Improving the productivity of fennel (*Foeniculum vulgare* Miller) plants by using some humic and salicylic acid treatments

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Abstract: This investigation aims to determine the influence of humic acid and salicylic acid on the growth, yield and production of volatile oil of fennel (*Foeniculum vulgare* Miller). Four levels of humic acid (0, 4, 8, 12 kg/ha) were used. While foliar spraying was carried out with salicylic acid at two concentrations of 0.100, 200 and 300 ppm. The results obtained showed that humic acid at all levels, as well as foliar spraying with salicylic acid, led to a significant increase in plant productivity. The highest values for growth and productivity measurements of fennel plants were obtained when humic acid was applied at a high level (12 kg/ha). Foliar spraying with salicylic acid at a concentration of 300 ppm gave the highest values for all measurements under this study. Most of the joint coefficients showed a significant increase in all the studied traits. It was found that adding humic acid at a high rate (12 kg/ha) and foliar spraying with salicylic acid at a concentration of 300 ppm was the best treatment compared to the other combined treatments under the conditions of this study. It is worth noting that this study is primarily economic, as alternatives to expensive mineral fertilizers were used to improve the productivity of the fennel plant, which is widely used in various pharmaceutical industries.

Keywords: Fennel, (*Foeniculum vulgare* Miller), Humic acid, salicylic acid.

تحسين انتاجية نباتات الشمر (*Foeniculum vulgare* Miller) باستخدام بعض معاملات أحماض الهيوميك والساليسيلك

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المستخلص: الهدف من هذه الدراسة هو تحديد تأثير حمض الهيوميك وحمض الساليسيليك في نمو وحاصل وإنتاج الزيت الطيار لنبات الشمر (*Foeniculum vulgare* Miller). تم استخدام أربعة مستويات من حامض الهيوميك (0، 4، 8، 12 كجم/هكتار). بينما تم الرش الورقي بحامض الساليسيليك بتركيزات، صفر 200,100و 300 جزء في المليون. وتبين من النتائج المتحصل عليها أن حامض الهيوميك بجميع مستوياته وكذلك الرش الورقي بحامض الساليسيليك أدى إلى زيادة معنوية في جميع الصفات المدروسة. تم الحصول على أعلى القيم لقياسات النمو والإنتاجية لنباتات الشمر عند إضافة حمض الهيوميك عند المستوي المرتفع (12 كجم/هكتار). وقد أعطى الرش الورقي بحمض الساليسيليك بتركيز 300 جزء في

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المليون أعلى القيم لجميع القياسات تحت هذه الدراسة. أظهرت معظم المعاملات المشتركة زيادة معنوية في جميع الصفات المدروسة. وقد وجد أن إضافة حامض الهيوميك بالمعدل المرتفع (12 كغم/هكتار) والرش الورقي بحامض الساليسيليك بتركيز 300 جزء في المليون قد أعطي أفضل النتائج عند المقارنة بالمعاملات المتداخلة الأخرى في ظل ظروف هذه الدراسة. ومن الجدير بالذكر أن هذه الدراسة اقتصادية بالدرجة الأولى، حيث تم استخدام بدائل للأسمدة المعدنية مرتفعة الثمن لتحسين إنتاجية نبات الشمر الذي يستخدم على نطاق واسع في الصناعات الدوائية المختلفة.

الكلمات االمفتاحية: نبات الشمر ،حامض الهيوميك و حامض الساليسلك.

Introduction:

Fennel (*Foeniculum vulgare* Mill) is an annual or biennial aromatic herbaceous plant that belongs to the Apiaceae family **(Farrell, K.T. (1988) and Wichtl and Bissel, 1994).** It is widely grown as a medicinal and aromatic plant in many countries, including Egypt, especially in the Middle Egypt region. The seeds contain an essential oil that is used in many food and pharmaceutical industries **(Lawless, 1997).** Fennel has been used in folk medicine as a carminative, sedative and diuretic **(Charles et al., 1993)** and diuretic, expectorant, emmenagogue and antispasmodic **(Chiej, R. 1984).** The essential oil of the plant contains a main compound, which is fenchone, which plays an important role in the pharmaceutical industry and in the confectionery industry (**Abdullah *et al.*, 1978**).

