Saudi Journal of Biological Sciences 29 (2022) 103314

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Original article

Impact of soil types on chemical composition of essential oil of purple basil

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ARTICLE INFO

Article history:
Received 27 February 2022
Revised 8 April 2022
Accepted 19 May 2022
Available online 22 May 2022

Keywords:
Purple basil
Soil types
Medicinal and aromatic plants
Essential oil
Methylcinnamate
Linalool
1,8-cineol

ABSTRACT

Purple basil is among the most important basil varieties and its essential oil is used for several purposes including medicinal and aromatic uses. Soil types may impact the plant growth, development, and essential oil composition. Hence, it is important to find the most suitable soil type which may produce basil plants having essential oil with the best composition and concentration. For this reason, plant samples of purple basil that were grown in areas with clay, loamy sand, and sandy-clay loam soil types were collected and evaluated to determine the changes in the yield and essential oil components. Essential oil contents were determined with the Clevenger Device, and essential oil compositions were determined by using GC and GC/MS analysis. The highest essential oil yield according to soil types was obtained from the plant samples that were grown in the loamy sand soil. It was also found that the main compounds present in Arapgir town purple basil were methylcinnamate and linalool that was also present in all Turkish purple basil under all types of soil. According to the soil types, the highest concentration (46.03%) of methylcinnamate was observed in loamy sand soils, and the lowest (42.33%) was obtained from sandy-clay loam soils and found to be significantly different. Data regarding correlations between soil types and essential oil ratios showed that organic matter and P_2O_5 had a significant negative correlation with methylcinnamate. The present study will help researchers and farmers to choose the most suitable soil type to achieve maximum essential oil production from purple basil.

1. 1.Introduction

Natural products obtained from medicinal and aromatic plants have been widely consumed for centuries due to their therapeutic properties (Genc et al., 2019). The importance of natural products obtained from medicinal and aromatic plants is due to the presence of active compounds including those of essential oils. (Erenler et al., 2016; Guzel et al., 2017). Basil (*Ocimum basilicum* L.) is a member of the Lamiaceae family; this family includes 7886 plant species out of which more than 150 species are aromatic and medicinal plants. Although the origin of this plant species was Mediterranean, Africa, America, and Asia, it is now widely grown in several countries worldwide (Sgherri et al., 2010). The plant is sold in fresh, dried, and frozen forms because of its importance in the medicinal and aromatic industries (Saadatianet al., 2014). Basil is annual plant with several pharmacological properties such as antioxidant, chemo preventive, anti-inflammatory, antimicrobial, and immunomodulatory activities (Ch et al., 2015).It has also been reported that basil has effects on dermal pathology and wound healing including acne, eczema, boils, psoriasis, and rashes (Antonescu (Mintas) et al., 2021). In addition, apigenin, linalool, and ursolic acid present in essential oils of basil show antiviral (Chiang et al., 2005), its basil oils with high methyl chavicol and linalool content show antifungal (Oxenham et al., 2005), the eugenol compound shows antimicrobial (Bassolé et al., 2010), and the linalool compound shows antibacterial effects (Hussain et al., 2008). The main components in its essential oil are Linalool, 1,8-cineol, eugenol, methyl cinnamate, camphor, methyl eugenol, methyl chavicol, β-elemene, βocimene, camphene, carvacrol, α-bergamotene, α-cadinol and geranial (Poonkodi, 2016; Simon et al., 1990; Simon et al.,1999), and different chemotypes of basil emerge according to the density of these components (Telci et al., 2006).

Basil essential oils are classified into four chemotypes based on their geographical locations and chemical compositions. The Euro-

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2022.103314
1319-562X/

pean type characterized by linalool and methyl chavicol as main oil components and grown in Europe, USA, and Africa, while the Reunion type with a high concentration of methyl chavicol is found in Comoros, Seychelles Islands, Africa, and Reunion Island. Another basil chemotype is named as tropical type; this is rich in methylcinnamate and found in India, Pakistan, Guatemala, Haiti, and Africa, and basil with eugenolas main component is found widely in North Africa, Russia, Eastern Europe, and some parts of Asia (Marotti et al., 1996; Grayer et al., 1996; Simon et al., 1999; Chalchat et al., 1999). Other basil essential oils were also reported to contain varying amounts of linalool, camphor, methyl chavicol, methylcinnamate and eugenol. Seven different chemotypes were characterized in Turkish basil and Arapgir purple basil, which has a geographical indication of the Arapgir/Malatya region, is grown widely by local producers as a spice, herbal tea, and beverage. Arapgir purple basil essential oil has a high content of 1,8-cineole, linalool and methylcinnamate.

The medicinal and commercial uses of these important compounds from Arapgir purple basil have been determined in several studies. Pharmacological studies on 1,8cineole have revealed that this compound has great potential in the treatment of various diseases (Campos and Berteina-Raboin, 2022).This compound is used as a flavoring additive in several food products (Jalilzadeh-Amin and Maham, 2015) as well as effective in the treatments of infectious respiratory diseases (Santos and Rao, 2001).It also possesses antifungal (Pattnaick et al., 1997), anthelmintic (Shah et al., 2011), antioxidant, cytotoxic, antitumor (Asanova et al., 2003), and analgesic (Asanova et al., 2003) properties. Linalool, on the other hand, is widely used in the food and pharmaceutical industries, and is used as a fragrance ingredient in many fragrance and non-cosmetic products (Kamatou and Viljoen, 2008; Sousa et al., 2010). Methylcinnamate is widely used in cosmetics, fragrances, shampoos, toilet soaps and other toiletries, as well as non-cosmetic products such as household cleaners and detergents. In addition, these two components (linalool and methylcinnamate) also have numerous biological activities such as antibacterial, antifungal and mosquito repellent properties (Padalia et al., 2017).

Essential oil compositions in aromatic plants vary based on various factors e.g., the genetic structure of the plant, soil type, climatic conditions, growth period, harvest time, and post-harvest practices. The physical and chemical features of the soil act as one of the most determining factors in various secondary products and play roles in the essential oil composition of different aromatic plant species (Rioba et al., 2015). Also, plants containing essential oil may differ in oil yield and quality according soil type and this provides an opportunity to find out soil types suitable for getting the highest essential oil yield and the best of its quality (Khalid et al., 2020).

Many medicinal plants are grown in different environmental conditions and soil types not only to increase crop yields, but also to improve essential oil content and yield. Purple basil is grown in areas with different soil features in the Arapgir region. No study has been conducted regarding the relationship between essential oil content of this medicinal plant and soil types. Therefore, the aim of this study was to evaluate the percentage and constituents of essential oil from purple basil when grown in either of the clay, loamy sand, and sandy-clay loam soils.

2. Material and method

2.1. Plant and soil materials

Arapgir purple basil, a landrace of basil cultivated by local farmers in Arapgir/ Malatya region of Turkey (39.01.51 °N, 38.29.15 °E) was used as the herbal material in the present study. It is classified in the "purple basil" morphological group among the Turkish basil (Telci, 2017). Plant specimens were classified in Malatya Turgut Özal University, Department of Medicinal and Aromatic Plants, and the voucher specimen was kept in the same department.

