (30 cm) produced shortest one which reached to 37.4 cm. The wider spacing was more effective to produce significant increment for branches number of rue plants. Increasing sowing distances gradually from 30 cm to 50 cm increased number of branches about 4.5%. Similarly, a positive relationship was noticed between plant distances and fresh or dry weights of stems, roots and whole rue plants. Thus the maximum weights were noticed as a result of wider distance (50 cm between plants) which gave an increment in fresh weight (comparing with narrow distance 30 cm) reached to 25 and 25.9% for stems and roots respectively while the increment in corresponding dry weight reached to 25.6 and 46.9% respectively. Otherwise, the medium distance (40cm), led in general to significant promotion for leaves fresh and dry weights.

Effect of the interaction between compost and plant distances on growth characters: Regarding to combined effect of various compost levels and different plant spacing (Table 2), the obtained data revealed that the maximum plant height and the heaviest fresh weight of leaves were recorded with plant supplied with highest compost level and grown under medium distance condition (40 cm). Meanwhile, the highest number of branches was obtained by treating plants with medium compost level combined with narrow plant distance. On the other hand, the pronounced increment in fresh and dry weight of other different plant organs of rue plants were occurred when the highest compost level was added to plants grown at wider distance (50 cm).

Table 3: Influence of compost fertilizer and sowing distance on flowers yield and essential oil of *Ruta graveolens* L. (means value of two seasons)

Treatments	Flower yield g/plant	Essential oil (%) Leaves	Essential oil (%) Flowers	Essential oil ml/hect. Leaves	Essential oil ml/hect. Flowers
A) Effect of compost:					
Comp 0	39.2	0.119	0.131	517.22	1288.34
Comp 1	36.2	0.121	0.164	425.0	1511.73
Comp 2	44.6	0.103	0.135	510.46	1491.21
Comp 3	64.8	0.112	0.109	712.93	1535.00
LSD %5	2.18	0.006	0.003	14.95	158.32
B) Effect of sowing distances:					
30 cm	43.4	0.131	0.133	726.69	1711.98
40 cm	45.6	0.110	0.144	568.63	1623.37
50 cm	49.6	0.100	0.128	363.66	1034.35
LSD %5	1.89	0.005	0.004	12.95	137.09
C) Effect of the interaction between compost and sowing distances:					
Comp0					
30 cm	40.0	0.099	0.123	637.82	1561.23
40 cm	38.3	0.125	0.127	525.46	1233.72
50 cm	39.3	o.134	0.143	388.42	1070.048
Comp1					
30 cm	32.7	0.171	0.180	590.22	1869.04
40 cm	39.1	0.116	0.163	462.01	1617.02
50 cm	36.7	0.076	0.150	222.77	1049.10
Comp2					
30 cm	37.7	0.140	0.143	774.26	1710.39
40 cm	42.1	0.100	0.172	530.55	1837.88
50 cm	54.0	0.068	0.090	226.58	925.344
Comp3					
30 cm	63.3	0.113	0.085	767.93	1707.22
40 cm	62.9	0.100	0.113	715.86	1804.87
50 cm	68.3	0.123	0.128	654.98	1092.90
LSD%5	3.77	0.012	0.009	21.3	208.98

Comp1: 78.54 Kg N/hect. Comp2: 159.46 Kg N/hect. Comp3: 238 Kg N/hect.

Flowers yield

Effect of compost fertilizer on flowers yield: The flowers yield of rue plants as affected by various compost levels were shown in Table 3. Significant promotion effect with two highest compost levels was recorded. Moreover, the highest compost level produced the highest flowers yield, which reached to 64.8 g/plant, in corresponding to 39.2 g flowers/plant for control plants.

Effect of plant distances on flowers yield: Data presented in Table 3 indicated that the wider distance (50 cm) was more favorable for producing highest flowers yield/plant. Significant increment was noticed with increasing plant distances from 30 to 50 cm.

