



Influence of Sowing Date and Foliar Application of Humic Acid on Yield and Volatile Oil of Sweet Fennel (*Foeniculum vulgare*) Plants



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A FIELD trial was conducted to assess the effect of humic acid concentrations (0, 1.5, 3.0 and 4.5 g/l) on growth, yield and volatile oil constituents of fennel sown on 15th October, 1st November and 15th November during the two successive seasons of 2017/2018 and 2018/2019. The earliest date (15th October) recorded the best results regarding all fennel growth, yield and fruit constituents of volatile oil yield. Foliar application of humic acid in high concentration (4.5 g/ml) showed significant impact on plant height, branch number/plant, stem diameter, number of umbels/plant, fruit yield/plant, total fruit yield/feddan, volatile oil percentage, volatile oil/plant and volatile oil/feddan during both seasons. Volatile oil of fruits collected from plants sown in mid-October induced the highest percentage of anethole (74.96 %) and the lowest percentage of estragole (15.37%) in comparison with the plants sown in the beginning and middle November. The higher concentration of humic acid increased the percentage of anethole comparing with other concentrations. The foliar application by humic acid in high concentration of fennel sown in mid-October seems to be the best combination for getting higher fruit yield and high quality of volatile oil.

Keywords: Fennel, *Foeniculum vulgare*, Climate changes, Humic acid, Volatile oil, Anethole.

Introduction

Fennel (*Foeniculum vulgare* Mill.) is an herbaceous and perennial plant. It belongs to the family of Apiaceae (Umbelliferae). The plants contain essential oils in the leaves at rate of 1-1.5%, in root at 0.6-0.7% and 2-6% of the fruit. Terpenes or terpenoids of fennel essential oil are formed more than thirty types of compounds. The most important of these compounds are anethole, fenchone, estragole (methyl chavicol). This plant

spreads in the Mediterranean and Southern Europe (Ghanbari et al., 2013).

Choosing suitable planting time plays a significant role in modification of plant growth stages, eligible environmental conditions leading to maximum yield. Planting time has a large impact on seed yield by influencing the yield ingredients through its effect on secondary branches/plant, the control of weeds, diseases and pests, harvest time, pods/plant, seed yield, and the product quality.

In very early seeding, the low temperatures of soil and frost damages cause a weak growth for plants in spring. On the other hand, very delaying seeding leads to a reduction in the growth period of plants and the chance of coincidence in the blossoming time with since high temperatures which will have an opposite impact on the plant growth. One of the most important factors of agricultural production management is choosing the suitable time for cultivation to obtain optimum use of natural resources during the growth season (Safaei *et al.*, 2017).

Assessment of sowing date and plant spacing and their interaction influence on yield, yield parameters and growth of *F. vulgare* was investigated. Three sowing dates (1st October, 1st November and 1st December) were studied. Fruit yield was significantly affected by changing of sowing date. Early sowing significantly increased the fruit yield combined with higher number of branches/plant, number of umbrellas/plant, number of fruits/plant and plant height. The percentage of increases of fruit and biological yield on 1st October were 34.4 and 32.2%, respectively compared with 1st December (Saddam *et al.*, 2012). Another field experiment was conducted to evaluate the influence of four planting methods on growth and yield of fennel cultivated on 14th Sep., 14th Oct. and 14th Nov. Fennel sown lately on 14th Nov. significantly resulted in a lowest seed yield than early sowing on 14th Sep. and 14th Oct. mainly due to lower stand density, number of umbels/plant and number of seeds per umbel. The sowing of *F. vulgare* in mid-October seems to be the best time for producing higher seed yield of *F. vulgare* (Ayub *et al.*, 2008).

