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Evaluation of Economic Yield and Quality of Anise and Curled Parsley Plants under Different Geographic Locations

Heba M. Amer[1], Wagdi S, Soliman[2], Saber F. Hendawy[1] and Mohamed S. Hussein[1]

[1]Medicinal and Aromatic Plants Research Department, National Research Centre, Dokki 12622, Cairo, Egypt.,

[2]Department of Horticulture, Faculty of Agriculture and Natural Resources, Aswan University, Aswan 81528, Egypt

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Corresponding author:
Heba M. Amer

Email:
dr.heba_nrc@yahoo.com

ABSTRACT

Understanding the diversities in medicinal and aromatic plants is essential for comprehensively characterizing their chemical composition, especially when dealing with specimens from various regions with distinct geographical backgrounds. The purpose of this study was to evaluate the chemical characteristics and economic yield of anise fruit and curled parsley plant volatile oils under various Egyptian locations. The study was carried out over two consecutive seasons, 2021/2022 and 2022/2023. Six sites were selected to assess anise and curled parsley plants cultivation across three distinct governorates: A) El-Minia Governorate (Old Land, Biosystem Farm, and Sekem Farm), B) Bahariya Oasis (Lena Farm and Sekem Farm), and C) Aswan Governorate (Wadi El-Noqra).The investigation revealed significant effects of location on the weight and yield of anise fruit, the old land in El-Minia's Governorate had the greatest values. The percentages of essential oils were different by location, with Sekem Farm (Oasis) having the greatest amount. Old Land (El-Minia) had the greatest amount of essential oil per plant. The GC-MS method identified the major components of anethole and estragole, these components were different in composition across locations. For the curled version of Parsley, the Lena Farm (Oasis) farm's herb weight and essential oil were the highest. In Egypt's cross country, the composition of oil was erratic in Parsley, the Wadi El-Nokra (Aswan) district had a different composition than the Lena Farm district. The appropriate choice of agro-ecological zone and location is pivotal in enhancing the essential oils' content and composition. El-Minia's clay-loam soil is beneficial to the cultivation of anise. Conversely, El-Bahariya Oasis has a sandy soil type and is ideal for cultivating fluffy Parsley.

KEYWORDS: Anise; Curled parsley; soil properties; essential oil; different locations

1. INTRODUCTION

Many countries' agricultural economies are dependent on medicinal and aromatic plants, these plants not only provide significant income, but also serve as a large part of traditional medicine. The genetic heritage, environmental conditions, cultivation methods, and the way plants are handled and stored all have an effect on the growth and qualitative properties of these plants (Marcelino *et al.*, 2023; Rashad *et al.*, 2024). The creation and destruction of metabolites with a secondary role, such as essential oils, occur constantly in plants during their development. The composition of genetic material in different species, genera, and

Genotypes typically have an effect on the volume of oil that is accumulated (Ramakrishna and Ravishankar, 2011; Arbona *et al.*, 2013; Rashad *et al.*, 2024). For crops that are just being introduced, it's important to assess the effectiveness of different production methods in different environmental settings. Plant life depends heavily on natural resources such as sunlight, water, carbon dioxide, and mineral nutrients. Climate factors like water availability, temperature, and solar radiation significantly impact the production of secondary metabolites (Shulaev *et al.*, 2008; Ramakrishna and Ravishankar, 2011; Arbona *et al.*, 2013).

Aside from regional and local climate, soil stands out as a critical resource for plants, with its physical, chemical, and microbiological properties greatly influencing plant growth. Different plant species have varying soil and nutritive requirements, a factor often overlooked in medicinal plant cultivation (Abou-Leila *et al.*, 1993; Elsayed *et al.*, 2023). Soil properties have a pronounced effect on the chemical constitution of essential oils and their major constituents (Hendawy *et al.*, 2017, 2019a).

The accumulated level of primary and secondary metabolites varies greatly across specimens of the same plant species under different environmental conditions. Plant biochemical responses are influenced by environmental stimuli and are regulated by the manufacture of secondary metabolites, which serve as a flexible and adaptive response to the surroundings (Edreva *et al.*, 2008; Oh *et al.*, 2009; Ramakrishna and Ravishankar, 2011; Gutbrod *et al.*, 2012; Pavarini *et al.*, 2012).

With the various geographic origins of plant materials, it is essential to recognize these variances to characterize the chemical composition of plants of the same species that have been collected from different regions (Lukas *et al.*, 2009; Stashenko *et al.*, 2010; Vilela *et al.*, 2013). Various processes, including long-term acclimation, seasonal differences, and geographical disparities, contribute to variations in metabolite levels within individual plant species (Telascrea *et al.*, 2007; Rahimmalek *et al.*, 2009).

Finding out how the environment affects plant metabolism can be done with the use of metabolomics. Through the analysis of metabolomic profiles, scientists can make comparisons between different species, individuals within populations that are exposed to varied environmental conditions, and variations in metabolite synthesis within a single population over the season (Bundy *et al.*, 2009; Kim *et al.*, 2010; Arbona *et al.*, 2013; Jones *et al.*, 2013). Evaluation of *Nigella sativa* across diverse locations has underscored the intricate interplay between weather patterns and soil characteristics, which significantly impact both the quality and quantity of oil produced by Nigella sativa plants (Salaheldin *et al.*, 2020). Selecting suitable locations within agro-climatic zones can be crucial for maximizing the content and composition of essential oils (Hendawy *et al.*, 2019b).

