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Improving Yield, Physical and Chemical Qualities of Sweet Fennel Bulbs by Spraying of Potassium Humate

[1]S.M. El-Sawy, [1]A.M. El-Bassiony, [1]Z.F. Fawzy and [2]Shaymaa I. Shedeed

[1]Vegetable Research Dept., Agricultural and Biological Research Division,
National Research Centre (NRC), 33 El-Buhouth St., 12622 Dokki, Giza, Egypt
[2]Plant Nutrition Dept., Agricultural and Biological Research Division,
National Research Centre (NRC), 33 El-Buhouth St., 12622 Dokki, Giza, Egypt

Abstract: Under the limited water resources and arid climate in Egypt, using the proper agricultural methods and techniques for increasing the vertical expansion through increasing the production per area unit is needed. Non-traditional vegetable crops are promising crops for local consumptions and exportation, increasing their production will increase the income. For this issue two field experiments were conducted during 2017/2018 and 2018/2019 seasons using two sweet fennel cultivars (Dolce and Zefa fino) to study the effect of foliar application of potassium humate concentrations at 0, 2, 3, 4 and 5 cm L^{-1} on vegetative growth parameters, chemical composition and yield and quality under sandy soil condition. The results revealed that Dolcy cv. showed superiority on Zefa fino cv., where the highest significant values for vegetative growth, leaf and bulb chemical compositions, yield and quality characteristics were obtained than the other cultivar. The results also illustrated that increasing the concentration of potassium humate application enhanced the vegetative growth, leaf and bulb chemical compositions, yield and quality of sweet fennel plants. Moreover, the maximum significant values were reported with 4 and 5 cm L^{-1} K-humate treatments as a foliar spraying. It could be recommended that, for producing sweet fennel in sandy soil in Egypt, Dolce cv. is the best choice with foliar application of K-humate at 4 and 5 cm L^{-1} two times (6 and 8 weeks from the planting date) for increasing the yield and quality as well as the essential oil content.

Key words: Sweet fennel · Cultivars · Potassium humate · Essential oil · Yield and quality

INTRODUCTION

Egypt is located in arid regions which facing many problems; high temperatures, salinity and drought stresses. As well as, in the new reclaimed sandy soil organic matter status comes down below 1% and adding the organic fertilizers only to increase the soil fertility has not proved to be very successful under high temperature conditions [1]. For improving the plant growth and increasing the production it should to supply plants by foliar fertilizers beside the normal way which plants absorb the soil fertilizers by roots especially under non suitable conditions in the arid lands. In the foliar spraying plants quickly absorb the nutrients by leaves and transport to the different parts of the plant [2].

Sweet fennel (*Foeniculum vulgare* Mill.; Fam. Apiaceae (Umbellifera)) is one of the non-traditional vegetable crops which cultivated in Egypt for export and local consumptions. In addition, it is considered as the most important economic medicinal and aromatic plant grown in Egypt [3]. Sweet fennel plants are used fresh for salads and cooking. Additionally, fennel oil is used as an aromatic carminative, stimulant and condiment. Sweet fennel is an essential medicinal and aromatic plant which their parts (stem bases, leaves and seeds) have essential oil and are used as flavoring agents in food products such as bread, pickles, pastries and cheese [4].Fennel is one of the real basic oil plants that have been developed and the concentration of the essential oil in the ripe fruits is between 3-6% [5]. There are many cultivars of

Corresponding Author: Sameh M.M. El-Sawy, Vegetable Research Dept., Agricultural and Biological Research Division, National Research Centre (NRC), Giza, Egypt.

sweet fennel, for this issue El-Bassiony *et al.* [6] studied the behavior of two sweet fennel cultivars grown under Egyptian conditions and found that the highest values of number of leaves, bulb height and fresh weight of leaves were recorded by Botanic cultivar. While, the highest amounts of bulb diameter, fresh weight of bulbs and dry weight percentage of leaves and bulbs as well as total yield of sweet fennel were recorded by Zefa fino cultivar.

