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Original Article

IMPACT OF CULTIVAR AND HARVEST TIME ON GROWTH, PRODUCTION AND ESSENTIAL OIL OF *ANETHUM GRAVEOLENS* CULTIVATED IN EGYPT

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ABSTRACT

Objective: The objective of this research was to compare growth and essential oil content and composition among eight dill cultivars harvested two times before the bolting of inflorescences.

Methods: A two years field experiment was conducted on eight cultivars of dill in 2010/2011 and 2011/2012 seasons. Growth, herb fresh weight (g/plant) and essential oil content of the eight cultivars of dill were recorded at the first and second harvests after 60 and 90 d from sowing. The volatile oil content was analyzed by GC/MS.

Results: Common cultivar was the best in plant height, the number of branches and fresh herb weight while Elephant cultivar was the best in the essential oil percentage. On the other, Compatto cultivar was least in plant height, the number of branches, fresh herb weight and essential oil %. The essential oil content was found to vary from 0.007-0.008% in the first harvest (harvest 60 d after sowing) and 0.042-0.045% in the second harvest (harvest 90 d after sowing). *Anethum graveolens* cv. Elephant was the highest in essential oil followed by cv. Bouquet, cv. Dukat and then cv. Common, cv. Tetra, cv. Vierling, cv. Local and finally cv. Compatto, which gave the lowest essential oil content. From the results of GC/MS obtained for the eight dill cultivars, six major compounds exist in eight cultivars, but with different percentages. α-phellandrene>limonene>dill apiol (*Anethum graveolens* cv. Local, cv. Compatto, cv. Common and cv. Bouquet); α-phellandrene>limonene>myristcin (*Anethum graveolens* cv. Tetra, cv. Vierling, cv. Dukat and cv. Elephant) were the major components in the first harvest (α-phellandrene chemotype). α-phellandrene>limonene>dill ether (*Anethum graveolens* cv. Local, cv. Tetra, cv. Vierling, cv. Ducat and cv. Common); α-phellandrene>limonene>p-cymene>dill ether (*Anethum graveolens* cv. Compatto, cv. Bouquet and cv. Elephant) were the major components in the second harvest(α-phellandrene and limonene chemotype). The second harvest gave the best values of growth, fresh herb weight and essential oil content as well as α-phellandrene, limonene, p-cymene and dill ether percentage in all cultivars than the first harvest. Except, myristcin which decreased in the European cultivars and increased in local cultivar in the second harvest than first one. Also, dillapiole increased only in Tetra cultivar in the second harvest and decreased in the other cultivars compared to the first harvest.

Conclusion: The results obtained in this research clearly indicated superiority of European cultivars (Common, Bouquet, Elephant, Dukat, Vierling and Tetra, except Compatto cultivar) than the Egyptian cultivar (Local) in fresh herb weight (g/plant) and volatile oil content. Also, Common cultivar was more superior in growth characters, fresh herb weight (g/plant), essential oil content and the percentage of both α-phellandrene, limonene and dill ether. Elephant cultivar gave the lowest % of dill apiol (2.30-0.25%) in the first and second harvests, respectively.

Keywords: Dill, Cultivar (cv.), Essential oil, α-phellandrene, Limonene, p-cymene, Dill ether, Dill apiol, Myristcin

INTRODUCTION

Dill (*Anethum graveolens* L., Apiaceae family) is an important aromatic annual herb originates from the Mediterranean and West Asia, and now grown worldwide. Dill is one of the first-known multi-purpose plants which have been used as a spice and medicine. The use of dill as a condiment or for medicinal purposes dates back to Egyptian times [1]. It has been extensively used as a traditional herbal medicine throughout many countries [2-4]. Dill herb used primarily as a condiment, carminative, stimulant, digestive and in flavour, food, perfumes, and cosmetics industries as well as a medicine for humans and animals [1, 5]. Dill herb oil has also been widely investigated in respect to their antimicrobial, antifungal, antioxidative and antispasmodic activities [6-11]. Other studies have shown beneficial effects of dill components due to their antiseptic and anticarcinogenic as well as antihyperlipidemic and antihypercholesterolemic effects [12].

Essential oils are synthesized by secondary metabolism pathways according to the growing stage. The knowledge of the composition of essential oils and their therapeutic properties has contributed to the development of their cultivation and markets. Essential oils are commercially important and are traded in the world market, and the world production and consumption of essential oils is increasing very fast [13, 14]. Since ancient times, essential oils are recognized for their medicinal value, and they are very interesting and powerful natural plant products until the present day [15]. It is also reported that the property of dill herb oil depends largely on the proportions of α-phellandrene and dill ether with lower amounts of carvone [16, 17]. Dill ether was assessed as the character impact compound of dill herb flavor [2, 18]. Brunkea *et al.* [19] reviled that α-phellandrene and dill ether compounds exhibited as majors. In another report, α-phellandrene, β-phellandrene and dill ether was the major components and carvone was not detected in the herb oil [20].

The essential oil quality and productivity of dill and other essential oil crops depend on many factors such as climate, cultivar, seeding date, harvest date and management practices [21-24]. Harvesting dill at the pre-blossoming phase was the optimal compromise between production and essential oil quality [25]. Santos *et al.* [1] reported α-phellandrene (62%), dillapiole (10%) and myristicin (7%) as the main components of the herbage oil. Similar herb oil composition, α-phellandrene, limonene, terpinene and phellandral were reported by Jianu *et al.* [8]. In another analysis of dill herb oil determined α-phellandrene, limonene and dill ether as the main components [26]; furthermore, Vokk *et al.* [9] reported the main components of dill herb oil to be α-phellandrene, β-phellandrene, dill ether, myristicin and limonene. Hajhashemi and Abbasi [27] found that the aerial parts contain α-phellandrene, limonene and carvone as major components.

The cultivar has played an important role in producing better yield and quality of plants. Different cultivars respond differently for their genotypic characters, input requirement, growth process and the prevailing environment during growing season. Dill has been grown throughout the world as a culinary crop, and an essential-oil-producing crop. Dill fresh yields range from 15.2 to 22.5 ton/ha [28]. Whereas the content of essential oil in fresh dill herbage varies from 0.0**6** to 0.34 ml/100 g [1, 28, 29].