When humic acid is added to the soil, it increases the effectiveness of fertilizers by 30%, which saves a significant amount of added fertilizer, and at the same time it does not affect the amount of production, and this is an important economic factor. Humic acid also helps improve soil composition and increases the soil's ability to retain water and nutrients, which helps the plant resist drought **(Zhou et al., 2019).** Humic acid helps prevent the loss of nutrients due to its high capacity for cation exchange, which leads to reducing the osmotic pressure of salts on the root system of plants, and at the same time helps preserve water-soluble inorganic fertilizers and prevents them from draining. Humic acid helps provide nutrients in a form suitable for plant absorption **(Rosa *et al*., 2018).**

Salicylic acid (SA) is an important acid because of its major role in the resistance of many plants to pathogens. It acts as an antioxidant, which helps in the oxidation of plant cells, thus preserving them from death, and acts as an initiator of the development of systemic acquired resistance **(Shirasu et al., 1997).** There are many studies that confirm the important role of salicylic acid in improving the plant's response to many abiotic stresses **(Yalpani *et al*., 1994; Senaratna et al., 2000**). One of the most important effects of salicylic acid is to participate in increasing temperature in thermophilic plants **(Raskin et al., 1987).** Treating mustard seedlings with exogenous SA increased the thermal acclimation of these plants **(Dat *et al*., 1998).** When corn plants are treated with salicylic acid, it stimulates antioxidant enzymes, which increases cold tolerance **(Janda *et al*., 1999).** Some research has used transgenic Arabidopsis expressing the salicylate hydroxylase (NahG) gene to reduce SA levels and monitor its response to ozone (O3). This discovery demonstrated that SA is required for O tolerance by maintaining cellular redox state and allowing defense responses (Sharma et al., 1996). However, using Cvi-0, an Arabidopsis genotype that accumulates high levels of SA, it has been shown that SA activates an oxidative burst and cell death pathway leading to O sensitivity **(Rao and Davis, 1999).**

The efficiency of salicylic acid in improving plant dry weight, number of umbels, fruit yield, essential oil percentage has been studied by many researchers, regarding the application of salicylic acid, **Tanious (2008) and Ali *et al.* (2017)** on fennel (*Foeniculum vulgare* Mill), **Gahory *et al.* (2022)** on coriander (*Coriandrum sativum* L.), **Eshak (2013)** on caraway **(*Carum carvi*)** and **Abdou *et al.* (2012)** on cumin (*Cuminum cyminum*)**.**

Materials and Methods:

This study was conducted at the Agricultural faculty farm of Al-Azhar University in Egypt during two consecutive seasons 2021/2022 and 2022/2023 Study of the effect of humic acid on rats 0, 4, 8, and 12 kg/ha. and salicylic acid at levels of 0, 100, 200 and 300 ppm and the interaction between them on growth, yield and percentage of essential oil. and content per plant (ml) and per ha (L) of fennel (*Foeniculum vulgare* Miller) fruits. Fennel seeds were obtained from Department of Medicinal and Aromatic Plants, Horticultural Research Institute, Giza, Egypt. Humic was obtained from the Egyptian Spanish Company, Egypt. The analysis of the components of the product used in this study was as follows: 75% humic acid, 10% K2O, 4% fulvic acid, 1% iron, and pH =6.2.