Organic agriculture is an alternative to the traditional farming system which leads to the sustainability of the environment and health. The world is increasingly interested in the production of medicinal and aromatic plants due to the demand increase for products of these plants, especially the use of organic farming system (Safaei *et al.*,
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2014). Organic materials enhance soil physical characteristics (structure and aggregation) and soil chemical properties (decrease soil pH, increase cation exchange capacity and improve the availability of most nutrients) that are important for plant growth and essential oil content (Snyman *et al.*, 1998). The use of chemical fertilizers leads to unsustainable land production and degradation, so the application of organic farming system with very little use of chemical fertilizers gives the best production (Anwar *et al.*, 2005). Humic acid is naturally found in the soil content of the organic matter. It dissolves in water. Humic acid increases plant growth, yield, and nutrient uptake (Aiyafar *et al.*, 2015). Humic acid increases the activity of microorganisms, the activity of absorption of elements, plant resistance to diseases and root growth (Safaei *et al.*, 2014). Humates are widely used as a soil optimizer as a fertilizer and soil supplement (Albayrak and Camas, 2005).

Humic acid is considered as one of the major components of humus and used as a growth regulator hormone to enhance plant growth and stress tolerance (Piccolo *et al.*, 1992; Albayrak and Camas, 2005). Influence of compost and/or humic acid on fruit yield and volatile oil percentage and content of sweet fennel sown in sand soil was studied. Humic acid or compost had a significant influence on fruit yield. Volatile oil and volatile oil content were more significant for compost or humic acid. Anethole, methyl chavicol and fenchone were found as major compounds in the volatile oil of fennel. The highest values of anethole (71.1 %), methyl chavicol (35.3%) and fenchone (8.6%) were obtained by 15 kg/ha of humic acid, 0 kg/ha of humic acid with compost and 5 kg/ha of humic acid with compost treatments, respectively (Khalid *et al.*, 2015).

According to the Egyptian Ministry of Agriculture, 89% of medicinal plants are cultivated in the fertile old lands. However, 9% of the new lands are planted with medicinal and aromatic plants, where the soil and climate are

suitable for growing medicinal and aromatic plants (Hassanein, 2009). Therefore, the current study aimed to evaluate production of fennel, as the most economically important medicinal and aromatic crop, in new reclaimed soils of Sohag, using organic cultivation and different sowing dates.

Materials and Methods

The present study was conducted at the Experimental Farm of the Faculty of Agriculture, Sohag University, Sohag Governorate, Egypt during the two successive seasons of 2017/2018 and 2018/2019. The aim of this study is to investigate the impact of different sowing dates and/or different concentrations of humic acid as well as their interaction on plant growth, yield components, oil production and chemical constituents of fennel (*Foeniculum vulgare* Mill.) plants grown under new reclaimed soils.

The seeds of fennel plants were sown in three different interval dates which were 15th October, 1st November and 15th November for the two experimental seasons. Seeds were sown in sandy soil and irrigated by the drip irrigation system. Tubes of drip irrigation system were distributed with 100 cm between each other. The distance between each drippers in the same tube was 35 cm. The period of irrigation was for 1 hour after sowing and continued daily for the first week, after that reduced to 20 min/48 hours, after mid-March the irrigation time increased to 40 min/48 hours. Irrigation was stopped 10 days before harvesting. Physical and chemical properties of the used soil were analysed in Soils and Water Department, Faculty of Agriculture, Sohag University according to Black *et al.* (1965) and Jackson (1973) and are shown in Table 1. The maximum and minimum temperature as well as the relative humidity of the experimental location were obtained from the Meteorological Station at Sohag Governorate and presented in Table 2.

The current experiment was set up in a split plot design with three replicates (each treatment

included 18 plants came from sowing several seeds beside each dripper and after two weeks from germination they were thinned to two seedlings per each dripper). The main plots included three different dates of sowing; 15th October, 1st November and 15th November, while the sub plots included the spraying of humic acid in different concentrations: control (tap water) and three different concentrations of humic acid; 1.5, 3, and 4.5 g/l. The first spray was 45 day after seed sowing and 6 sprays as total were done with 15 days intervals. Humic acid (Humix Care 85%) was obtained from Agrar Atsaa Republik Deutschland, Germany and imported by Agro Care Co., Egypt. The chemical contents of the used product were: humic acid 70%; fulvic acid 5% and potassium dioxide 10%.

