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(Original Article)

Growth and Productivity of Dutch Fennel Plant as Affected by Planting Date and Fulvic Acid

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Abstract

A field experiment was conducted during 2020/2021 and 2021/2022 seasons at the Experimental Farm of Floriculture, Faculty of Agriculture, Assiut University, Egypt to study the effect of planting dates (15th October, 7th November and 25th November) and fulvic acid levels (control, 500, 1000 and 2000 ppm) on vegetative growth, essential oil percentage, fruit and oil yield as well as chemical constituents of Dutch fennel plants. Results revealed that the planting on 7th November was the most effective treatment for increasing plant height, number of main branches, herb dry weight, umbel number/plant, essential oil percentage, fruit and oil yields as well as contents of photosynthetic pigments, total carbohydrates and phenols compared to the other planting dates. The highest values were obtained from plants sown in 7th November, followed by plants sown on 15th October, while the lowest values were recorded with the late planting date. Spraying plants with fulvic acid at different concentrations greatly improved all studied characteristics compared to the control. The highest values of these parameters were obtained from plants treated with 2000 ppm fulvic acid, followed by 1000 ppm. The combined treatment of planting on 7th November and spraying with 2000 ppm fulvic acid resulted in the best vegetative parameters, fruit and oil yield as well as chemical components compared with the other combined treatments. Therefore, it could be recommended to cultivate Dutch fennel plants on 7th November and spraying plants with 2000 ppm fulvic acid for obtaining high values of vegetative growth, fruit and oil yield parameters.

Keywords: *Chemical constituents, Dutch fennel, Fruit yield, Fulvic acid, Oil yield, Planting date*

Introduction

Fennel (*Foeniculum vulgare*, Mill.) is one of the most important economic medicinal and aromatic plants for exporting in Egypt, which belongs to the *Apiaceae* (*Umbelliferae*) family. It is ranked first in terms of quantity on the list of Egyptian exports of herbs and spices (Mohamed, 2020). Fennel plant is native to Mediterranean area and cultivated in many places of the world i.e. Europe, Africa, Asia, North and South America (Brender *et al*., 1997). It is used as a colic in children, diuretic, indigestion, expectorant, flavoring agents, perfumery and

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essence in cosmetics, anticancer, anti-inflammatory, antioxidant, antimicrobial and antidiarrheic (Gori *et al*., 2012). The flavor of fennel oil depends upon its main components: estragole, fenchone which is a bitter tasting element and anethole with a sweet anise-like flavor (Braun and Franz, 1999). Proportions of these ingredients vary according to region and strains (Osman and Abd El-Wahab, 2003). The Egyptian bitter fennel type (*Foeniculum vulgare* var. *vulgare*) contains lower percentage of anethole which reaches 15.8% and high content of estragole which is about 88% (Shahat *et al*., 2011). Estragole is considered one of the substances prohibited for use in the manufacture of children's medicines (El Laban *et al*., 2017). Dutch fennel is a new sweet fennel genotype that was imported from Netherlands by Sekem Company and has been cultivated in different regions of Egypt during the past few years. It is characterized by higher oil yield, higher anethole percentage (75.9%) and lower estragole percentage (4.2%) compared to local fennel (Abu El-Leel and Yousef, 2017).

Choosing the appropriate planting date plays a great role in modification of vegetative growth stages and qualifying environmental conditions, which leads to achieve maximum productivity (Safaei *et al*., 2017). Planting date has a major impact on seed yield by influencing the yield ingredients through its effect on number of branches/plant, control of weeds, diseases and pests, harvesting time, seed yield and product quality. In very early planting, low soil temperatures and frost damages result in weak plant growth in the spring. On the other hand, delaying planting date can result in a reduction in plant growth period and the chance of coincidence in the flowering time with higher temperatures, which will have an opposite impact on the plant growth. In this regard, many researchers have pointed out the effectiveness of sown date on growth, fruit and oil yield of fennel plants (Abd Ellatief, 2023).