Due to its high economic value and its use for medicinal and culinary purposes, dill constitutes important new cash crops for growers. However, in our opinion, such goal may be achieved by introducing new cultivars of dill to be tested under local conditions. There has been no evaluation of these imported European dill cultivars under Egyptian conditions. Therefore, the aim of this study was to evaluate these cultivars of dill as potential new cash crops for essential oil production. To make this study more representative, seven European cultivars were chosen for this study and compared with the local cultivar. Specifically, growth, essential oil content, and composition in dill cultivars grown under field conditions were evaluated. Evaluating the performance of these cultivars will help to select the superior cultivars in terms of productivity and essential oil production, which might have important economical implications to growers.

MATERIALS AND METHODS

Plant material and optimization of growing conditions

A field experiment was conducted at the Experimental Farm of the Faculty of Pharmacy, Cairo University, Giza, Egypt, during two successive seasons (2010/2011 and 2011/2012). The physical and chemical properties of the soil sample were determined according to Jackson [30] to indicate that the field soil is sandy loam, having a physical composition as follows: 51.1% sand, 25% silt, 23.9 % clay and 0.47% organic matter. Soil chemical analysis was as follows: pH= 8.05; E. C (ds/m) = 4.9; and available N, P and K =0.07, 0.53 and 2.8 mg/kg, respectively. The seeds of eight cultivars of dill, (*Anethum graveolens*) viz., cv. Tetra, cv. Bouquet, cv. Compatto, cv. Dukat, cv. Vierling, cv. Elephant and cv. Common was introduced from the HEM ZADEN B. V-P. O. Box 4-1606 ZG Venhuizen, The Netherlands, besides the seeds of the Local cultivar of dill in Egypt. The seeds of the eights cultivars were sown on 15th October in the two seasons into 3 x 3.5 m plots with 60 cm spaced rows, and 20 cm between the hills. The normal agricultural practices normally done for the dill were performed for all varieties. The plants were harvested on 15th December and 15th January (60 and 90 d after sowing) at the vegetative herbs for essential oil. The experimental layout was a complete randomized block design with three replications.

Data recorded and extraction of essential oil

Plant height, number of branches, fresh herb weight (g/plant) and essential oil percentage of each replicate were measured at the first and second harvests after 60 and 90 d from sowing, respectively. The essential oil of eight cultivars was extracted from the fresh herb of each cultivar separately at the first and second harvests by water distillation using Clevenger apparatus for 2 hr according to the method described in the British Pharmacopoeia [31] and expressed as (ml/100g fresh herb). The resulted essential oils were dehydrated over anhydrous sodium sulfate and were kept in the refrigerator until GC-MS analyses.

GC/MS analyses conditions

The volatile oil of eight cultivars was analyzed by gas chromatography-mass spectrometry (GC-MS) instrument stands at the Department of Medicinal and Aromatic Plants Researches, National Research Centre with the following specifications. Instrument: a TRACE GC Ultra Gas Chromatographs (THERMO Scientific Corp., USA), coupled with a THERMO mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The GC/MS system was equipped with a TG-WAX MS column (30 m x 0.25 mm i.d., 0.25 μm film thickness). The carrier gas was helium at a flow rate of 1.0 mL/min and a split ratio of 1:10 using the following temperature program: 40 °C for 1 min; rising at 4.0 °C/min to 160 °C and held for 6 min; rising at 6 °C/min to 210 °C and held for 1 min. The injector and detector temperatures were held at 210 °C. Diluted samples (1:10 hexane, v/v) of 0.2 μl of the mixtures were always injected. Mass spectra were obtained by electron ionization (EI) at 70 eV, using a spectral range of m/z 40-450. Most of the compounds were identified using mass spectra (authentic chemicals, Wiley spectral library collection, and NIST library).

Statistical analysis

Except for the constituents of the volatile oil, the data in this study were analyzed with the analysis of variance (ANOVA) using JMP 10 program (SAS Institute, NC, USA). The mean values of treatments were compared using Tukey's HSD test. Values accompanied by different letters are significantly different at $p \leq 0.05$.

RESULTS AND DISCUSSION

Growth characteristics and essential oil content

Tables I and 2 show that there was a significant difference between the first and second harvest dates, and the plants harvested in the second date gave the highest results in plant height, number of branches, fresh herb weight and essential oil percentages in all cultivars. Also, there are significant differences between the cultivars under study, where Local, Common, and Dukat cultivars as well as cv. Bouquet gave the tallest plants at the second harvest in the first and second seasons, respectively. Common cultivar gave the highest values of number of branches and fresh herb weight in the first and second seasons of two harvests. With respect to essential oil %, Bouquet and Elephant cultivars in the first season as well as Elephant, Bouquet, Dukat and Common cultivars in the second season in two harvests gave the highest essential oil %. No significant differences were observed between Bouquet and Elephant cultivars in the first season of two harvests and also, between Elephant, Bouquet, Dukat and Common cultivars in the second season at the second harvest. Elephant cultivar was superior in essential oil % than the rest of cultivars followed by Bouquet, Dukat, Common, Tetra, Veirling, Local and then Compatto cultivar had the lowest essential oil % at two harvests in the two seasons. The content of essential oil in dill fresh herbage varies from 0.0**6**% to 0.34% [1, 22, 28, 29].