Experimental design:

In this experiment, the treatments were distributed in the split-plot system once according to a randomized complete block design (RCBD), and each treatment was repeated three times. The main scheme was to apply humic acid to rats at 0, 4, 8, and 12 kg/ha. Humic acid was used twice, the first time after 35 days and the second time after 65 days of transplantation with irrigation, while salicylic acid (SA) was sprayed in the subplots at concentrations of 0,100,200 and 300 ppm foliar spray three times as follows: December 20, 5 and January 20th. For the first, second and third sprays, respectively, for the two experimental seasons. Planted the fennel seeds on November 5th of the bathing season. Each subplot with dimensions of 3.0 x 3.20 m has 5 rows and a spacing of 60 cm. The planting distance is 40 cm between one plant and another. After 33 days of planting, the plants were thinned to two plants per hill. Before planting, all agricultural practices were carried out as usual. Growth measurements were recorded during the first week of May, including plant height (cm), number of branches/plant, fresh and dry weight of herb (g), number of umbels/plant, fruit yield/plant (g), and fruit yield/ha (kg). Essential oil percentage, essential oil content per plant (ml) and per hectare. (L).

Volatile oil isolation:

Seeds from each treatment were collected separately for the two growing seasons and weighed to extract the essential oil; 100 g of each replicate was taken for all treatments by hydrodistillation (HD) for 4 h using a Clevenger-type apparatus (Clevenger 1928). Volatile oil content was calculated as relative percentage (v/w). In addition, total Volatile oil was calculated as ml/100 plants using dry weight. Essential oils extracted from fennel plants were collected during the two seasons of each treatment and dried on anhydrous sodium sulfate for chemical identification.

Statistical data analysis:

The data obtained were collected, tabulated and then statistically analyzed according to **MSTATE-C (1986)** and means were compared using L.S.D. test at 5% according to **Mead et al. (1993).**

Table (1): Some physical and chemical characteristics of the soil used in the study.

Texture	PH (1:2.5)	E.C. (m.mohs/cm)	CaCo3 %	O.M. %	Total N%	Available		Water soluble ions (meg/l) in the soil paste				
						P ppm	K (mg/100g soil)	Ca	Mg	Co3+Hco3	Cl	So4
Loamy Sandy	7.85	2.23	2.49	0.53	0.14	0.15	3.3	3.5	2.0	2.8	2.3	6.5

Results and discussion

Growth metrics:

The results presented in Table 2 indicate growth measurements (plant height, number of branches/plant, and vegetative and dry weight in grams/plant) of fennel (*Foeniculum vulgare* Miller) plants. Its effect was significant when plants were treated with humic acid in the two experimental seasons. It appears that treating plants with humic acid at all rates led to a significant increase in plant height, number of branches per plant, and wet and dry weight compared to untreated plants in both seasons. It is noted from the recorded data that adding a high level of humic acid (12 kg/ha) gave the best values for these characteristics, as it was found that the height of the plant, the number of branches per plant, and the wet and dry weight. The plant increased. by 8.27, 8.96, 16.43, 19.14, 5.54, 4.64, 16.45 and 18.01% on untreated plants in both experimental seasons, respectively.

Previous results indicate that the use of humic acid was effective, as the efficiency of biological processes increased, as well as improved absorption of fertilizer elements, with a decrease in water evaporation from the soil, which works to increase the formation of chlorophyll and also increases the efficiency of the photosynthesis process, which positively affects all growth characteristics. .

These results are consistent with **Tawfik (2022)** on fennel (*Foeniculum vulgare* Miller) plants**, El-Shazly** and **Ghieth (2019)** on olive seedlings (*Olea europaea*), **Abd El-Aleem *et al.* (2017)** on dutch fennel (*Foeniculum vulgare*) plants, **Abou El-Khair *et al.* (2010)** on garlic (*Allium sativum*) and **Khater et al. (2022)** on *Ruta graveolens*.

The data recorded in Table 2 show the effect of foliar spraying with levels of 0,100,200 and 300 ppm salicylic acid on plant height (cm), number of branches/plant and fresh and dry weights of fennel herb (*Foeniculum vulgare* Miller). Plants experienced a significant increase compared to the untreated plants in the two seasons. However, the best growth was the result of spraying with SA (3) at a level of 300 ppm. and SA(2) 200. In general growth indices gradually improved with increasing salicylic acid levels. Foliar spraying with salicylic acid at a level of 300 ppm gave the best results for plant height (cm), branches number /plant and fresh & dry weights of herb (g) by 11.21, 30.55, 8.35% and 29.97% in the first season and 14.88. 31.49, 7.89 and 32.56% in the second season in a row on control in the two seasons.