2.2. Cultivation of purple basil

For growing nursery, seeds of purple basil were sown in a mixture of sand, fertilizer and mulch (1:1:1) at the end of March. Purple basil seedlings having a 10–15 cm height were transplanted to the fields in mid May with 50 cm row to row and 30 cm plant to plant spacing. A fertilizer dose of 50 kg ha^{-1}N and 50 kg ha^{-1} P_2O_5 was applied. Weed management was done with traditional agricultural practices. At flowering, the plants were cut 15 cm above the soil surface and dried in the shade. Three cuttings were obtained from all the soil types.

Weather data during the growing seasons were obtained from Turkish General Directorate of Meteorology (Table 1). Annual average temperature during the growing season for 2021 was 20.6 °C while annual precipitation was 72.8 mm (Table 1). The growing area has a cool climate and precipitation was not sufficient for crop growth so fields were irrigated with drip irrigation according to crop needs.

The plant and soil samples were taken from locations with three different soil textures (clay, loamy sandy and sandy-clay loam). Ten randomly selected plant samples from each planting area at each cutting time (30 plants in total, approximately 2 kg) were harvested before flowering. Then, the samples were dried at room temperature until they had a constant dry weight and were kept in paper bags until the essential oil was extracted.

2.3. Soil sampling and analyses

Some physical and chemical features of soil samples taken from 0 to 30 cm depth, where the roots of the sampled plants were dense, are given in Table 2. After collecting the soil samples, it was stored in a plastic bag and identified. Soil samples were air-dried and passed through 2-mm sieve and made ready for analyses. Clay, silt and sand fractions were identified with hydrometer method according to Demiralay (1993). Soil pH values were determined from 1:1 (w:v) soil-water suspension with a pH meter; soil electrical conductivity (EC) as a measure of the amount of salt in the soil (soil salinity) was determined from the same soil-water suspension with an EC meter (Kacar, 1994). Modified Walkley-Black method was used to determine the organic matter (OM) content of the soil samples. Total calcium carbonate ($CaCO_3$) contents were determined with a Scheibler calcimeter by using volumetric method (Kacar, 1994). Available P (P_2O_5) content was determined through extraction with 0.5 M $NaHCO_3$ at pH 8.5 (Olsen et al., 1954), while the extractable K (K_2O) content was determined by flame photometer after extraction with 1 *N* Ammonium Acetate (pH = 7.0) solution (Soil Survey Staff, 1992).

Table 1
Climatic data during the purple basil growing season (2021).

Months	Average temperature (^{0}C)	Total precipitation (mm)
April	13.2	13.8
May	19.6	3.8
June	22.4	4.2
July	26.8	1.0
August	26.4	18.8
September	21.0	7.2
October	14.7	24.0
Average	20.6	–
Total	–	72.8

Table 2
Physical and chemical properties of the collected soils.

Compounds	Soil types		
	Clay	Loamy sand	Sandy-clay loam
Sand (%)	34	80	60
Silt (%)	20	14	14
Clay (%)	46	6	26
pH	8.4	8.36	8.22
Soil salinity (EC (dS m^{-1}))	0.13	0.80	0.19
Organic matter (OM) (%)	1.44	0.96	1.99
Total calcium carbonate ($CaCO_3$) (%)	3.92	8.63	15.69
P_2O_5 (kg ha^{-1})	15.4	2.23	37.21
K_2O (kg ha^{-1})	71.09	15.13	55.96

2.4. Essential oil distillation

The essential oils were extracted by using a 5 L Clevenger distiller device. Essential oil was obtained from air-dried purple basil leaves with Clevenger in a 3-hour distillation period, and the oil yield (%) was calculated. A total of 100 g of plant material was used during each distillation cycle. The essential oil distilled with water was passed through tap water on the receiving arm of the apparatus and was collected separately into a clean sample bottle. In this way, the oil phase was separated and dried over anhydrous sodium sulphate and kept in the dark at 4 °C in amber bottles until used in analysis and experiments. The extraction was performed in triplicate.

2.5. Essential oil (EO) GC/MS analysis

The characterization of the compounds in essential oil (EO) was obtained with Gas Chromatography and Mass Spectrometry. The conditions during the analysis are explained in Table 3 (Yilmaztekin and Sislioglu, 2015). The n-Alkane mixture was used to determine and calculate the Linear Retention Index (Kovats Indexes) of each compound in essential oil under the same temperature used for the analyses (Adams, 2009). The mass spectra of the essential oil components were compared with those of the references mentioned in the NIST and Wiley Database. The temporal identifications of the compounds in this experiment and their temporal indicators were compared with those of NIST. Quantitative analysis of the essential oil components (% area) were also performed by measuring peak rate normalization as the average of three repeated analytical assays (NIST, 2013)..

Table 3
GC/MS conditions (Yilmaztekin and Sislioglu, 2015).

System	Shimadzu QP 2010 Plus (Shimadzu, Kyoto, Japan) GC
Colon	TRB-Wax (Teknokroma, Barcelona, Spain) fused silica capillary column (60 m × 0.25 mm i.d. and film thickness, 0.25 μm)
Temperature programme	40 °C/5 min, 3 °C/1 min, 240 °C/15 min (total running: 86 min)
Injector	AOC-20i/20 s auto sampler
Injection volume	1 μL (1 part of essential oil/100 part of n-hexane, v/v)
Carrier gas	Helium (flow rate, 1 mL/min)
Detector	MS-QP 2010 series mass-selective detector
Split ratio	1/50
Electron energy	70 eV
Mass spectra	35–450 *m/z*
Scanning rate	1 scan/s

2.6. Statistical analysis

The data were analyzed statistically using General Linear Model one way analysis of variance (ANOVA). Significance of the results was determined according to p values ($p < 0.05$ = significant, $p < 0.01$ = moderate significant, $p < 0.001$ = highly significant). Multivariate Analysis was made for the bilateral correlation experiments between soil features and essential oils in the experiment. The SPSS 25.0 package program was used in the analysis of variance and correlation studies.

3. Results

3.1. Essential oil yield and components

Significant differences were detected in essential oil percentage in purple basil samples taken from different soil types. The highest essential oil percentage (0.75%) was obtained in purple basil plants grown in loamy sand soil type, followed by sandy-clay loam (0.61%), and clay (0.5%) types, respectively (Table 4.). The higher percentage of sand in the soil increased the essential oil yield, while the increased amount of clay in the soil caused a decrease in the essential oil yield.

3.2. Essential oil contents

A total of 89 compounds were determined in the essential oils obtained from plant samples taken from three different soil types where the purple basil plant was grown. The highest number of components were obtained in clay soil type (72 compounds), followed by sandy-clay loam soil type. The lowest number of components was obtained in loamy sand soil type (44 compounds), together with the highest percentage of essential oil content (Table 5). Increase in the sand content in the soil caused an increased number of compounds and decreased percentage of essential oil. The opposite was true when the clay ratio increased in the soil.

