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Comparative Chemical Composition of Essential Oils in Dill (*Anethum graveolens* L.) Ecotypes: Focus on Univariate and Factor Analysis

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Abstract
Anethum graveolens L. is a vegetable-aromatic medicinal herb of Apiaceae family and cultivated in different parts of the world including Iran. The aim of this study was to study the chemical composition of essential oils in four Iranian dill ecotypes. The extracted essential oils compositions were different in the ecotypes so that 38, 27, 25, and 24 volatile constituents were identified in Ardabil, Isfahan, Mashhad, and Kerman ecotypes, respectively. Eighteen compounds such as Toluene, α-thujene, camphene, sabinene, β-pinene, β-myrcene, α-phellandrene, α-terpinene, β-phellandrene, undecane, sabinol, dill ether, carvacrol, germacrene D, dill apiole, neophytadiene, hexahydrofarnesyl acetone, and phytol were recognized in all ecotypes but in different amounts. Analysis of variance showed the significancy of α-thujene, β-pinene, β-myrcene, α-phellandrene, β-phellandrene, undecane, dill ether, sabinol, germacrene D, dill apiole, neophytadiene, and hexahydrofarnesyl acetone at 0.001 probability levels. Means comparison of significant compounds showed highest mean values for β-pinene, undecane, germacrene D, neophytadiene, hexahydrofarnesyl acetone, and phytol in Ardabil ecotype; α-thujene, β-myrcene, β-phellandrene, and dill ether in Mashhad ecotype; and α-phellandrene, sabinol, and dill apiole in Kerman ecotype. Factor analysis indicated that three main and independent factors accounted for 100% of the total variance. The first, second, and third factors with 47.5, 31.9, and 20.63 % of variance included 9, 6, and 4 compounds, respectively. The knowledge of essential oil compositions of the studied ecotypes could be useful to choose the appropriate for breeding purposes based on phytochemical diversity or for use in pharmaceutical and food industries for extraction of special compounds.

Keywords: Carvacrol, dill apiole, dill ether, germacrene D, α-phellandrene, β-phellandrene.

Introduction

Apiaceae family is one of the most important plant genetic resources and are among the top plant families due to their rich aromatic compounds and valuable medicinal plant species (Armand and Jahantab, 2019). *Anethum* has many species and dill (*Anethum graveolens* L.) is the only one that is cultivated as edible vegetable in Iran (Mozafarian, 1996). The dill is native to southwest Asia or southeast Europe (Bailer et al., 2001; Tian et al., 2011) but is widely cultivated around the world. This medicinal vegetable contains volatile essential oils that vary in different organs, different climatic

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conditions, and different ecotypes. It has been shown that the amounts of essential oil gradually increase since the beginning of flowering and reach a peak at the flowering stage and then gradually decrease in *Anethum graveolens* (Hornok, 1992: Bailer et al., 2001). The highest percentage of essential oils has been found in mature seeds (2 to 5 and maximum 7.5%) and the lowest in stem (0.1 to 0.5%). Flowers also contain a high percentage of essential oils (Hornok, 1980). Leaves and seeds of dill are used as an edible part. Although, all parts of the plant contain essential oils, the amount in the mature seeds is higher than the vegetative organs (Omid beige, 2007). According to the previous studies, the compounds such as α-phellandrene, limonene, dill ether, carvone, and *trans*-dihydrocarvone make up more than 95% of the Iranian dill ecotype (Sefidkon, 2001). But in general, the most important constituents of essential oils in the vegetative parts were D-carvone and α-phellandrene, while the most important constituents of the essential oils from mature seeds were D-carvone and limonene (Duke, 2001). Dill have antifungal (Tian *et al.*, 2012; Weisany et al., 2019), antibacterial (Soylu et al., 2009; Salehiarjmand et al., 2014; Tanruean et al., 2014; Ruangamnart et al., 2015), diabetes control (Goodarzi et al., 2016), antioxidant (Tanruean et al., 2014; Kazemi, 2015; Li et al., 2018; Wasli et al., 2018; Hajimohammadi and Khalaji-Verjani, 2019; Kaur et al., 2019), antimicrobial (Yili et al., 2009; Jianu et al., 2012; Roomiani et al., 2013; Kazemi, 2015), hypolipidemic (Hajhashemi and Abbasi, 2008), antigiardial (Sahib et al., 2014), and anti-inflammatory activities (Naseri et al., 2012; Kazemi, 2015). Growth of medicinal plants like other crops is influenced by environmental and genetic factors (Yousefi and Jaimand, 2018; Etehadpour et al., 2019; Reaisi et al., 2019) and maximum yield is obtained when appropriate combination of these factors is provided (Rassam et al., 2006). Identifying native ecotypes and studying their phytochemical components are useful and effective for selecting, oil extraction and breeding of this plant.