Using organic and biological fertilizers in the production of medicinal plants in a sustainable agricultural system is important for achieving high product quality, environmental protection and community health (Aminifard *et al*., 2020). In this concern, fulvic acid is naturally found in the soil content of the organic matters. It is produced by the biodegradation of organic matter with lignin content (Malan, 2015). Fulvic acid is considered as one of the major components of humus that dissolves in water and used as a growth regulator hormone to enhance vegetative growth and stress tolerance (Abd El-Rheem *et al*., 2021). Besides, it contains many nutrients which are beneficial in improving yield along with improving the physicochemical and biological environment of soils (Daur and Bakhashwain, 2013). Khalid *et al. (*2015) and Abd El-Rheem *et al*. (2021) on fennel plant revealed that fulvic acid had a great influence on increasing fruit yield and volatile oil percentage and content of sweet fennel.

Therefore, the aim of the present study was to investigate the impact of sown date and fulvic acid on growth, fruit and oil yield as well as chemical constituents of Dutch fennel plant under Assiut governorate, Egypt conditions.

Materials and Methods

The present study was conducted during the two successive seasons of 2020/2021 and 2021/2022 at the Experimental Farm of Floriculture, Faculty of Agriculture, Assiut University, Assiut, Egypt to evaluate the influence of different planting dates and fulvic acid concentration on growth, fruit and oil yield as well as chemical constituents of Dutch fennel (*Foeniculum vulgare*, Mill.) plants.

The experiment was included 12 treatments which presented the combinations between three planting dates (15th October, 7th November and 25th November) and four concentrations of fulvic acid (control "tap water", 500, 1000 and 2000 ppm). The fulvic acid (Fulvo Max,60%) was obtained from Agrochemical Company, China (City Max). Triton B at 0.1% was to the fulvic acid solutions as wetting agents. The experiment was arranged in a split-plot design, with four replicates. The three planting dates were contributed as the main plots, while fulvic acid concentrations represented in the sub-plots. The soil was clay loam in texture. Some physical and chemical properties of the experimental soil were determined according to the methods described by Jackson (1973) as presented in Table (1). The maximum and minimum temperatures as well as the relative humidity during 2020/2021 and 2021/2022 seasons were obtained from the Meteorological Station at Assiut Governorate, Egypt and are shown in Table (2).

Table 1. Some physical and chemical properties of the soil used at the beginning of the experiment (average of 2020/2021 and 2021/2022 seasons)

Soil type	Soluble ions meq/100 g soil*							Soluble K mg/100g soil	pH†	EC* dS m^{-1}	Organic matter%
	Cations				Anions						
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	$SO_4^{=}$				
Clay loam	3.2	2.50	3.81	0.007	3.26	3.62	2.63	0.23	8.14	0.97	1.72

Abbreviations: * Soil-water extract (1:5); †Soil-water suspension (1:2.5)

Table 2. Meteorological data of Assiut governorate during 2020/2021 and 2021/2022 seasons*

Months	First season (2020/2021)					Second season (2021/2022)				
	Temp. C°			Relative Humidity %	Day light	Temp. C°			Relative Humidity %	Day light
	Min.	Max.	Average			Min.	Max.	Average		
October	25.56	40.32	32.94	17.07	11.35	23.14	38.09	35.12	47.28	11.29
November	18.90	32.26	25.58	17.00	10.59	18.98	34.46	26.72	53.31	10.54
December	14.00	31.06	22.53	14.32	10.30	14.64	24.23	19.44	57.20	10.26
January	10.97	27.70	19.34	13.49	10.42	8.00	22.71	15.36	60.11	10.39
February	10.25	27.97	19.11	16.13	11.14	10.16	27.11	18.64	53.09	11.08
March	24.41	40.19	32.3	18.86	11.58	19.64	34.25	26.95	42.16	11.50
April	26.35	42.73	34.54	17.20	12.57	24.73	42.34	33.54	29.19	12.53
May	26.46	44.11	35.28	17.07	13.35	25.34	41.56	33.45	27.34	13.27

*EMA, Egyptian Meteorological Authority

Dutch fennel fruits were obtained from the Agriculture Research Center, El Dokki, Giza and cultivated in 2 x 2 m plots during the three planting dates in the two seasons. Each plot included three rows. The plant spacing was 30 cm in the row and 60 cm between the rows. Thinning was done after 45 days from planting,

leaving one plant per hill (18 plants/plot) i.e. 18,000 plants/fed. Fulvic acid treatments were applied as spray three times at 3 weeks interval and the first treatment was added after 45 days from planting.