The changes in main components (methylcinnamate, linalool and 1,8-cineol) were moderately ($p < 0.01$) and highly ($p < 0.001$) significant (Table 5). The main components of purple basil essential oil were methylcinnamate (44.61%, 46.03%, and 42.33%), linalool (24.22%, 23.1%, and 21.6%), and 1,8-cineol (6.18%, 3.92%, and 6.29%) according to clay, loamy sand, and sandy-clay loam soils, respectively. Although methylcinnamate, which is the main component of purple basil, was obtained from the samples taken from loamy sand soils, the other important component, linalool, was determined as the highest in the samples taken from clay soil Moreover, methylcinnamate concentration was highest in the basil plant among all three soil types.

The identified compounds of purple basil essential oils in all three soil types with different textures were classified into five groups; aromatic compounds (47.14–47.99%), monoterpenes (31.40–40.46%), sesquiterpenes (2.24–12.82%), diterpenes (1.09–1.45%) and others (0.39–1.23%). According to the soil types, the changes in the aromatic compounds were insignificant, while the monoterpene, diterpene and other groups were moderately significant ($p < 0.01$). Sesquiterpenes were determined to be highly significant ($p < 0.001$) among all soil types. Aromatic compounds were the highest in purple basil essential oils, followed by monoterpenes and sesquiterpenes. Aromatic components in the essential oil ranged from 47.14 to 47.99% in three different soil types. The components in the monoterpene group were obtained at the highest amount in sandy-clay loam soils and the lowest in loam sandy soils. The lowest sesquiterpenes were obtained from loam sandy soil type with the lowest clay content. Although the

Table 4.P
urple basil essential oil ratios in different soil types (%).

	Soil types			
	Clay	Loamy sand	Sandy-clay loam	*F ration*
Essential oil (%)	0.5b ± 0.1	0.75 a ± 0.05	0.61b ± 0.03	10.815*

*p < 0.05 (significant).

decrease in the clay ratio of the soil increased the number of aromatic compounds, it caused a decrease in sesquiterpenes. On the other hand, although there were variations in the ratios of monoterpenes and sesquiterpenes in all three soils with different textures, no variations were detected in aromatic compounds (Table 5).

The correlations of methylcinnamate, linalool, and 1,8-cineol essential oils, which are the most important components of purple basil plant, among all three soil types were derived (Table 6). Among the derived correlations, 1,8-cineol had a negative correlation with EC increase but a positive relation with K_2O. Moreover, there was a negative correlation of methylcinnamate with organic matter and P_2O_5, and linalool had a negative correlation with $CaCO_3$ increase.

The curves of three important compounds obtained from different soil types are given in Fig. 1.. Although the sand and EC values of the soil increased in loamy sand and silt, clay, soil and K_2O values increased in clay soils due to which essential oil ratios increased. Moreover, the increase in organic matter, $CaCO_3$ and P_2O_5 amounts in sandy-clay loam soils caused an increase in the ratios of essential oil (Fig. 1.a, b, c, d, e, f, g, h).

4. Discussion

The percentage and components of purple basil essential oil exhibited variation in previous studies. It was reported by different researchers that these rates vary between 0.36 and 1.67% (Telci et al., 2006; Souza et al., 2020; Melo et al., 2021). In the current study, it was determined that essential oil ratios vary between 0.50 and 0.75% depending on soil types (Table 4.). The similarities or differences between essential oil yields were due to factors such as physiological characteristics of the plants, the extraction methods (dry or fresh leaves) in the production of essential oils, the stages of the plants, nutrients applied, harvest times and soil types (Cabello et al., 2014; Hendawy et al., 2017).

In this study, it was determined that the essential oil composition of purple basil grown in Arapgir town of Malatya consisted of aromatic compounds, monoterpenes and sesquiterpenes. Methylcinnamate, which is one of the important aromatic compounds, was determined to be the main component of the essential oil followed by linalool, which is a monoterpene. In other words, it was observed that the main component of Arapgir purple basil used in the study was methylcinnamate and then linalool (Table 5). Similarly, the same compounds were detected by Tursun and Telci (2020) in their study. It was reported that purple basil has various chemotypes (Simon et al., 1990), including methylcinnamate and methylcinnamate/linalool, and the dark color Turkish basil *O. basilicum* var. *purpurescens* that was used in this study is of methylcinnamate rich chemotype (Telci et al., 2006; Gupta, 1996). Arapgir purple basil obtained from Arapgir town of Malatya region was similar to *O. basilicum* var. *purpurescens* with its rich methylcinnamate content (Tursun and Telci, 2020). However, it is also already known that not all purple basil species are rich in methylcinnamate, and there are purple basil chemotypes that are rich in linalool (Telci et al., 2006; Telci, 2017). Also, the absence of components structurally similar to carcinogenic phenylpropanoids such as methyl eugenol and methyl chavicol (estragole) in Arapgir purple basil, and the presence of components such as linalool and methyl cinnamate used in the food and perfume industries enable this chemotype to be preferred for cultivation (Telci et al., 2006). Also, this chemotype is a mixture of European and tropical chemotypes that have high methyl cinnamate and linalool contents.

Due to the lack of previous studies on the effect of soil types on essential oils of purple basil, the results obtained were compared with some previous studies on essential oils of other plants. The soil type affects plant growth in different ways, i.e., plant roots grow faster in sandy soil, but water and nutrient uptake can be limited due to insufficient contact from the soil. On the other hand, the opposite situation occurs in clay soils (Passioura, 1991), and this may lead to changes in the yield and essential oil components of plants (Mehalaine and Chenchouni, 2020). As a result of the study, it was found that essential oil yields varied depending on the soil types and the highest essential oil yield was obtained in the basil plants grown in sandy soils while the least was obtained from clayey soils. In terms of the main components of the essential oil, significant changes were observed especially in monoterpenes and sesquiterpenes. The lowest essential oil content was obtained from loamy sand soils. No variation was detected in the obtained aromatic compounds. Although methylcinnamate, which is one of the most important components of the essential oils, was obtained from loamy sand soil (46.3%), the other important compound, linalool, was found at the highest rate in clay soil types (24.22%) (Table 5). These results may be due to the fact that in sandy soil, plants are exposed to stress factors such as salinity, drought, high pH, and low nutrient concentrations, and because of these stress conditions, the plants in sandy soils have higher essential oil contents than clay soils (Jeshni et al., 2017; Bhatla and Lal, 2018; Khalid and Ahmed, 2021). Similarly, it has been reported that the chemical quality of essential oils is also affected by soil properties (Aboukhalid et al., 2017).Aziz et al. (2008) and Said-Al Ahl et al. (2019) found that the production rate of some essential oil parent compounds in *Thymus vulgaris* was higher when grown in sandy soil than when grown in clayey soil. Khalid and Ahmed (2021) also obtained similar results in citrus. This means that essential oil yields of medicinal plants can be increased by increasing sand contents of a soil; the same results were obtained in our study.

The correlation effects were detected between essential oil compounds and soil types (Table 6). The essential oil ratios showed changes in all three soil types according to the increased amount of clay, sand, and silt. Increasing the amount of sand also increased the amount of essential oil in loamy sand soils and increasing the amount of silt and clay increased the amount of essential oil in clay soils (Fig. 1.a, b, and c). However, although the increased amount of EC in loamy sand soils increased the essential oil ratio, the increase in the amount of $CaCO_3$, organic matter, and P_2O_5 in sandy clay loam soils caused an increase in the ratio of essential oils (Fig. 1.d, e, f, g). On the other hand, increased K_2O in sandy soils also increased the amount of essential oil (Fig. 1. h). It was determined that there is a strong and negative correlation between EC (dS m^{-1}) 1,8-cineole, organic matter, and P_2O_5 (kg ha^{-1}) methylcinnamate, and $CaCO_3$ (%) and linalool. However, a positive relation was determined between 1,8-cineol and K_2O (kg ha^{-1}).