All plants were sprayed with the recommended dose of 20-20-20 NPK fertilizer (Pluto obtained from Shoura chemicals Co., Egypt). The dose used was 3 g/l and the plants were sprayed four times; the first time was 50 day after sowing and the period between them was 15 day intervals. All fennel plants were harvested in the beginning of May, when fruits became sufficiently hard and greenish yellow in color. All growth, flowering, yield and oil production characteristics were recorded. Ten random samples were taken from plants of the middle of the plot and data were recorded on plant height, branch number/plant, stem diameter, number of umbels/plant, fruit yield per plant, total fruit yield per feddan, volatile oil percentage, and volatile oil yield.

Dried samples of fennel (100 g) were subjected to hydro-distillation for 6 hours using the Clevenger apparatus for essential oils (Clevenger, 1928) in which water is heated to produce steam, which carries the most volatile chemicals and aromatic material. Essential oils are usually floated on the surface Hydrosol (a component of distilled water). Extracted essential oil is stored in a clean Eppendorf glass, in the dark at 4 °C. Essential oil content in the air dried flowers and essential oil yield was calculated.

TABLE 1. Characteristics of the soil used at the beginning of the experiment (average of both seasons)

Particle size distribution (%)		Texture grade	pH (1:2.5) soil suspension	EC: ds/m (1:5) soil extract	Total CaCO ₃ (%)	Organic matter (%)	Soluble ions (mg/kg, soil)									
Sand	Silt						clay	Anions					Cations			
79.67	4.77	15.56	7.83	4.31	6.72	0.75	1242	-	3050	240	460	440	3100	105	210	490
							Cl ⁻	CO ₃ ⁼	HCO ₃ ⁻	SO ₄ ⁼	Ca ⁺	Mg ⁺	Na ⁺	K ⁺	NH ₄ ⁺	N ⁻ ON

TABLE 2. Monthly average of metrological data of the experimental farm during 2017/2018 and 2018/2019 seasons.

Months	First season (2017-2018)			Second season (2018-2019)		
	Air temperature (C°)		Average relative humidity (%)	Air temperature (C°)		Average relative humidity (%)
	Max	Min	Average	Max	Min	Average
October	30.00	16.38	23.18	32.44	18.64	25.54
November	24.72	10.69	17.70	26.24	12.48	19.36
December	22.8	8.71	15.75	20.54	7.89	14.21
January	19.61	6.25	12.93	19.01	6.14	11.94
February	25.73	11.09	18.41	21.44	7.97	14.40
March	30.32	13.98	22.15	24.46	10.00	17.22
April	32.11	16.41	24.25	29.53	14.14	21.57
May	37.46	21.51	29.48	37.34	22.33	29.78

Fully Random samples selected and analyzed by gas chromatography–mass spectrometry (GC-MS) assay. The chemical constituents of each sample were executed with the Trace GC-ISQ mass spectrometer apparatus (Thermo Scientific, Austin, USA). The capillary column used was TG–5MS (30 m x 0.25 mm x 0.25 µm film thickness). Oven temperature was initially held at 50°C and then increased by 5°C /min to 250 °C hold for 2 min. and then increased to the final temperature 310°C by 30°C/min and hold for 2 min. The injector and MS transfer line temperatures were constants at 270, 260°C, respectively; Carrier gas (helium) used at constant flow rate of 1 ml/min. The solvent delay was 3 min and 1 µl of diluted samples were injected using Autosampler AS1300 coupled with GC apparatus. EI mass spectra were collected at 70 eV ionization voltages over the range of m/z 50–650 in full scan mode. Temperature of ion source was set at 250 °C. The active compounds were identified by comparison of their retention times (RT) and mass spectra with those of WILEY version 09 and NIST version 11 mass spectral database.

Data were subjected to the statistical analysis using the “F” Test (Snedecor and Cochran, 1989) and L.S.D. values for the comparison between means of treatments according to Steel and Torrie (1982). Statistical analysis was performed using Statistix 8.1 program.

Results and Discussions

Data presented in Tables 3, 4 and 5 show that sowing date had a significant influence on plant height, branch number/plant, stem diameter, number of umbels/plant, fruit yield/plant, fruit yield/feddan, volatile oil percentage, volatile oil/plant and volatile oil/feddan in both growing seasons. Among the three tested sowing dates, the earliest date (15th October) recorded the best results regarding all fennel growth, yield and fruit constituents of volatile oil yield. Plants grown in 1st November significantly surpassed those grown on 15th November in almost all parameters. Plants grown on 15th October reached 126.39 and 102.66 cm height, in both seasons respectively, and were characterized by more branches (4.70 and 3.14).