Table: (2) The interaction effect of Humic acid and Salicylic acid treatments on growth parameters of fennel plants during 2021/2022and 2022/2023 seasons:

Humic acid (kg/ha.)	Salicylic acid (ppm)											
	Plant height (cm)											
	0	100	200	300	Mean	SD	0	100	200	300	Mean	SD
	First season						Second season					
0	**84.3**	**86.3**	**90.7**	**92.0**	**88.3**	3.63	**86.3**	**88.3**	**92.7**	**94.3**	**90.4**	3.73
4	**86.7**	**88.3**	**92.3**	**95.0**	**90.6**	3.78	**88.0**	**91.3**	**94.0**	**99.3**	**93.2**	4.78
8	**88.7**	**90.0**	**94.3**	**98.3**	**92.8**	4.37	**89.7**	**92.3**	**95.7**	**105.7**	**95.8**	7.01
12	**90.0**	**92.0**	**97.0**	**103.3**	**95.6**	5.93	**90.7**	**94.0**	**101.0**	**108.3**	**98.5**	7.82
Mean	**87.4**	**89.2**	**93.6**	**97.2**			**88.7**	**91.5**	**95.8**	**101.9**		
SD	2.5	2.4	2.7	4.8			1.9	2.4	3.6	6.3		
L.S.D0.05	**A:2.3 B:2.6 AB:5.2**						**A:3.8 B:2.9 AB:5.4**					

Number of branches											
0	**26.0**	**27.3**	**28.7**	**32.3**	**28.6**	2.72	**27.0**	**28.3**	**31.0**	**34.7**	**30.3**	3.40
4	**27.0**	**28.3**	**30.0**	**34.7**	**30.0**	3.37	**28.0**	**29.7**	**32.3**	**36.0**	**31.5**	3.48
8	**28.0**	**29.7**	**32.0**	**37.0**	**31.7**	3.91	**29.7**	**32.7**	**33.3**	**38.0**	**33.4**	3.43
12	**29.0**	**30.7**	**34.0**	**39.7**	**33.3**	4.71	**31.0**	**34.0**	**36.0**	**43.3**	**36.1**	5.24
Mean	**27.5**	**29.0**	**31.2**	**35.9**			**28.9**	**31.2**	**33.2**	**38.0**		
SD	1.3	1.5	2.3	3.2			1.8	2.6	2.1	3.8		
L.S.D0.05	**A:2.6 B:2.1 AB:4.2**						**A:2.9 B:2.1 AB:4.2**					
Shoot fresh weight (g/plant)											
0	**123.7**	**127.0**	**128.7**	**133.0**	**128.1**	3.87	**127.7**	**131.3**	**130.7**	**136.7**	**131.6**	3.75
4	**126.0**	**129.0**	**132.7**	**136.3**	**131.0**	4.47	**129.3**	**130.7**	**133.7**	**140.0**	**133.4**	4.75
8	**128.0**	**131.0**	**134.7**	**138.7**	**133.1**	4.63	**131.7**	**133.0**	**135.7**	**141.7**	**135.5**	4.44
12	**130.0**	**132.3**	**136.3**	**142.0**	**135.2**	5.26	**133.3**	**135.3**	**137.3**	**144.7**	**137.7**	4.98
Mean	**126.9**	**129.8**	**133.1**	**137.5**			**130.5**	**132.6**	**134.3**	**140.8**		
	2.7	2.3	3.3	3.8			2.5	2.1	2.8	3.3		
L.S.D0.05	**A:3.4 B:2.1 AB:4.2**						**A:3.8 B:2.5 AB:5.0**					
Shoot dry weight (g/plant)											
0	**27.0**	**28.7**	**31.0**	**35.0**	**30.4**	3.46	**28.0**	**30.7**	**33.0**	**37.0**	**32.2**	3.81
4	**28.0**	**31.7**	**33.0**	**36.3**	**32.3**	3.43	**29.3**	**33.7**	**35.7**	**39.0**	**34.4**	4.06
8	**29.0**	**33.0**	**35.0**	**38.0**	**33.8**	3.77	**30.7**	**35.0**	**37.7**	**40.0**	**35.8**	4.00
12	**30.7**	**34.3**	**36.7**	**40.0**	**35.4**	3.92	**32.3**	**36.0**	**40.0**	**43.7**	**38.0**	4.93
Mean	**28.7**	**31.9**	**33.9**	**37.3**			**30.1**	**33.8**	**36.6**	**39.9**		
	1.6	2.4	2.5	2.2			1.8	2.3	3.0	2.8		
L.S.D0.05	**A:3.8 B:2.3 AB:4.6**						**A:3.1 B:2.7 AB:5.4**					