Table 1: Plant height, branches number, fresh herb and essential oil % of the vegetative herb of different dill (*Anethum graveolens*) cultivars cultivated under Egyptian conditions at the first season

Cultivar	Plant height		Branches No.		Fresh herb (g/plant)		Essential oil%	
	1st cut	2nd cut	Ist cut	2nd cut	Ist cut	2nd cut	Ist cut	2nd cut
Local	30.8±1.5ef	55.0±1.2a	4.0±0.58gh	12.3±0.67bc	9.73±1.55hi	17.7±1.2e-g	0.01±0.0g	0.025±0.003d-f
Compatto	25.3±2.2f	30.7±0.3ef	3.67±0.33h	7.33±0.88ef	8.17±0.73i	13.0±1.0g-i	0.008±0.001g	0.022±0.002ef
Tetra	30.7±1.5ef	38.7±0.9cd	5.33±0.33f-h	9.0±1.0de	13.2±0.0.73f-i	19.33±0.67d-g	0.017±0.003fg	0.038±0.002a-c
Vierling	33.9±1.0de	40.3±0.3c	6.33±0.33e-h	13.7±0.33bc	16.2±0.60f-h	26.3±0.8bc	0.015±0.003fg	0.035±0.003a-d
Dukat	42.3±0.9c	55.8±0.4a	7.07±0.07e-g	12.67±0.88bc	15.3±0.88f-h	23.0±1.15c-e	0.030±0.0c-e	0.042±0.002ab
Common	44.2±1.3bc	52.7±1.3a	8.00±0.23ef	17.0±0.58a	24.9±0.55b-d	34.87±3.09a	0.023±0.03ef	0.039±0.001a-c
Bouquet	30.0±0.6ef	50.0±0.6ab	6.00±0.00e-h	11.33±0.67cd	16.5±0.29e-g	29.3±0.67a-c	0.03±0.0c-e	0.043±0.002a
Elephant	32.0±1.5e	43.7±1.3c	6.67±0.33e-h	15.3±0.88ab	19.7±1.2d-f	30.3±1.86ab	0.032±0.002b-e	0.045±0.0a

*Numbers accompanied by different letters for each parameter are significantly different at $P \leq 0.05$ using two-way ANOVA.

Through the tables [1, 2] we can conclude that Common cultivar was the best in plant height, number of branches and herb fresh weight, while Elephant cultivar was the best in the essential oil percentage. On the other hand, Compact cultivar was least in plant height, number of branches, fresh herb weight and essential oil values.

From tables [1, 2], it is clear that the cultivar has a significant impact on studied characters like plant height, number of branches and herb fresh weight as well as volatile oil %. As it turned out that all studied characters were higher in the second harvest compared to the first harvest. Where there was an increase in plant height, number of branches and thus increasing the weight of the fresh herb as well as an increase in the volatile oil %.

The yield of dill was obtained just before the bolting of inflorescences, the growth stage that was suggested by Singh *et al.* [32], who found that the yield of the green mass of dill increased up to the commencement of inflorescence. At a plant height of 30 cm, a total yield of 138 kg/100 m^2 was previously recorded [33]. In a different experiment, the yields from plants in the phase of growth before the setting of umbels ranged from a few to about 300 kg/100 m^2 depending on the cultivar and site [34].

In another experiment, the yield from plants harvested at a height of 30-35 cm and 53-55 d after sowing, was 110-325 kg/100 m^2 [35]. Kmiecik *et al.* [36] reported that harvest at a height of 20, 30, 40, 50 and 60 cm led to an increase in the total and marketable yields with increasing height of plants. The content of volatile oils also increased. According to Buczkowska [37], the three-year mean yield of the green mass of dill was 197 kg/100 m^2. However, this author did not report the height of plants or the period from sowing to harvest.

Table 2: Plant height, branches number, fresh herb and essential oil % of the vegetative herb of different dill (*Anethum graveolens*) cultivars cultivated under Egyptian conditions at the second season

Cultivar	Plant height		Branches No.		Fresh herb (g/plant)		Essential oil%	
	1st cut	2nd cut	Ist cut	2nd cut	Ist cut	2nd cut	Ist cut	2nd cut
Local	29.3±0.67fg	53.7±0.67a	3.33±0.33f	13.67±0.67ab	10.2±0.44gh	20.7±0.67c-e	0.012±0.002g	0.03±0.002d-f
Compatto	25.9±1.95g	34.7±1.45c-f	3.0±0.58f	8.67±0.88cd	8.83±0.93h	11.7±1.20f-h	0.007±0.00g	0.022±0.001ef
Tetra	29.0±2.08fg	37.3±0.3b-e	5.33±0.33ef	10.3±0.33c	10.3±0.33gh	22.0±1.0b-e	0.020±0.00f	0.038±0.002ab
Vierling	33.9±1.04d-f	38.0±1.15b-d	6.33±0.33de	14.33±0.88ab	17.0±0.0d-f	24.9±1.58bc	0.012±0.002g	0.035±0.00a-c
Dukat	40.3±0.33bc	54.0±1.53a	6.83±0.17de	14.0±0.0ab	16.2±1.59e-g	24.7±2.4bc	0.030±0.0cd	0.040±0.00a
Common	44.6±1.45b	54.3±0.33a	7.07±0.07de	16.0±0.58a	22.7±0.33b-d	34.7±0.67a	0.028±0.002c-e	0.040±0.00a
Bouquet	31.7±0.67e-g	49.0±0.58a	6.33±0.33de	13.0±0.0b	17.67±1.2d-f	27.0±1.53b	0.032±0.002b-d	0.042±0.002a
Elephant	32.7±1.20d-f	41.0±0.6b	6.0±0.58e	14.0±0.58ab	18.0±0.58de	26.3±1.20bc	0.035±0.003a-c	0.042±0.002a

*Numbers accompanied by different letters for each parameter are significantly different at P ≤0.05 using two-way ANOVA.

GC/MS of essential oil

Genetic, physiological and environmental factors, as well as processing conditions, which are, may play an important role on essential oil quality [38-40]. However, dill essential oil quantity and chemical composition varies depending on various factors, such as climate, cultivar, seeding date, management practices, plant parts and the developing stage of the plant at harvest time [23, 24, 26]. The genetic variability had the major effect on essential oil constituents in a germplasm collection of dill [20].

The relative percentage of main constituents of the essential oil extracted from the herb before flowering stage (60 and 90 d after sowing) of the studied dill cultivars during the season of 2011/2012 and analyzed with GC-MS are shown in Tables [3-5]. The identified compounds of essential oil in both of harvests (60 and 90 d after sowing) were grouped into three items, i.e., major compounds (more than 10%), minor compounds (less than 10% and more than 1%) and trace ones (less than 1%).