Sandy soil is poor in the organic matter and mineral elements so it should to add the organic fertilizers regularly, on the other hand, soils in the arid regions have high pH and EC which negatively affect on the availability of mineral elements [7] for absorbing by plant roots. The humic substances are commercially available in the form of potassium humate, potassium fulvates and humins [8]. The addition of humic acid increase soil organic matter content and fertility on a sustainable basis which positively reflect on the plant growth and productivity [7]. As well as, foliar application of humic acid is considered one of the solutions to avoid the problems facing plants in the cultivation soil. Potassium humate (K combined with humic acid) can be rapidly absorbed and incorporated into plants, whether via soil or foliar application methods [9]. Potassium humate (K-humate) improve plant growth and increase the production may be due to the role of K-humate in configuration of bio-stimulants and increase plant growth promoters as well as its role in the cellular dam and the cytoplasm, including improvement of photosynthesis, respiration levels, enzymatic efficiency, protein structure [10] which contribute in enhancingthe antioxidant system in plants that are exposed to environmental stress [11].

For the effect of foliar application of potassium humate on plant growth and productivity many investigators reported that, the highest plant growth rate, total yield and nutrients for cucumber plants were reported with humic acid of 1.5 g/L [12], while the highest values of number of leaves and branches per plant, plant fresh weight and total yield were achieved with foliar spraying of humic acid at4g/L^{-1} [13]. Furthermore, seedlings which treated by K-humate at 4 ml.L^{-1} produced the highest significant values of vegetative growth parameters as well as the percentage of dry matter, protein, total chlorophyll, N, P and K contents of leaf [14], in addition, Abd El-Rheem *et al.* [15] found that the foliar spraying of potassium humate (2 ml L^{-1}) and amino acids (1000 ppm) produced the highest values of vegetative growth, total and marketable yield and nutrient balance (N, P and K content) of potato plants. Also, foliar application of potassium humate (4 gm/L) increased the growth, grain yield and oil content of soybeans under water stress conditions [16]. On the other hand, applying the K-humate to the soil enhanced the vegetative growth and produced the highest significant values of fruit yield (g $plant^{-1}$), essential oil (%) and essential oil yield (ml plant-1) compared to the untreated plants [17]. Potassium is an essential plant nutrient which has the strongest influence on the production and quality parameters of fruits and vegetables [18]. In this concern, Jifon and Lester [19] reported thatfoliar spraying of K thiosulfate resulted in higher plant tissue K concentrations, TSS, total sugars and bioactive compounds (ascorbic acid and β-carotene) of cantalup fruits.

The present study was conducted to study the effect of potassium humate concentrations on vegetative growth, yield and quality as well as the chemical composition and essential oil extracted of two sweet fennel cultivars grown in sandy soil under Egyptian conditions.

MATERIAL AND METHODS

Site Description: Two field experiments were conducted during the two consecutive winter seasons 2017/2018 and 2018/2019 in the Experimental and Production Station of National Research Centre, El-Noubaria region, Beheira Governorate, north of Egypt. The aim of the experiments was to study the effect of foliar application of potassium humate on the vegetative growth, yield, chemical composition and essential oil extracted of two sweet fennel cultivars grown in sandy soil under Egyptian conditions. Physical and chemical properties of the experimental soil were presented in Table (1).

Drip irrigation lines were elongated over the ditches. Irrigation were taken place three days before cultivation. Healthy 60 days old seedlings were cultivated in the first week of November. The irrigation lines were 75cm apart and the spacing between the drippers was 30cm. All agriculture practices were performed as recommended by Egyptian Ministry of Agriculture and Land Reclamation for sweet fennel cultivation under sandy soil conditions.