Table 5
Influence of soil types on essential oil compounds of purple basil.

No	Compounds (%) RI* RT**			Soil types			F ratio
				Clay	Loamy Sand	Sandy-clay loam	
1	α-Pinene	988	11,883	0.41 ± 0.01 a	0.25 ± 0.00b	0.32 ± 0.01 a	24.12 **
2	Camphene	1031	13,750	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.0 ns
3	β-Pinene	1077	15,817	1.08 ± 0.05 a	0.25 ± 0.03b	0.87 ± 0.13 a	27.12**
4	Sabinene	1091	16,467	0.54 ± 0.02 a	0.3 ± 0.02b	0.4 ± 0.03c	25.58 **
5	3-Carene	1118	17,750	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.0 ns
6	β-Myrcene	1134	18,567	0.31 ± 0.03 a	0.21 ± 0.01b	0.38 ± 0.01 a	18.38**
7	α-Terpinene	1149	19,283	0.03 ± 0.01	0.01 ± 0.00	0.02 ± 0.01	4.50 ns
8	2,3-Dehydro-1,8-cineole	1162	19,950	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.0 ns
9	Bornylene	1169	20,283	0.28 ± 0.01 a	0.15 ± 0.02c	0.23 ± 0.02b	20.66**
10	β-phellandrane	1175	20,586	–	0.03 ± 0.00	0.06 ± 0.02	0.0 ns
11	**1.8-Cineole**	**1181**	**21,133**	**6.18 ± 0.59 a**	**3.92 ± 0.062b**	**6.29 ± 0.64 a**	**4,68****
12	2-Hexenal	1186	21,160	–	0.04 ± 0.01	0.02 ± 0.00	0.0 ns
13	*cis*-β-Ocimene	1204	22,000	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.0 ns
14	γ-Terpinene	1215	22,517	0.05 ± 0.01	–	0.04 ± 0.01	0.0 ns
15	Trans-β-Ocimene	1221	22,817	0.18 ± 0.01b	0.16 ± 0.01b	0.24 ± 0.01 a	13.81**
16	Terpinolene	1251	24,300	0.03 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	4.50 ns
17	Octanal	1258	24,600	0.04 ± 0.01	0.02 ± 0.00	0.02 ± 0.00	2.00 ns
18	Sulcatone	1304	26,850	0.01 ± 0.00	–	0.01 ± 0.00	0.0 ns
19	3-Octanol	1362	29,533	0.01 ± 0.00	–	0.01 ± 0.00	0.0 ns
20	Fenchone	1367	29,750	0.01 ± 0.00	–	0.01 ± 0.00	0.0 ns
21	3-Methyl-hepta-1,6-dien-3-ol	1377	30,233	0.01 ± 0.00	–	0.01 ± 0.00	0.0 ns
22	β-Thujone	1391	30,858	–	–	3.27 ± 1.10	0.0 ns
23	1-Octen-3-ol	1416	31,983	0.07 ± 0.02	0.03 ± 0.01	0.04 ± 0.00	5.10 ns
24	*trans*-Sabinenehydrate	1434	32,783	0.13 ± 0.01 a	0.03 ± 0.01b	0.06 ± 0.01b	22.39**
25	Nonylacetate	1441	33,073	–	0.03 ± 0.00	0.05 ± 0.01	0.0 ns
26	Caprylyl-acetate	1447	33,367	0.05 ± 0.02	–	0.02 ± 0.00	0.0 ns
27	2,4-Heptadienal	1457	33,800	0.04 ± 0.00	–	0.01 ± 0.00	0.0 ns
28	α-Copaene	1461	33,966	–	–	0.04 ± 0.01	0.0 ns
29	Benzaldehyde	1485	35,000	0.07 ± 0.02b	0.04 ± 0.01b	3.76 ± 1.00 a	13.85**
30	α-Bourbonene	1497	35,567	0.07 ± 0.02	–	0.05 ± 0.02	0.0 ns
31	**Linalool**	**1526**	**36,750**	**24.22 ± 0.01 a**	**23.1 ± 0.11b**	**21.6 ± 0.23c**	**79.03 *****
32	1-Octanol	1530	36,917	0.16 ± 0.02 a	0.04 ± 0.01b	0.04 ± 0.01b	21,12**
33	β-ylangene	1552	37,761	0.62 ± 0.03	0.58 ± 0.02	0.57 ± 0.03	0.36 ns
34	Bornyl-acetate	1555	37,735	–	0.4 ± 0.10b	1.39 ± 0.10 a	78.47**
35	Germacrene D	1560	37,867	0.14 ± 0.03b	0.02 ± 0.01b	0.76 ± 0.16 a	17.58 ***
36	α-Bergamotene	1564	38,350	2.19 ± 0.13 a	–	0.04 ± 0.05b	269.75**
37	Caryophyllene	1574	38,733	0.35 ± 0.08 a	0.08 ± 0.01b	0.48 ± 0.04 a	14.88***
38	Terpinene-4-ol	1568	38,497	–	0.03 ± 0.00	–	0.0 ns
39	(+)-Aromadendrene	1582	39,067	0.02 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	1.50 ns
40	Methylbenzoate	1586	39,233	0.06 ± 0.02	–	0.01 ± 0.00	0.0 ns
41	β-Cyclocitral	1590	39,433	0.02 ± 0.00	–	0.02 ± 0.00	0.0 ns
42	Benzeneacetaldehyde	1602	39,900	0.04 ± 0.01	–	–	0.0 ns
43	Bicyclosesquiphellandrene	1607	40,100	0.07 ± 0.02	–	0.04 ± 0.01	0.0 ns
44	Hexanoicacid, 4-hexenyl ester	1620	40,617	0.02 ± 0.00	–	–	0.0 ns
45	(E)-Verbenol	1622	40,683	0.02 ± 0.00	–	–	0.0 ns
46	Farnesene	1628	40,950	0.38 ± 0.52 a	0.04 ± 0.20b	0.38 ± 0.52 a	21.61**
47	α-Humulene	1641	41,467	1.68 ± 0.13 a	0.77 ± 0.10b	1.56 ± 0.10 a	19,23**
48	*cis*-Verbenol	1643	41,547	–	–	0.02 ± 0.00	0.0 ns
49	p-menth-1-en-8-ol	1660	42,213	–	–	0.77 ± 0.21	0.0 ns
50	α-Terpineol	1663	42,317	0.08 ± 0.01	0.37 ± 0.03	0.1 ± 0.01	65.93**
51	Borneol L	1666	42,435	–	–	0.38 ± 0.10	0.0 ns
52	β-Cubebene	1680	42,983	1.53 ± 0.30	–	–	0.0 ns
53	delta-Guaiene	1683	43,133	0.51 ± 0.07b	0.64 ± 0.06b	1.19 ± 0.03 a	43.197**
54	α-Bulnesene	1679	43,145	0.06 ± 0.01c	0.28 ± 0.03b	0.39 ± 0.03 a	49.64**
55	Bicyclogermacrene	1702	43,850	0.88 ± 0.05 a	0.27 ± 0.03c	0.46 ± 0.04b	55.15**
56	γ-Cadinene	1728	44,833	1.04 ± 0.03 a	0.01 ± 0.00b	0.05 ± 0.02b	625.16**
57	Nerol	1760	46,000	0.04 ± 0.01	–	–	0.0 ns
58	Geraniol	1805	47,667	0.04 ± 0.00	–	–	0.0 ns
59	Methylmalononitrile	1966	53,400	0.14 ± 0.01b	0.25 ± 0.03 a	0.10 ± 0.01b	16.22**
60	Methyl-Eugenol	1974	53,650	0.29 ± 0.08b	2.07 ± 0.15 a	–	127.25**
61	β-Selinene	1980	53,871	–	–	0.06 ± 0.01	0.0 ns
62	Nerolidol	1992	54,280	–	–	0.11 ± 0.03	0.0 ns
63	HumuleneOxide	2004	54,677	–	–	0.8 ± 0.03	0.0 ns
64	Cubedol	2021	55,226	–	–	0.14 ± 0.04	0.0 ns
65	**Methylcinnamate**	**2062**	**56,533**	**44.61 ± 0.40 a**	**46.03 ± 0.58 a**	**42.33 ± 0.19b**	**19.82****
66	Spathulenol	2087	57,333	0.23 ± 0.08	–	0.21 ± 0.06	0.0 ns
67	Ethylcinnamate	2089	57,417	0.07 ± 0.02	0.08 ± 0.01	–	0.0 ns
68	9-Methyl-*cis*-decalin-1,8-dione	2111	58,117	0.08 ± 0.01b	0.85 ± 0.20 a	0.04 ± 0.01b	15.39**
69	Eugenol	2116	58,262	2.36 ± 0.21b	1.88 ± 0.05b	5.01 ± 0.58 a	22.51**
70	α-Cadinol	2133	58,833	3.12 ± 0.71	–	–	0.0 ns
71	α-Bisabolol	2170	60,000	0.03 ± 0.00	–	–	0.0 ns
72	β-Eudesmol	2188	60,583	0.45 ± 0.05 a	0.12 ± 0.03b	0.15 ± 0.03b	28.54**
73	Isocyclocitral	2196	60,840	–	–	0.02 ± 0.00	0.0 ns