These results are consistent with those obtained **Gahory *et al.* (2022), Hekmat *et al.* (2016),**, **Said *et al.* (2014)** and **Hesami *et al*. (2012)** on coriander (*Coriandrum sativum* L.) plant, **Talaat *et al.* (2014)** on *Ammi visnaga* and **Bashir (2023)** on Pea (*Pisum sativum*) plant.

It is clear from the results recorded in Table 2 that the interaction between the factors under this study was significant in both seasons. The best results for growth indicators were obtained when plants were sprayed with salicylic acid at a concentration of 300 ppm and humic acid at a rate of 12 kg/ha. This is when compared to other interference parameters under the conditions of this study in both seasons.

Yield measurements:

The data recorded in Table (3) indicate that the main effect of humic acid treatments in the two experimental seasons treatments on umbels number/plant, fruit yield /(g) plant and fruit yield/ (ton) hectare of fennel (*Foeniculum vulgare* Miller) plants was statistically significant in the two growing seasons. From the results obtained it can be observed that by increasing humic acid treatments, There was a significant increase in the umbels number /plant, seed yield/(g) plant and seed yield/(kg) hectare. Therefore, the highest value of these parameters was observed when the plants received a high percentage of humic acid (12 kg/ha), ranging between 13.24, 16.37, 8.03, 7.75, 8.76, and 8.45, compared to the screening treatment in the two seasons respectively.

The positive effect of humic acid on the yield has been confirmed, **Tawfik (2022)** on fennel (*Foeniculum vulgare* Miller) plants**, El-Shazly** and **Ghieth (2019)** on olive seedlings (*Olea europaea*), **Abd El-Aleem *et al.* (2017)** on dutch fennel (*Foeniculum vulgare*) plants, **Abou El-Khair *et al.* (2010)** on garlic (*Allium sativum*) and **Khater et al. (2022)** on *Ruta graveolens*.

Table: (3) The interaction effect of Humic acid and Salicylic acid treatments on Yield measurements of fennel plants during 2021/2022and 2022/2023 seasons:

Humic acid (kg/ha.)	Salicylic acid (ppm)											
	umbels number/plant											
	0	100	200	300	Mean	SD	0	100	200	300	Mean	SD
	First season						Second season					
0	25.0	26.3	28.0	29.3	27.2	1.89	25.7	27.3	29.0	30.3	28.1	2.00
4	26.0	27.7	29.0	30.7	28.3	1.99	27.0	29.3	30.0	32.3	29.7	2.18
8	27.0	29.0	30.3	32.0	29.6	2.11	28.0	30.3	31.0	33.7	30.8	2.35
12	28.0	29.7	32.0	33.7	30.8	2.51	29.3	31.3	34.7	35.3	32.7	2.84
Mean	26.5	28.2	29.8	31.4			27.5	29.6	31.2	32.9		
SD	1.3	1.5	1.7	1.9			1.5	1.7	2.5	2.1		
L.S.D0.05	A:2.2 B:2.1 AB:4.2						A:2.2 B:2.1 AB:4.2					
Seed yield/plant (g)												
0	46.00	47.67	50.33	51.33	48.83	2.44	47.00	49.67	51.67	54.00	50.58	2.97
4	47.33	49.00	51.67	53.33	50.33	2.68	48.33	51.33	53.67	57.00	52.58	3.67
8	48.67	50.00	53.00	54.33	51.50	2.62	49.67	52.00	54.33	57.67	53.42	3.41
12	49.67	51.67	54.33	55.33	52.75	2.57	50.67	53.33	55.33	58.67	54.50	3.37
Mean	47.92	49.58	52.33	53.58			48.92	51.58	53.75	56.83		
SD	1.60	1.69	1.72	1.71			1.60	1.52	1.55	2.01		
L.S.D0.05	A:2.4 B:2.1 AB:3.9						A:2.8 B:3.7 AB:7.2					
Seed yield/ Hectare (ton)												
0	3.35	3.48	3.60	3.74	3.54	0.17	3.43	3.52	3.77	3.94	3.66	0.23
4	3.45	3.57	3.77	3.89	3.67	0.20	3.53	3.74	3.91	4.16	3.84	0.27
8	3.55	3.65	3.86	3.96	3.76	0.19	3.62	3.79	3.96	4.21	3.90	0.25
12	3.62	3.77	3.96	4.04	3.85	0.19	3.69	3.89	4.03	4.28	3.97	0.25
Mean	3.49	3.62	3.80	3.91			3.57	3.74	3.92	4.14		
SD	0.12	0.12	0.15	0.13			0.11	0.16	0.11	0.15		
L.S.D0.05	A:0.14 B:0.14 AB:0.18						A:0.14 B:0.17 AB:0.36					

Seed yield/ Hectare (ton)												
0	3.35	3.48	3.60	3.74	3.54	0.17	3.43	3.52	3.77	3.94	3.66	0.23
4	3.45	3.57	3.77	3.89	3.67	0.20	3.53	3.74	3.91	4.16	3.84	0.27
8	3.55	3.65	3.86	3.96	3.76	0.19	3.62	3.79	3.96	4.21	3.90	0.25
12	3.62	3.77	3.96	4.04	3.85	0.19	3.69	3.89	4.03	4.28	3.97	0.25
Mean	3.49	3.62	3.80	3.91			3.57	3.74	3.92	4.14		
SD	0.12	0.12	0.15	0.13			0.11	0.16	0.11	0.15		
L.S.D0.05	A:0.14 B:0.14 AB:0.18						A:0.14 B:0.17 AB:0.36					

d 300 ppm

treatments led to a positive improvement in the number of canopies/plant and seed yield/(g) plants and seed yield/(ton) hectare in the two successive experimental seasons and the increase was significant. The highest values for these measurements were obtained when fennel plants were treated with salicylic acid (300 ppm), and they were higher than the unsprayed treatment by 18.49 and 19. 64, 11.81, 16.17, 12.03 and 15.97 in the two experimental agricultural seasons, respectively, as shown in Table (3). The best effect of salicylic acid on improving productivity has been observed by **Gahory *et al.* (2022), Hekmat *et al.* (2016)**,, **Said *et al.* (2014)** and **Hesami *et al.* (2012)** on coriander (*Coriandrum sativum* L.) plant, **Talaat *et al.* (2014)** on *Ammi visnaga* and **Bashir (2023)** on Pea (*Pisum sativum*) plant.

The effect of the interaction between the two factors on measurements of fennel plant productivity was positive for the two experimental seasons of this study. The most effective of these treatments was when adding a high rate of humic acid (12 kg/ha) with a high concentration of salicylic acid (300 ppm), when compared to the other combined treatments for both experimental seasons, as recorded in Table (3).