It is evident that, α-phellandrene, limonene and dillapiole exhibited as majors of Local, Compatto, Common and Bouquet cultivars, whereas, α-phellandrene, limonene and myristicin were majors in Tetra, Vierling, Dukat and Elephant cultivars in the first harvest time (60 d. after sowing). At the second harvest time (90 d after sowing), α-phellandrene, limonene and dill ether were the major components in Local, Tetra, Vierling, Ducat and Common cultivars, while in Compatto, Bouquet and Elephant cultivars, α-phellandrene, limonene, p-cymene and dill ether were the major compounds.

Table 3: The main differences in major compounds (more than 10 %) of different studied dill cultivars essential oils

Compound	Cultivar							
	Local	Compatto	Tetra	Vierling	Dukat	Common	Bouquet	Elephant
	First harvest 60 d from sowing							
	%							
α-phellandrene	37.43	36.83	38.57	38.52	38.54	42.70	37.64	39.38
limonene	18.14	17.08	17.79	17.63	17.56	19.03	17.00	18.23
p-cymene	7.72	5.88	9.01	7.20	7.12	7.56	7.36	8.26
dill ether	2.27	2.24	7.04	7.40	5.36	6.73	6.89	6.63
myristcin	2.07	7.02	13.00	11.84	10.99	7.24	9.20	10.86
dillapiole	12.88	17.45	2.70	5.03	9.14	10.89	11.67	2.30
Second harvest, 90 d from sowing								
α-phellandrene	45.08	43.66	45.22	46.48	46.15	46.47	44.82	44.15
limonene	20.46	20.57	20.65	21.35	20.92	21.41	21.32	20.66
p-cymene	7.76	11.27	9.53	7.47	9.04	7.78	10.51	10.58
dill ether	12.26	15.53	10.73	14.64	13.36	17.57	16.35	14.63
myristcin	4.88	3.44	2.81	3.65	2.39	1.56	1.34	3.42
dillapiole	5.39	2.35	6.72	0.50	3.74	2.50	3.27	0.25

From table [3] it was obviously clear that *Anethum graveolens* cv. Common showed the highest % of α-phellandrene (42.70%) followed by cv. Elephant (39.38%), cv. Tetra (38.57%), cv. Ducat (38.54%), cv. Vierling (38.52%), cv. Bouquet (37.64%) and cv. Local (37.43%), then Compatto cultivar (36.83%) in the first harvest. Whereas, *Anethum graveolens* cv. Vierling showed the highest % of α-phellandrene (46.48%), followed by cv. Common (46.47%), cv. Dukat (46.15%), cv. Tetra (45.22%), cv. Local (45.08%), cv. Bouquet

(44.82%), cv. Elephant (44.15%), and then cv. Compatto (43.66%) in the second harvest.

As noted in table [3], the percentage of α-phellandrene, limonene and p-cymene was increased in the second harvest than the first harvest in all cultivars under study and vice dill ether and dillapiole, which decreased in the second harvest than the first harvest. Myristicin decreased in all European cultivars in the second harvest and exhibits adverse behavior in the local cultivar which increased in the second harvest than the first harvest. Common cultivar gave the highest % of α-phellandrene (42.70%) and limonene (19.03%) in the first harvest, and limonene (21.41%) and dill ether (17.57%) in the second harvest. Vierling cultivar gave the highest % of dill ether in the first and α-phellandrene in the second harvest. Tetra cultivar gave the highest % of p-cymene and myristicin in the first harvest and of dillapiole in the second harvest. Compatto cultivar gave the highest % of dillapiole and p-cymene in the first and second harvests, respectively. However, the highest % of dillapiole in the first harvest was obtained by local cultivar. On the other hand, Local cultivar gave the dill ether and myristicin in the first harvest and least % of limonene in the second harvest. Compatto cultivar gave the least % of α-phellandrene in the first and second harvests and p-cymene in the first harvest. Tetra and Vierling cultivars gave the least % of dill ether and p-cymene in the second harvest, respectively. Also, Bouquet gave the least % of limonene (17.00%) and myristcin in the first and second harvests, respectively. However, Elephant cultivar gave the least % of dillapiole (2.30 and 0.25%) in the first and second harvests, respectively. These results are in agreement with some previous results that indicated that the amount of aroma constituents of *Anethum graveolens* (whole herb) varied widely depending on harvesting time. Five major aroma compounds (α-phellandrene, β-phellandrene, limonene, p-cymene and dill ether) comprised together 65-80% of the total components identified in the essential oil of dill [41]. Furthermore, Huopalahti [18] found the main components of dill herb oil as α-phellandrene, myristicin, and limonene. Similarly, α-phellandrene, dill ether, myristicin, methyl 2-methylbutanoate and limonene were identified as the major compounds [42], while Benzofuranoid, α-phellandrene, β-phellandrene and p-cymene were the majors in another study [43]. The three major constituents in the dill herb oil were α-phellandrene, β-phellandrene and dill ether in the herb oil [20]. α-phellandrene, dill ether, β-myrcene and (z)-dihydrocarvone [16] As well as α-phellandrene (31.8 %), dill apiole (15.3 %), dill ether (13.2 %), limonene (11.8 %), geraniol (10.6 %) and p-cymene (5.3 %) [44] were identified as the major compounds in the dill essential oil. In the aerial parts, dill ether and p-cymene were the major components of the oils [45].

Previous results reported regarding the herb oil composition revealed differences in the main compounds in which α-phellandrene, dill ether, limonene and p-cymene [3]; β-camphene, β-pinene, anethole, ionone, umbelliferone and carvone [46]; α-phellandrene, myristicin, dill ether, β-phellandrene and limonene [9]; α-phellandrene, β-phellandrene, dill ether, α-pinene, β-pinene, α-thujene, myrcene and p-cymene [47]; trans-dihydrocarvone, dill ether, α-phellandrene and limonene [48]. Radulescu *et al.* [26] found that the main components in dill were α-phellandrene, limonene and anethofuran in Romania. Santos *et al.* [1] reported α-phellandrene, dillapiole, and myristicin as the main components of dill herbage oil. Jana and Shekhawat [49] noticed that α-phellandrene, limonene, dill ether, myristicin were the predominant odorant of dill herb in India. Blank and Grosch [50] and Bonnlander and Winterhalter [51] reported that α-phellandrene, dill ether, and myristicin are the compounds, which form the important odor of dill herb. These results indicate that different chemotypes of dill are existing in dill populations, which are widely influenced with both the genetic variation and the environmental conditions.