Effect of the interaction between compost and plant distances on flowers yields: It is appeared from Table 3 that flowers yield recorded variable effect with applied different compost levels combined with various plant distances. However, it is cleared that the highest compost level combined with various plant distances, recorded in general heaviest flowers yield compared with medium or low compost level. Meanwhile, the highest significant increment of flowers yield (68.3 g/plant) were noticed with plant treated with compost level (238 Kg N/hect.) and grown on wider distance (50 cm), which increased flowers yield about 70.8% over the control treatment.

Essential oil content (%) and yield

Effect of compost fertilizer on essential oil content (%) and yield: Data tabulated in Table 3 indicated that compost fertilizers had a significant effect on essential oil content (%) and yield (cc/hect.) for both leaves and flowers. The results cleared that essential oil content (%) for flowers was higher compared with essential oil content (%) for leaves. Moreover, compost at different levels caused significant effect on essential oil content (%). Low compost level was more favorable for promoting essential oil accumulation in leaves as well as flowers, which their content (%) reached to 0.121 and 0.164% respectively comparing to 0.119 and 0.131% for control treatment. On the otherwise, essential oil yield in leaves and flowers showed maximum values as a result of highest compost level (238Kg N/hect.).

Effect of plant distances on essential oil content (%) and yield: According to the data in Table 3, an opposite trend was noticed between essential oil (content (%) and yield) for leaves and plant distances, where the narrow distance (30 cm) produced the highest percentage and yield. This promotion effect was decreased with increasing sowing distances. On the other hand the medium distance (40 cm) produced the maximum values for essential oil percentage and yield in flowers.

Effect of the interaction between compost and plant distances on essential oil content (%) and yield: Essential oil content (%) and yield for both leaves and flowers showed various pronounced increments with some exceptions as a result of compost application under different sowing distances. The maximum mean values of essential oil percentage were obtained as a result of the combination treatment between the first compost level (78.54Kg N/hect.) and 30 cm distance between plants. The combination between Compost (159.46Kg N/hect.) and 30 cm distance between plants gave the highest essential oil yield for leaves while the combination between compost (159.46Kg N/hect.) and 40 cm distance between plants gave the highest essential oil yield for flowers.

Table 4: Influence of compost fertilizer and sowing distance on rutin and cumarin (%) of *Ruta graveolens* L. (means value of two seasons)

Treatments	Total rutin (%)	Total cumarin (%)
A) Effect of compost:		
Comp 0	1.31	0.0127
Comp 1	1.43	0.0143
Comp 2	1.51	0.0150
Comp 3	1.52	0.0153
B) Effect of sowing distances:		
30 cm	1.45	0.0145
40 cm	1.40	0.0140
50 cm	1.46	0.0145
C) Effect of the interaction between compost and sowing distances:		
Comp0		
30cm	1.20	0.0120
40cm	1.21	0.0120
50cm	1.42	0.0140
Comp1		
30cm	1.50	0.0150
40cm	1.51	0.0150
50cm	1.31	0.0130
Comp2		
30cm	1.51	0.0150
40cm	1.42	0.0140
50cm	1.61	0.0160
Comp3		
30cm	1.60	0.0160
40cm	1.51	0.0150
50cm	1.52	0.0150

Comp1: 78.54 Kg N/hect. Comp2: 159.46 Kg N/hect. Comp3: 238 Kg N/hect.

Rutin and coumarin content (%)

Effect of compost fertilizer on rutin and coumarin content: The results in Table 4 pointed out that rutin percentage increased with different compost levels. The highest increment was noticed with second compost level (159.46 Kg N/hect.). Mean while the accumulation increment at this level reached to 13.6% over the control treatment. Similarly, the coumarin percentages appeared a marked stimulation with various compost levels. The two highest compost levels produced the highest coumarin percentage, which recorded 15.4% over control plants.