(*continued on next page*)

Table 5 (*continued*)

No	Compounds (%) RI* RT**			Soil types			F ratio
				Clay	Loamy Sand	Sandy-clay loam	
74	Ethylhexadecanoate	2202	61,017	0.06 ± 0.01	–	0.09 ± 0.03	0.0 ^{ns}
75	Epiglobulol	2209	61,233	0.05 ± 0.02	–	–	0.0 ^{ns}
76	Caryophylleneoxide	2239	62,119	–	–	0.29 ± 0.06	0.0 ^{ns}
77	Ocimene	2246	62,324	–	–	0.04 ± 0.00	0.0 ^{ns}
78	Farnesol	2301	63,967	0.03 ± 0.00	–	–	0.0 ^{ns}
79	*trans*-Longipinocarveol	2314	64,350	0.02 ± 0.00	–	0.07 ± 0.02	0.0 ^{ns}
80	Geranylacetate	2320	64,517	0.02 ± 0.00	–	–	0.0 ^{ns}
81	Valerenol	2327	64,733	0.04 ± 0.00	–	–	0.0 ^{ns}
82	Linolenicalcohol	2332	64,867	0.02 ± 0.01	–	–	0.0 ^{ns}
83	Longifolenealdehyde	2380	66,283	0.06 ± 0.00	–	–	0.0 ^{ns}
84	Cembrene	2392	66,650	0.02 ± 0.00	–	0.05 ± 0.01	0.0 ^{ns}
85	Pentacosane	2439	67,950	0.01 ± 0.00	–	–	0.0 ^{ns}
86	Phytol, acetate	2458	68,483	0.18 ± 0.12	0.04 ± 0.03	–	87.53**
87	Methyllinoleate	2472	68,867	0.02 ± 0.00	–	–	0.0 ^{ns}
88	Benzylbenzoate	2575	71,683	0.01 ± 0.00	–	–	0.0 ^{ns}
89	Manool	2614	72,817	1.14 ± 0.08b	1.41 ± 0.06 a	1.04 ± 0.06b	8.33*
Aromatic compounds				***47.14* ± 1.75**	***47.99* ± 1.55**	***47.35* ± 2.15**	**0.018 ^{ns}**
Monoterpenes				***34.19* ± 1.24b**	***31.40* ± 1.10b**	***40.46* ± 1.18 a**	***15.57*****
Sesquiterpenes				***12.82* ± 1.15 a**	***2.24* ± 0.14c**	***7.25* ± 0.58b**	***49.84*******
Diterpenes				***1.34* ± 0.04b**	***1.45* ± 0.03 a**	***1.09* ± 0.02c**	***42.54*****
Others				***0.70* ± 0.12b**	***1.23* ± 0.13a**	***0.39* ± 0.05b**	***16.08*****
	TOTAL			**96.19**	**84.31**	**96.54**	

*RI: retention index;
**RT: retention time;
*p < 0.05 (significant); **p < 0.01 (moderate significant); ***p < 0.001 (highly significant); ns, non-significant, All values are given as mean (%) ± SD.

Table 6
Correlation between soil and important essential oil components in purple basil plants in three different soil types (P < 0.05).

Soil	Essential Oils	Correlation	Sig.
Sand (%)	1.8-Cineole	−0.802	0.407
	Linalool	−0.493	0.672
	Methylcinnamate	0.310	0.799
Silt (%)	1.8-Cineole	0.464	0.693
	Linalool	0.821	0.387
	Methylcinnamate	0.133	0.915
Clay (%)	1.8-Cineole	0.845	0.360
	Linalool	0.426	0.720
	Methylcinnamate	−0.380	0.752
EC (dS m^{-1})	**1.8-Cineole**	**−0.993**	**0.078**
	Linalool	0.003	0.998
	Methylcinnamate	0.740	0.470
Organic matter (%)	1.8-Cineole	0.867	0.332
	Linalool	−0.602	0.589
	Methylcinnamate	**−0.996**	**0.060**
$CaCO_3$ (%)	1.8-Cineole	0.155	0.901
	Linalool	**−1.000**	**0.020**
	Methylcinnamate	−0.697	0.509
P_2O_5 (kg ha^{-1})	1.8-Cineole	0.811	0.397
	Linalool	−0.681	0.523
	Methylcinnamate	**−1.000**	**0.005**
K_2O (kg ha^{-1})	**1.8-Cineole**	**0.954**	**0.195**
	Linalool	0.180	0.885
	Methylcinnamate	−0.605	0.587