Therefore, the main purpose of this study was to investigate the phytochemical diversity of dill ecotypes, which can be useful for identifying quantitative and qualitative chemical compositions of the essential oils and establishing research areas in food and pharmaceutical industries.

Materials and Methods

Growing, caring, harvesting, and essential oils extraction

In this study, the seeds of four Iranian dill ecotypes were collected from Kerman, Esfahan, Ardabil, and Mashhad provinces, Iran (Table 1), and tested for germination vigor. After selections, seeds were cultivated under Ardabil climate conditions in June-July in 2018 with the soil characteristics listed in Table 2. Average annual rainfall, average annual minimum temperature, average annual maximum temperature, average annual temperature, average annual relative humidity, and the average number of frosty days in this experimental farm were 303.4 mm, 3 °C, 15.1 °C, 9 °C, 70 %, and 127 days, respectively. Irrigation was done twice a week until the plant samples had reached the flowering stage (in the final stages of flowering times) (Fig. 1). Then, the leaves with flowers were separated from the stem and dried at ambient temperature (25 ˚C) in the shade and away from direct sunlight. Subsequently, dried samples were grinded and prepared for essential oils extraction. Hydro-distillation method was used for essential oils extraction in a Clevenger apparatus (Bailer et al., 2001) for 4 hours. After extraction of the essential oils, the excess water was dehydrated by using sodium sulfate and stored in dark glass containers and injected in GC/MS with three replicates. Then, individual components were identified by retention indices and compared with constituents known from the literatures (Adams, 1995; and NIST WebBook (https://webbook.nist.gov)).

Table 1. Geographical characteristics of collected dill (*Anethum graveolens* L.) ecotypes used in this study

Collection site	Latitude	Longitude	Elevation (m)
Ardabil	38˚15'13"	48˚17'56"	1348
Esfahan	32˚39'22"	51 ˚40'19"	1580
Kerman	30˚16'53"	57 ˚05'11"	1764
Mashhad	36˚15'56"	59 ˚36'39"	982

Table 2. Soil characteristics of experimental farm used for growing dill (*Anethum graveolens* L.) ecotypes in this study

Factor	Unit	Amount	Test
EC	ds/m	2.38	Electrical Conductivity
pH	-	6.85	Electrometric
Sand	%	43.2	Pipette method
Silt	%	43.1	Pipette method
Clay	%	13.7	Pipette method
Texture	-	Loam	Pipette method
Fe	mg/kg	4.8	Atomic Absorption

Fig. 1. Cultivated dill (A *Anethum graveolens* L.) ecotypes in the field and their different growth stage.

Device specifications and essential oils analysis

After essential oils extraction from four ecotypes with three replications, analysis of its chemical constituents was done by Gas Chromatography-Mass Spectrometry (Agilent 7890B series GC-Agilent 5977A Series MSD). The MSD was equipped with an EI ionization system and its Single Quadrupole analyzer. It also has a Triple-Axis Detector (EMP) with very low Noise and Drift to achieve high sensitivity. The chromatography column was HP-5MS (30 m×0.25 mm×0.25 µm) (Narrobore). Essential oils analysis was performed by Helium gas as carrier (1 mL/min) in a gas chromatograph equipped with an injector (1 µL). The essential oil components were identified by Wiley and NIST library data and were analyzed under the same conditions as the essential oils of the ecotypes to calculate the Retention Index of each compound.