Treatments: Sweet fennel (*Foeniculum vulgare* Mill.) plants were exposed to the potassium humate concentrations as follow:

- Sweet fennel cultivars: (Dolce and Zefa fino)
- Potassium humate concentrations: (0 cm L^{-1} (sprayed with only water), 2, 3, 4 and 5 cm L^{-1})

Table 1: Physical and chemical properties of the experimental soil

Physical properties	2017-2018	2018-2019	Chemical properties	2017-2018	2018-2019
Sand %	72.85	73.20	pH	7.84	7.82
			E.C.(dS m^{-1})	2.52	2.46
Clay %	5.60	5.95	Nitrogen %	0.17	0.19
			Phosphorus %	0.06	0.08
Silt %	21.55	20.85	Potassium %	0.12	0.12
			CaMeq/L	8.92	7.41
Texture	Sandy	Sandy	Mg Meq/L	0.724	0.634
			Na Meq/L	0.935	0.875
			HCO_3Meq/L	1.37	1.43
			ClMeq/L	0.478	0.511

All Potassium humate concentrations were applied as a foliar application two times after 6 and 8 weeks from the planting date.

The experimental design was split plot design with 3 replications, in which the two varieties (Dolce and Zefa fino) in the main plots and foliar application of potassium humate treatments were randomly assigned within the subplots.

Experimental Design: The experiment was arranged in a split-plot design with three replications. Sweet fennel cultivars were arranged in the main plots and potassium humate concentrations were assigned in the sub-plots.

Data Collection

Vegetative Growth Parameters: Five plants were randomly chosen from each plot after 90 days from planting date and the following data were recorded (plant height (cm); leaf number per plant; leaves, bulbs and total plant fresh weights as well as leaves, bulbs and total plant dry weights (g/plant)).

Total Yield and Quality: After 120 days from planting date an area of 4.5 m^2 was devoted for estimating total yield of sweet fennel bulbs (ton/fed.), while bulb quality (length, width and thickness) and total soluble solids (TSS) which measured by a hand refract on plant basis from five plants were randomly chosen from each plot.

Chemical and Essential Oil Contents: The percentage of nitrogen, phosphorus and potassium in the tissues of leaves and bulbs of sweet fennel plants were determined, where nitrogen was measured using the modified micro Kjeldah method (Hanon 8910, digital) according to the described method of [21]. Phosphorus content was determined using the modified colorimetric method using spectrophotometer (Spectronic 200, Milton Roy Co., Ltd, USA) according to [21]. While potassium content was measured using flame photometer method (JENWAY, PFP-7, ELE Instrument Co. Ltd., UK) according to the method of [22]. Essential oil content (ml./plant) in leaves and bulbs were determined according to [23].

Statistical Analysis: The obtained data were subjected to the analysis of variance procedure and means were compared using the least significant differences (L.S.D) test at 5% level [20].

RESULTS AND DISCUSSION

Vegetative Growth: The effect of potassium humate concentrations (0, 2, 3, 4 and 5 cm L^{-1}) on vegetative growth characteristics (plant length, number of leaves /plant, leaves fresh weight, bulb fresh weight and plant fresh weight) of sweet fennel cultivars (Dolce and Zefa fino) is given in Table (2). The results revealed that Dolce cultivar (cv.) had the highest significant values for plant length, bulb fresh weight and plant fresh weight while the highest significant values for leaves fresh weight where achieved with Zefa fino cultivar. On the other hand, there were no significant differences between the two sweet fennel cultivars for the number of leaves per plant, in both seasons. The differences in vegetative growth of two sweet fennel cultivars were mainly due to the genotype of each cultivar. These results are consistent with the findings by Abou El-Magd and El-Basion [24] and El-Bassiony *et al.* [25], with sweet fennel plants.

Regarding the potassium humate (K-humate) concentrations, data in Table (2) clearly indicated that foliar application of K-humateat 2, 3, 4 and 5 cm L^{-1} significantly increased vegetative growth characteristics; plant length, number of leaves per plant, leaves fresh weight, bulb fresh weight and plant fresh weight of sweet fennel plants compared to control treatment (0cm L^{-1}).