Since ancient times, people have used anise (*Pimpinella anisum* L.), a member of the *Apiaceae* family, as a spice and an aromatic herb. It has been grown extensively across Europe (Hansel *et al.*, 1999). There are a variety of known uses for anise in traditional folk medicine, such as an appetizer, sedative, and diuretic (Tyler *et al.*, 1988; Lawless, 1999). Additionally, it is applied in the treatment of dyspeptic complaints, respiratory tract catarrh, and as a mild expectorant. Furthermore, extracts from anise fruits have been reported to exhibit therapeutic benefits across a range of conditions, including gynecological and neurological disorders (Czygan and Anis, 1992; Lawless, 1999). Many different compounds can be found in the ethanolic extract of anise fruits; among its main constituents are trans-anethole, methylchavicol (estragole), eugenol, psedoisoeugenol, anisaldehyde, coumarins (umbelliferon, scopoletin), derivatives of caffeic acid (chlorogenic acid), flavonoids, fatty oils, proteins, minerals, polyenes, and polyacetylenes (Hansel *et al.,* 1999). Amer and Aly (2019) offer insights into the antioxidant and antimicrobial potency of Anise plants and provide a basis for further phytochemical and pharmacological research.

Parsley, scientifically referred to as *Petroselinum crispum* (Mill.) fuss, is an aromatic herb that belongs to the *Apiaceae* family and the *Petroselinum* genus (Agyare *et al.,* 2017). Originating from the Mediterranean region and Western Asia, parsley is now cultivated worldwide. It has been used for centuries as an aromatic vegetable, adding flavor and fragrance to various dishes and salads (Akıncı *et al.,* 2017; Alan *et al.,* 2017). Additionally, parsley finds applications in the food industry, perfume manufacturing, and traditional and folk medicine (Farzaei *et al.,* 2013; Akıncı *et al.,* 2017). Despite being a biennial plant, parsley is commonly grown as an annual for its edible and aromatic leaves (Dadan *et al.,* 2018). The parsley plant contains a wide range of bioactive compounds found in its leaves, stems, and roots. These include furanocoumarins (like xanthoxin, trioxalen, and angelicin), flavonoids (like quercetin, apiol, myristicin, apigenin, luteolin, and their glycosides), carotenoids (like neoxanthin, β-carotene, lutein, and violaxanthin), vitamins (like tocopherols, A, C, and B complex), minerals (like iron, zinc, calcium, and phosphorus), and fatty acids (like linolenic and palmitic acid) (Petropoulos *et al.,* 2008; Petropoulos *et al.,* 2010; Calderón-Montaño *et al.,* 2011; Agyare *et al.,* 2017; Chauhan and Aishwaya, 2018; Dadan *et al.,* 2018; El-Sayed *et al.,* 2018; Dobričević *et al.,* 2019). Numerous medicinal benefits are exhibited by these compounds, such as hepatoprotective, neuroprotective, analgesic, anti-diabetic, and spasmolytic actions (Agyare *et al.,* 2017; Chauhan and Aishwaya, 2018). Particularly, parsley leaves exhibit a range of bioactive characteristics, including anti-inflammatory, menorrhagic, immunosuppressive, anti-anemic, and anti-tumoral effects (Chauhan and Aishwaya, 2018; El-Sayed *et al.,* 2018; Roshankhah *et al.,* 2020). Additionally, it's employed to minimize the warning signs and symptoms of thrombosis, Alzheimer's, allergies, chronic bronchitis, and strokes (Chauhan and Aishwaya, 2018). In addition, parsley leaves have been used as a diuretic and anticoagulant, and they are used to treat skin conditions, rheumatism, cystitis, edema, kidney stones, liver cleansing, and menstruation problems (Calderón-Montaño *et al.,* 2011; Agyare *et al.,* 2017; Chauhan and Aishwaya, 2018; Dadan *et al.,* 2018).

This study was designed to evaluate the quality and economic production of curled parsley and anise plants in different parts of Egypt. The results are intended to provide Egyptian exporters and local manufacturers with thorough analytical data. In addition, this study will determine the most suitable locations for growing these plants.

2. MATERIALS AND METHODS

The study was carried out during two consecutive seasons: 2021/2022 and 2022/2023. Anise and curly parsley plants were grown at six different sites, and their composition, economic output, and essential oil content were evaluated. These sites were distributed across three different governorates as follows: A) El-Minia Governorate (Old Land, Biosystem Farm, Sekem Farm), B) Bahariya Oasis (Lena Farm, Sekem Farm), and C) Aswan Governorate (Wadi El-Noqra).

Soil samples were collected from each site and prepared for analysis (Texture properties and chemical properties for different locations were presented in Tables (1 and 2). Samples of the water used for irrigation at these locations were gathered, and chemical analyses were performed on them (Table 3). In compliance with the procedures described by Page (1982) and Klute (1986), the physical and chemical analyses of the soil and water samples were carried out.

During the middle of October every year, the anise and curled parsley seeds were sowed straight in the open field. The experimental area (plot) was 30 m² (4 × 7.5 m) and had 15 rows, with a gap of 50 cm between rows and 25 cm between hills. Forty-five days after the open field plants were planted, they

Table 1. Texture properties of soil in the studied locations.

Locations	Course Sand (%)	Soft Sand (%)	Silt (%)	Clay (%)	Texture
A) El-Minia					
1- Old Land	8.9	19.2	36.3	35.0	Clay Loam
2- Biosystem Farm	33.40	60.26	3.97	2.37	Sandy
3-Sekem Farm	37.4	38.2	17.9	6.5	Sandy Loam
B) Bahariya Oasis					
4- Lena Farm	40.3	46.5	10.7	2.5	Sandy
5- Sekem Farm	30.0	39.3	10.2	22.1	Clay Loamy Sand
C) Aswan					
6- Wadi El-Noqra	34.0	38.4	19.0	8.6	Sandy Loam

Table 2. Chemical properties of soil in the studied locations.

