agronomy

Article

Essential Oil Diversity of Turnip-Rooted Parsley Cultivars

Robert Gruszecki and Magdalena Walasek-Janusz *

Department of Vegetable and Herb Crops, Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin, Doświadczalna 50a, 20-280 Lublin, Poland
* Correspondence: magdalena.walasek@up.lublin.pl; Tel.: +48-818836711

Abstract: The quality of turnip-rooted parsley (*Petroselinum crispum* var. *tuberosum*) as a seasoning ingredient depends on the content and composition of the essential oil. The content of essential oil is influenced by many factors, the main of which are genetic variations and environmental conditions. The presented work presents for the first time a comparison of such numerous cultivars of root parsley in terms of the essential oil content in both the roots and the leaves. The experiment compared the content and composition of the essential oils of fifteen parsley cultivars in two growing seasons. The essential oil was obtained by the hydrodistillation method, and the composition analysis was performed using the GC/MS technique. The essential oil content in parsley roots ranged from 0.013 to 0.045 mL 100 g^{-1} FW, while in leaves, it was within the range of 0.041–0.121 mL 100 g^{-1} FW. The leaf essential oil yield was also higher than the roots, proving that parsley leaves are a valuable spice and should not be treated as a waste product as before. It was observed in the research that the content of essential oils changed significantly due to the weather conditions in the analysed growing seasons; however, some cultivars, such as 'Kinga', 'Eagle', and 'Berlińska PNE', had a stable content of essential oils in the analysed period. The dominant component of the essential oils obtained from the roots of all cultivars was apiol. However, in the case of the essential oils obtained from the leaves, the main ingredients were myristicin, β-pinene, Z-falcarinol, and β-phellandrene, but their content was highly varied depending on the weather conditions in the analysed growing seasons.

Keywords: *Petroselinum crispum* var. *tuberosum*; cultivars; chemical compounds

check for updates

Citation: Gruszecki, R.; Walasek-Janusz, M. Essential Oil Diversity of Turnip-Rooted Parsley Cultivars. *Agronomy* **2022**, *12*, 1949. https://doi.org/10.3390/agronomy12081949

Academic Editors: Renata Nurzyńska-Wierdak, Agnieszka Najda and Anita Biesiada

Received: 22 July 2022
Accepted: 17 August 2022
Published: 18 August 2022

1. Introduction

In addition to their nutritional value, vegetables can also act as a source of valuable bioactive ingredients that benefit the health and functioning of the human body. Therefore, it is necessary to know the composition and determine the variability of the main components depending on the weather conditions or the part of the plant we eat. In Poland, turnip-rooted parsley (*Petroselinum crispum* (Mill.) Nym. var. *tuberosum*) is an essential plant used to flavour dishes. In the case of parsley as a spice plant, its essential oil content and composition are of primary importance [1–3]. The content of 1,3,8-p-mentatriene, apiol, β-phellandrene, and myristicin determines the taste and aroma of parsley [4]. The essential oil is present in all parts of this plant. Still, its content and composition are varied [5–10]. In turnip-rooted parsley, both the roots and leaves are used as spices, although they contain less essential oil than the seeds [6–9,11,12]. Many factors influence the content and composition of the essential oil, for example, cultivar, fertilisation, salinity, sowing time, root size, growth phase at harvest, and weather conditions during plant growth [5,7,10,11,13–17]. One of the most critical factors affecting the contents and composition of essential oil is the genetic differences between plants [10,18,19]. The composition of essential oil is significant because not all the parsley essential oil components have a typical parsley aroma [20–23]. The composition of essential oil is very important also because components have different cancer chemoprotective potential or antioxidant activities [24–30]. The main components of essential oils obtained from parsley root can be apiol, myristicin, β-phellandrene, β-pinene, β-myrcene, 1,3,8-p-menthatriene, trans-β-farnese, terpinolene, limonene, or falcarinol [6–8,11,16,17,31–33]. The dominant component of parsley root essential oil is apiol, but it can also be myristicin or β-pinene [7,8,11]. The most essential ingredients in parsley leaf oil are: p-mentha-1,3,8-triene, myristicin, myrcene, β-phellandrene, and apiol [1–3,7,8,19,34]. These components are present in very different amounts, which may vary from the dominant component to the amount almost below the limit of quantification [19,35].