Table 2: Effect of cultivars and potassium humate on vegetative growth of sweet fennel plants during 2017/2018 and 2018/2019 seasons

Treatments		2017/2018					2018/2019				
		Plant length (cm.)	No. of leaves /plant	Leaves fresh weight (g.)	Bulb fresh weight(g.)	Plant fresh weight (g.)	Plant length (cm.)	No. of leaves /plant	Leaves fresh weight (g.)	Bulb fresh weight(g.)	Plant fresh weight (g.)
Cultivars											
Dolce		58.62	9.92	174.17	140.84	315.01	61.43	10.19	178.25	143.00	321.26
Zefa fino		49.60	9.88	184.56	125.80	310.36	50.05	10.14	187.66	124.38	312.04
LSD at 5%		6.67	NS	4.12	5.71	NS	7.57	NS	5.68	9.07	6.33
Potassium humate treatments											
0 cm		48.87	8.45	144.06	108.68	252.74	49.15	8.37	146.98	103.19	250.17
2 cm		50.98	9.60	153.53	118.89	272.42	51.77	9.79	158.71	115.82	274.53
3 cm		55.29	9.95	176.77	130.46	307.22	57.10	10.23	187.47	130.14	317.61
4 cm		57.31	10.50	194.26	144.52	338.77	59.59	10.91	201.83	147.55	349.38
5 cm		58.11	11.00	228.22	164.08	392.30	61.08	11.53	219.79	171.77	391.56
LSD at 5%		2.15	1.12	8.67	8.92	12.65	1.85	1.42	7.15	11.56	15.31
Interaction											
Dolce	0 cm	54.32	8.50	135.67	113.99	249.66	55.90	8.43	136.60	109.76	246.36
	2 cm	56.09	9.70	141.88	128.18	270.06	58.09	9.92	144.29	127.33	271.61
	3 cm	59.52	9.80	174.15	139.56	313.71	62.34	10.04	184.23	141.41	325.65
	4 cm	61.63	10.40	192.87	153.82	346.69	64.95	10.78	207.40	159.07	366.47
	5 cm	61.56	11.20	226.27	168.67	394.94	65.86	11.77	218.75	177.45	396.20
Zefa fino	0 cm	43.42	8.40	152.44	103.37	255.81	42.41	8.31	157.36	96.62	253.97
	2 cm	45.87	9.50	165.18	109.59	274.77	45.44	9.67	173.13	104.32	277.44
	3 cm	51.06	10.10	179.38	121.35	300.73	51.86	10.41	190.71	118.87	309.58
	4 cm	52.98	10.60	195.64	135.21	330.85	54.24	11.03	196.26	136.03	332.29
	5 cm	54.65	10.80	230.16	159.49	389.65	56.31	11.28	220.83	166.08	386.91
LSD at 5%		1.33	1.03	11.18	6.19	16.77	1.69	1.31	7.72	7.22	12.87

Increasing the concentration of K-humate increased the vegetative growth of sweet fennel plants where the highest significant values of leaves fresh weight, bulb fresh weight and plant fresh weight were obtained with foliar spraying of 5 cm L^{-1} of K-humate treatment, while the maximum significant values of plant length and number of leaves per plant were noticed with 4 and 5 cm L^{-1} of K-humate treatments in both tested seasons. It's clear to notice that increasing the concentrations of potassium humate improved the sweet fennel growth and increased different vegetative growth characteristics and this may be due to the role of potassium in plants. Such effect may be due to potassium role in plant and it is considered a remarkable mineral element which involved in numerous biochemical and physiological processes in plants for stimulating the plant growth, yield and quality. Although it is not a constituent of any functional molecules or plant structures [25]. For humic substances action in promoting plant growth Chen *et al.* [26] and Khaled and Fawy [27] reported that humic acid increasing cell membrane permeability, oxygen uptake, respiration rate and photosynthesis and enzymatic activities which stimulate plant growth through regulating many biochemical and physiological processes [28], this may be due to humic substances contain cytokinin [29] and auxins [30] and thus positively affect in plant growth.