Statistical analysis

The essential oil constituents of dill ecotypes with different values are given in Table 3. Because the data are in percentage, the geometric mean was used for all replicates. The experimental design was randomized complete block design (RCBD) with three replicates and GLM procedure of SAS was used to analysis of variance (ANOVA). The assumptions of ANOVA were tested by insuring that the residuals were random and homogenous. Differences among means were determined using the Least Significant Difference (LSD) test at the 0.05 probability levels. Factor analysis was carried out in SPSS version 16 software. For separation of factors, factor rotation and the Varimax method were used. Factor loading values higher than 0.6 were considered significant in main and independent factors.

Results

In this study, a total of 39 volatile compounds were detected, that varied qualitatively and quantitatively in the studied ecotypes. In general 38, 27, 25, and 24 volatile compounds were identified in Ardabil, Isfahan, Mashhad and Kerman ecotypes, respectively. Dodecane, β-damascenone, β-selinene, Germacrene B, Eicosane, and Heneicosane were identified only in Ardabil ecotype (Table 3). Essential oil yield (v/w %) was varied among ecotypes (Table 3).

Table 3. Chemical composition of essential oils in Iranian dill (*Anethum graveolens* L.) ecotypes ± standard error (SE)

Nob.	Compounds	Formula	RI	Kerman (%)	Esfahan (%)	Ardabil (%)	Mashhad (%)
1	Toluene	C_7H_8	773	0.04±0.003	0.03±0.005	0.04±0.008	0.05±0.008
2	Octane	C_8H_{18}	800	-	0.09±0.003	0.41±0.008	-
3	α-thujene	$C_{10}H_{16}$	930	0.59±0.008	0.56±0.005	0.56±0.003	0.63±0.005
4	α-pinene	$C_{10}H_{16}$	939	3.05±0.006	-	-	3.12±0.008
5	Camphene	$C_{10}H_{16}$	951	0.06±0.005	0.07±0.005	0.07±0.004	0.07±0.003
6	Sabinene	$C_{10}H_{16}$	975	0.22±0.008	0.21±0.006	0.21±0.006	0.24±0.014
7	β-pinene	$C_{10}H_{16}$	979	0.21±0.008	0.22±0.006	0.29±0.005	0.22±0.005
8	β-myrcene	$C_{10}H_{16}$	992	0.81±0.006	0.78±0.005	0.79±0.003	0.84±0.01
9	α-phellandrene	$C_{10}H_{16}$	1002	57.49±0.005	55.51±0.012	52.88±0.005	44.44±0.014
10	α-terpinene	$C_{10}H_{16}$	1017	0.12±0.011	0.12±0.008	0.11±0.011	0.13±0.008
11	*p*-cymene	$C_{10}H_{14}$	1024	8.34±0.005	-	9.87±0.012	-
12	o-cymene	$C_{10}H_{14}$	1026	-	9.31±0.008	0.43±0.008	9.37±0.003
13	β-phellandrene	$C_{10}H_{16}$	1029	14.02±0.008	14.07±0.006	12.95±0.008	14.47±0.017
14	*Cis*-ocimene	$C_{10}H_{16}$	1037	-	0.05±0.005	0.05±0.005	0.04±0.006
15	*Trans*-β-ocimene	$C_{10}H_{16}$	1048	0.04±0.006	0.04±0.003	0.06±0.008	-
16	γ-terpinene	$C_{10}H_{16}$	1059	0.07±0.008	0.06±0.003	0.06±0.005	-
17	Undecane	$C_{11}H_{24}$	1100	0.07±0.005	0.07±0.008	0.16±0.008	0.05±0.008
18	Nonanal	$C_9H_{18}O$	1102	-	-	0.04±0.006	0.03±0.006
19	1-Terpineol	$C_{10}H_{18}O$	1133	0.08±0.003	-	0.06±0.003	0.09±0.017
20	Sabinol	$C_{10}H_{16}O$	1149	0.38±0.011	0.1±0.018	0.08±0.008	0.28±0.008
21	Dill ether	$C_{10}H_{16}O$	1186	6.2±0.088	5.78±0.011	3.73±0.014	7.86±0.016
22	Dodecane	$C_{12}H_{26}$	1200	-	-	0.05±0.014	-
23	Carvacrol	$C_{10}H_{14}O$	1299	0.29±0.008	0.34±0.008	0.33±0.098	0.3±0.026
24	Cinnamyl alcohol	$C_9H_{10}O$	1304	-	0.32±0.005	0.07±0.006	-
25	β-damascenone	$C_{13}H_{18}O$	1364	-	-	0.07±0.008	-
26	β-elemene	$C_{15}H_{24}$	1394	-	0.14±0.006	0.25±0.005	-
27	Germacrene D	$C_{15}H_{24}$	1485	1.3±0.057	1.77±0.008	3.38±0.012	0.81±0.015
28	β-ionone	$C_{13}H_{20}O$	1488	-	-	0.17±0.002	0.06±0.014
29	β-selinene	$C_{15}H_{24}$	1490	-	-	0.27±0.008	-
30	Myristicin	$C_{11}H_{12}O_3$	1518	0.05±0.003	-	0.69±0.003	-
31	Germacrene B	$C_{15}H_{24}$	1561	-	-	0.13±0.011	-
32	Dill apiole	$C_{12}H_{14}O_4$	1620	4.09±0.012	3.22±0.008	2.65±0.008	3.19±0.02
33	Neophytadiene	$C_{20}H_{38}$	1840	0.24±0.017	0.45±0.005	0.98±0.005	0.19±0.003
34	Hexahydrofarnesyl acetone	$C_{18}H_{36}O$	1847	0.05±0.003	0.04±0.008	0.24±0.005	0.04±0.014
35	Elaol	$C_{16}H_{22}O_4$	1877	-	0.04±0.003	0.08±0.008	-
36	Phytol	$C_{20}H_{40}O$	1943	0.08±0.005	0.17±0.005	0.52±0.012	0.09±0.011
37	Palmitic acid	$C_{16}H_{32}O_2$	1970	-	-	0.15±0.006	0.07±0.008
38	Eicosane	$C_{20}H_{42}$	2000	-	-	0.02±0.011	-
39	Heneicosane	$C_{21}H_{44}$	2100	-	-	0.02±0.003	-
	Essential oil yield (v/w %)	-	-	0.46	0.22	0.1	0.2