Table 4: The main differences in minor compounds (less than 10%) in the essential oil of different dill cultivars

Compound	Cultivar							
	Local	Compatto	Tetra	Vierling	Ducat	Common	Bouquet	Elephant
	First harvest 60 d from sowing							
	%							
nonane	1.00	0.46	0.29	0.54	0.59	0.32	0.38	0.36
α-pinene	4.42	1.88	4.04	3.92	4.11	3.28	3.54	4.42
β-thujene	1.26	0.44	1.19	1.19	1.19	0.88	0.96	1.39
β-pinene	6.57	3.04	1.75	0.62	1.99	1.05	1.37	1.51
undecane	4.84	3.92	2.61	4.39	2.67	2.50	2.85	2.05
α-ocimene	0.99	5.75	3.58	4.12	4.32	4.00	3.20	3.16
α-terpinolene	1.37	2.43	4.62	2.23	2.49	1.14	2.66	2.96
α-cubebene	2.14	1.22	0.58	0.93	0.65	0.72	1.28	0.68
anethole	-	0.37	0.27	-	-	0.20	-	4.66
Second harvest, 90 d from sowing								
nonane	0.10	0.09	0.15	-	0.11	0.07	-	-
α-Pinene	5.40	5.10	4.31	5.60	6.14	4.60	5.23	5.64
β-thujene	1.71	1.47	1.11	1.74	1.38	1.57	1.48	1.72
β-Pinene	0.78	0.45	0.94	0.67	0.74	0.66	0.68	0.59
undecane	1.26	0.65	0.70	1.27	0.50	1.01	0.66	0.95
α-ocimene	1.32	0.61	1.41	1.06	0.72	1.00	0.10	0.76
α-terpinolene	0.80	0.79	1.07	1.54	0.96	0.89	0.87	0.77
α-cubebene	0.82	0.92	1.13	0.79	0.62	0.49	1.60	0.85
1-hexadecanol, 2-methyl	0.44	0.47	1.24	0.71	0.80	0.43	0.12	0.96

In table [4], compounds were represented as minors (less than 10% and more than 1%). Also, table [4] showed that α-pinene and β-thujene increased in the second harvest compared to the first harvest, and the highest % of α-pinene (4.42 and 6.14%) was obtained by Elephant and local cultivars in the first and second harvests, respectively and Local cultivar gave the highest % of β-thujene (1.39% and 1.72%) in the first and second harvests. Nonane, β-pinene, undecane, α-ocimene, α-terpinolene and α-cubebene contents decreased in the second harvest more than the first harvest. Local cultivar gave the highest % of nonane, β-pinene, undecane and α-cubebene in the first harvest, and in the second harvest, tetra cultivar gave the highest % of α-cubebene and β-pinene and Vierling cultivar gave the highest % of undecane and the highest % of nonane was obtained by Ducat cultivar. Compatto and Local cultivars gave the highest % of α-ocimene (5.75% and 1.32%) in the first and second harvests, respectively. Also, the highest % of α-terpinolene (4.62%) in the first harvest and (1.54%) in the second harvest was obtained by Tetra and Vierling cultivars, respectively. It was also noted that, anethole compound presented in Compatto, Tetra, Common and Elephant cultivars in the first harvest only, and disappeared in all cultivars at the second harvest. Elephant cultivar gave the highest % of anethole (4.66%). Conversely, 1-

Hexadecanol,2-methyl existed only in the second harvest in all cultivars and Tetra cultivar gave the highest % (1.24%). This conforms the idea that the accumulation of essential oil compounds is genetically controlled in specific tissues at certain phonological stage. Interaction been environmental conditions with the genetic factors determines the makeup of the essential oil, and therefore the chemo type dominating in particular location.

Table 5: The main differences in trace compounds (less than 1%) in the essential oil of different dill cultivars