Effect of plant distances on rutin and coumarin content: It is clearly observed from data presented in Table 4 that increased plant distance from 30 cm to 40 cm increased rutin content (%) and this increment reached to 6.7%. More wider in distance to 50 cm, caused opposite effect.

For coumarin content (%), the results indicated that sowing at various distances had no pronounced effect on mean values of coumarin accumulation which ranged between 0.014 to 0.0146%.

Table 5: Influence of compost fertilizer and sowing distance on nutrients content of *Ruta graveolens* L. (means value of two seasons)

	%			ppm		
Treatments	N	P	K	Zn	Fe	Mn
A) Effect of compost:						
Comp 0	2.19	0.81	1.29	555	2129	162
Comp 1	2.71	0.88	1.49	632	2344	197
Comp 2	2.68	0.94	1.53	634	2379	226
Comp 3	2.97	0.97	1.55	642	2371	232
B) Effect of sowing distances:						
30 cm	2.44	0.88	1.42	601	2263	193
40 cm	2.54	0.87	1.45	603	2290	196
50 cm	2.60	0.90	1.45	619	2300	197
C) Effect of the interaction between compost and sowing distances:						
Comp0						
30 cm	2.14	0.80	1.28	551	2112	166
40 cm	2.21	0.82	1.33	555	2141	160
50 cm	2.22	0.82	1.25	560	2135	160
Comp1						
30 cm	2.56	0.88	1.47	6.23	2316	194
40 cm	2.72	0.86	1.49	618	2353	199
50 cm	2.86	0.91	1.51	657	2364	200
Comp2						
30 cm	2.62	0.90	1.50	628	2362	220
40 cm	2.70	0.94	1.52	635	2377	228
50 cm	2.72	0.98	1.58	640	2400	230
Comp3						
30 cm	2.76	0.95	1.54	633	2358	229
40 cm	2.99	0.97	1.55	638	2371	233
50 cm	3.17	0.99	1.56	655	2384	234

Comp1: 78.54 Kg N/hect. Comp2: 159.46 Kg N/hect. Comp3: 238 Kg N/hect

Effect of the interaction between compost and plant distances on rutin and coumarin content: Data recorded in Table 4 indicated that there were marked differences in rutin percentage in leaves due to interaction applied of various compost levels with different sowing distances. Generally, increasing the applied compost dose with increasing plant distances caused more accumulation in rutin content. However, the maximum rutin percentage was recorded with applied second compost level (159.46Kg N/hect.) and sowing plants at 30 cm distance.

For coumarin, it is clearly noticed that application of medium compost level (159.46 Kg N/hect.) with wider sowing distance or the combined treatment between the highest compost level (238 Kg N/hect.) with narrow plant distance accumulated the highest coumarin (%). Moreover, increasing distance from 30 cm till 50 cm with highest compost level produced the same value of coumarin (0.015%).

Table 6: Percentage composition of the leaves essential oil of *Ruta graveolens* L. as influenced by compost and plant distance