Nine plants of each experimental plot were taken at the harvesting period for determination of plant height, number of main branches/plant, herb dry weight/plant, essential oil percentage, fruit and oil yields as well as photosynthetic pigments, total carbohydrates percentage and total phenols content. The essential oil percentage was determined in the dried fruits by hydro distillation for 2 hours using a Clevenger type apparatus as described in the

Chlorophyll "a", chlorophyll "b" and carotenoids contents in freshly collected leaf samples (after 10 days from the last spray) was determined colorimetrically according to Metzner *et al*. (1965).

Total carbohydrates percentage in fennel fruits was colorimeterically determined with the anthron sulphuric acid method according to Fales (1951). The total phenols content in fruits was estimated colorimeterically by Folin ciocalteau reagent method according to Vasco *et al*. (2008). Data obtained during the two seasons were statistically analyzed using Statistix 8.1 analytical software. Means were compared using the least significant difference (L.S.D.) test at 5% level of probability according to Snedecor and Cochran (1989).

Results and Discussion

1-Vegetative growth characteristics

The obtained results in Table 3 showed that the vegetative parameters; plant height, number of main branches/plant and herb dry weight/plant of Duch fennel plants were remarkably affected by planting date in both seasons. The highest values of vegetative parameters were obtained from plants sown on 7th November, followed by plants sown on 15th October, while the lowest values were recorded with the late planting date (25th November). These results are in agreement with those obtained by El-Shoura *et al*. (2019), Abdul-Hafeez *et al*. (2020) and Abd Ellatief (2023), who reported that early planting date in 2nd week of October to 1st November increased fennel growth compared to the late planting dates from 2nd to 4th week of November in different parts of the world. Similar results were supported by Abd El-Wahab and Mehasen (2009) on Indian fennel, who reported that the earliest planting date on 7th November produced the highest vegetative growth parameters comparing with the later dates on 15th and 21st November in El-Minia, Assiut, Sohag and Qena governorates, Egypt. These effects may be attributed to longer photoperiod and the higher temperatures during early planting date which can give plants the opportunity to build up more stored foods compared to later planting date and this may be reflected on faster growth of plants with more umbel number than under the colder conditions (Abdul-Hafeez *et al*., 2020; Abd Ellatief, 2023). Cultivation of fennel plants at the optimal time can be beneficial for nutrient uptake and overall plant health, which can be beneficial for plant growth, higher umbel number, better cell and tissue development, resulting in improved plant health and stress tolerance (El-Danasoury *et al*., 2020). The

decrease in growth parameters with delayed planting can be due to the short vegetative growth period and the negative effect of low temperatures in the early growth stages, which may have slowed down the vegetative growth of plants (Ayub *et al*., 2008). However, it is important to note that the optimal planting date may vary depending on the specific climate, soil conditions of each location and genetic traits of the crop plants (El-Sayed and El-Kersh, 2014). It is obvious that the impact of planting date is correlated with climatic parameters such as temperature, humidity and photoperiod as show in Table (2). It is clear that the optimum climate conditions in the second planting date (1st November) caused a noticed improvement in the vegetative parameters of Dutch fennel plants.

Table 3. Effect of different planting dates and fulvic acid levels on plant height (cm), number of main branches/plant and herb dry weight (gm) of Dutch fennel plants during the 2020/2021 and 2021/2022 seasons