Essential oil content:

The traits recorded in (Table 4) show characteristics of the essential oil (essential oil % and yield of essential oil ml/plant, L/ha). Fennel plants (*Foeniculum vulgare* Miller) had a significant effect when humic acid was added at all levels in both excremental seasons. The increase was gradual with increasing humic acid rates to range between 8.39, 17.34 and 17.40 in the first season and 9.32, 18.17 and 18.19 in the second season over the control, respectively, when a high percentage of humic acid (12 kg) was used. /ha) compared to untreated plants.

Regarding spraying with salicylic acid, the data presented in (Table 4) showed that spraying treatment of vegetative growth with salicylic acid resulted in an increase in the percentage of essential oil and the essential oil yield ml/plant and liters/ha. The increase was significant in both seasons under this study, when compared to unsprayed plants. It was found that foliar spraying with salicylic acid at a concentration of 300 ppm was the best in increasing essential oil production (ml/plant) and essential oil production (l/ha). It reached 20.95, 35.60, and 35.54 in the first season, and 23.29, 43.89, and 43.83 in the second season of control in a row. These results are consistent with those obtained by **Gahory *et al.* (2022), Said et al. (2014), Hesami *et al*. (2012)**, and **Hekmat *et al.* (2006)** on coriander**, Talaat *et al.* (2014)** on khella, **Abd El-Latif (2007)** on borage.

Table: (4) The interaction effect of Humic acid and Salicylic acid treatments on essential oil production of fennel plants during 2021/2022and 2022/2023 seasons:

Humic acid (kg/ha.)	Salicylic acid (ppm)											
	Essential oil %											
	0	100	200	300	Mean	SD	0	100	200	300	Mean	SD
	First season						Second season					
0	1.907	1.943	2.020	2.187	2.014	0.124	1.937	1.963	2.060	2.237	2.049	0.136
4	1.930	1.960	2.043	2.297	2.058	0.167	1.950	1.997	2.077	2.357	2.095	0.182
8	1.943	1.997	2.177	2.400	2.129	0.206	1.967	2.023	2.200	2.460	2.163	0.222
12	1.953	2.097	2.210	2.470	2.183	0.219	1.977	2.130	2.250	2.603	2.240	0.267
Mean	1.933	1.999	2.113	2.338			1.958	2.028	2.147	2.414		
SD	0.020	0.069	0.095	0.123			0.018	0.072	0.093	0.155		
L.S.D0.05	A:0.078 B:0.077 AB:0.154						A:0.121 B:0.046 AB:0.092					
Essential oil /plant(ml)												
0	0.877	0.927	1.018	1.123	0.986	0.108	0.910	0.975	1.066	1.208	1.040	0.129
4	0.914	0.960	1.056	1.228	1.040	0.139	0.943	1.025	1.115	1.346	1.107	0.174
8	0.946	0.998	1.155	1.308	1.102	0.164	0.975	1.052	1.157	1.422	1.151	0.195
12	0.970	1.085	1.201	1.370	1.157	0.171	1.002	1.137	1.246	1.532	1.229	0.225
Mean	0.927	0.992	1.108	1.257			0.957	1.047	1.146	1.377		
SD	0.040	0.068	0.085	0.107			0.040	0.068	0.076	0.136		
L.S.D0.05	A:0.142 B:0.086 AB: N.S						A:0.155 B:0.092 AB:0.184					
Essential oil /Hectare (L)												
0	63.97	67.57	74.25	81.58	71.84	7.76	66.38	71.09	77.75	88.11	75.83	9.42
4	66.65	70.03	77.02	89.57	75.82	10.13	68.74	74.77	81.18	98.17	80.71	12.70
8	68.96	72.77	84.22	95.35	80.33	11.93	71.07	76.73	84.34	103.66	83.95	14.22
12	70.76	79.09	87.60	99.92	84.34	12.45	73.04	82.88	90.86	111.71	89.62	16.43
Mean	67.58	72.36	80.77	91.60			69.81	76.37	83.53	100.41		
SD	2.94	4.96	6.19	7.91			2.88	4.93	5.58	9.91		
L.S.D0.05	A:5.04 B:7.0 AB:14.0						A:6.40 B:5.29 AB:10.58					

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