Compound	Cultivar							
	Local	Compatto	Tetra	Vierling	Ducat	Common	Bouquet	Elephant
	First harvest 60 d from sowing							
	%							
2,4-hexadienal	-	-	-	-	**0.11**	-	-	**0.08**
camphene	0.17	-	0.13	0.13	0.13	0.09	0.11	0.15
hexanal	0.15	-	0.09	0.16	0.10	-	0.07	0.09
α-terpinene	0.15	0.10	0.11	0.12	0.10	0.14	0.09	0.12
2-hexenal	0.35	0.22	**0**.28	0.37	0.15	0.12	0.27	0.24
ç-terpinene	0.20	0.22	0.16	0.19	0.14	0.13	0.16	0.41
cumene	0.95	0.50	0.88	0.94	0.58	0.58	0.49	0.58
tridecane	0.52	0.57	0.25	0.41	0.18	0.27	0.28	0.13
nonanal	0.27	0.16	0.08	0.09	0.08	0.07	0.07	0.15
α-fenchyl acetate	0.61	0.22	0.11	0.12	0.17	0.15	0.13	0.08
α-bourbonene	0.17	-	-	-	-	-	-	-
linalool	-	-	-	-	0.10	-	0.10	-
α terpineol	0.34	0.09	0.20	0.26	0.17	0.15	0.21	0.22
α-elemene	0.32	-	-	-	-	-	-	-
dihydrocarvone	0.18	-	-	-	-	-	-	-
trans-caryophyllene	0.17	-	-	-	-	-	-	-
carvone	0.43	0.18	0.22	0.32	0.25	0.24	0.34	-
2-methylnaphthalene	0.22	0.19	0.24	0.25	0.12	0.07	0.12	0.12
p-mentha-2,8-dien-1-ol	-	-	0.08	-	-	-	0.08	-
limonene dioxide	-	-	-	-	-	-	-	0.10
sabinyl acetate	-	-	-	-	-	0.06	0.10	-
α-ionone	-	0.12	-	-	-	0.05	-	-
p-methylbenzyl alcohol	0.16	0.10	0.14	-	0.08	-	-	0.37
globulol	0.62	0.46	0.31	0.47	0.23	0.26	0.46	0.21
2-octadecenal	-	-	-	0.16	-	-		-
1-tetradecanol	-	0.13	-	-	-	0.07	0.10	-
Second harvest, 90 d from sowing								
2,4-hexadienal	-	0.08	-	-	0.17	0.11	-	0.12
camphene	0.17	0.16	0.13	0.18	0.15	0.19	0.16	0.18
hexanal	0.07	0.07	-	0.08	0.12	0.09	0.06	-
α-terpinene	0.12	0.11	0.10	0.14	0.10	0.13	0.12	0.11
2-hexenal	0.10	0.11	0.10	0.15	0.24	0.20	0.22	0.28
ç-terpinene	0.20	0.23	0.29	0.30	0.18	0.20	0.26	0.22
nonanal	0.31	0.29	0.38	0.46	0.59	0.33	0.18	0.43
α-terpineol	0.25	0.22	0.08	0.20	0.12	0.30	0.37	0.17
sabinyl acetate	0.14	0.30	0.13	0.26	0.20	0.52	0.12	0.35
α-elemene	-	-	-	-	-	-	0.28	-
carvone	-	0.12	0.18	0.13	-	-	-	-
limonene dioxide	-	-	0.24	0.27	0.12	0.21	0.07	-
cis carvone oxide	-	-	-	-	-	-	-	0.58
p-menth-1-en-9-ol	-	0.14	-	-	-	0.21	-	0.25
α-ionene	-	0.25	0.12	-	0.28	-	-	-
α-terpinyl acetate	0.11	-	0.14	-	0.11	0.15	0.09	-
bicyclopentyl-1,1-diene	-	-	0.35	0.09	-	-	0.06	-
1-phenyl-2-pentanol	-	-	-	-	-	0.42	-	-
carvacrol	-	0.15	0.29	-	-	-	0.06	0.12
1-hexadecanol	0.28	0.29	-	0.51	-	-	0.06	0.55
3-octadecenal	0.07	0.10	-	-	-	-	-	-
1-docosanol	0.44	0.47	-	-	-	-	0.12	-
p-methylbenzyl alcohol	-	-	0.07	0.16	0.38	-	-	0.28
globulol	0.09	0.21	0.14	0.13	0.11	0.13	0.25	
2-octadecenal	-	0.10	-	-	-	-	-	-
1-tetradecanol	-	-	0.14	0.07	-	-	-	-

Other compounds were considered as traces, such as 2,4-hexadienal; camphene; hexanal; α-terpinene; 2-hexenal; ç-terpinene; cumene; tridecane; nonanal; α-fenchyl acetate; α-bourbonene; linalool; α-terpineol; α-elemene; dihydrocarvone; trans-caryophyllene; carvone; 2-methylnaphthalene; p-mentha-2,8-dien-1-ol; limonene dioxide; sabinyl acetate; α-ionone; p-methylbenzyl alcohol; globulol; 2-octadecenal and 1-tetradecanol in the first harvest. In the second harvest, 2,4-hexadienal; camphene; hexanal; α-terpinene; 2-hexenal; ç-terpinene; nonanal; α-terpineol; sabinyl acetate; α-elemene; carvone; limonene dioxide; cis carvone oxide; p-menth-1-en-9-ol; α-ionene; α-terpinyl acetate; bicyclopentyl-1,1-diene; 1-phenyl-2-pentanol; carvacrol; 1-hexadecanol; 3-octadecenal; 1-docosanol; p-methylbenzyl alcohol; globulol; 2-octadecenal and 1-tetradecanol were considered as traces[5].

In our study, results of GC/MS analysis of the essential oil obtained from eight dill cultivars in the two harvests revealed both qualitative and quantitative changes. The major compounds were as follows: α-phellandrene>limonene>dill apiol (*Anethum graveolens* cvs. Local, Compatto, Common and Bouquet); α-phellandrene> limonene> myristcin (*Anethum graveolens* cvs. Tetra, Vierling, Dukat, Elephant) in the first harvest. α-phellandrene>limonene>dill ether (*Anethum graveolens* cvs. Local, Tetra, Vierling, Ducat and Common); α-phellandrene>limonene>p-cymene>dill ether (*Anethum graveolens* cvs. Compatto, Bouquet and Elephant) in the second harvest. These differences are mainly attributed to the genetic variation, but there are other factors, which may potentially affect the essential oil percentage determined, such as the extraction method employed [52], the age and organ of the plant used for study and the environmental conditions under which the plants have been grown[53-55].

The plant cultivars used for the present study were all of the same age (vegetative stage), they were grown under the same conditions, and the same organs (herbs) were extracted, and the age (60 and 90 d after sowing), so that the results are comparable, and differences in chemical profiles should reflect genetical differences between the various cultivars. Based on Grayer *et al.* [56] study, and our study, the chemotypes can be summarized as shown in table (3): chemotype 1) α-phellandrene in all eight dill cultivars at the first harvest (60 d after sowing) and chemotype 2) α-phellandrene and limonene in all eight dill cultivars at the second harvest (90 d after sowing). Classification of dill cultivars based on the accumulation of specific components could be an important approach for phytotaxonomy. In addition, studying the composition of essential oil enables the identification of marker compounds that are responsible for exerting the characteristic aroma of dill.

CONCLUSION

It may be concluded from this study that European cultivars have better performance than the Local cultivar under Egyptian conditions; therefore, their cultivation is recommended and represents a promising cash crop for growers. Among all cultivars studied, Common cultivar was more superior in growth characters, herb fresh weight (g/plant), essential oil content and the percentages of α-phellandrene, limonene and dill ether. This study also has demonstrated that the date of cut influenced the profile of the metabolites in the essential oil of dill. These qualitative changes presumably affect the quality of essential oil obtained from each cultivar and could be valuable in tailoring the use a particular cultivar in certain applications in cosmetic or culinary industries.