Note: Nob= Number, RI= Retention Index.

The highest essential oil yield was observed in Kerman ecotype (0.46%) and the lowest in Ardabil ecotype (0.1%). Essential oil yield of Esfahan (0.22%) and Mashhad (0.2%) ecotypes was close to each other. In all ecotypes, the compounds such as toluene, α-thujene, camphene, sabinene, β-pinene, β-myrcene, α-phellandrene, α-terpinene, β-phellandrene, undecane, sabinol, dill ether, carvacrol, germacrene D, dill apiole, neophytadiene, hexahydrofarnesyl acetone, and phytol were extracted with varying amounts and the highest values were for α-phellandrene, β-phellandrene, and dill ether, respectively. Analysis of variance in eighteen similar compounds with the assumption of the residuals were random and homogenous, showed the significancy of α-thujene, β-pinene, β-myrcene, α-phellandrene, β-phellandrene, undecane, dill ether, sabinol, germacrene D, dill apiole, neophytadiene, and hexahydrofarnesyl acetone at 0.001 probability level (Table 4).

Means comparison of significant compounds using least significant difference (LSD) test indicated that the Kerman ecotype had the highest mean value for α-phellandrene, sabinol, and dill apiole; Ardabil ecotype had the highest mean value for β-pinene, undecane, germacrene D, neophytadiene, hexahydrofarnesyl acetone, and phytol; and Mashhad had the highest mean value for α-thujene, β-myrcene, β-phellandrene, and dill ether (Table 5).

Table 4. Analysis of variance (mean squares) for studied essential oils constituents in Iranian dill (*Anethum graveolens* L.) ecotypes

S.O.V	DF	V1	V2	V3	V4	V5	V6	V7	V8	V9
Block	2	0.0001^{ns}	0.0001^{ns}	0.0001^{ns}	0.0000^{ns}	0.0001^{ns}	0.0004^{***}	0.0000^{ns}	0.00007^{ns}	0.0091
Treat	3	0.0002^{ns}	0.0033^{***}	0.00007^{ns}	0.0006^{ns}	0.0041^{***}	0.0021^{***}	99.0426^{***}	0.0004^{ns}	1.1576^{***}
Error	6	0.0001	0.0001	0.0006	0.0008	0.0006	0.0000	0.0008	0.0006	0.0486
C.V. (%)	-	25.00	1.70	14.81	5.24	4.25	0.00	0.02	8.49	0.64

Note: S.O.V= Source Of Variation, DF= Degree of Freedom, V1= Toluene, V2= α-thujene, V3= Camphene, V4= Sabinene, V5= β-pinene, V6= β-myrcene, V7= α-phellandrene, V8= α-terpinene, V9= β-phellandrene, ***= Significant at the 0.001 probability levels, ^{ns}= not significant, C.V. = Coefficient of Variation.