Locations	EC 1:5 dSm^{-1}	PH (2.5:1)	Soluble Cations (meq L^{-1})				Soluble Anions (meq L^{-1})			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
A) El-Minia										
1- Old Land	5.83	0.76	1.00	0.40	1.90	0.60	-	1.33	1.50	1.00
2-Biosystem Farm	8.27	2.82	5.00	2.90	18.70	1.50	-	1.90	11.00	15.20
3-Sekem Farm	7.69	1.14	3.40	2.40	5.10	0.80	-	1.40	7.50	2.80
B)Bahariya Oasis										
4- Lena Farm	8.11	0.70	2.30	1.50	2.60	0.60	-	2.10	2.50	2.40
5- Sekem Farm	7.78	0.43	0.70	0.30	2.60	0.50	-	1.10	2.00	1.00
C) Aswan										
6-Wadi El-Noqra	8.00	0.56	1.00	0.50	3.60	0.90	-	1.90	3.50	0.60

Table 3. Chemical properties of water irrigation in the studied locations.

Locations	EC 1:5 dSm^{-1}	PH (2.5:1)	Soluble Cations (meq L^{-1})				Soluble Anions (meq L^{-1})			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
A) El-Minia										
1- Old Land	0.37	7.38	1.30	0.5	1.6	0.32	-	1.10	2.30	0.32
2- Biosystem Farm	0.42	8.96	1.10	0.4	2.3	0.32	-	1.0	2.50	0.62
3-Sekem Farm	0.96	7.82	4.0	1.2	3.6	0.87	-	0.9	2.80	5.97
B) Bahariya Oasis										
4- Lena Farm	0.45	7.16	1.20	1.0	1.7	0.20	-	1.3	2.3	0.5
5- Sekem Farm	0.38	7.14	1.10	0.5	1.8	0.50	-	1.3	2.3	0.5
C) Aswan										
6- Wadi El-Noqra	0.69	8.08	2.1	0.80	3.80	0.30	-	1.50	5.0	0.5

were thinned, leaving two plants per hill. Every season, May was the time for plant harvesting.

a. Yield component

During May of each season, the yield component was recorded as fruit weight per plant as well as fruit yield per feddan.

b. Essential oil content and Constituents

The essential oil percentage of anise seeds as well as curled parsley herbs under different locations was determined using water distillation methods using a Clevenger-type apparatus (Clevenger, 1928). The essential oil content per plant and yield per feddan have been calculated.

A gas chromatography-mass spectrometry apparatus located at the Department of Medicinal and Aromatic Plants Research, National Research Center, was utilized to analyze the essential oil samples during the second season. The instrument utilized was a TRACE GC Ultra Gas Chromatograph (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 measuring 30 m x 0.25 mm inner diameter and 0.25 µm film thickness. Analyses were conducted employing helium as the carrier gas at a flow rate of 1.0 mL/min and a split ratio of 1:10, following this temperature program: starting at 40°C for 1 min; ramping up at 4.0°C/min to 160°C and holding for 6 min; further increasing at 6°C/min to 210°C and holding for 1 min. Both the injector and detector were maintained at 210°C. Diluted samples (1:10 hexane, v/v) of 0.2 µL of the mixtures were consistently injected. Mass spectra were acquired through electron ionization (EI) at 70 eV, within a spectral range of m/z 40-450. Identification of most compounds relied on two analytical methods: (a) KI, Kovats indices referencing n-alkanes (C9-C22) from the National Institute of Standards and Technology (2009), and (b) mass spectra comparison (including authentic chemicals, the Wiley spectral library collection, and NSIT library).

c. Statistical analysis

The study's data were statistically analyzed using Snedecor and Cochran's (1980) recommended procedures. The Tukey HSD multiple range test was used to compare the means of each location. The MS-DOS/CoStat Exe application was used to perform an additional analysis of variance (ANOVA) on the data.

3. RESULTS

3.1. Anise fruits

3.1.1. Fruits yield

Analysis of variance revealed that locations highly affected fruit weight and yield of anise plants (Table 4). Results showed that anise plants cultivated under old land at El-Minia Governorate resulted in the maximum mean values of fruit weight (21.32 and 25.80 g/plant) and yield/feddan (596.96 and 722.40 Kg/Fed) in the 1st and 2nd season, respectively. For anise plants, Fruit yield can be arranged in descending order by locations as follows: Old Land (El-Minia) > Lena Farm (Oasis) > Sekem farm (El-Minia) > Sekem farm (Oasis) > Wadi El-Noqura (Aswan) > Biosteam (El-Minia).

Table 4. Fruit weight/plant and fruit yield/Fed of anise plants under different locations in the 1st and 2nd season.

Locations	Fruit weight (g/plant)		Fruit yield (kg/Fed)	
	1st season	2nd season	1st season	2nd season
A) El-Minia				
1- Old Land	21.32 a	25.80 a	596.96 a	722.40 a
2- Biosystem Farm	16.54 b	18.90 b	463.12 e	529.20 b
3-Sekem Farm	17.54 b	16.35 b	491.12 c	457.80 d
B) Bahariya Oasis				
4- Lena Farm	18.03 b	18.40 b	504.84 b	515.20 bc
5- Sekem Farm	17.41 b	16.95 b	487.48 d	474.60 d
C) Aswan				
6- Wadi El-Noqra	17.38 b	17.93 b	486.64 d	502.00 c
***F* value**	125.61**	31.86***	99028***	2490***

Differences in means within the columns that are denoted by different letters are considered statistically significant at $P = 0.05$.