Mehalaine and Chenchouni (2020) reported positive results regarding the correlations between the composition obtained from aromatic plants and the chemical properties of the soil with total calcium carbonate ($CaCO_3$). In addition, it was reported that aromatic plants have higher essential oil yield in calcareous soils than sandy soils (Aboukhalid et al., 2017). In the present study, although the increased $CaCO_3$ amount showed similarities in terms of soil types with higher essential oil ratios in loamy sand soils when compared to clay soils, a very strong and negative relation was detected for linalool (Table 6). Alizadeh et al. (2010) found that the increased K_2O caused an increase in essential oil yields in the *Satureja hortensis* L. plant, which is similar to the findings of the present study. EC might affect the chemical profile of the essential oil components in aromatic plants (Hasani et al., 2017). In the present study, the higher levels of EC caused increase in amounts of essential oil in loamy sand soils when compared to other soil types. Moreover, stress factors such as saline soil, saline irrigation water, drought and minerals can significantly change the essential oil composition and yield of various aromatic plants (Khalid and Shedeed, 2014; Bhatla and Lal, 2018). Therefore, it is possible to alter the quality and yield of essential oil by changing soil chemical properties or by inducing plant stress (Mehalaine and Chenchouni, 2020). The current study provides a base in choosing the appropriate cultivation soil type to obtain higher essential oil from purple basil plant.

5. Conclusion

It was concluded in the present study that the essential oil content (%) and compounds of Arapgir purple basil have a significant relationship with soil type. The essential oil content (%) was found higher in sandy soils than in other soil types. Although several aromatic compounds were obtained but the methylcinnamate was determined as the most important one from all the essential oils. It is suggested that the purple basil plant grown in sandy soil produced high percentage of essential oil especially methylcinnamate. In addition, due to the low organic matter content in areas with sandy soils, the cultivation of medicinal aromatic plants such as purple basil will help these areas to participate in production. In future, this study will assist to investigate the relationship between the quality and quantity of essential oil production under different soil and environmental conditions. Further, this is important to investigate vegetative characteristics and yield studies of purple

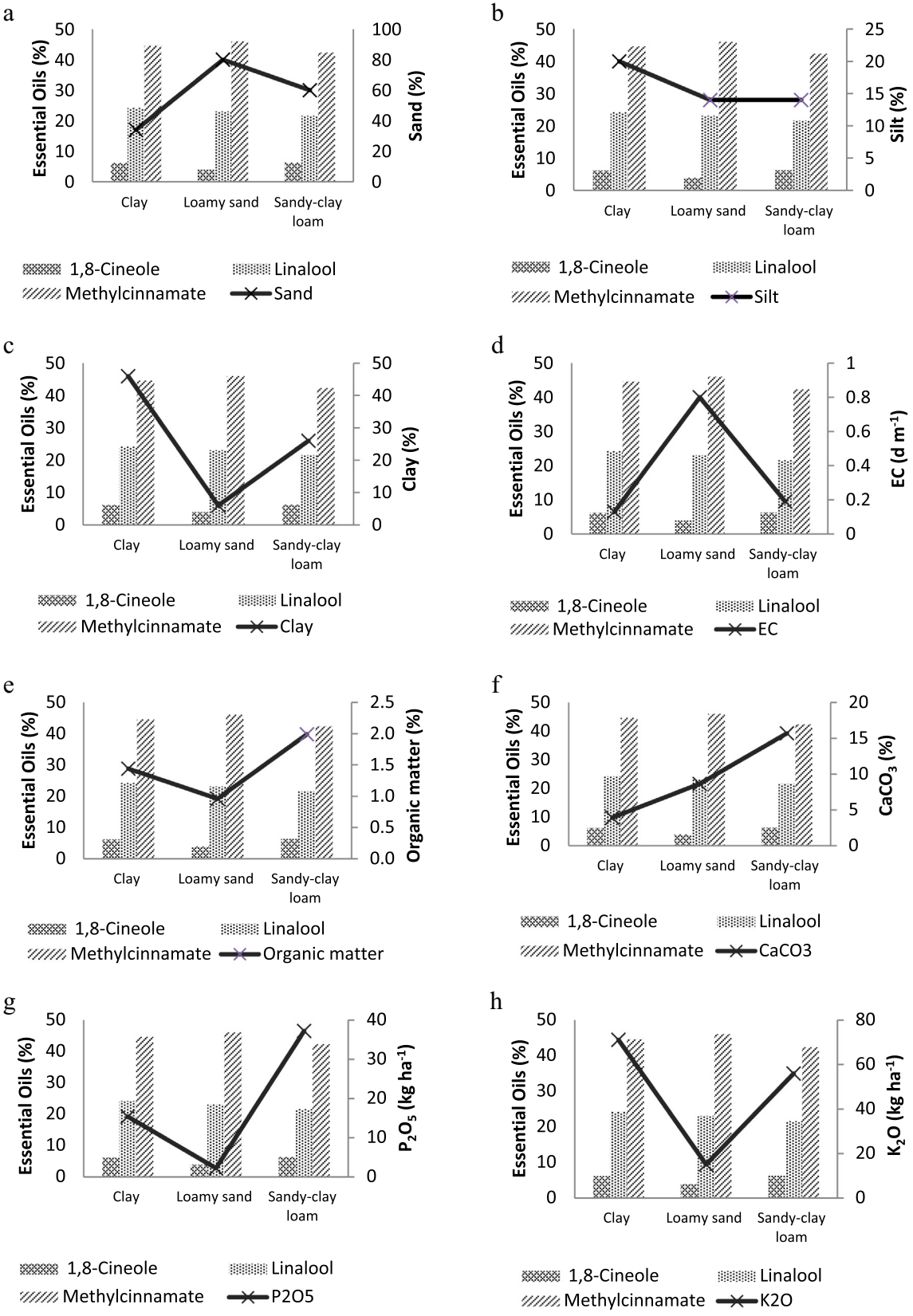

Fig. 1. The average essential oils and soil types in purple basil. a) the relations among three important compounds and sand, b) the relations among three important compounds and silt, c) the relations among three important compounds and clay, d) the relations among three important compounds and EC, e) the relations among three important compounds and organic matter, f) the relations among three important compounds and $CaCO_3$, g) the relations among three important compounds and P_2O_5, and h) the relations among important compounds and K_2O.

basil plant, which was not explored in this study, in different environments and soil types in future studies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

I thank Ferhat OĞURLU and Mehmet Veysel AKSAKAL, who helped for soil analysis in the laboratory at Republic of Turkey Ministry of Agriculture and ForestryGap International Agricultural Research and Training Center.

References

Aboukhalid, K., Alfaiz, C., Douaik, A., Bakha, M., Kursa, K., AgackaMołdoch, M., Machon, N., Tomi, F., Lamiri, A., 2017. Influence of environmental factors on essential oil variability in *Origanum compactum* BENTH growing wild in Morocco. Chem. Biodivers. 14, (9). https://doi.org/10.1002/cbdv.201700158 e1700158.

Adams, R.P., 2009. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry. Allured Publishing Corporation, Carol Stream, Ill, USA.

Alizadeh, A., Khoshkhui, M., Javidnia, K., Firuzi, O., Tafazoli, E., Khalighi, A., 2010. Effects of fertilizer on yield, essential oil composition, total phenolic content and antioxidant activity in *Satureja hortensis* L. (Lamiaceae) cultivated in Iran. J. Med. Plants Res. 4 (1), 33–40. https://doi.org/10.5897/JMPR09.361.