In this concern, many investigators reported that foliar application of humic acid increased the vegetative growth parameters (plant length, leaves number, leaf area, leaves fresh and dry weights for snap bean [31], common bean [32], Pea [33], corn [34]andEgyptian clover plants [35]. Finally, from the above results and discussion, it's clear to approve that potassium humate has been used in the configuration of bio-stimulants to enhance the antioxidant system in plants (such as proline and protecting both protein and chlorophyll from free radical degradation) that are exposed to environmental stress because of their phytohormonal activities [11, 16]. Concerning the interactions of sweet fennel cultivars and K-humatetreatments, the obtained data showed that Dolce cv. plants which received 4 or 5 cm L^{-1} of K-humateproduced the highest significant values of plant length, while the maximum significant values of leaves fresh weight and plant fresh weight were observed with Dolce and Zefa fino cultivars which treated by 5 cm L^{-1} of K-humate, in the in the two studied seasons. Furthermore, the sweet fennel cultivars (Dolce and Zefa fino) which received 4 or 5 cm L^{-1} of K-humateproduced the highest significant values of number of leaves per plant. On the other hand, the maximum significant values of bulb fresh weight were noticed with Dolce cv. plants with foliar application of K-humate at 5 cm L^{-1} in both tested seasons.

Chemical Composition: Data in Table (3) showed the effect of potassium humate concentrations on chemical composition of sweet fennel leaves (N, B and K %) and dry weights of leaves and bulb of the two sweet fennel cultivars. The results illustrated that sweet fennel plants Zefa fino cv. had the highest significant values of leaf

Table 3: Effect of cultivars and potassium humate on N, B and K % in leaves and dry weight of sweet fennel plants during 2017/2018 and 2018/2019 seasons

		2017/2018					2018/2019				
					Dry weight (g.)					Dry weight (g.)	
Treatments		N%	P%	K%	Leaves	Bulb	N%	P%	K%	Leaves	Bulb
					Cultivars						
Dolce		2.42	0.36	1.73	11.35	9.08	2.65	0.39	1.79	11.51	8.90
Zefa fino		2.48	0.37	1.77	11.39	9.05	2.73	0.42	1.82	11.56	8.86
LSD at 5%		0.03	NS	0.02	NS	NS	0.06	NS	0.02	NS	NS
					Potassium humate treatments						
0 cm		2.20	0.32	1.39	9.61	8.24	2.38	0.36	1.38	9.56	7.86
2 cm		2.29	0.35	1.60	10.42	8.47	2.49	0.39	1.64	10.55	8.14
3 cm		2.37	0.35	1.79	11.65	9.00	2.59	0.39	1.87	12.07	8.79
4 cm		2.64	0.40	1.89	12.42	9.56	2.93	0.44	1.99	12.48	9.49
5 cm		2.75	0.41	2.09	12.78	10.07	3.06	0.46	2.14	13.03	10.12
LSD at 5%		0.11	NS	0.16	0.48	0.27	0.09	NS	0.21	0.74	0.23
					Interaction						
Dolce	0 cm	2.18	0.31	1.36	9.55	8.27	2.36	0.34	1.34	9.48	7.90
	2 cm	2.25	0.34	1.52	10.32	8.55	2.45	0.38	1.54	10.43	8.24
	3 cm	2.28	0.32	1.79	11.76	8.94	2.48	0.36	1.88	12.22	8.73
	4 cm	2.65	0.38	1.89	12.38	9.48	2.94	0.43	2.00	12.44	9.39
	5 cm	2.72	0.43	2.11	12.75	10.17	3.03	0.45	2.17	12.98	10.25
Zefa fino	0 cm	2.21	0.33	1.42	9.67	8.21	2.40	0.37	1.42	9.63	7.82
	2 cm	2.33	0.35	1.68	10.51	8.38	2.54	0.39	1.74	10.67	8.03
	3 cm	2.45	0.37	1.79	11.53	9.05	2.69	0.42	1.86	11.93	8.86
	4 cm	2.63	0.41	1.88	12.45	9.63	2.92	0.44	1.99	12.52	9.58
	5 cm	2.78	0.39	2.06	12.81	9.96	3.10	0.47	2.11	13.07	9.99
LSD at 5%		0.08	NS	0.09	0.57	0.32	0.11	NS	0.13	0.63	0.17

N and K percentage compared to Dolce cv. in the both studied seasons. While there were no significant differences between the two cultivars for leaf P%, leaves and bulb dry weights in the both tested seasons.