3.1.2. Essential oil content and its composition

Results tabulated in Table (5) showed that locations significantly affected essential oil content during both seasons. In terms of essential oil percentage (%), there was no significant difference among locations in the 1st season. Meanwhile, in the 2nd season the differences were significant. Essential oil percentage reached to its maximum value under Sekem Farm (Oasis) which recorded 2.51% and the lowest yield under Lena Farm (Oasis) which gave 2.04% in the 2nd season.

Data regarding essential oil content per plant and yield per feddan under different locations were presented in Table (5). It can be noticed that plants cultivated under Old Land (El-Minia) gave the maximum mean values of essential oil content (0.667 ml/plant and 18.68 L/Fed in the 1st season) as well as (0.606 ml/plant and 16.97 L/Fed. in the 2nd season). For essential oil yield, it can be arranged in descending order by locations as follows: Old Land (El-Minia) > Sekem Farm (Oasis) > Lena Farm (Oasis) > Sekem (Minia) > Biosteam (El-Minia) > Wadi El-Noqura (Aswan).

In Table (6), GC-MS analysis of anise fruit essential oil from different locations identified 41 compounds, and the major compounds were anethole and Estragole (Methyl Chavicol). There were clear variations in the chemical composition of anise fruit essential oil, especially its major compounds. Anethole content ranged between 48.2% to 95.01% of essential oil. The highest anethole content was shown in anise plants cultivated under Lena (El-Bahrya Oasis) followed by Sekem (El-Minia), and the lowest anethole was shown under Old Land (El-Minia) conditions. The 2nd main component was Estragole (Methyl Chavicol) which ranged from 0.85% to 24.42% of essential oil. The highest Estragole was shown under Old Land (El-Minia) conditions, and the lowest was shown under Lena (El-Bahrya Oasis) conditions.

Table 5. Essential oil percentage (%), content (ml/plant) and yield (L/Fed) of anise plants under different locations in the 1st and 2nd season.

Locations	Essential oil (%)		Essential oil (ml/plant)		Essential oil (L/Fed)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
A) El-Minia						
1- Old Land	3.13 a	2.35 b	0.667 a	0.606 a	18.68 a	16.97 a
2- Biosystem Farm	2.99 a	2.32 b	0.495 c	0.438 b	13.86 c	12.28 b
3-Sekem Farm	3.20 a	2.15 c	0.561 b	0.352 b	15.71 b	16.09 a
B) Bahariya Oasis						
4- Lena Farm	3.20 a	2.04 d	0.577 b	0.375 b	16.16 b	10.51 b
5- Sekem Farm	3.60 a	2.51 a	0.627 ab	0.425 b	17.56 ab	11.91 b
C) Aswan						
6- Wadi El-Noqra	2.55 a	2.33 b	0.443 c	0.418 b	12.40 d	11.70 d
***F* value**	3.88***	0.069***	0.142***	0.021***	111.01***	19.65***

Differences in means within the columns that are denoted by different letters are considered statistically significant at *P* = 0.05.

3.2. Curled parsley

3.2.1. Herb yield

Concerning the analysis of variance results in Table (7), it can be noticed that locations had a high significant effect on herb yield characters of curled parsley plants. Lena Farm (Oasis) was the suitable location for herb yield which was judged by maximum herb weight (454.28 and 340.15 g/plant) resulting greatest yield (12.72 and 9.52 ton/Fed.) in the 1st and 2nd season, respectively, followed by Old Land (El-Minia) which produced (430.67 and 344.53 g/plant) and (12.06 and 9.65 ton/Fed) in the 1st and 2nd season, respectively. Herb yield can be arranged in descending by the locations as follows: Lena Farm (Oasis) > Old land (El-Minia) > Sekem Farm (El-Minia) > Wadi El-Noqura (Aswan) > Sekem (Oasis) > Biosteam Farm (El-Minia).

Table 6. Essential oil components relative percentage of *Pimpinella anisum* L. (2^{nd} Season).