Compounds	Con.	1	2	3	4	5
Limonene	0.10	0.06	0.08	0.08	0.04	0.06
Geyrene	1.26	1.41	1.34	1.09	1.20	1.33
1-Nonene	2.45	2.19	3.00	2.18	2.53	2.30
2-Nonene	3.07	2.99	2.85	3.25	3.41	2.56
Undecene	3.51	3.44	2.67	3.88	3.69	4.40
Anthracene	1.21	1.00	1.10	1.14	0.95	0.81
Neophytadiene	0.03	0.06	0.04	0.10	0.05	0.05
3, 4-Dihydrobenzo [b] fluoranthene	2.63	2.91	1.86	2.84	2.64	2.47
Total hydrocarbon	14.26	14.06	12.94	14.56	14.51	13.98
2-Octanone	1.60	1.72	1.36	1.55	1.70	1.38
2-Nonanone	10.15	10.27	11.08	11.59	12.61	12.92
Teteradecanal	1.22	1.40	2.02	1.30	1.53	1.44
Dodecanal	2.00	2.16	2.57	2.45	2.30	2.61
2-Docanone	1.73	1.96	1.23	1.07	1.95	1.62
2-Undecanone	51.00	51.28	51.20	51.94	50.01	51.00
2-dodecanone	2.77	2.91	3.06	2.81	2.67	2.84
9-Methyl-10-Methylene-Tricyclo (4.2.1.1.2.5) Decan-9-ol	0.15	0.15	0.09	0.03	0.08	0.07
1-Dodecanol, 3.7.11-trimethyl	0.51	0.49	0.36	0.47	0.43	0.52
2-Tridecanone	0.57	0.84	0.88	0.87	0.92	0.90
12-Methyl-oxa-cyclododec -6-EN-2-one	2.36	2.71	2.36	2.86	2.46	2.14
Elemol	1.98	2.30	2.19	2.18	2.98	2.48
9-Methyl4-(1,3-benzodioxol -5-yl) butanoate	0.75	0.42	0.68	0.54	0.82	0.95
Nepetalactol	0.11	0.12	0.14	0.14	0.20	0.15
Ascaridol	0.03	0.11	0.07	0.06	0.10	0.10
Guaiol	0.12	0.19	0.12	0.13	0.13	0.11
Eudesmol	0.19	0.20	0.35	0.15	0.22	0.18
Methyl 4-(1,3-benzodioxol -5-yl) butanoate	0.24	0.22	0.16	0.11	0.17	0.13
Hexadecanal	0.38	0.34	0.29	0.40	0.37	0.35
(Z)-8-(3,5-dimethyl-4-hydroxyphenyl)-2-octene	0.50	0.66	0.82	0.85	0.69	0.75
9,12,15-Octadecatrienal	0.85	1.02	1.11	1.25	1.51	1.32
Hexadecanoic acid	0.44	0.68	0.75	0.91	0.59	0.66
3-Ethoxy-4-hydroxy-4-(4-methoxyphenyl) cyclopent-2-enone	0.10	0.17	0.13	0.11	0.08	0.05
9,12,15-Octadecatrienoic acid methyl ester	0.55	0.92	0.38	0.51	0.80	0.74
Total oxygenated	80.30	83.24	83.40	84.28	85.32	85.41
Total identified	94.56	97.30	96.34	98.84	99.83	99.39

1 = compost 0+ 30cm 2 = compost 0+ 40cm 3 = compost0 + 50cm 4 = compost 1 + 30cm 5 = compost 2 + 30cm

Table 7: Percentage composition of the flowers essential oil of *Ruta graveolens* L. as influenced by compost and plant distance