Table 4 (Continued). Analysis of variance (mean squares) for studied essential oils constituents in Iranian dill (*Anethum graveolens* L.) ecotypes

S.O.V	DF	V10	V11	V12	V13	V14	V15	V16	V17	V18
Block	2	0.0000^{ns}	0.0022^{ns}	0.0001^{ns}	0.0022^{ns}	0.0033^{ns}	0.0001^{ns}	0.00002^{ns}	0.0004^{***}	0.0001
Treat	3	0.0072^{***}	8.6115^{***}	0.0628^{***}	0.0062^{ns}	3.706^{***}	1.0644^{***}	0.3914^{***}	0.0290^{***}	0.1289^{***}
Error	6	0.0008	0.0160	0.0006	0.160	0.0139	0.0001	0.0001	0.0000	0.0006
C.V. (%)	-	13.19	0.87	4.76	15.21	2.65	0.30	2.39	0.00	4.65

Note: S.O.V= Source Of Variation, DF= Degree of Freedom, V10= Undecane, V11= Dill ether, V12= Sabinol, V13= Carvacrol, V14= Germacrene D, V15= Dill apiole, V16= Neophytadiene, V17= Hexahydrofarnesyl acetone, V18= Phytol, ***= Significant at the 0.001 probability levels, ^{ns}= not significant, C.V. = Coefficient of Variation.

Table 5. Compare means of significant essential oil constituents in Iranian dill (*Anethum graveolens* L.) ecotypes

Ecotype	V2	V5	V6	V7	V9	V10	V11	V12	V14	V15	V16	V17	V18
Kerman	0.59^{b}	0.21^{b}	0.81^{b}	57.49^{a}	14.02^{b}	0.07^{b}	6.2^{b}	0.38^{a}	1.30^{c}	4.09^{a}	0.24^{c}	0.05^{b}	0.08^{c}
Esfahan	0.56^{c}	0.22^{b}	0.78^{d}	55.51^{b}	14.07^{b}	0.07^{b}	5.78^{c}	0.10^{c}	1.77^{b}	3.22^{b}	0.46^{b}	0.04^{c}	0.17^{b}
Ardabil	0.56^{c}	0.29^{a}	0.79^{c}	52.88^{c}	12.95^{c}	0.16^{a}	3.74^{d}	0.08^{d}	3.38^{a}	2.65^{d}	0.98^{a}	0.24^{a}	0.52^{a}
Mashhad	0.63^{a}	0.22^{b}	0.84^{a}	44.44^{d}	14.37^{a}	0.05^{b}	7.86^{a}	0.28^{b}	0.82^{d}	3.19^{c}	0.19^{d}	0.04^{c}	0.09^{c}

Note: V2= α-thujene, V5= β-pinene, V6= β-myrcene, V7= α-phellandrene, V9= β-phellandrene, V10= Undecane, V11= Dill ether, V12= Sabinol, V14=Germacrene D, V15= Dill apiole, V16= Neophytadiene, V17= Hexahydrofarnesyl acetone, V18= Phytol.

Note: Means followed by the same letters in each column are not significantly different in ecotypes.

Also, Means followed by the same letters in each column of Table 5 are not significantly different in the studied ecotypes.

Factor analysis results showed that three main and independent factors accounted for 100% of the total variance (Table 6). Factor loading values more than 0.6 were considered as significant and extraction method was based on principle component analysis (PCA). The first factor, with 47.51%, included hexahydrofarnesyl acetone, undecane, β-phellandrene, β-pinene, phytol, germacrene D, neophytadiene, dill ether, and α-terpinene. The second factor with the compounds of toluene, β-myrcene, sabinene, α-thujene, α-phellandrene, and carvacrol accounted for 31.876% of the variance. The compounds such as camphene, dill apiole, sabinol, and carvacrol were in the third factor, accounting for 20.613% of the variance. Also, hexahydrofarnesyl acetone, toluene, and camphene had the highest significant amount in first (0.982), second (0.991), and third (0.987) components, respectively.