		RT	L-1	L-2	L-3	L-4	L-5	L-6
1	**α-pinene**	4.74	1.65	0.06	0.02	0.03	0.08	0.24
2	**sabinene**	5.80	0.08	0.03	--	--	0.02	0.03
3	**β-pinene**	5.95	0.14	--	0.09	--	--	0.02
4	**β-myrcene**	6.24	0.21	--	--	--	--	--
5	**α-phellandrene**	6.83	0.18	--	--	--	--	--
6	**α-terpinene**	7.15	0.07	--	--	--	--	--
7	**d-limonene**	7.59	10.8	0.56	0.09	--	0.26	0.73
8	**β-phellandrene**	7.70	0.02	--	0.07	--	0.09	--
9	**cis-β-ocimene**	7.77	0.51	--	--	--	--	--
10	**γ-terpinene**	8.63	--	--	--	--	--	0.07
11	**l-fenchone**	9.92	0.29	0.32	--	0.03	0.28	0.23
12	**l-linalool**	10.29	--	--	--	0.11	--	0.53
13	**geyrene**	11.83	0.1	0.02	--	--	0.04	0.03
14	**isomenthone**	12.71	0.1	--	--	--	--	--
15	**l-menthone**	13.09	0.55	0.04	0.06	--	--	--
16	**p-menth-1-en-4-ol**	13.77	0.14	--	--	0.05	--	--
17	**estragole**	14.63	24.42	4.90	1.71	0.85	5.07	6.71
18	**(±)-pulegone**	16.40	0.13	0.05	0.05	--	--	--
19	**anethole**	18.68	48.20	80.55	93.61	95.01	91.12	84.78
20	**δ-eiemene**	20.12	0.31	0.03	0.04	0.11	0.05	0.13
21	**alfa.-copaene**	21.91	0.09	--	--	--	--	--
22	**β-elemene**	22.56	0.10	--	--	0.03	0.04	0.05
23	**aromadendrene**	23.83	0.14	--	--	--	--	--
24	**α-himachalene**	25.14	0.33	0.07	0.06	0.18	--	0.12
25	**isolongifolene, 4,5-dehydro-**	25.87	0.05	0.08	0.06	--	0.04	0.04
26	**longifolene-**	26.43	3.43	0.88	0.74	1.16	1.03	1.49
27	**germacrene-d**	26.54	1.02	0.31	--	0.23	--	0.34
28	**zingiberene**	27.21	0.25	--	--	--	--	--
29	**α-longipinene**	27.31	0.26	0.08	0.06	0.11	0.09	0.20
30	**cis-farnesol**	27.81	0.12	0.05	--	--	--	--
31	**γ-muurolene**	27.92	0.07	--	--	--	--	--
32	**δ-cadinene**	28.09	--	0.09	0.04	--	0.03	0.05
33	**β-cedrene**	28.48	0.08	--	--	--	--	0.05
34	**α-guaiene**	29.79	0.06	0.04	--	--	--	0.04
35	**caryophyllene oxide**	30.70	0.04	0.03	--	--	--	--
36	**junipene**	30.74	0.06	0.03	--	--	--	--
37	**spathulenol**	32.84	0.09	0.17	0.14	0.05	0.09	0.10
38	**tau.-cadinol**	33.31	0.13	--	--	--	--	--
39	**α-acorenol**	33.55	0.06	0.05	0.03	--	0.02	0.03
40	**acetisoeugenol**	40.54	4.51	9.38	2.49	1.19	1.07	3.10
41	**carbofuran 3-oh**	42.49	0.4	1.66	0.28	0.14	0.12	0.47
	total		99.19	99.48	99.64	99.28	99.54	99.58

L-1= Old Land (El-Minia), L-2= Biosystem (El-Minia), L-3= Sekem (El-Minia), L-4= Lena (El-Bahrya Oasis), L-5= Sekem (El-Bahrya Oasis), L-6= El-Nokra (Aswan).

Table 7. Herb weight/plant and fruit yield/Fed of curled parsley plants under different locations in the 1st and 2nd season.

Locations	Fruit weight (g/plant)		Fruit yield (ton/Fed)	
	1st season	2nd season	1st season	2nd season
A) El-Minia				
1- Old Land	430.67 b	344.53 a	12.06 a	9.65 a
2- Biosystem Farm	70.82 e	116.41 f	1.96 de	3.26 b
3-Sekem Farm	152.30 d	120.52 e	4.26 bc	3.37 b
B) Bahariya Oasis				
4- Lena Farm	454.28 a	340.15 b	12.72 a	9.52 a
5- Sekem Farm	89.21 e	117.27 f	2.50 cde	3.28 b
C) Aswan				
6- Wadi El-Noqra	136.20 d	135.16 d	3.81 bcd	3.78 b
***F* value**	75954***	31469.7***	59.63***	24.68***

Means within the columns that are followed by different letter are significantly different at $P = 0.05$.

3.2.2. Essential oil content and its composition

According to the analysis of variances for essential oil percentage and yield, Table (8) revealed that locations significantly affected essential oil (%) and yield. The maximum essential oil percentage (0.573 and 0.390 %), as well as essential oil content (2.603 and 1.326 ml/plant) and yield (72.89 and 37.14 L/fed) were obtained under Lena Farm (Oasis) in the 1st and 2nd seasons, respectively. For essential oil yield, it can be arranged in descending by the locations as follows: Lena Farm (Oasis) > Old land (El-Minia) > Sekem Farm (El-Minia) > Wadi El-Noqura (Aswan) > Sekem (Oasis) > Biosteam Farm (El-Menia).

Table 8. Essential oil percentage (%), content (ml/plant) and yield (L/Fed) of curled parsley plants under different locations in the 1st and 2nd season.

Locations	Essential oil (%)		Essential oil (ml/plant)		Essential oil (L/Fed)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
A) El-Minia						
1- Old Land	0.356 b	0.351 cd	1.533 b	1.210 b	42.93 b	33.87 b
2- Biosystem Farm	0.353 b	0.359 bcd	0.247 e	0.418 e	6.92 e	11.70 e
3-Sekem Farm	0.406 b	0.379 ab	0.618 d	0.454 d	17.30 d	12.79 d
B) Bahariya Oasis						
4- Lena Farm	0.573 a	0.390 a	2.603 a	1.326 a	72.89 a	37.14 a
5- Sekem Farm	0.363 b	0.363 bc	0.324 e	0.426 de	9.08 e	11.92 de
C) Aswan						
6- Wadi El-Noqra	0.387 b	0.381 ab	0.526 d	0.515 c	14.74 d	14.42 c
***F* value**	0.018***	0.001***	58.035***	12.608***	1624.97***	353.01***

Means within the columns that are followed by different letter are significantly different at $P = 0.05$.

Cultivation of curled Parsley in different locations inside Egypt caused great variation in the composition of its volatile oil. The total identified compounds in the Parsley samples ranged from 98.18 to 99.56 representing about 67 compounds (Table 9). The phenylpropanoid myristicin was the major component in all samples where it ranged from 11.56 to 35.3%. The highest relative percentage of Myristicin (35.3 %) was obtained from plants cultivated under Wadi El-Nokra (Aswan). The 2nd main component was 1,8-Cineole (acyclic ether and a monoterpenoid) ranged from 3.52 to 25.83%. Lena Farm gave the maximum relative percentage value of of 1,8-Cineole which recorded 25.38%. This was followed by the acyclic monoterpene hydrocarbon β-Myrcene where Sekem Farm (El- Bahariya Oasis) produced the highest relative percentage (12.33%).