Planting date	Fulvic acid levels (ppm)									
	1st season (2020/2021)					2nd season (2021/2022)				
	Cont.	500	1000	2000	Mean	Cont.	500	1000	2000	Mean
Plant height (cm)										
15th October	79.5	92.5	99.8	109.3	95.4	68.8	80.1	86.4	94.5	82.4
7th November	91.6	107.4	120.6	124.3	111.0	79.2	92.9	104.3	107.6	96.0
25th of November	75.0	81.9	87.7	93.1	84.4	64.9	70.8	75.9	80.6	73.0
Mean	82.0	94.1	102.7	108.9	----	71.0	81.3	88.9	94.2	----
L.S.D. at 0.05	Date = 7.2	FA = 3.7	Interaction = 6.5			Date = 6.2	FA = 3.3	Interaction = 5.7		
No. of main branches/plant										
15th October	5.32	6.37	6.95	7.15	6.45	4.57	5.46	5.96	5.88	5.47
7th November	6.25	6.73	7.12	8.14	7.18	5.48	5.77	6.10	6.98	6.08
25th November	4.75	5.97	5.99	6.34	5.76	4.08	5.11	5.14	5.44	4.94
Mean	5.61	6.36	6.68	7.21	----	4.71	5.45	5.73	6.10	----
L.S.D. at 0.05	Date= 0.45	FA = 0.50	Interaction = N.S.			Date = 0.46	FA= 0.33	Interaction = N.S.		
Herb dry weight/plant (gm)										
15th October	120.0	156.2	204.6	302.9	195.9	101.3	131.6	170.1	253.6	164.1
7th November	188.0	276.0	306.3	393.2	290.9	160.1	232.2	257.0	330.3	244.9
25th November	92.1	112.9	128.0	143.9	119.2	77.6	95.0	107.5	120.2	100.1
Mean	133.4	181.7	212.9	280.0	----	113.0	152.9	178.2	234.7	----
L.S.D. at 0.05	Date= 39.2	FA= 30.7	Interaction= 53.2			Date = 36.3	FA= 24.0	Interaction= 41.5		

On the other hand, foliar application of fulvic acid at different levels considerably improved all vegetative growth parameters (plant height, number of main branches/plant and herb dry weight/plant) of Duch fennel plants compared to untreated plants during both seasons (Tables 3 to 5). The highest values of growth parameters were obtained from plants sprayed with 2000 ppm fulvic acid, followed by 1000 and 500 ppm, respectively. These results are in accordance with those obtained by Aminifard *et al*. (2020), Abd El-Rheem *et al.* (2021) and Ali *et al.* (2022). They stated that spraying plants with different rates of fulvic acid greatly improved growth parameters, especially at higher rates compared to untreated plants. These promotive effects of fulvic acid on vegetative and root growth of Dutch fennel plants may be attributed to its important properties, since fulvic acid

is low molecular weight and is highly biologically active (Abd El-Baky *et al*., 2020). Fulvic acid has an important role in increasing the permeability of cell membranes, which contributes and accelerates the absorption of nutrients through the leaves and their transfer to different parts of the plant (Yildirim, 2007). In addition, fulvic acid contains many nutrients which are beneficial in improving vegetative growth parameters (Daur and Bakhashwain, 2013). In addition to its role in improving the chemical and physical properties of the soil, enhancing its moisture content, improving aeration and preventing the exposure of nutrients to washing by irrigation water, which increases the cation exchange capacity (Farid *et al*., 2018).

2-Fruit and oil characteristics

It appeared from presented data in Tables 4 and 5 that cultivation Dutch fennel plants on 7th November positively affected and produced the highest values of umbel number/plant, fruit yield per plant, fruit yield per feddan, essential oil percentage, essential oil yield per plant and essential oil yield per feddan, followed by planting date of 15th October. Meanwhile, the late planting date of 25th November recorded the lowest values. The increments were 44.3% and 72.8% in umbel number per plant, 16.2% and 75.9% in fruit yield per plant, 15.5% and 75.0% in fruit yield per feddan, 3.65% and 10.73% in essential oil percentage, 20% and 95.1% in oil yield per plant, 19.9% and 95.6% in essential oil yield per feddan over the planting dates of 15th October and 25th November, respectively as average mean of both seasons.

Similar results were obtained by many investigators, who stated that early planting date increased fruit and oil yield of fennel plants compared to delayed planting dates (Abd El-Wahab and Mehasen, 2009; Abdul-Hafeez *et al*., 2020; Abd Ellatief, 2023). These increments in volatile oil percentage, fruit and oil yield during the early date than in the late once might be due to the higher temperature and longer photoperiod during early sowing date. Accordingly, that can give the plants a chance to build up more stored foods than the later sowing dates and this may be reflected on faster plant growth with a greater number of umbels per hill and consequently a higher fruit yield per plant than under the colder conditions (Abd El-Aleem *et al*., 2017). In addition, the increments in fruit and oil yield can be due to greater umbel number/plant and fruit number/umbel (Ayub *et al*., 2008). Additionally, changes in temperature can affect the timing and duration of flowering, which can impact the availability of floral resources for pollinators (Hegland *et al.,* 2009).