Table 6. Rotated component matrix of same essential oils constituents in Iranian dill (*Anethum graveolens* L.) ecotypes

	Component		
Constituents	1	2	3
Hexahydrofarnesyl acetone	0.982	- 0.034	0.183
Undecane	0.967	- 0.204	0.153
β-phellandrene	- 0.952	0.299	- 0.074
β-pinene	0.936	- 0.011	0.351
Phytol	0.920	- 0.168	0.354
Germacrene D	0.892	- 0.375	0.253
Neophytadiene	0.884	- 0.304	0.355
Dill ether	- 0.836	0.541	- 0.089
α-terpinene	- 0.831	0.556	0.031
Toluene	0.056	0.991	- 0.120
β-myrcene	- 0.315	0.928	- 0.198
Sabinene	- 0.447	0.893	- 0.051
α-thujene	- 0.456	0.877	- 0.150
α-phellandrene	0.128	- 0.861	- 0.493
Camphene	0.112	0.113	0.987
Dill apiole	- 0.538	- 0.092	- 0.838
Sabinol	- 0.415	0.440	- 0.797
Carvacrol	0.236	- 0.614	0.753
Eigenvalues	8.552	5.738	3.710
% of Variance	47.511	31.876	20.613
% Cumulative	47.511	79.387	100

Note 1: Factor loading values more than 0.6 were considered as significant, i.e. the bold numbers are the highest loading for each factors.
Note 2: Extraction method is based on Principle Component Analysis (PCA).

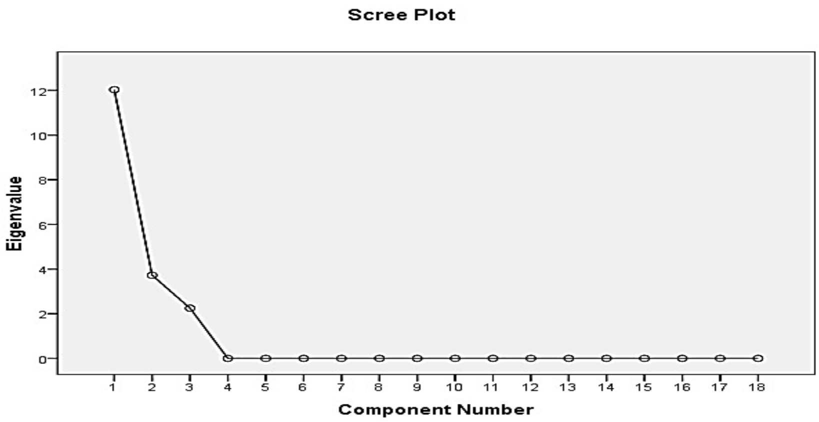

Fig. 2. Scree plot to determine the number of factors in factor analysis of essential oils composition in Iranian dill (*Anethum graveolens* L.) ecotypes