Consumers expect the flavour and aroma of the spices used to be stable. For this reason, it was decided to conduct research on various parsley cultivars in terms of yield, content, and composition of essential oils to indicate that the content and composition of these valuable compounds are high and stable. The selection of such cultivars with the appropriate composition of essential oils can also be used in medicine, as some studies indicate their high pharmacological activity [36].

2. Materials and Methods

2.1. Description of The Station's Location

The field experiment was conducted in the Agricultural Experimental Farm Felin (51°13′37″ N 22°37′58″ E, 214 m a.s.l.) of the University of Life Sciences in Lublin, located in central-eastern Poland.

2.2. Details of Field Experiment

Fifteen parsley cultivars were studied: 'Alba' (Moravoseed Ltd., Mikulov, Czech Republic), 'Aroma', 'Eagle' (Bejo Zaden B.V, Warmenhuizen, The Netherlands), 'Berlińska PNE', 'Lenka', 'Ołomuńcka' (PNOS Ożarów Mazowiecki S.A., Duchnice, Poland), 'Brandenburska' (Spójnia HiNO sp. z o.o., Nochowo, Poland), 'Bubka RZ' (Rijk Zwaan Netherlands B.V., De Lier, The Netherlands), 'Cukrowa', 'Kinga', 'Vistula' (KHiNO Polan, Kraków, Poland), 'Gazela' (Vera-Agra Sp. z o.o., Guzowice, Poland), 'Hamburska' (Hortag Seed Co., Chapel Hill, NC, USA), 'Kaśka' (Plantico HiNO Zielonki sp. z o.o., Zielonki, Poland), and 'Omega' (Seminis Vegetable Seeds Inc., Oxnard, CA, USA). The field experiment was a randomised complete block design with four replications. The plants were grown on grey-brown podzolic soil (1.75% of organic matter, pH in KCl 6.7). The soil texture was loam with 39.0% silt, 35.2% sand, and 25.8% clay. The plants were fertilised, based on the chemical analysis of the soil, to the level of (in mg·dm^3 of soil): N 80, P 100, and K 250. The seeds, 2 kg ha^{-1}, were sown on 29 April in the first season (2015) and 28 April in the second season (2016), in two rows on the ridge, 0.675 m apart (the 0.23 m high and 0.20 m wide on top ridges). The area of one plot was 5.4 m^2 (0.675 m × 8.0 m). Parsley was cultivated following commonly accepted recommendations. Harvest was performed in the second half of October (first season—22 October, and the second—20 October).

The lowest temperature, except in April, was reported in the first growing season. The sum of precipitation was the lowest, and the differences between the sum of month precipitations were highest in the second growing season (Table 1).

Table 1. Mean air temperature and precipitation.

Month	Temperature		Precipitation	
	Growing Season			
	I	II	I	II
April	9.1	8.7	18.6	30.3
May	13.1	13.6	98.0	59.5
Juni	15.7	16.9	55.9	37.9
July	19.2	21.8	109.8	6.8
August	16.9	17.5	109.1	198.3
September	14.9	15.6	18.0	11.0
October	8.9	9.9	8.6	14.2
Mean	13.9	14.8	418	358

2.3. Essential Oil Isolation and Analyses

For the analysis, roots with a diameter of 30–50 mm and leaves fully developed, healthy, and without discoloration or damage caused by pests were used.

In order to obtain essential oil from the roots and leaves of a given variety of parsley, samples weighing 250 g of roots and 100 g of leaves were prepared, which were then hydrodistilled for 3 h. Samples were stored in the dark in fridge at the temperature of 2 °C.