Compounds	Con.	1	2	3	4	5
Limonene	0.20	0.10	0.03	0.05	0.06	0.08
Geyrene	3.55	4.02	3.92	2.83	3.85	2.74
1-Nonene	2.31	1.92	2.40	2.50	1.66	1.39
2-Nonene	1.94	1.63	1.92	1.88	1.80	1.33
1-Undecene	3.14	4.00	3.28	2.92	3.29	3.35
Anthracene	0.52	0.24	0.61	0.54	0.44	0.31
Neophytadiene	0.13	0.02	0.25	0.11	0.08	0.11
3,4-Dihydrobenzo[b]fluoranthene	1.11	0.95	0.88	1.17	1.20	1.32
Pentacosane	0.24	0.30	0.39	0.17	0.22	0.15
Total hydrocarbon	13.14	13.36	13.68	12.17	12.6	10.78
2-Nonanone	9.36	11.0	9.55	9.12	9.65	10.36
Cyclotridecanone	o.10	0.14	0.18	0.09	0.11	0.02
2-Docanone	3.15	2.83	3.15	3.42	2.12	3.55
2-Undecanone	60.12	63.05	62.13	64.58	65.0	65.07
Ethyl 3-phenyl propionate	0.34	0.28	0.19	0.28	0.30	0.12
2-Dodecanone	4.02	5.00	3.45	3.98	3.81	3.90
9-Methyl-10-Methylene-Tricyclo (4.2.1.1.2.5) Decan-9-ol	0.08	0.01	0.04	0.15	0.12	0.09
2-Tridecanone	0.41	0.13	0.16	0.29	0.44	0.29
1-Dodecanol, 3.7.11-trimethyl	0.11	0.06	0.08	0.08	0.17	0.17
Epiglobulol	0.12	0.09	0.14	0.23	0.11	0.30
Elemol	0.15	0.01	0.01	0.08	0.03	0.11
2-Tetradecanone	0.08	0.02	0.03	0.04	0.01	0.02
Cycloundecanone	0.13	0.02	0.05	0.08	0.02	0.19
Guaiol	0.20	0.11	0.13	0.09	0.22	0.17
Eudesmol	0.24	0.10	0.16	0.17	0.33	0.30
Cis-2-(3,4-dimethoxy) phenlcyclopetanonol	1.17	1.01	0.25	1.42	1.00	1.15
1-(3,4-dimethoxyphenyl)-1 -Acetoxy-z-propene	0.05	0.01	0.01	0.02	0.07	0.02
(Z)-8-(3,5-dimethyl-4-hydroxyphenyl)-2-octene	1.02	0.66	0.88	0.54	0.83	0.95
9,12,15-Octadecatrienal	0.10	0.01	0.06	0.01	0.02	0.05
Hexadecanoic acid	0.12	0.03	0.11	0.06	0.03	0.12
9,12,15-Octadecatrienoic acid methyl ester	1.11	0.05	0.82	1.03	0.39	0.99
Total oxygenated	82.18	84.62	81.58	85.78	84.78	87.94
Total identified	95.32	97.98	95.26	97.95	97.38	98.72

1=compost 0+ 30cm 2= compost 0+ 40cm 3=compost0 + 50cm
4= compost 1 + 30cm 5= compost 2 + 30cm

Nutrients content

Effect of compost fertilizer on nutrients content: Table 5 showed the concentration of macronutrients N, P, K as well as micronutrients Zn, Fe and Mn in leaves of *Ruta graveolens* as affected by compost fertilizer. It is clear that different levels of compost caused a pronounced increment in all nutrients content. The highest mean values content of various nutrients were obtained with highest compost dose with one exception recorded with Fe. However, the highest increments in macro elements N,P and K in comparison with control reached to 3.56, 19.8 and 20.2% respectively, while the microelements Zn, Fe and Mn reached to 15.7, 11.7 and 43.2% respectively.

Effect of plant distances on nutrients content: Data in Table 5 indicated that the macro and micro elements content increased gradually with increasing sowing distance. The highest increment in nutrients content were recorded with applied wider distance of 50 cm reached to 6.6, 2.3 and 2.1% for N,P and K respectively, corresponding to plants sowing at 30 cm distance. Similarly, microelements content of Zn, Fe and Mn appeared enhanced accumulation with sowing at 50 cm than 30cm distance represented about 3.16, 1.6 and 2.1%, respectively from same three elements.

Effect of the interaction between compost and plant distances on nutrients content: It is clear in Table 5 that the highest compost level combined with wider sowing distance produced the highest accumulation for the nutrients content of N,P,Fe and Mn for *Ruta graveolens* plants. Thus, the applied 238 Kg N/hect. + 50 cm sowing distance increasing the content of these minerals by 48.1, 23.8, 12.9 and 41.0% over the control.