As for effect of fulvic acid levels, it is evident from data presented in Tables 4 and 5 that all studied fruit and oil traits of Dutch fennel plants; umbel number/plant, fruit yield/plant and feddan, volatile oil percentage, volatile oil yield/plant and feddan were gradually increased with increasing of fulvic acid concentrations over the control with superiority of 2000 ppm. The increments were 90.4 in umbel number/plant, 64.5 in fruit yield/plant, 63.3 in fruit yield/feddan, 52.5 in essential oil percentage, 149.5 in essential oil yield/plant and 149.2 in essential oil yield/feddan over the control as average mean of both seasons.

Table 4. Impact of different planting dates and fulvic acid levels on umbel number/plant, fruit yield/plant (gm) and fruit yield/feddan (kg) of Dutch fennel during the 2020/2021 and 2021/2022 seasons

Planting dates	Fulvic acid levels (ppm)									
	1st season (2020/2021)					2nd season (2021/2022)				
	Cont.	500	1000	2000	Mean	Cont.	500	1000	2000	Mean
Umbel number/plant										
15th October	19.4	25.2	28.1	38.5	27.8	16.3	20.6	23.6	32.2	23.2
7th November	27.5	33.5	42.0	57.2	40.0	23.1	28.0	35.2	48.0	33.6
25th November	17.4	22.9	25.2	27.1	23.1	14.7	19.2	21.2	22.8	19.5
Mean	21.5	27.2	31.9	40.9	----	18.0	22.6	26.7	34.3	----
L.S.D. at 0.05	Date= 2.2 FA= 1.9 Interaction = 3.3					Date= 1.7 FA= 1.6 Interaction = 2.7				
Fruit yield/plant (gm)										
15th October	26.6	33.4	44.7	48.2	38.2	22.4	28.2	37.7	40.6	32.2
7th November	33.0	42.4	49.0	53.0	44.4	27.8	35.7	41.3	44.7	37.4
25th November	20.2	23.7	27.1	30.0	25.2	17.0	20.0	22.8	25.3	21.3
Mean	26.6	33.2	40.3	43.7	----	22.4	27.9	33.9	36.9	----
L.S.D. at 0.05	Date = 1.3 FA = 1.9 Interaction = 3.3					Date = 1.1 FA= 1.6 Interaction = 2.8				
Fruit yield/feddan (kg)										
15th October	478.8	601.7	805.1	866.7	688.1	404.6	507.9	680.6	732.4	581.4
7th November	594.5	763.2	881.6	926.9	791.5	502.0	645.2	745.1	805.8	674.5
25th November	363.2	426.2	487.4	539.7	454.1	306.8	360.2	411.9	456.1	383.7
Mean	478.8	597.0	724.7	777.8	----	404.5	504.4	612.6	664.7	----
L.S.D. at 0.05	Date = 29.2 FA = 36.1 Interaction = 62.5					Date = 19.5 FA=29.9 Interaction = 51.8				

These results are in harmony with findings reported by Aminifard *et al*. (2020), Abd El-Rheem *et al.* (2021) and Ali *et al*. (2022), who revealed that foliar application of fulvic acid enhanced seed yield, volatile oil percentage and oil yield, especially at higher levels compared to control. This improvement in Dutch fennel fruit yield as a result of fulvic acid application may be attributed to its role in enhancing the nutrients absorption by affecting cell membranes, leading to improvement of protein synthesis and phytohormone activation as well as enhancing photosynthesis and carbohydrate accumulation (El-Sawy *et al*., 2020). According to Abd El-Rheem *et al.* (2021), the fulvic acid stimulates plant auxin production and improves the ability of the plasma membrane to sense other growth hormones such as cytokinin and gibberellic acid. In addition, a positive relationship between growth traits and fruit and oil yield was observed in the current study. On the other hand, the increase in volatile oil yield may be a result of an increase in fruit yield and/or volatile oil percentage (Abd Ellatief, 2023).