Differences in plant stem diameter were spectacular where 15th October-grown plants measured from two to three fold of those grown in either later dates. Number of umbels, as an important yield determining trait for fennel, which was significantly improved by early sowing date (17.35 and 15.38 for both seasons, respectively).

Mid-October sowing date significantly induced higher fruit yield/plant (30.36 and 32.78 g), and total fruit yield/feddan (759.04 and 874.16 kg), in both seasons, respectively. Fruit content of volatile oil yield/plant reached 0.55 and 0.66 ml on 15th October-grown plants comparing with 0.32 and 0.54 ml on 1st November and 0.40 and 0.39 ml on 15th November-grown plants in the both seasons, respectively. Fruits collected from the 15th November-grown plants showed superiority in the volatile oil percentage followed by 15th October-grown plants.

The current study assessed the impact of changing sowing date on fennel growth, fruit yield and volatile oil content in conjunction with the foliar application of different humic acid concentrations. The results showed a significant effect of sowing date on plant growth characteristics which were highly improved by early sowing date in 15th October.

As sowing date was delayed, all growth characteristics were significantly and negatively affected. It is clear that the effect of sowing date is associated with changes in climatic parameters such as temperature and humidity which appeared in Table 2. Optimum climatic condition on 15th October led to the improvements noticed in growth characteristics of fennel. Nevertheless, assessment of crop growth and productivity in other sowing dates is very helpful under such vulnerability to climatic changes we live nowadays.

Several studies conducted in different parts of the world have shown that earlier planting dates give a great opportunity to get higher vegetative growth qualities because the environmental condition turn out more suitable, and consequently give higher seed weight/plant in earlier times which agree with those reached on fennel plants by El-Khayat and Gouda (2005), Sudeep et al. (2005), Tunio et al. (2005), and Sudeep et al.

TABLE 3. Effect of different sowing dates and humic acid applications on plant height, branch number/plant and stem diameter of fennel during 2017/2018 and 2018/2019 seasons.

Sowing dates	Humic acid	Plant height (cm)		Branch number/plant		Stem diameter (cm)	
		Seasons		Seasons		Seasons	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
15 th October	Control	122.84	93.18	3.66	2.35	2.15	1.38
	1.5 g/l	125.74	97.76	4.71	2.80	2.20	1.44
	3 g/l	126.74	101.02	4.74	2.89	2.37	1.50
	4.5 g/l	130.24	118.67	5.67	4.53	2.46	1.70
Mean		126.39	102.66	4.70	3.14	2.30	1.51
1 st November	Control	95.16	91.46	1.91	1.54	1.23	1.20
	1.5 g/l	100.27	100.88	2.05	1.79	1.35	1.25
	3 g/l	110.33	103.57	2.25	1.82	1.48	1.31
	4.5 g/l	113.00	112.10	2.38	1.93	1.51	1.37
Mean		104.69	102.00	2.15	1.77	1.39	1.28
15 th November	Control	96.79	92.00	2.04	1.22	1.07	0.97
	1.5 g/l	101.00	93.39	2.10	1.28	1.10	1.02
	3 g/l	106.67	101.67	2.12	1.32	1.15	1.05
	4.5 g/l	108.09	104.67	2.26	1.44	1.19	1.12
Mean		103.14	97.93	2.13	1.32	1.13	1.04
Means of humic acid treatments	Control	104.93	92.21	2.54	1.70	1.48	1.18
	1.5 g/l	109.01	97.35	2.95	1.96	1.55	1.24
	3 g/l	114.58	102.09	3.04	2.01	1.67	1.29
	4.5 g/l	117.11	111.81	3.44	2.63	1.72	1.40
LSD 0.05	Sowing dates	2.45	2.23	0.07	0.07	0.04	0.04
	Humic acid	1.96	1.74	0.06	0.06	0.03	0.04
	Interaction	3.81	3.41	0.11	0.11	0.05	0.07

(2006). They noticed that the earliest cultivated plants positively influenced on plant growth. The same fact was supported by the findings of Kashyap et al. (1994) who studied the effect of sowing dates on fennel (*Foeniculum vulgare*, Mill.) plants. They found that the sowing date of October gave the best productivity (3.2 q/ha), compared to the sowing in December and January (1.1 q/ha). Therefore, adapted crop sowing date estimation seems crucial for arid areas such as Egypt.