Results clearly indicated that, while N%, K% and the dry weights of leaves and bulbs increased with increasing the K-humate concentrations, there were no significant differences between the K-humate treatments on leaf P percentage in the two studied seasons. The highest significant values for N and K percentages as well as the dry weights of leaves and bulbs were observed with foliar application of 4 or 5 cm L^{-1} of K-humate treatments compared to the other concentrations in the two seasons. This result are in harmony with these obtained by Srivastava [36] who mentioned that, humic acid treatments increased photosynthetic rate, nutrient uptake and play an important role in translocation of these nutrients to fruits. In addition, foliar application of potassium humate increased leaf N content and total carbohydrates in dry seeds of common bean [37, 38]. While, Asik*et al.* [39] suggested that the lowest doses of both soil and foliar application of humic substances increased the nutrient uptake of wheat. In general, potassium humate treatments improved the overall metabolism of crop plants and photosynthetic rate [40]. Regarding the interactions of sweet fennel cultivars and K-humatetreatments, data in Table (3) revealed that Dolce and Zefa fino cultivars which received the highest concentrations of K-humate (4 or 5 cm L^{-1}) had the maximum significant values of leaf N and K percentages and leaves and bulbs dry weights, while there were no significant differences were noticed among the treatments for leaf P percentage in the two studied seasons.

The effect of potassium humate concentrations on chemical composition of sweet fennel bulbs (N, P and K %) and leaves and bulb essential oil contents of two sweet fennel cultivars was presented in Table (4). As for the behavior for two sweet fennel cultivars (Dolce and Zefa fino), data revealed that Dolcy cv. showed a significant superiority in the bulbs N percentage (and bulbs K percentage in the second season) in two studied seasons. Whereas, bulb P% (and bulbs K percentage in the first season) and leaves and bulb essential oil contents parameters didn't reach at the 5% level of significant.

Concerning the effect of K-humate concentrations on the above mentioned characteristics, data in Table (4) clearly indicated that increasing the foliar application of

Table 4: Effect of cultivars and potassium humate on N, P and K % in bulbs and essential oil of sweet fennel plants during 2017/2018 and 2018/2019 seasons

		2017/2018					2018/2019				
					Essential oil per plant (ml.)					Essential oil per plant (ml.)	
Treatments		N%	P%	K%	Leaves	Bulbs	N%	P%	K%	Leaves	Bulbs
					Cultivars						
Dolce		1.74	0.36	2.03	0.33	0.20	1.81	0.41	2.15	0.36	0.21
Zefa fino		1.67	0.34	2.02	0.34	0.21	1.73	0.39	2.09	0.38	0.22
LSD at 5%		0.05	NS	NS	NS	NS	0.06	NS	0.03	NS	NS
					Potassium humate treatments						
0 cm		1.39	0.31	1.75	0.25	0.16	1.38	0.34	1.82	0.26	0.15
2 cm		1.60	0.34	1.81	0.30	0.16	1.64	0.38	1.89	0.33	0.16
3 cm		1.69	0.38	1.95	0.33	0.20	1.75	0.42	2.07	0.37	0.21
4 cm		1.89	0.36	2.22	0.38	0.24	1.99	0.41	2.35	0.42	0.25
5 cm		1.96	0.38	2.43	0.42	0.28	2.09	0.43	2.47	0.47	0.31
LSD at 5%		0.13	NS	0.11	0.03	0.03	0.11	NS	0.09	0.04	0.04
					Interaction						
Dolce	0 cm	1.42	0.33	1.67	0.24	0.16	1.42	0.37	1.73	0.26	0.16
	2 cm	1.63	0.34	1.85	0.28	0.15	1.68	0.38	1.95	0.31	0.15
	3 cm	1.75	0.39	1.90	0.32	0.18	1.83	0.44	2.01	0.36	0.18
	4 cm	1.91	0.37	2.26	0.37	0.23	2.02	0.42	2.46	0.42	0.24
	5 cm	1.97	0.38	2.47	0.42	0.27	2.10	0.43	2.62	0.48	0.29
Zefa fino	0 cm	1.36	0.29	1.82	0.25	0.15	1.34	0.32	1.91	0.27	0.15
	2 cm	1.57	0.34	1.76	0.31	0.17	1.60	0.38	1.84	0.34	0.17
	3 cm	1.62	0.36	1.99	0.34	0.22	1.67	0.41	2.12	0.38	0.23
	4 cm	1.86	0.35	2.17	0.38	0.24	1.96	0.39	2.25	0.43	0.26
	5 cm	1.95	0.38	2.38	0.41	0.29	2.07	0.43	2.31	0.47	0.32
LSD at 5%		0.07	NS	0.12	0.02	0.03	0.12	NS	0.07	0.05	0.03