Table 5. Effect of different planting dates and fulvic acid levels on essential oil percentage, volatile oil yield per plant (ml) and volatile oil yield per feddan (L) in Dutch fennel fruits during the 2020/2021 and 2021/2022 seasons

Planting dates	Fulvic acid levels (ppm)									
	1st season (2020/2021)					2nd season (2021/2022)				
	Cont.	500	1000	2000	Mean	Cont.	500	1000	2000	Mean
Volatile oil percentage										
15th October	0.89	1.23	1.29	1.34	1.19	0.75	1.04	1.09	1.13	1.00
7th November	0.92	1.29	1.33	1.39	1.23	0.77	1.09	1.12	1.17	1.04
25th November	0.84	1.09	1.24	1.29	1.11	0.71	0.92	1.05	1.09	0.94
Mean	0.88	1.20	1.29	1.34	----	0.74	1.02	1.09	1.13	----
L.S.D. at 0.05	Date= 0.05 FA= 0.04 Interaction = N.S.					Date = 0.04 FA= 0.04 Interaction = N.S.				
Volatile oil yield per plant (ml)										
15th October	0.238	0.412	0.575	0.645	0.468	0.201	0.348	0.485	0.544	0.394
7th November	0.303	0.549	0.653	0.739	0.561	0.256	0.463	0.550	0.623	0.473
25th November	0.169	0.256	0.336	0.386	0.287	0.143	0.216	0.284	0.326	0.242
Mean	0.236	0.405	0.522	0.590	----	0.200	0.342	0.439	0.498	----
L.S.D. at 0.05	Date= 0.013 FA= 0.028 Interaction= 0.048					Date= 0.015 FA = 0.023 Interaction = 0.040				
Volatile oil yield per feddan (L)										
15th October	4.28	7.42	10.36	11.61	8.42	3.66	6.33	8.84	9.90	7.18
7th November	5.45	9.88	11.75	13.29	10.09	4.65	8.43	10.02	11.33	8.61
25th November	3.04	4.60	6.06	6.95	5.16	2.59	3.93	5.16	5.93	4.40
Mean	4.26	7.30	9.39	10.62	----	3.634	6.227	8.01	9.05	----
L.S.D. at 0.05	Date= 0.24 FA= 0.50 Interaction = 0.87					Date= 0.29 FA = 0.42 Interaction = 0.73				

3-Chemical constituents

From the obtained results in Tables 6 and 7, it can be clearly noticed that the different planting dates considerably affected chlorophyll (a), chlorophyll (b), carotenoids and total phenols contents as well as total carbohydrates percentage in both seasons. The maximum values could be achieved in the early planting date of 7th November, followed by 15th of October, while the lowest values were detected in the late planting date of 25th of November. These results are in agreement with those reported by Hassan *et al.* (2019), Abdul-Hafeez *et al*. (2020) and Abd Ellatief (2023), who reported that the earliest planting dates from 15th October to 1st November gave the highest content of chlorophyll (a), chlorophyll (b), total chlorophyll and carotenoids as well as total carbohydrates percentage compared with the other planting dates. These increases in the content of chemical constituents of Dutch fennel plants may be due to the appropriate temperature and relative humidity, which is reflected in the vegetative growth, consequently, yield and quality as well as chemical constituents (Abd El-Wahab and Mehasen, 2009). Exposure to high temperatures can lead to oxidative stress, which can damage cell membranes and reduce the efficiency of photosynthesis (Hasanuzzaman *et al.*, 2013).

On the other hand, all studied chemical constituents were remarkably increased as a result of fulvic acid foliar application comparing with the untreated plants (Tables 6 and 7). Among fulvic acid levels, the highest values of chlorophyll (a), chlorophyll (b), carotenoids and total phenols contents as well as total carbohydrates percentage were recorded with 2000 ppm, followed by 1000 and 500 ppm, respectively.