Table 9. Essential oil components relative percentage of curled parsley (2nd Season).

	RT	L-1	L-2	L-3	L-4	L-5	L-6
1. α-Pinene	4.69	8.95	7.44	4.38	0.90	0.19	6.37
2. Camphene	5.13	0.13	0.10	0.1	--	--	0.09
3. Sabinene	5.71	0.50	--	0.24	--	--	0.22
4. β-Pinene	5.87	5.03	3.90	2.51	0.50	0.21	3.19
5. β-Myrcene	6.13	6.43	6.90	3.22	1.06	0.32	6.57
6. p-Mentha-1(7),8-diene	6.63	0.17	0.02	0.15	--	--	0.17
7. α-Phellandrene	6.71	1.27	0.75	0.47	0.12	--	0.92
8. o-Cymene	7.34	0.78	1.08	0.6	0.15	--	0.85
9. D-Limonene	7.43	4.47	4.95	2.72	0.93	0.25	3.31
10. 1,8-Cineole	7.52	25.83	5.85	23.06	3.73	3.52	24.89
11. trans-β-Ocimene	8.00	0.05	0.22	--	--	0.31	0.05
12. DELTA.3-Carene	8.44	0.22	0.61	--	--	0.32	0.19
13. α-Terpinolene	9.39	2.15	6.27	0.96	0.71	--	2.11
14. p-Cymenene	9.75	5.00	7.04	1.52	0.6	0.27	3.06
15. 1,3,8-p-Menthatriene	10.58	3.35	8.80	0.14	--	--	0.18
16. (-)-Carvyl acetate	11.44	0.14	0.34	--	--	--	--
17. cis-p-Menthan-3-one	12.75	0.28	--	1.02	--	0.51	--
18. cis-p-mentha-1(7),8-dien-2-ol	13.35	0.07	0.12	--	0.15	--	0.06
19. p-Cymen-8-ol	13.88	0.26	0.26	0.36	0.29	0.17	0.11
20. Pulegone	15.85	0.61	0.46	0.65	--	--	0.11
21. Limonen-6-ol, pivalate	16.29	0.18	--	--	--	--	--
22. Phellandral	17.71	--	--	--	0.27	0.33	--
23. Dihydroedulan II	17.86	--	--	--	0.12	--	0.12
24. α-Copaene	19.95	--	--	--	0.13	0.14	--
25. α-Cubebene	21.19	0.03	--	0.33	1.08	1.07	0.17
26. β-copaene	21.29	0.04	--	0.12	0.21	0.28	0.08
27. Alloaromadendrenoxid-(1)	21.50	0.05	0.07	0.23	0.87	1.45	0.37
28. trans-β-Damascenone	21.62	--	--	--	0.78	0.8	0.18
29. β-elemene	21.81	0.32	0.71	2.69	14.43	15.17	2.87
30. Dehydro-β-ionone	22.87	--	--	--	0.83	--	--
31. Caryophyllene	23.01	0.06	--	0.36	0.99	0.9	0.62
32. γ-Elemene	23.45	--	--	0.2	0.37	0.4	0.11
33. α-Bergamotene	23.57	--	--	--	0.24	0.23	0.04
34. Alloaromadendrene	23.74	--	--	--	0.21	0.26	--
35. cis-β-Farnesene	24.51	--	--	--	0.28	--	0.05
36. β-Cedrene	24.62	--	--	--	0.3	0.72	0.06
37. α-Gurjunene	25.24	0.05		0.15	0.42	0.42	0.15
38. Germacrene-D	25.57	0.18	0.17	0.89	1.04	0.78	0.53
39. Cedren-13-ol, 8-	25.71	--	--	--	0.23	0.11	--
40. Dihydro-β-agarofuran	25.89	0.51	0.36	1.85	3.77	3.9	1.24
41. α-selinene	26.19	--	0.08	0.17	1.11	0.74	0.2
42. α-acorenol	26.38	--	--	--	0.15	0.14	0.04
43. germacrene A	26.64	0.33	0.59	1.88	1.98	0.72	0.57
44. β-Bisabolene	26.70	--	0.1	--	1.15	0.97	0.17
45. δ-Cadinene	27.08	0.04	0.05	0.22	0.78	0.64	0.17
46. β-Sesquiphellandrene	27.37	0.40	1.48	1.38	11.56	8.38	2.31
47. Epiglobulol	27.50	0.63	0.42	1.89	2.93	3.5	1.3
48. Myristicin	27.72	22.51	35.3	29.98	7.78	18.26	25.7
49. Germacrene B	28.65	0.56	0.31	2.97	4.29	3.17	1.48
50. Dihydro-β-agarofuran	28.81	1.32	1.7	1.83	2.1	2.56	1.13

Table 9.