Essential oil components: The essential oil compounds of leaves and flowers collected at second season were identified by GC/MS (Table 6 and 7). The identified compounds in leaves were 32 compounds (represented about 94.56%) and for flowers 33 compounds (represented about 96.45%). The hydrocarbon terpenes were 8 compounds (contain 14.26%) and 9 compounds (contain 13.4%) for both leaves and flowers, respectively. Meanwhile, the oxygenated compounds for leaves were 24 compounds contain 80.30% and for flowers were 22 compounds contain 83.1%.

It was found that 2-undecanone was the major compound for leaves and flowers, as it was found in all cases more than half of the oil compounds and it was about 50.01 to 51.94% in leaves and 60.12 to 65.70% in flowers. However, the main constituents previously in *Ruta graveolens* oil for leaves were in a descending order, 1-undecen, 2-nonene, 1-nonene and 2-dodecanone whereas, for flowers oil were 2-nonanone, 2-dodecanone, geyrene and 1-undecene.

On the other hand, applied various compost fertilizer levels increased the total identified compounds for oil of both leaves and flowers. However, the major compound of leaves did not affect by compost treatments, while essential oil of flowers appeared marked increment with all treatments.

It is clear to notice the highest identified compounds and major constituents for leaves and flowers recorded with highest compost level combined with narrow plant distance (50 cm).

DISCUSSION

The improvement effects of compost fertilization treatments on vegetative growth characters can be rendered to the important role of compost on soil properties, moisture retention, better nutrient availability which resulting in good plant growth production [11, 27]. The promotion effect of compost on rue vegetative growth with one exception (number of branches/plant), were coincide with various medicinal and aromatic plants, i.e. Naguib [28] on *Chamomille recutita,* Aly [29] on *Lupinus termis*, Khalil and El-Sherbeny *et al.* [30] on three *Mentha spp.* and El-Sherbeny *et al.* [16] on *Sideritis montana* L.

The variable effect of plant distances on plant height are reported by Shalaby and Razin [31] who recorded that wider hill spacing resulted in shorter rosella plants, while El-Kashlan [32] found that rosella plant height increased with increasing plant distance. Similariy [16] on *Sideritis montana* L. reported that 40 cm distance between plant was the most favourable distance to produced tallest plants comparing with two other distances of 30 cm and 50 cm.

On the other hand, the improvement of fresh and dry weights of *Ruta graveolens* plants may be attributed to the wider plant spacing rendered to the availability of more inter plant spacing enabling the plants to grow will utilizing the growth factors. Similar results has been recorded with El-Gengaihi *et al.* [17] on *Dracocephalum moldavica,* Mokhtar [33] on *Lupinus termis* and El-Sherbeny *et al.* [16] on *Sideritis montana L.*

Regarding to interaction treatments and their effects on growth characters, the results obtained coincide with the findings of El-Sherbeny *et al.* [16] on *Sideritis montana* L and Hussein *et al.* [34] on *Dracocephalum moldavica*.

Concerning the effect of compost levels and plant distances on flowers yield, it is clear that the highest significant increment of flowers yield was noticed as a result of the highest compost level combined with the widest distance. These results may be attributed to the role of macro-and micro-nutrients provided by compost in stimulating metabolic processes, encouraging growth and flowers yield. Moreover, the widest distance resulted in increment the herb which plays an important role for encouraging flowers yield. In this respect, Mohamed and Wahba [35] on *Tagetes erecta* indicated that narrow distance of 36cm gave the heaviest fresh and dry weights of flowers where 48 and 60 cm spacing produced the next values. In contrast, Umesha *et al.* [36] suggested that the greatest plant density gave the maximum yield of leaves and inflorescence of basil.