Table 6. Effect of different planting dates and fulvic acid levels on chlorophyll (a), chlorophyll (b) and carotenoids contents (mg/g fresh weight) in fresh leaves of Dutch fennel as affected by during the 2020/2021 and 2021/2022 seasons

Planting dates	Fulvic acid levels (ppm)									
	1st season (2020/2021)					2nd season (2021/2022)				
	Cont.	500	1000	2000	Mean	Cont.	500	1000	2000	Mean
Chlorophyll (a) content (mg/g fresh weight)										
15th October	1.665	2.080	2.383	2.640	2.192	1.450	1.875	2.243	2.620	2.047
7th November	2.125	2.695	2.900	3.155	2.719	1.923	2.513	2.938	3.175	2.637
25th November	1.303	1.855	2.063	2.383	1.901	1.150	1.600	1.855	2.305	1.728
Mean	1.698	2.210	2.448	2.726	----	1.508	1.996	2.345	2.700	----
L.S.D. at 0.05	Date = 0.141 FA = 0.136 Interaction = N.S.					Date = 0.165 FA = 0.116 Interaction = N.S.				
Chlorophyll (b) content (mg/g fresh weight)										
15th October	0.498	0.675	0.755	0.808	0.684	0.485	0.575	0.693	0.788	0.635
7th November	0.648	0.783	0.890	1.015	0.834	0.608	0.760	0.843	0.930	0.785
25th November	0.428	0.530	0.608	0.660	0.556	0.365	0.485	0.618	0.648	0.529
Mean	0.524	0.663	0.751	0.828	----	0.486	0.607	0.718	0.788	----
L.S.D. at 0.05	Date = 0.0.064 FA = 0.056 Interaction = N.S.					FA = 0.052 FA = 0.034 Interaction = N.S.				
Carotenoids content (mg/g fresh weight)										
15th October	0.775	0.933	1.048	1.203	0.989	0.738	0.915	1.098	1.228	0.994
7th November	0.920	1.153	1.298	1.463	1.208	0.915	1.135	1.325	1.538	1.228
25th November	0.683	0.845	0.948	1.060	0.884	0.628	0.795	0.935	1.080	0.859
Mean	0.793	0.977	1.098	1.242	----	0.760	0.948	1.119	1.282	----
L.S.D. at 0.05	Date = 0.039 FA = 0.069 Interaction = N.S.					Date = 0.075 FA = 0.070 Interaction = N.S.				

These results are in accordance with those obtained by Aminifard *et al*. (2012) and El-Sawy *et al*. (2020). In this concern, Ali *et al*. (2022), showed that application of fulvic acid increased the content of photosynthesis pigments and total phenols as well as total carbohydrates percentage, especially at the highest concentrations. These results may be due to the role of fulvic acid as natural chelators which increase the mobilization and transportation of micronutrients (Bocanegra *et al*., 2006) and enhance the photosynthesis rate and increase chlorophyll content, which reflect on the plant growth and fruit yield (El-Sawy *et al*., 2020). According to Liang *et al*. (2009), exogenous fulvic acid can improve the stability of chloroplast structure and reduce damage to photosynthetic mechanisms. Fulvic acid also increased photosynthesis, reduced stomata opening

status and transpiration, stimulating growth and reducing water loss. On the other hand, the accumulation of carotenoids in plant tissue appears to be shaped by physiological, genetic and biochemical attributes of a plant species, as well as by environmental growth factors such as light, temperature and fertility (Aminifard *et al*., 2012). In addition, non-enzymatic antioxidants such as phenols and carotenoids were affected by humic substances application (Canellas *et al*., 2015). In the same context, Bayat *et al*. (2021) reported that fulvic acid increased the total phenol content in yarrow plants compared to the control.