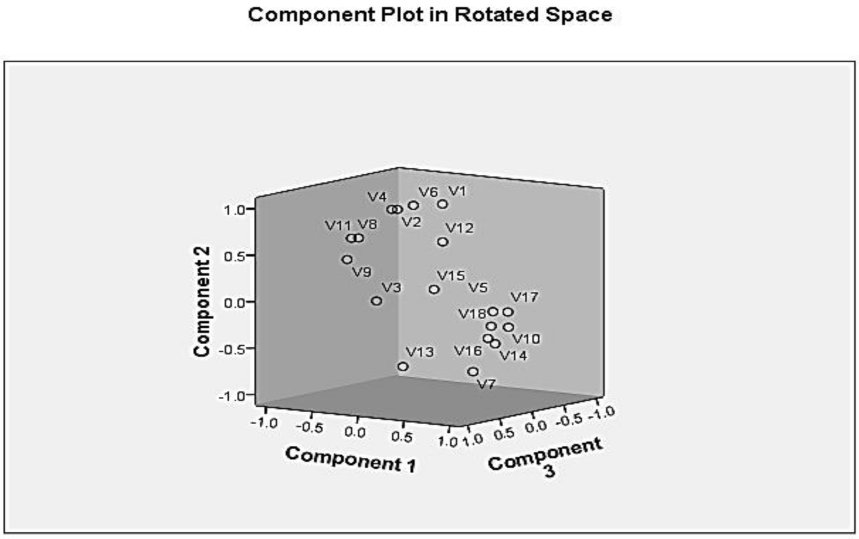

Fig. 3. Component 3D in rotated space in factor analysis of essential oils composition in Iranian dill (*Anethum graveolens* L.) ecotypes

Discussion

The results of the present study showed various compounds in all ecotypes with different amounts. Plant growth stage, genetic or environmental factors affect the biosynthesis of essential oils in a particular plant. Thus, a plant species with diverse genetic structure can produce essential oils with different compounds at different environmental conditions (Callan et al., 2007; Orhan et al., 2013). α-phellandrene, β-phellandrene, and dill ether had the highest amount in all studied ecotypes. This experimental finding is supported as well by previous studies (Radulescu et al., 2010; Vokk et al., 2011; and El-Zaeddi et al., 2016). Comparison of the results of this study with the other studies done on the dill shows that the α-phellandrene is the major compound of essential oils in *Anethum graveolens* (Huopalahti and Linko, 1983; Charles et al., 1995). Huopalahti et al., (1988) reported that the main compounds of essential oils of the dill are 3,6-Dimethyl-2,3,3a,4.5,7a hexahydro benzofuran (36.7 %), α-phellandrene (32.1 %), *p*-Cymene (5.7 %), and β-phellandrene (5.6 %) (using hydrodistillation method). Whereas in other study, major compounds were α-phellandrene (24.88 %), 3,9-epoxy-p-menth-1-ene (14.85 %), carvone (14.50 %), and *p*-Cymene (14.38 %) (Pino et al., 1995). Of these compounds, monoterpenes, which are widely used in various industries, were the most detected compounds. Both α-phellandrene and β-phellandrene are cyclic monoterpenes and double-bond isomers. (El-Zaeddi et al., 2016). Pervious researches demonstrated that α-phellandrene have wound healing activity (de Christo Scherer et al., 2019), enhances the immune response and antibacterial (Wu et al., 2019), anti-inflammatory (Siqueira et al., 2016), antinociceptive (Lima et al., 2011), antitumor (Hsieh et al., 2015), and antifungal (Zhang et al., 2017) activities. In addition, this compound is the character-impact compound of the dill flavor which is rounded off by the additive effect of dill ether (Blank et al., 1992).

The results of variance analysis indicate that different compounds can be statistically investigated in different ecotypes and can be isolated from essential oils for specific purposes in different industries. In addition to molecular studies, phytochemicals can be considered for breeding ecotypes. Factor analysis is an extension of principal component analysis (PCA) and in both methods it is attempted to approximate the covariance matrix, but this approximation is more accurate and finite in the factor analysis model (Zare-Chahouki, 2011). Figure 2 shows the changes of the eigenvalues in relation to the factors. This figure is used to determine the optimal number of components and it can be seen that from the third factor onwards the eigenvalue changes are reduced so three factors can be extracted as the most important factors in explaining the data variance. The distribution of the variables for the first, second, and third factors indicates that the results of factor analysis in Table 6 are highly accurate (Fig. 3). Significant compounds in these agents were highly correlated with each other and were independent of other factors. In this method, the intrinsic correlation among several observable variables is interpreted through factors that are not observable, and these factors are unobserved because of the common cause of the correlation between the main variables.

Conclusion

Medicinal plants are rich resources for curing diverse human diseases. They can be one of the most valuable national assets of any country that have long been used to treat a wide range of diseases. One of the most important factors in increasing investment in herbal research is the profitability of herbal medicine production due to their impacts on public health. The results of this study showed that the dill ecotypes have diverse compounds with different values and could provide a basis for future research for both scientific and industrial purposes.

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Conflict of interest

The authors indicate no conflict of interest for this study.

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