	RT	L-1	L-2	L-3	L-4	L-5	L-6
51. Isoshyobunone	29.02	0.37	0.38	1.04	6.48	9.93	2.13
52. Ledene oxide-(II)	29.44	--	--	--	0.54	0.46	0.1
53. (-)-Caryophyllene oxide	29.62	--	--	0.13	0.31	0.29	0.07
54. Junipene	29.75	--	--	--	0.49	0.3	--
55. Murolan-3,9(11)-diene-10-peroxy	30.23	--	--	--	0.44	0.53	0.13
56. Carotol	30.46	3.63	1.71	4.95	4.89	6.96	3.38
57. β-Guaiene	31.06	--	--	--	0.25	0.2	0.04
58. Calarene epoxide	31.37	0.05	--	0.19	1.06	1.27	0.26
59. Isoaromadendrene epoxide	31.60	0.15	0.14	0.76	1.83	1.96	0.5
60. α-Cadinol	32.03	--	--	0.21	0.4	0.25	0.09
61. Ledene	32.65	--	--	0.16	0.96	0.29	0.12
62. (-)-Spathulenol	33.07	--	--	0.16	0.76	0.54	0.09
62. Apiol	33.45	1.69	0.28	1.24	0.31	--	0.21
63. 4-Bromo-1-naphthalenamine	34.49	--	--	0.17	0.63	0.12	0.08
64. Santalol, cis,α-	34.62	--	--	0.23	0.42	0.24	0.12
65. Longipinocarveol, trans-	35.11	--	--	0.29	1.3	0.47	0.13
66. Phytol	38.68	--	--	0.14	0.82	--	--
67. Hexahydrofarnesyl acetone	39.05	--	--	0.16	6.75	3.27	--
Total Identified compounds	--	98.79	98.96	99.07	98.18	99.19	99.56

L-1= Old Land (El-Minia), L-2= Biosystem (El-Minia), L-3= Sekem (El-Minia), L-4= Lena (El-Bahrya Oasis), L-5= Sekem (El-Bahrya Oasis), L-6= El-Nokra (Aswan).

4. DISCUSSION

In this study, the economic yield represented by the fruit yield of anise and herb yield of curled parsley showed significant differences among locations. The highest yield of anise plants was shown under old Land in El-Minia governorate. These region characteristics by loamy sand soil with less EC value. On the other hand, the highest curled parsley yield was shown under Lena Farm in Old Land in El-Minia governorate and El-Bahariya Oasis governorate. In contrast to Old Land, Lena farm characteristics by sandy soil with high EC. Crop production hinges on environmental conditions, serving as the primary determinant of crop success within specific regions. Strategic consideration of agro-climatic zones and the selection of suitable locations are crucial for optimizing both the yield and quality of medicinal plants (Hendawy *et al.,* 2019a; Salaheldin *et al.,* 2020). Additionally, soil type significantly influences growth parameters and the composition of essential oils (Hendawy *et al.,* 2017, 2019b). It serves as a critical factor that constrains plant growth, productivity, and biochemical composition
(Kahkashan *et al.,* 2016).

Loam is a nutrient-rich soil consisting of approximately two-fifths sand, two-fifths silt, and one-fifth clay, amalgamates the favorable qualities of each soil type, rendering it conducive for the growth of almost any plant species. Its composition facilitates the free flow of moisture and nutrients around plants, with its dark, moist, and porous nature ensuring excellent drainage. Plants thriving in soils adept at both retaining and draining water tend to exhibit robust health and productivity. Loamy soil harbors essential natural elements such as bacteria, fungi, and earthworms, which collectively act as decomposers, breaking down organic matter to form humus. Humus, in turn, fosters root growth while effectively retaining water and air. Soil texture primarily dictates the chemical and physical properties of soil, including water-holding capacity, nutrient retention, drainage, strength, and thermal characteristics. The suitability of soil for specific crops depends on various factors such as texture, depth, water table level, salinity, and alkalinity. Loamy soils, with their intermediate properties, retain more water and nutrients compared to sandy soils, while also boasting superior drainage, aeration, and tillage properties compared to clay soils.

Consequently, loamy soils are widely regarded as optimal for agricultural production (Hendawy *et al.*, 2017).

In this study, the quality represented by essential oil percentage and its composition showed significant differences among locations. The highest essential oil percentage of anise fruits was shown under Sekem Farm in El-Bahariya Oasis governorate, and the highest essential oil yield was shown in Old Land in El-Minia governorate. Sekem Farm characteristics by clay loamy sand with a little higher EC value. The highest anesole (95.01%) and lowest estragole (0.85%) were shown under Lena Farm, while the lowest anesole (48.20%) and highest estragole (24.42%) were shown under old Land. These results reflected the important role of soil properties on the essential oil compositions of anise fruits. From the literature, anise fruits contain 1.5–6.05% volatile oil consisting primarily of *trans*-anethole (Besharati-Seidani *et al.,* 2005). Numerous studies have demonstrated the diversity of compounds found in anise fruit essential oil. Major ingredients were identified by Gulcin et al. (2003) as eugenol, trans-anethole, methyl chavicol, anisaldehyde, estragole, coumarins, scopoletin, umbelliferone, estrols, terpene hydrocarbons, polyenes, and polyacetylenes. Trans-anethole (93.9%) and estragole (2.4%) were found to be the most common compounds in Özcan and Chalchat's (2006) GC and GC-MS analysis of *Pimpinella anisum* L. fruits. Other significant constituents included (E)-methyleugenol, α-cuparene, α-himachalene, β-bisabolene, p-anisaldehyde, and cis-anethole. According to Orav et al. (2008), trans-anethole (76.9–93.7%) and γ-himachalene (0.4–8.2%) were found to be the main constituents in the essential oil composition of *Pimpinella anisum* L. fruits from various European regions, along with p-anisaldehyde, methylchavicol, and trans-pseudoisoeugenyl 2-methylbutyrate. Additionally, Trans-anethole, the compound that makes up 57.4% of the whole plant oil and 75.2% of the seed oil, is the main constituent, according to Embong et al.'s (1997) analysis of the parts of whole plants and seeds of *Pimpinella anisum* from Alberta. Other compounds that are also present include cis-anethole, carvone, β-caryophyllene, dihydrocarvyl acetate, estragole, and limonene.