The analysis composition of the essential oil was determined by GC/MS. The essential oils were analysed by gas chromatography using a GCQ apparatus (Thermo Finnigan, Santa Clara, CA, USA). Helium with a flow rate of 0.5 mL min^{-1} was used as the carrier gas. Automatic dosing with a sample division (1 µL) with a division ratio of 1: 100 was used in the analysis. The analysis was performed using a Rtx-5MS column (Restec), 20 m, 0.18 mm in diameter and with 0.2 µm-thick stationary phase film. Temperature increase was applied during the analysis where the starting was 50 °C and was held for 1 min, then increased to 280 °C by 4 °C min^{-1}. Compounds were detected with a Vatran 4000 MS/MS detector. The mass sectrometer worked in the mass scanning range of 40–1000 m z^{-1}, while the scanning speed was 0.8 s scan^{-1}.

In the second year, essential oils were analysed by gas chromatography using a Varian 4000 GC/MS/MS instrument. Helium with a flow rate of 0.5 mL min^{-1} was used as the carrier gas. Automatic dosing with a sample division (1 µL) with a division ratio of 1: 100 was used in the analysis. The analysis was performed using a VF-5ms column (DB-5 equivalent), a temperature increase was applied during the analysis where the starting temperature was 50 °C and was held for 1 min, then increased to 250 °C by 4 °C min^{-1}. Compounds were detected with a Vatran 4000 MS/MS detector. The mass sectrometer worked in the mass scanning range of 40–1000 m z^{-1}, while the scanning speed was 0.8 s scan^{-1}.

Retention indices (Kovats'a) were calculated using a series of n-alkanes C6-C40. The qualitative analysis was made based on MS spectrums, comparing them with the spectrums of the NIST library (62.000 spectrums) and LIBR terpene library (TR), provided by the Finnigan MAT company. Literature data confirmed the identification of the compounds. Essential oil components were reported as a relative percentage of the total oil by peak area. Values $\geq$ 0.1 were considered significant.

2.4. Statistical Analysis

The obtained results are presented as means that were statistically analysed by ANOVA according to a completely randomised design, and the averages were compared using Tukey's HSD test at the probability level α = 0.05. Statistical analyses were calculated using Statistica 10.0 PL software (StatSof Inc., Tulsa, OK, USA).

3. Results

The analyses showed a large variation in the content of essential oils in the leaves and roots of the examined parsley cultivars. The average content of essential oils in the roots ranged from 0.019 ('Hamburska') to 0.043 cm^3 100 g^{-1} FW ('Eagle'), and in the leaves from 0.053 ('Gazela') to 0.110 cm^3 100 g^{-1} FW ('Kinga'). The varied content of essential oils was influenced not only by the cultivar, but also by the weather conditions during the growing season. Higher average temperature and lower rainfall recorded in the second cultivation season had a positive effect on the content of oils in the roots of the cultivars 'Alba', 'Aroma', 'Brandenburska', 'Cukrowa', and 'Gazela', and in the leaves of the cultivars 'Berlińska PNE', 'Cukrowa', 'Eagle', and 'Gazela'. However, such conditions harmed the oil content in the roots of 'Hamburska' and 'Omega', and the leaves of 'Kinga' and 'Ołomuńcka'. In some cultivars, the content of the essential oils in the roots ('Berlińska BCE', 'Kaśka', 'Kinga', and 'Vistula') and leaves ('Alba', 'Aroma', 'Brandenburska', 'Bubka', 'Hamburska', 'Kaśka', 'Lenka', 'Omega', and 'Vistula') was stable, and the differences did not exceed 10% (Table 2).

Table 2. Effect of cultivar and year on essential oil content in turnip-rooted parsley roots and leaves ($cm^3 \cdot 100g^{-1}$ FW).