Antonescu (Mintas), A.-I., Miere (Groza), F., Fritea, L., Ganea, M., Zdrinca, M., Dobjanschi, L., Antonescu, A., Vicas, S.I., Bodog, F., Sindhu, R.K., Cavalu, S., 2021. Perspectives on the combined effects of *Ocimum basilicum* and *Trifolium pratense* extracts in terms of phytochemical profile and pharmacological effects. Plants 10 (7), 1390. https://doi.org/10.3390/plants10071390.

Asanova, Z.K., Suleimenov, E.M., Atazhanova, G.A., Dembitskii, A.D., Pak, R.N., Dar, A., Adekeno, S.M., 2003. Biological activity of 1,8-cineole from levant wormwood. Pharm. Chem. J. 37, 28–30.

Aziz, E.E., Hendawi, S.T., Ezz El Din, A., Omer, E.A., 2008. Effect of soil type and irrigation intervals on plant growth, essential oil yield and constituents of *Thymus vulgaris* plant. Am.-Eurasian J. Agr. Environ. Sci. 4 (4), 443–450.

Bassolé, I.H.N., Meda, A., Bayala, B., Tirogo, S., Franz, C., Novak, J., Nebié, R.C., Dicko, M.H., 2010. Composition and antimicrobial activities of *Lippia multiflora* Moldenke, *Mentha x piperita* L. and *Ocimum basilicum* L. essential oils and their major monoterpene alcohols alone and in combination. Molecules 15 (11), 7825–7839. https://doi.org/10.3390/molecules15117825.

Bhatla, S.C., Lal, M.A., 2018. Secondary metabolites. In: Bhatla SC, Lal MA (eds) Plant physiology, development and metabolism. Springer, Singapore, pp. 1099–1166. https://doi.org/10.1007/978-981-13- 2023-1.

Cabello, J.V., Lodeyro, A.F., Zurbriggen, M.D., 2014. Novel perspectives for the engineering of abiotic stress tolerance in plants. Curr. Opin. Biotechnol. 26, 62–70.

Campos, J.F., Berteina-Raboin, S., 2022. Eucalyptol, an all-purpose product. Catalysts 12 (48), 1–22. https://doi.org/10.3390/catal12010048.

Chalchat, J.C., Garry, R.P., Sidibe, L., Marama, M., 1999. Aromatic plants of Mali (I): chemical composition of essential oils of *Ocimum basilicum* L. J. Essent. Oil Res. 11 (3), 375–380. https://doi.org/10.1080/10412905.1999.9701159.

Ch, M., Naz, S., Sharif, A., Akram, M., Saeed, M., 2015. Biological and pharmacological properties of the sweet basil (*Ocimum basilicum*). J. Phar. Res. Int. 7 (5), 330–339.

Chiang, L.-C., Ng, L.-T., Cheng, P.-W., Chiang, W., Lin, C.-C., 2005. Antiviral activities of extracts and selected pure constituents of *Ocimum basilicum*. Clin. Exp. Pharmacol. Physiol. 32 (10), 811–816. https://doi.org/10.1111/j.1440-1681.2005.04270.x.

Demiralay, I. 1993. Soil physical analysis. Ataturk Univ. Agric. Fac. Pub. No:143, Erzurum, Turkey.

Erenler, R., Pabuccu, K., Yaglioglu, A.S., Demirtas, I., Gul, F., 2016. Chemical constituents and antiproliferative effects of cultured *Mougeotia nummuloides* and *Spirulina major* against cancerous cell lines. Z. Naturforsch., C 71 (3–4), 87–92. https://doi.org/10.1515/znc-2016-0010.

Genc, N., Yıldız, I., Karan, T., Eminagaoglu, O., Erenler, R., 2019. Antioxidant activity and total phenolic contents of *Galanthus woronowii* (Amaryllidaceae). Turk. J. Biodiv. 2 (1), 1–5. https://doi.org/10.38059/biodiversity.515111.

Grayer, R.J., Kite, G.C., Goldstone, F., Bryan, S.E., Paton, A., Putiesky, E., 1996. Intraspecific taxonomy and essential oil chemotypes in sweet basil *Ocimum basilicum*. Phytochemistry 43 (5), 1033–1039. https://doi.org/10.1016/S0031-9422(96)00429-3.

Gupta, S.C., 1996. Variation in herbage yield, oil yield and major component of various *Ocimum* species/varieties (chemotypes) harvested at different stages of maturity. J. Essent. Oil Res. 8 (3), 275–279. https://doi.org/10.1080/10412905.1996.9700613.

Guzel, A., Aksit, H., Elmastas, M., Erenler, R., 2017. Bioassay-guided isolation and identification of antioxidant flavonoids from *Cyclotrichium origanifolium* (Labill.) manden and scheng. Pharmacogn. Mag. 13 (50), 316–320. https://doi.org/10.4103/0973-1296.204556.

Hasani, R., Mehregan, I., Larijani, K., Nejadsattari, T., Scalone, R., 2017. Survey of the impacts of soil and climatic variations on the production of essential oils in *Heracleum persicum*. Biodiv. 18 (1), 365–377. https://doi.org/10.13057/biodiv/d180147.

Hendawy, S.F., Hussein, M.S., Amer, H.M., El-Gohary, A.E., Soliman, W.S.A., 2017. Effect of soil type on growth, productivity, and essential oil constituents of rosemary *Rosmarinus officinalis*. Asian J. Agri. Biol. 5 (4), 303–311.

Hussain, A.I., Anwar, F., Sherazi, S.T.H., Przybylski, R., 2008. Chemical composition, antioxidant and antimicrobial activities of basil (*Ocimum basilicum*) essential oils depends on seasonal variations. Food Chem. 108 (3), 986–995. https://doi.org/10.1016/j.foodchem.2007.12.010.

Jalilzadeh-Amin, G., Maham, M., 2015. The application of 1,8- cineole, a terpenoid oxide present in medicinal plants, inhibits castor oil-induced diarrhea in rats. Pharm. Biol. 53 (4), 594–599. https://doi.org/10.3109/13880209.2014.935862.

Jeshni, M.G., Mousavinik, M., Khammari, I., Rahimi, M., 2017. The changes of yield and essential oil components of German Chamomile (*Matricaria recutita* L.) under application of phosphorus and zinc fertilizers and drought stress conditions. J. Saudi Soc Agric. Sci. 16 (1), 60–65. https://doi.org/10.1016/j.jssas.2015.02.003.

Kamatou, G.P.P., Viljoen, A.M., 2008. Linalool: A review of a biologically active compound of commercial importance, Nat. Prod. Commun. 3, 1183–1192.

Khalid, A.K., Shedeed, M.R., 2014. Influence of kinetin on growth and biochemical accumulation in *Nigella sativa* plants grow under salinity stress conditions. Thai J. Agric. Sci. 47, 195–203.

Khalid, A.K., El-Gohary, A.E., Ahmed, A.M.A., 2020. Raising the efficiency of lemon trees to produce essential oil by exogenous cysteine under various soil structures. J. Essen. Oil. Bear. Plant. 23 (1), 194–203. https://doi.org/10.1080/0972060X.2020.1736646.