Foliar application of humic acid exhibited a significant effect on plant height, branch number/plant, stem diameter, number of umbels/plant, fruit yield/plant, total fruit yield/feddan, volatile oil percentage, volatile oil/plant and volatile oil/feddan in the first and second growing seasons. Although plant height significantly differed according to the humic acid treatment, the higher level of humic acid (4.5 g/l) showed the highest plant heights (117.11 and 111.81 cm for

both seasons, respectively) in comparison with the other concentrations and control plants. The same treatments in the same order similarly affected branch number/plant, stem diameter and number of umbels/plant. Application of the higher concentration of humic acid resulted in a significant superiority to the other treatments in terms of fruit yield/plant (29.19 and 32.80 g during both seasons, respectively) and the total fruit yield/feddan (729.64 and 874.58 kg during both seasons, respectively). The same level of humic acid showed the highest content of volatile oil per plant and total volatile oil yield per feddan for both seasons, in addition to the volatile oil percentage parameter which increased comparing with the other treatments and control plants (2.16 and 2.18 % during the first and second seasons, respectively).

Foliar application of the higher concentration of humic acid significantly had a positive effect on yield and quantitative parameters of fennel

comparing to the control and other concentrations. Humic acid is a natural polymer that contains of H⁺ positions related to acidic carboxyl of benzoic and phenolic agents (cation exchange sites). This acid is an organic complex macromolecule formed by chemical and bacterial phenomena in soil. The final result of the act of humification, is relatively high molecular weight of stain acid of 104 to 106 dalton and 50% of its molecular weight is composed of carbon. Humic acid can have a direct positive effect on leaf growth (Ariafar and Forouzandeh, 2017). Russo and Berlya (1990) showed that humic acid is the large component of organic matter in soil and increase the height of plant due to improvements of photosynthesis, respiration, root growth and elements uptake. These results explain the reasons of enhancing in the growth and fruit yield and their constituents

of the volatile oil of fennel in the current study. Mostafa (2015) indicated that fennel (*Foeniculum vulgare* Mill.) plants treated with 3 rates of humic acid (1, 2 and 3 g/l) as foliar application. Treating with 3 g/l humic acid significantly enhanced in terms of plant height and fruit weight/plant. Working on coriander (*Coriandrum sativum* L.) plants, Abou-Sreeaer et al. (2017) applied four foliar applications of potassium humate included 65% humic acid (0, 1, 2 and 3 g/l). They recorded that applying 3 g/l potassium humate gave the best plant heights, branch numbers/plant, fresh and dry weights/plant, number of umbels/plant, and fruit yield/plant in comparing with the untreated plants.

Both foliar application of humic acid and sowing date significantly interacted with respect to all characteristics of fennel plants in both seasons. The best results were noticed on 15th

TABLE 4. Effect of different sowing dates and humic acid applications on number of umbels/plant, fruit yield/plant and total fruit yield/feddan of fennel during 2017/2018 and 2018/2019 seasons.