K-humate from 2 to 5 cm L^{-1} increased the chemical composition in the bulbs as well as increased essential oil contents in the leaves and bulb of sweet fennel plants. Where, the highest significant values of bulbs N percentage were obtained with foliar application of 4 and 5 cm L^{-1} of K-humate. While, the maximum significant values of bulbs K percentage and leaves and bulb essential oil contents were noticed with 5 cm L^{-1} of K-humate treatments only. On the other hand, there were no significant differences were observed among the treatments for leaf P percentage in the two studied seasons. The results agree with these obtained by Said-AlAhl and Abdou [41] and Zaghloul *et al.* [42] who reported that potassium humate treatments leaded to an increment in oil content in dragonhead and *Thuja orientalis* plants. Also Erik *et al.* [43] found that humic acids treatments increased plant growth and significantly increased the mineral elements of P, K, Ca, Mg, Fe, Zn and Mn in plant tissues. Furthermore, Said-Al Ahl and Hussein [44] mentioned that the foliar spray of K-humate promoted the plant growth and increased the oil yield in oregano plant. The maximum values of crude protein, oil, N, P and K% were obtained with Egyptian clover plants which received K-humate at 10 ml/L [35]. The valuable effect of humic acid may be due to its role in accelerating metabolic reactions as well as stimulating enzymatic systems responsible for the biosynthesis of essential oil [17, 45]. Respecting the interactions of sweet fennel cultivars and K-humatetreatments, data showed that Dolce and Zefa fino plants which received 4 or 5 cm L^{-1} of K-humate as a foliar application produced the highest significant values of bulbs N percentage and leaves essential oil content. While, the maximum significant values of K percentage and bulb essential oil content was obtained with Dolce and Zefa fino plants with foliar application of K-humate at 5 cm L^{-1} in both tested seasons. On the other hand, bulbs P percentage didn't reach at the 5% level of significant, in the both tested seasons.

Yield and Quality: Data in Table (5) showed the effect of potassium humate concentrations on yield and quality characteristics (bulb length, bulb width, bulb thickness, T.S.S and total yield) of the two sweet fennel cultivars. The results illustrated that sweet fennel plants Dolce cv. showed a significant superiority in the bulb length, bulb width and total yield parameters compared to Zefa fino cv. in the both studied seasons. While there were no significant differences between the two cultivars for bulb thickness and TSS in the both tested seasons.

Table 5: Effect of cultivars and potassium humate on yield and quality of sweet fennel plants during 2017/2018 and 2018/2019 seasons