As for the effect of applying compost on essential oil content (%) and oil yield, it can be noticed that compost at (78.54 Kg N/Hect.) caused an increment in essential oil content (%) for both leaves and flowers. On the other hand, the maximum value of essential oil yield (ml/plant) was obtained as a result of applying compost at (238 Kg N/Hect.).This result may be due to effect of compost on accelerating metabolism reactions as well as stimulating enzymes. This increment may be due to the effect of compost on mass production or/and oil content (%). Concerning the effect of plant spacing, it is found that the narrow distance and medium one gave the highest value of oil content for leaves and flowers respectively, while the maximum value of oil yield was obtained as a result of narrow space. In this respect, El-Sherbeny *et al.* [16], reported that wider space (40 cm between plants) led to the highest accumulation in oil percentage and yield of *Sideritis montana* L.They added that essential oil yield per feddan decrease by increasing planting distances from 20 to 40 cm. Meanwhile, Sadek *et al.* [37] on rosemary plants, El-Dean and Ahmed [38] on black cumin seed found that oil percentage and yield increased by increasing plant spacing. Hussein *et al.* [34] on *Dracocephalum moldavica* concluded that wider treating plants with highest compost level (16.5 ton/fed.) combined with a wider plant spacing (40 cm) had a promotive effect on oil percentage and oil yield.

The promotive effect of compost or/and sowing distance on rutin and coumarin content (%) may be due to it's effect on growth, photosynthetic pigments, nutrient status and enzymes. In this connection, El-Gengaihi and Abd-El-Fattah [39] revealed that the nitrogen forms had no effect on rutin and coumarin content. They added that the increment or decrement of rutin as well as total flavonoids were almost a diurnal variation. This means that these substances increased during the day and a corresponding decrease occurred during the night. Also, the increment or decrement of flavonoids may be attributed to the seasonal variation or plant age [40]. On the other hand, Pereira *et al.* [41], indicated that coumarin concentration was raised by organic fertilization (humus or manure) while inorganic nutrient (different levels of nitrogen) induced increased phytomass of stem and leaf yield of *Mikania glomerata*.

From the above results it could be indicated that to produce plants contain highest nutrients content, plants must be treated with compost at 238 Kg N/Hect.combined with sowing at 50 cm distance.The results were in harmony with those obtained by Herrera *et al.* [12] who indicated that minerals content of N, P, K, Ca and Mg of thyme seedlings were increased by increasing compost ratio in growth media. In addition, Krishnan *et al.* [42] reported that compost application caused enhancement of N and K in fenugreek plants. Meanwhile, Aly [29] on *Lupinus termis* revealed that N and K content increased significantly by increasing compost levels, but contrast was true for P, Fe, Mn and Zn which the accumulation were inhibited gradually by increasing compost level from 0 to 16 ton/fed.

Concerning oil constituents, results obtained revealed that 2-undecanone was detected as the major compound for leaves and flowers. In this connection several authors identified similar major compound of *Ruta graveolens* L. Pino [43] indicated that leaf oil of *Ruta graveolens* L. grown in Cuba identified 32 components and the major constituents was 2-undecanone (48.67%) followed by curcuphenol (8.18%) and hexadecanonic acid (5.68). Stashenko [44] found that the main constituents of extracts from leaves, flowers, stems and roots were 2-nonanone (8.9%), 2-undecanone (13.4%0, chalepensin (13.0%) and geijerene (19.3%), respectively. The above results which were mentioned the effect of compost and/or sowing distances coincided with those of [14] on *Rosmarinus officinalis* and [16] on *Tagets erecta* who reported that compost level at 3.5 ton/fed. and 7 ton/fed. increased the percentage of the identified constituents over the control.

CONCLUSION

According to previous results, it appears that the two factors of compost at different levels and various sowing distances have an important role in growth and flowers characters as well as essential oil, rutin and coumarin accumulation for *Ruta graveolens* plants. It could recommend fertilizing plants with compost at level of 238 Kg N/Hect. Combined with 50 cm as sowing distance to produce the highest yield for both leaves and flowers (g/plant) while for maximum values of essential oil yield (Kg/Hect.), it could apply (compost at 159.46 Kg N/Hect. X 30 cm.) or (compost at 78.54Kg N/Hect.X30cm) for leaves and flowers respectively.

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