Cultivar	Roots			Leaves		
	Growing Season			Growing Season		
	I	II	Mean	I	II	Mean
'Alba'	0.022 ab	0.035 c–f	0.029 a–d	0.063 b–d	0.059 a	0.061 a
'Aroma'	0.029 a–f	0.042 e–f	0.036 c–f	0.086 ef	0.091 de	0.089 c
'Berlińska PNE'	0.024 a–c	0.022 a–d	0.023 ab	0.068 b–e	0.094 de	0.081 bc
'Brandenburska'	0.018 a	0.042 ef	0.030 b–e	0.060 a–d	0.063 ab	0.062 a
'Bubka'	0.037 d	0.038 cf	0.038 d–f	0.090 f	0.084 cd	0.087 c
'Cukrowa'	0.020 a	0.029 a–f	0.025 ab	0.066 b–e	0.084 cd	0.075 b
'Eagle'	0.040 fg	0.046 f	0.043 f	0.078 c–f	0.093 de	0.086 bc
'Gazela'	0.033 b–g	0.044 ef	0.039 ef	0.041 a	0.065 ab	0.053 a
'Hamburska'	0.025 a–d	0.013 a	0.019 a	0.079 d–f	0.075 bc	0.077 bc
'Kaśka'	0.036 c–g	0.033 b–f	0.034 c–f	0.063 b–d	0.064 ab	0.063 a
'Kinga'	0.039 fg	0.040 d–f	0.039 ef	0.121 g	0.099 e	0.110 d
'Lenka'	0.038 e–g	0.045 f	0.041 f	0.058 a–c	0.059 a	0.059 a
'Ołomuńcka'	0.029 a–f	0.015 ab	0.022 ab	0.068 b–e	0.054 a	0.061 a
'Omega'	0.042 g	0.020 a–c	0.031 b–e	0.054 ab	0.054 a	0.054 a
'Vistula'	0.026 a–e	0.026 a–e	0.026 a–c	0.074 b–f	0.082 cd	0.078 bc
Mean	0.031	0.033	0.032	0.071	0.075	0.073

Means followed by the same letter in the columns do not differ significantly by the Tukey test at 5% of probability.

Apiol was a predominant component of essential oils from parsley roots, and its share ranged from 18.7% to 46.3% in the first growing season, and from 24.6% to 46.7% in the second growing season. A higher share also had myristicin (6.5–27.7% in the first and 6.8–25.6% in the second season), β-pinene (6.1–19.8% in the first, and 4.7–15.9% in the second season), Z-falcarinol (1.0–14.3% in first, and 5.2–23.3% in the second season), and β-phellandrene (4.4–17.5% in first, and 2.8–10.9% in the second season). Moreover, weather conditions resulted in high variability in the chemical composition of essential oils during growing seasons. In the case of 'Brandenburska', 'Cukrowa', 'Eagle', 'Gazela', 'Alba', and 'Lenka', it was observed that the weather conditions in the second growing season had a positive effect on the content of the main ingredient—apiol. On the other hand, the high stability of the share of this compound was found in 'Berlińska PNE', 'Kinga', 'Vistula', and 'Bubka', and these were the cultivars which were additionally characterised by a high level of essential oil content in both studied growing seasons. The most significant variability occurred at the roots of 'Brandenburg', which was characterised by the greatest fluctuations in the oil content depending on the growing season. However, it is also possible that the growing conditions influenced this, as most of the cultivars with the lowest variability were bred and reproduced in Poland and were therefore adapted to local climatic conditions. Among the analysed cultivars, the lowest variability in the share of the five essential components (apiol, myristicin, β-pinene, Z-falcarinol, and β-phellandrene) was observed in 'Vistula', then 'Hamburska', and 'Kaśka', while the highest in 'Eagle' and 'Ołomuńcka' (Tables 3 and 4).

The composition of the essential oils produced by the parsley plants in the leaves differed significantly from the essential oils in the roots in terms of the basic components. The primary ingredient of leaf oil was not the same in all cultivars and also changed depending on weather conditions, e.g., in the cultivars 'Berlińska', 'Eagle', and 'Gazela'.

Table 3. Composition of the essential oils of turnip-rooted parsley cultivar roots in first season (in %).