Treatments		2017/2018					2018/2019				
		Bulb length (cm.)	Bulb width (cm.)	Bulb thickness(cm.)	TSS	Total yield ton/fed.	Bulb length (cm.)	Bulb width (cm.)	Bulb thickness (cm.)	TSS	Total yield ton/fed.
Cultivars											
Dolce		10.74	9.92	4.18	9.46	3.83	10.96	10.14	4.15	9.37	3.87
Zefa fino		9.67	8.66	3.95	9.51	3.70	9.63	8.58	3.86	9.43	3.71
LSD at 5%		0.49	1.03	NS	NS	0.10	1.02	1.13	NS	NS	0.11
Potassium humate treatments											
0 cm		8.99	7.55	3.50	8.90	3.24	8.79	7.69	3.30	8.68	3.14
2 cm		9.64	8.25	3.71	9.06	3.44	9.59	8.18	3.56	8.87	3.39
3 cm		10.22	9.41	4.26	9.42	3.68	10.31	9.31	4.24	9.32	3.69
4 cm		10.75	10.21	4.39	9.83	4.02	10.96	10.30	4.40	9.83	4.10
5 cm		11.44	11.03	4.50	10.23	4.45	11.82	11.31	4.53	10.32	4.64
LSD at 5%		0.67	1.53	0.26	0.12	0.21	0.46	1.17	0.17	0.17	0.31
Interaction											
Dolce	0 cm	9.31	7.63	3.55	8.87	3.22	9.18	8.10	3.36	8.64	3.12
	2 cm	10.29	8.72	3.83	8.98	3.46	10.40	8.45	3.71	8.78	3.41
	3 cm	10.82	10.24	4.35	9.36	3.71	11.05	10.34	4.35	9.25	3.72
	4 cm	11.38	11.08	4.52	9.84	4.12	11.75	11.38	4.57	9.84	4.23
	5 cm	11.92	11.93	4.67	10.26	4.65	12.42	12.43	4.75	10.36	4.89
Zefa fino	0 cm	8.67	7.47	3.45	8.93	3.26	8.39	7.28	3.24	8.71	3.17
	2 cm	8.98	7.77	3.58	9.14	3.42	8.78	7.91	3.40	8.97	3.36
	3 cm	9.62	8.58	4.16	9.48	3.65	9.57	8.28	4.12	9.39	3.65
	4 cm	10.11	9.34	4.25	9.82	3.91	10.17	9.22	4.23	9.82	3.97
	5 cm	10.96	10.12	4.32	10.19	4.25	11.23	10.19	4.32	10.27	4.39
LSD at 5%		0.56	1.22	NS	0.87	0.18	0.77	1.08	NS	0.12	0.24

Regarding the effect of K-humate concentrations on yield and quality characteristics of sweet fennel plants, data in Table (5) revealed that the highest significant values for bulb length, T.S.S and total yield characteristics were observed with plants which treated by K-humate at 5 cm L^{-1}as a foliar application.While the maximum significant values of bulb width and bulb thickness parameters were obtained with sweet fennel plants which received K-humate at 4 or 5 cm L^{-1} as a foliar spraying in the two studied seasons. From the above results and discussion, it's clear to confirm that potassium humate treatments positively improved the vegetative growth of sweet fennel plants as well as increased the chemical composition and essential oil content which reflected on the yield and quality. This may be due to the role of potassium in plants and its stimulating effect on plant growth, which reflects on the fruit production and quality. In this concern it's clear to approve that adequate K nutrition has been associated with increased yields, fruit size, increased TSS and Vit. C concentrations, improved fruit color, increased shelf life and shipping quality of many horticultural crops [46, 47]. In addition, Delfine*et al*. [48] showed that, these results may be due to the function of humic acid in increasing the activity of enzyme and thus improving the photosynthetic activity of plants and its yield. Potassium humate treatments significantly increased the yield of soybean [49, 50]. The effect of interaction between sweet fennel cultivars and K-humate treatments, the results showed that when Dolce cv. plants produced the highest significant values of bulb length and bulb width with foliar application of K-humate at 4 or 5 cm L^{-1}, the maximum yield were obtained with Dolce cv. plants which treated by K-humate at 5 cm L^{-1} only with significant differences among the other treatments. While there were no significant differences were noticed among the treatments for bulb thickness characteristic in the two studied seasons. With the two cultivars (Dolce and Zefa fino) of sweet fennel TSS recorded the highest significant values with the high concentrations of K-humate (4 or 5 cm L^{-1}).

CONCLUSION

It could be concluded from this study that sweet fennel (Dolce cv.) yield and quality grown under sandy soil conditions could be effectively improved by foliar spray of potassium humate at 4 or 5 cm L^{-1} two times (6 and 8 weeks from the planting date) during the season.

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