Sowing dates	Humic acid	Number of umbels/plant		Fruit yield/plant (g)		Total fruit yield/feddan (kg)	
		Seasons		Seasons		Seasons	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
15 th October	Control	13.37	12.41	23.35	28.90	583.80	770.66
	1.5 g/l	14.50	12.57	26.48	30.46	662.04	812.36
	3 g/l	17.81	14.96	30.14	31.20	753.61	832.11
	4.5 g/l	23.70	21.59	41.47	40.56	1036.72	1081.50
Mean		17.35	15.38	30.36	32.78	759.04	874.16
1 st November	Control	9.13	6.13	15.50	28.44	387.57	758.53
	1.5 g/l	9.37	7.20	15.91	29.37	397.69	783.22
	3 g/l	9.64	7.28	18.17	30.17	454.34	804.45
	4.5 g/l	13.17	8.23	23.88	34.35	597.04	916.06
Mean		10.33	7.21	18.37	30.58	459.16	815.57
15 th November	Control	6.71	5.17	13.10	20.15	327.60	537.44
	1.5 g/l	7.07	5.43	14.90	20.80	372.40	554.72
	3 g/l	7.55	6.59	14.87	21.09	371.76	562.48
	4.5 g/l	10.38	7.86	22.21	23.48	555.16	626.18
Mean		7.93	6.26	16.27	21.38	406.73	570.21
Means of humic acid treatments	Control	9.74	7.90	17.32	25.83	432.99	688.88
	1.5 g/l	10.31	8.40	19.10	26.88	477.38	716.77
	3 g/l	11.67	9.61	21.06	27.49	526.57	733.01
	4.5 g/l	15.75	12.56	29.19	32.80	729.64	874.58
LSD 0.05	Sowing dates	0.59	0.48	0.42	0.38	10.38	10.18
	Humic acid	0.34	0.63	0.32	0.43	8.10	11.43
	Interaction	0.78	1.06	0.63	0.74	15.84	19.81

TABLE 5. Effect of different sowing dates and humic acid applications on volatile oil percentage, volatile oil yield/plant and volatile oil yield/feddan of fennel during 2017/2018 and 2018/2019 seasons.

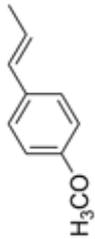
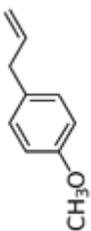
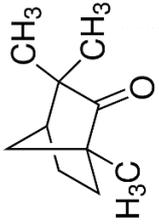
Sowing dates	Humic acid	Volatile oil (%)		Volatile oil yield/plant (ml)		Volatile oil yield/feddan (liter)	
		Seasons		Seasons		Seasons	
		2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
15 th October	Control	1.62	1.33	0.38	0.38	9.48	9.58
	1.5 g/l	1.74	1.87	0.46	0.57	11.50	14.21
	3 g/l	1.78	2.24	0.54	0.70	13.41	17.47
	4.5 g/l	1.93	2.41	0.80	0.98	20.04	24.43
Mean		1.77	1.96	0.55	0.66	13.61	16.42
1 st November	Control	1.68	1.45	0.26	0.41	6.53	10.31
	1.5 g/l	1.72	1.53	0.27	0.45	6.85	11.26
	3 g/l	1.77	1.97	0.32	0.59	8.04	14.84
	4.5 g/l	1.81	2.07	0.43	0.71	10.79	17.75
Mean		1.75	1.76	0.32	0.54	8.05	13.54
15 th November	Control	2.07	1.58	0.27	0.32	6.79	7.98
	1.5 g/l	2.37	1.78	0.35	0.37	8.81	9.27
	3 g/l	2.43	1.82	0.36	0.38	9.03	9.58
	4.5 g/l	2.75	2.05	0.61	0.48	15.27	12.03
Mean		2.41	1.81	0.40	0.39	9.98	9.72
Means of humic acid treatments	Control	1.79	1.45	0.30	0.37	7.60	9.29
	1.5 g/l	1.94	1.73	0.36	0.46	9.05	11.58
	3 g/l	1.99	2.01	0.41	0.56	10.16	13.96
	4.5 g/l	2.16	2.18	0.61	0.72	15.37	18.07
LSD 0.05	Sowing dates	0.02	0.06	0.01	0.02	0.29	0.47
	Humic acid	0.05	0.05	0.02	0.02	0.35	0.40
	Interaction	0.07	0.09	0.03	0.03	0.59	0.76

October-grown plants treated with the higher level of humic acid in the rate of 4.5 g/l. Fennel fruit content of volatile oil recorded its highest values when plants were sprayed with 4.5 g/l humic acid when they were sown on 15th October.