CONFLICT OF INTERESTS

Declared none

REFERENCES

1. Santos PAG, Figueiredo AC, Lourenco PML, Barroso JG, Pedro LG, Oliveira MM, *et al.* Hairy root cultures of *Anethum graveolens* (dill): establishment, growth, time course study of their essential oil and its comparison with parent plant oils. J Biotechnol Lett 2002;24:1031-6.
2. Huopalahti R, Lahtinen R, Hiltunen R, Laakso I. Studies on the essential oils of dill herb, *Anethum graveolens* L. Flavour Fragrance J 1988;3:121-5.
3. Vera RR, Chane-Ming J. Chemical composition of essential oil of dill (*Anethum graveolens* L.) Growing in Reunion Island. J Essent Oil Res 1998;10:539-42.
4. Babri RI, Khokhar ZM, Mahmud S. Chemical composition and insecticidal activity of the essential oil of *Anethum graveolens.* l Sci Int 2012;24:453-5.
5. Ferrie AMR, Bethune TD, Arganosa GC, Waterer D. Field evaluation of doubled haploid plants in the Apiaceae: dill (*Anethum graveolens* L.), caraway (*Carum carvi* L.), and fennel (*Foeniculum vulgare* Mill.). Plant Cell Tissue Organ Cult 2011;104:407-13.
6. Singh G, Maurya S, Lampasona MP, Catalan C. Chemical constituents, antimicrobial investigations and antioxidative potentials of *Anethum graveolens* L. essential oil and acetone extract. J Food Sci 2005;70:208-15.
7. Zeng H, Tian J, Zheng Y, Ban X, Zeng J, Mao Y, *et al. In-vitro* and *in-vivo* activities of essential oil from the seed of *Anethum graveolens* L. against *Candida* spp. J Evidence Based Complementary Altern Med 2011:1-8. doi.org/ 10.1155/ 2011/659704. [Article in Press]
8. Jianu C, Misca C, Pop G, Rusu C, Ardelean L, Gruia AT. The chemical composition of the essential oil obtained from dill (*Anethum graveolens* L.) grown in Western Romania. Rev Chim 2012;6:641-5.
9. Vokk R, Lõugas T, Mets K, Kravets M. Dill (*Anethum graveolens* L.) and parsley (*Petroselinum crispum* (Mill.) Fuss) from Estonia: seasonal differences in essential oil composition. Agron Res 2011;9:515-20.
10. Yili A, Aisa HA, Makshimov VV, Veshkurova ON, Salikhov SI. Chemical composition and antimicrobial activity of the essential oil from seeds of *Anethum graveolens* growing in Uzbekistan. Chem Nat Compd 2009;45:280-1.
11. Mahmoodi A, Roomiani L, Soltani M, Basti AA, Kamali A, Taheri S. Chemical composition and antibacterial activity of the essential oils and extracts from *Rosmarinus officinalis, Zataria multiflora*, *Anethum graveolens* and *eucalyptus globulus.* Global Vet 2012;9:73-9.
12. Yazdanparast R, Alavi M. Antihyperlipidaemic and antihypercholesterolaemic effects of *Anethum graveolens* leave after the removal of furocoumarins. Cytobios 2001;105:185-91.
13. Baylac S, Racine P. Inhibition of 5-lipoxygenase by essential oils and other natural fragrant extracts. Int J Aromather 2003;13:138-42.
14. Sivropoulou A, Kokkini S, Lanaras T, Arsenakis M. Antimicrobial activity of mint essential oils. J Agric Food Chem 1995;43:2384-8.
15. Wei A, Shibamoto T. Antioxidant/lipoxygenase inhibitory activities and chemical compositions of selected essential oil. J Agric Food Chem 2010;58:7218-25.
16. Pino JA, Rosado A, Goire I, Roncal E. Evaluation of characteristic flavor compounds in dill herb essential oil by sensory analysis and gas chromatography. J Agric Food Chem 1995;43:1307-9.
17. Callan W, Johnson DL, Westcott MP, Weity LE. Herb and oil composition of dill (*Anethum graveolens* L.): effect of crop maturity and plant density. Ind Crops Prod 2007;25:282-7.
18. Huopalahti R. Gas chromatoaphic and sensory analyses in the evaluation of the aroma of dill herb *Anethum graveolens* L. Lebensm Wiss U Technol 1986;19:27.
19. Brunkea EJ, Hammerschmidta FJ, Koestera FH, Maira P. Constituents of dill (*Anethum graveolens* L.) with sensory importance. J Essent Oil Res 1991;3:257-67.
20. Charles DJ, Simon JE, Widrlechner MP. Characterization of essential oil of dill (*Anethum graveolens* L.) J Essent Oil Res 1995;7:11-20.
21. Kruger H, Hammer K. A new chemotype of *Anethum graveolens* L. J Essent Oil Res 1996;8:205-6.
22. Badoca A, Lamartib A. A Chemotaxonomic evaluation of *Anethum graveolens* L. (dill) of various origins. J Essent Oil Res 1991;3:269-78.
23. Faber B, Bangert K, Mosandl A. GC-IRMS and enantioselective analysis in biochemical studies in dill (*Anethum graveolens* L.). Flavour Fragrance J 1998;12:305-7.
24. Yili A, Yimamu H, Maksimov VV, Aisa HA, Veshkurova ON, Salikhov SI. Chemical composition of essential oil from seeds of *Anethum graveolens* cultivated in China. Chem Nat Compd 2006;42:491-2.
25. Tibaldi G, Fontana E, Nicola S. Influence of maturity stage at harvest on essential oil composition of dill leaves (*Anethum graveolens* L.) and of postharvest treatments on freshness of fresh-cut dill. Acta Horticulturae 880: International symposium postharvest pacifica 2009-pathways to quality: V International symposium on managing quality in Chains+Australasian postharvest horticultural conference; 2009.
26. Radulescu V, Popescu ML, Ilies D. Chemical composition of the volatile oil from different plant parts of *Anethum graveolens* L. (Umbelliferae) cultivated in Romania. Farmacia 2010;58:594-600.
27. Hajhashemi V, Abbasi N. Hypolipidemic activity of *Anethum graveolens* in rats. Phytother Res 2008;22:372-5.