In this study, the quality represented by essential oil percentage and its composition showed significant differences among locations. The highest essential oil percentage and yield of curled parsley herb was shown under Lena Farm in El-Bahariya Oasis governorate where the lowest major compound Myristicin (7.78%) was observed. The highest Myristicin (35.30%) was shown under Biosystem Farm in El-Minia governorate which is characterized by sandy soil. These results reflected the important role of soil properties on essential oil compositions of curled parsley herb. Genetic, physiological, environmental, and processing variables are among several factors that have been found to have an impact on the quality of essential oils. (Hay and Svoboda, 1993; Lawrence, 2002). Different chemotypes exist within parsley populations due to genetic variation and environmental conditions, as demonstrated by Bernath (1986) and Simon and Quinn (1988) who showed that genetic variability had a significant impact on essential oil constituents in a parsley germplasm collection. Pino et al. (1997) observed that myristicin and apiole were the main ingredients in parsley herb oil, instead Vokk et al. (2011) showed that myristicin, β-phellandrene, p-1,3,8-menthatriene, and β-myrcene were the main contents in parsley leaves. Furthermore, differences in main components were noted amongst parsley cultivars by Aziz et al. (2013), with myristicin, β-phellandrene, and 1,3,8-menthatriene being prevalent in various cultivars. According to Mangkoltriluk et al. (2015), the main ingredients in fresh parsley leaves are apiole, pinene, myrcene, phellandrene, and 1,3,8-p-Menthatriene. Parsley leaf oil is mostly composed of p-1,3,8-menthatriene, β-phellandrene, myristicin, and myrcene, according to Orav et al. (2013). Smaller amounts of terpinolene, α-phellandrene, limonene, 1-methyl-4-isopropenylbenzene, β-pinene, and α-pinene are also found. These results align with those of other scientists (Simon and Quinn, 1988; Banks *et al.,* 2013; Bahukhandi *et al.,* 2014) who also detected comparable main components in parsley leaves and roots.

5. CONCLUSION

The findings of this study demonstrate that careful consideration of both optimum sites and agro-climatic zones is required to optimize both the amount and composition of essential oils. El-Minia governorate under clay loam soil is most suitable for anise cultivation to provide high yield and quality. Meanwhile, El-Bahariya Oasis governorate under sandy soil is most suitable for curled parsley to obtain high yield and quality.

Author Contribution

HMA: Concept study design data, literature overview discussion; WSS: literature overview discussion, data analysis; SFH and MSH: Experiments working, collection statistical analysis. All authors contribute to the writing, editing, and approval of the final manuscript version.

Competing Interests

The authors declare no competing interests.

Ethical Approval.

All the methods and handling of the plant is characterized plant were performed by relevant guidelines and regulations.

Data Availability

This published publication contains all of the data gathered or analyzed during this investigation.

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الملخص العربي

تقييم المحصول الاقتصادي وجودة نباتات اليانسون والبقدونس المجعد تحت مواقع جغرافية مختلفة

يعد فهم التنوع في النباتات الطبية والعطرية أمرًا ضروريًا لتوصيف تركيبها الكيميائي بشكل شامل، خاصة عند التعامل مع عينات من مناطق مختلفة ذات خلفيات جغرافية متميزة. كان الغرض من هذه الدراسة هو تقييم الخصائص الكيميائية والمحصول الاقتصادي للزيوت الطيارة من ثمرة اليانسون ونبات البقدونس المجعد في مواقع مصرية مختلفة. وقد أجريت الدراسة على موسمين متتاليين ٢٠٢١/٢٠٢٢ و٢٠٢٢/٢٠٢٣. تم اختيار ستة مواقع لتقييم زراعة نباتات اليانسون والبقدونس المجعد في ثلاث محافظات متميزة: أ) محافظة المنيا (الأرض القديمة، ومزرعة النظام الحيوي، ومزرعة سيكم)، ب) الواحة البحرية (مزرعة لينا ومزرعة سيكم)، و ج) محافظة أسوان (وادي النقرة). وجدت الدراسة تأثيرات كبيرة للموقع على وزن ثمرة اليانسون وإنتاجيتها، حيث أظهرت الأراضي القديمة بمحافظة المنيا أعلى القيم. تختلف نسبة الزيوت العطرية حسب الموقع، حيث تنتج مزرعة سيكم (الواحة) أعلى نسبة. أنتجت الأرض القديمة (المنيا) أكبر كمية من الزيت العطري لكل نبات. حدد تحليل GC–MS المكونات الرئيسية وهي الأنيثول والإستراجول، مع تركيبات مختلفة عبر المواقع. بالنسبة للبقدونس المجعد، أنتجت مزرعة لينا (الواحة) أعلى وزن عشبي وزيت عطري. في جميع أنحاء مصر، تباين تكوين الزيت الطيار في البقدونس، مع وجود اختلافات ملحوظة في وادي النقرة (أسوان) ومزرعة لينا. تعد المنطقة والموقع المناخي الزراعي المناسبين أمرًا بالغ الأهمية لتحسين محتوى الزيوت الأساسية وتكوينها. تعتبر المنيا، بتربتها الطينية، البيئة الأكثر ملائمة لزراعة اليانسون. وعلى العكس من ذلك، تعتبر الواحات البحرية، التي تتميز بتربتها الرملية، الاختيار الأمثل لزراعة البقدونس المجعد.

الكلمات المفتاحية: الينسون ، البقدونس المجعد ، خصائص التربة ، زيت اساسي ، أماكن مختلف