Twenty constituents were identified in fruits volatile oil of all samples and accounted for total constituents and presented in Table 6. The main constituents of fennel volatile oil were anethole (54.78 – 74.96 %), estragole (15.37 – 37.18%) and fenchone (1.74 – 3.94%). Volatile oil of fruits collected from plants sown in mid-October induced high percentage of anethole in comparison with the plants sown at the beginning and middle November. The higher concentration of humic acid increased the percentage of anethole comparing with the other concentrations.

The increase in the percentage of anethole was accompanied by a decrease in the ratio of estrogole, and on the contrary, the decrease in anethole was accompanied by an increase in the ratio of estrogole. Plants were sprayed with higher level of humic acid and sown in mid-October showed the highest percentage of anethole comparing with other interaction treatments. Obtained results was in agreement with those of Khalid *et al.* (2015) who reported that the highest values of anethole (71.1 %), methyl chavicol (35.3%) and fenchone (8.6%) were resulted from 15 kg/ha of humic acid, 0 kg/ha of humic acid with compost and 5 kg/ha of humic acid with compost, respectively.

TABLE 6. Effect of different sowing dates and humic acid applications on the relative percentage of the main constituents of the essential oil of fennel.

Component	M.W	R.T	Humic acid treatments (g/l)											
			15 th October				1 st November				15 th November			
			0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5	0.0	1.5	3.0	4.5
Anethole 	148	14.41	58.41	70.82	73.52	74.96	56.09	70.33	70.67	71.56	54.78	68.00	68.33	70.14
Estragole 	148	12.96	32.80	16.98	16.22	15.37	34.74	18.69	17.99	18.05	37.18	22.19	22.06	20.21
Fenchone 	152	9.7	3.35	3.94	3.84	2.39	2.39	1.74	2.04	1.99	2.54	2.25	2.52	2.79

Conclusion

A significant difference of effect was found among the three sowing dates and the four concentration of humic acid used and within their interactions. Sowing fennel seeds in mid-October enhanced all yield and volatile oil parameters measured in the plants. Higher concentration of humic acid significantly influenced in the measured parameters also. In general, given the results of the study, early sowing of fennel in mid-October with the high concentration of humic acid (4.5 g/l) can be recommended for the cultivation of fennel in Sohag Governorate.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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تأثير مواعيد الزراعة والمعاملة الورقية بحامض الهيوميك على المحصول والزيت الطيار لنباتات الشمر

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أجريت التجربة بهدف تقييم أربعة تركيزات من حامض الهيوميك (٠، ١,٥، ٣,٠ و ٤,٥ جم/لتر) على النمو، المحصول و محتوى الزيت الطيار لنباتات الشمر المنزرعة في منتصف أكتوبر، بداية نوفمبر ومنتصف نوفمبر خلال موسمي الزراعة ٢٠١٧/٢٠١٨ و ٢٠١٨/٢٠١٩. موعد الزراعة المبكر في منتصف أكتوبر سجل أفضل النتائج فيما يتعلق بصفات النمو، المحصول ومحتوى الثمار من الزيت الطيار. المعاملات الورقية بحامض الهيوميك بالتركيز الأعلى (٤,٥ جم/لتر) أظهرت تأثير معنوي في ارتفاع النبات، عدد الفروع لكل نبات، قطر الساق، عدد النورات لكل نبات، محصول الثمار لكل نبات، المحصول الكلي للثمار لكل فدان، النسبة المئوية للزيت الطيار، محتوى الزيت الطيار لكل نبات بالإضافة إلى محصول الزيت الطيار لكل فدان خلال الموسمين. الزيت الطيار للثمار التي جمعت من النباتات المنزرعة في منتصف أكتوبر أنتجت أعلى نسبة من الأنيثول (٧٤,٩٦٪) وأقل نسبة من الاستراجول (١٥,٣٧٪) مقارنة مع النباتات المنزرعة في بداية ومنتصف نوفمبر. التركيز الأعلى من حامض الهيوميك زاد من نسبة الأنيثول مقارنة مع التركيزات الأخرى. المعاملة الورقية بالتركيز الأعلى من حامض الهيوميك لنباتات الشمر المنزرعة في منتصف أكتوبر تعتبر أفضل توليفة للحصول على أعلى محصول ثمار وجودة مرتفعة للزيت الطيار.