Kacar, B., 1994. Toprak Analizleri. Bitki ve Toprağın Kimyasal Analizleri III.. A.Ü. Zir. Fak. Eğitim, Araştırma ve Geliştirme Vakfı Yayınları, No.3, Ankara.

Khalid, K.A., Ahmed, A.M.A., 2021. Effect of soil type on Grapefruit and Shaddock essential oils. J. Soil Sci. Plant Nutr. 21 (3), 2048–2056. https://doi.org/10.1007/s42729-021-00501-4.

Marotti, M., Piccaglia, R., Giovanelli, E., 1996. Differences in essential oil composition of basil (*Ocimum basilicum* L.) Italian cultivars related to morphological characteristics. J. Agric. Food Chem. 44 (12), 3926–3929. https://doi.org/10.1021/jf9601067.

Mehalaine, S., Chenchouni, H., 2020. Plants of the same place do not have the same metabolic pace: soil properties affect differently essential oil yields of plants growing wild in semi arid Mediterranean lands. Arab. J. Geosci. 13, 1263. https://doi.org/10.1007/s12517-020-06219-4.

Melo, A.S., Leite, W.R.M., Kato, M.T., Barrosa, K.K., 2021. Essential oil and linalool contents in basil (*Ocimum basilicum*) irrigated with reclaimed water. AQUA-Water Infrastruct., Ecosyst. Soc. 70 (5), 773–782. https://doi.org/10.2166/aqua.2021.057.

Nist.,, 2013. National Institute of Standards and Technology. Gaithersburg, MD, USA.

Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean, L.A. Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Dep. of Agric. Circ. 939.

Oxenham, S.K., Svoboda, K.P., Walters, D.R., 2005. Antifungal activity of the essential oil of Basil (*Ocimum basilicum*). J. Phytopathol. 153 (3), 174–180. https://doi.org/10.1111/j.1439-0434.2005.00952.x.

Padalia, C., Verma, R.S., Chauhan, A., Goswami, P., Singh, V.R., Verma, S.K., Darokar, M.P., Kurmi, A., Singh, N., Saikia, D., Chanotiya, C.S., 2017. Essential oil composition and antimicrobial activity of methylcinnamate-linalool chemovariant of *Ocimum basilicum* L. from India Rajendra. Rec. Nat. Prod. 11 (2), 193–204.

Passioura, J.B., 1991. Soil structure and plant growth. Aust. J. Soil. Res. 29, 717–728. https://doi.org/10.1071/SR9910717.

Pattnaick, S., Subramanyam, V.R., Bapaji, M., Kole, C.R., 1997. Antibacterial and antifungal activity of aromatic constituents of essential oils. Microbios. 89, 39–46.

Poonkodi, K., 2016. Chemical composition of essential oil of *Ocimum basilicum* L. (Basil) and its biological activities–an overview. J. Crit. Rev. 3 (3), 56–64.

Rioba, N.B., Itulya, F.M., Saidi, M., Dudai, N., Bernstein, N., 2015. Effects of nitrogen, phosphorus and irrigation frequency on essential oil content and composition of sage (*Salvia officinalis* L.). J. Appl. Res. Med. Arom. Plant. 2 (1), 21–29.

Saadatian, M., Peyvast, G.h., Olfati, J.A., Ramezani-kharazi, P., 2014. Different species of basil need different ammonium to nitrate ratio in hydroponics' system. Acta Agric. Slov. 103 (2), 223–232.

Said-Al Ahl, H.A., Sabra, A.S., Alataway, A., Astatkie, T., Mahmoud, A., Bloem, E., 2019. Biomass production and essential oil composition of *Thymus vulgaris* in response to water stress and harvest time. J. Essent. Oil. Res. 31 (1), 63–68. https://doi.org/10.1080/10412905.2018.1518794.

Santos, F.A., Rao, V.S.N., 2001. 1,8-Cineol, a food flavoring agent, prevents ethanol-induced gastric injury in rats. Dig. Dis. Sci. 46, 331–337.

Shah, A.J., Gilani, A.-H., Abbas, K., Rasheed, M., Ahmed, A., Ahmad, V.U., 2011. Studies on the chemical composition and possible mechanisms underlying the antispasmodic and bronchodilatory activities of the essential oil of *Artemisia maritima* L. Arch. Pharm. Res. 34 (8), 1227–1238.

Sgherri, C., Cecconami, S., Pinzino, C., Navari-Izzo, F., Izzo, R., 2010. Levels of antioxidants and nutraceuticals in basil grown in hydroponics and soil. Food Chem. 123 (2), 416–422. https://doi.org/10.1016/j.foodchem.2010.04.058.

Simon, J.E., Quinn, J., Murray, R.G., 1990. Basil: A Source of Essential Oils. In: Janick, J., Simon, J.E. (Eds.), Advances in New Crops. Timber Press, Portland, pp. 484–489.

Simon, J.E., Morales, M.R., Phippen, W.B., Vieira, R.F., Hao, Z., 1999. Basil: A Source of Aroma Compounds and a Populer Culinary and Ornamental Herb. Perspective on New Crops and New Uses (Ed): J. Janick. ASHS Press, Alexanderia, VA. pp 499–505.

Soil Survey Staff, 1992. Procedures for collecting soil samples and methods of analysis for soil survey. Rep. I. U.S. Gov. Print. Office, Washington D.C, Soil Survey Invest.

Souza, J.V.R.S., Santos, M.A.L., Sartori, M.M.P., Simon, J.E., Juliani, H.R., Saa, J.C.C., 2020. Content of basil essential oil on a loam texture soil under water regimes and different harvest stages. Int. J. Innov. Educ. Res. 8 (8), 250–266. https://doi.org/10.31686/ijier.vol8.iss8.2513.

Sousa, D.P., Nobrega, F.F.F., Camila, Santos, C.C.M.P., de Almeida, N.R., 2010. Anticonvulsant activity of the linalool enantiomers and racemate: Investigation of chiral influence. Nat. Prod. Commun. 5, 1847–1851

Telci, I., Bayram, E., Yilmaz, G., Avci, B., 2006. Variability in essential oil composition of Turkish Basils (*Ocimum basilicum* L.). Biochem. Syst. Ecol. 34 (6), 489–497. https://doi.org/10.1016/j.bse.2006.01.009.

Telci, I., 2017. Morphological properties, chemical composition and using area of basil genotypes from Turkey. In: International Symposium on Medicinal, Aromatic and Dye Plants Malatya, pp. 29–35.

Tursun, A.O., Telci, I., 2020. The effects of carbon dioxide and temperature on essential oil composition of purple basil (*Ocimum basilicum* L.). J. Essent. Oil-Bear. Plants 23 (2), 255–265. https://doi.org/10.1080/0972060X.2020.1741452.

Yilmaztekin, M., Sislioglu, K., 2015. Changes in volatile compounds and some physicochemical properties of European Cranberry bush (*Viburnum opulus* L.) during ripening through traditional fermentation. J. Food Sci. 80 (4), C687–C694. https://doi.org/10.1111/1750-3841.12836.