28. Wall DA, Friesen GH. The effect of herbicides and weeds on the yields and composition of dill (*Anethum graveolens* L.) oil. Crop Prot 1986;5:137-42.
29. Said-Al Ahl HAH. Physiological studies on growth, yield and volatile oil of dill (*Anethum graveolens*). Ph. D. Thesis, Fac. Agric., Cairo Univ., Cairo, Egypt; 2005.
30. Jackson ML. Soil chemical analysis prentice-Hall of India; 1973.
31. British Pharmacopoeia. British approved names. A dictionary of drug names for regulatory use in the UK. Stationary office press: London, UK; 2002.
32. Singh A, Randhawa GS, Mahey RK, Singh A. Growth and yield of dill (*Anethum graveolens* L.) as affected by nitrogen and harvesting stages. Crop Res Hisar 1993;6:217-21.
33. Halva S. Studies on production techniques of some herb plants: II. Row spacing and cutting height of dill herb (*Anethum graveolens* L.). J Agric Sci Finl 1987a;59:37-40.
34. Halva S. Yield and aroma of dill varieties (*Anethum graveolens* L.) in Finland. Acta Agric Scand 1987b;37:329-34.
35. HaLva S, Puukka L. Studies on fertilization of dill (*Anethum graveolens* L.) and basil (*Ocimum basilicum* L.) I. Herb yields of dill and basil affected by fertilization. J Agric Sci Finl 1987;59:11-7.
36. Kmiecik W, Lisiewska Z, Słupski J. Relationship between the yield and quality of green dill and the height of plants. Folia Horticultuae Ann 2005;17:37-52.
37. Buczkowska H. Usefulness of a slidable foil tunnel in accelerated vegetable growing. Acta Hortic 1994;371:297-304.
38. Hay RKM. Physiology. In: Volatile oil crops: Their biology, biochemistry and production. Hay RKM, Waterman PG. eds. Longman Scientific and Technical, Harlow; 1993.
39. Hay RKM, Svoboda KP. Botany. In: Volatile oil crops: their biology, biochemistry and production. Hay RKM, Waterman PG. eds. Longman Scientific and Technical, Harlow; 1993.
40. Lawrence BM. Commercial essential oils: Truths and consequences. In: Advances in flavours and fragrances: From the sensation to the synthesis. Swift KAD. ed. Royal Society of Chemistry RSC, Cambridge; 2002.
41. Huopalahti R, Linko RR. Composition and content of aroma compounds in dill, *Anethum graveolens* L., at three different growth stages. J Agric Food Chem 1983;31:331-3.
42. Blank I, Sen A, Grosch W. Sensory study on the character-impact flavour compounds of dill herb (*Anethum graveolens* L.). Food Chem 1992;43:337-43.
43. Halva S, Craker LE, Simon JE, Charles DJ. Light quality, growth, and essential oil in dill (*Anethum graveolens* L.). J Herbs Spices Med Plants 1992;1:59-69.
44. Rana VS, Blazquez MA. The chemical composition of the essential oil of *Anethum graveolens* aerial parts. J Essent Oil-Bear Plants 2014;17:1219-23.
45. Abdelkader MSA, Lockwood GB. Essential oils from the plant, hairy root cultures and shoot cultures of Egyptian *Anethum graveolens* (dill). J Essent Oil Res 2015;27:1-9.
46. Dhalwal K, Shinde VM, Mahadik KR. An efficient and sensitive method for quantitative determination and validation of umbelliferone, carvone and myristcin in (*Anethum graveolens* L.) and (*Carum carvi* L.) seed. India J Chrom 2008;67:163-7.
47. Tsamaidi D, Karapanos IC, Passam HC, Daferera D, Polissiou M. The yield and composition of dill essential oil in relation to N application, the season of cultivation and stage of harvest. ISHS Acta Horticulturae 936: XXVIII International horticultural congress on science and horticulture for people (IHC2010): International symposium on quality-chain management of fresh vegetables: From Fork to Farm; 2010.
48. Sharapov FS, Wink M, Gulmurodov IS, Isupov SJ, Zhang H, Setzer WN. Composition and bioactivity of the essential oil of *Anethum graveolens* L. from Tajikistan. Med Aroma Plants 2013;3:125-30.
49. Jana S, Shekhawat GS. *Anethum graveolens* an Indian traditional medicinal herb and spice. Pharmacogn Rev 20104;8:179-84.
50. Blank I, Grosch W. Evaluation of potent odorants in dill seed and dill herb (*Anethum graveolens* L.) by aroma extract dilution analysis. J Food Sci 1991;56:63-7.
51. Bonnlander B, Winterhalter P. 9-Hydroxypiperitone beta-D-glucopyranoside and other polar constituents from dill (*Anethum graveolens* L.) herb. J Agric Food Chem 2000;48:4821-5.
52. Charles DJ, Simon JE. Comparison of extraction methods for the rapid determination of essential oil content and composition of basil (*Ocimum* spp.). J Am Soc Hortic Sci 1990;115:458-62.
53. Singh RS, Bordoloi DN. Changes in the linalool and methyl cinnamate amount in a methyl cinnamate-rich clone of *ocimum basilicum* at different growth stages. J Essent Oil Res 1991;3:475-6.
54. Bonnardeaux J. The effect of different harvesting methods on the yield and quality of basil oil in the Ord River irrigation area. J Essent Oil Res 1992;4:65-9.
55. Werker E, Putievsky E, Ravid U, Dudai N, Katzir I. Glandular hairs and essential oil in developing leaves of *ocimum basilicum* L. (Lamiaceae). Ann Bot 1993;71:43-50.
56. Grayer RJ, Kite GC, Goldstone FJ, Bryan SE, Paton A, Putievsky E. Infraspecific taxonomy and essential oil chemotypes in sweet basil, *ocimum basilicum*. Phytochemistry 1996;43:1033-9.