Table 7. Impact of different planting dates and fulvic acid levels on total carbohydrates percentage and total phenols content (mg GAE/g dry weight) in fruits of Dutch fennel plants during the 2020/2021 and 2021/2022 seasons

Planting date	Fulvic acid con. (ppm)									
	1st season (2020/2021)					2nd season (2021/2022)				
	Cont.	500	1000	2000	Mean	Cont.	500	1000	2000	Mean
Total carbohydrates percentage										
15th October	14.3	14.9	16.7	19.6	16.4	13.2	15.3	15.6	16.6	15.2
7th November	16.6	18.6	19.0	23.0	19.3	15.2	16.8	18.6	21.6	18.0
25th November	12.6	14.8	15.5	18.5	15.3	12.7	14.3	15.3	16.0	14.6
Mean	14.5	16.1	17.1	20.4	----	13.7	15.4	16.5	18.1	----
L.S.D. at 0.05	Date= 2.2 FA = 2.1 Interaction = N.S.					Date= 2.1 FA = 2.3 Interaction = N.S.				
Total phenols content (mg GAE/g dry weight)										
15th October	7.33	9.28	11.00	12.91	10.13	6.14	7.83	9.50	11.10	8.65
7th November	10.05	11.44	11.85	13.93	11.82	7.69	9.63	9.97	12.13	9.86
25th November	6.92	9.10	10.01	11.69	9.43	5.83	7.43	8.51	9.84	7.91
Mean	8.10	9.94	10.95	12.84	----	6.56	8.29	9.33	11.02	----
L.S.D. at 0.05	Date= 0.49 FA = 0.44 Interaction = N.S.					Date= 0.38 FA = 0.33 Interaction = N.S.				

Conclusion

From the obtained results, it appears that cultivation of Dutch fennel plants on 7th November and spraying fulvic acid at a rate of 2000 ppm was the most effective treatment for improving the growth parameters and gave the best fruit yield per plant and feddan, essential oil percentage, essential oil yield per plant and feddan as well as the highest contents of photosynthetic pigments, total phenols and total carbohydrates, followed by planting on 7th November + 1000 ppm fulvic acid and planting on 15th October + 2000 ppm fulvic acid.

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نمو وإنتاجية نبات الشمر الهولندى متأثرة بميعاد الزراعة وحمض الفولڤيك

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الملخص

أجريت هذه الدراسة بمزرعة أبحاث نباتات الزينة بكلية الزراعة - جامعة أسيوط خلال موسمي 2021/2020، 2022/2021 م بهدف دراسة تأثير مواعيد الزراعة المختلفة (15 أكتوبر، 7 نوفمبر، 25 نوفمبر)، وتركيزات حمض الفولڤيك (الكنترول "ماء الصنبور"، 500، 1000، 2000 جزء في المليون) على نمو ومحصول الثمار والزيت والتركيب الكيميائي لنباتات الشمر الهولندي.

أظهرت النتائج المتحصل عليها أن الزراعة المبكرة في السابع من شهر نوفمبر، يليها منتصف شهر أكتوبر كانت أكثر تأثيراً في زيادة قيم الصفات الخضرية (ارتفاع النبات، عدد الفروع الرئيسية على النبات، الوزن الجاف للعشب) وكذلك عدد النورات/نبات، محصول الثمار لكل نبات وللفدان، نسبة الزيت الطيار، محصول الزيت الطيار لكل نبات وللفدان، محتوى صبغات البناء الضوئى في الأوراق الخضراء، وكذلك محتوى الثمار من الكربوهيدرات والفينولات الكلية مقارنة بالزراعة المتأخرة في نهاية شهر نوفمبر. من ناحية أخرى، فإن الرش الورقي للنباتاتت بحمض الفولڤيك أدت لتحسن ملحوظ في جميع الصفات المدروسة مقارنة بالنباتات غير المعاملة خلال موسمي الزراعة. القيم الأعلى سجلت مع النباتات المعاملة بحمض الفولڤيك بتركيز 2000 جزء في المليون، يلي ذلك 1000، 500 جزء في المليون، على التوالي. حققت المعاملة المشتركة لزراعة نبات الشمر الهولندي في السابع من شهر نوفمبر والرش بحمض الفولڤيك بتركيز 2000 جزء في المليون أفضل القيم للصفات الخضرية، محصول ثمار وزيت طيار، كذلك محتوى النبات من المكونات الكيميائية مقارنة بالمعاملات المشتركة الأخرى. وبناءً على ذلك، يمكن التوصية بزراعة نباتات الشمر الهولندي في السابع من شهر نوفمبر والرش بحمض الفولڤيك بتركيز 2000 جزء في المليون للحصول على أعلى القيم لصفات النمو الخضري، محصول الثمار والزيت.