Compound	RT	RI	'Alba'	'Aroma'	'Berlińska PNE'	'Brandenburska'	'Bubka'	'Cukrowa'	'Eagle'	'Gazela'	'Hamburska'	'Kaśka'	'Kinga'	'Lenka'	'Ołomuńcka'	'Omega'	'Vistula'	Mean
α-Pinene	7.26	936	1	1.2	0.9	0.8	1.6	1.2	1	2.4	1.4	0.8	0.7	0.7	0.5	1.2	0.6	1.1
β-Pinene	8.56	979	10.7	15.3	10.6	12.3	17.1	15.2	11.7	19.8	15.1	13	6.1	10.5	6.9	11.1	9.4	12.3
β-Myrcene	9.01	994	3.7	3.1	2.8	2.9	4.6	3.2	2.4	3.1	2.1	2.4	2.8	2.3	0.9	1.2	1.6	2.6
α-Phellandrene	9.47	1008	1		1	0.9	0.8	0.7	0.8	0.3	0.5	0.5	0.6	0.6	0.4	0.8	0.4	0.6
β-Phellandrene	10.28	1032	15.8	5.5	17.5	14.2	11.5	9.7	13.7	4.4	6.4	6.3	10.5	9.4	8.1	11.7	8.7	10.2
γ-Terpinene	11.30	1062	0.5	1.4	0.3	0.4	0.9	0.9	0.4	0.5	1.3	0.7	0.3	0.4	0.2	0.3	0.5	0.6
1,3,8-p-Menthatriene	13.15	1114	3.6	2.1	3.1	2.5	3	3.5	2.1	3.4	2	0.3	3	0.5	0.3	1.2	0.3	2.1
Not identified	26.61	1529	5.3	4	4.7	3.9	5.7	4.1	9.2	5.1	1.8	6.7	3.3	7.1	4.1	5.3	6.2	5.1
Myristicine	26.67	1531	18.2	9.7	15.9	19	8.3	15.1	6.5	11.8	8.6	9.8	24.2	20.7	27.7	14.5	19.9	15.3
Elemicine	27.62	1565	1.4	0.9	2.2	1.8	1.3	1.5	1.5	2.1	0.5	0.3	1	1.2	1.6	1	1.4	1.3
3-N-Butylphthalide	30.52	1666	0.7	0.7	0.9	1.7	0.7	1	0.7	1.1	0.1	0.9	1.2	0.7	0.7	0.5	1.2	0.9
Apiol	31.29	1694	25	40.6	23	18.7	25.6	25.5	30.9	25	43.5	37.8	33.4	28.6	43	46.3	34.3	32.1
Sedanolide	32.42	1737	0.7	1.5	0.9	1.1	1	1.7	1.6	1.5	0.2	1.2	1.5	0.7	0.6	0.2	1.6	1.1
Z-Ligustilide	32.78	1750	1.5	3	2.4	2.3	2.2	3.6	2.9	1.2	0.7	2.2	1.9	1.6	2.1	0.9	2.6	2.1
Z-Falcarinol	40.50	2064	8	5.3	10.2	13.7	10.4	8.1	10.3	14.3	12	13.3	6.8	11.5	1	1.3	7.7	8.9
Sum			97.1	94.7	96.4	96.2	94.7	95	95.7	96	96.2	96.2	97.3	96.5	98.1	97.5	96.4	96.3

Table 4. Composition of the essential oils of turnip-rooted parsley cultivar roots in second season (in %).

Compound	RT	RI	'Alba'	'Aroma'	'Berlińska PNE'	'Brandenburska'	'Bubka'	'Cukrowa'	'Eagle'	'Gazela'	'Hamburska'	'Kaśka'	'Kinga'	'Lenka'	'Ołomuńcka'	'Omega'	'Vistula'	Mean
α-Pinene	7.436	935	0.7	1.4	0.7	0.6	1	0.7	0.3	0.6	1	1.1	0.8	1	0.3	1.1	1.3	0.8
β-Pinene	8.811	982	8.3	11.3	5.7	10.2	10.5	8.2	4.7	7.1	10.6	9.2	7	13.3	5.3	15.9	15.5	9.5
β-Myrcene	8.994	988	1.9	3.4	1.7	2.5	3.4	3.3	0.9	1.6	3.3	4.9	2.2	3.7	1.9	3.2	3.8	2.8
Limonene	10.38	1032	0.4	0.8	0.5	0.6	0.6	0.5	0.3		0.6	0.7	0.8	0.5	1.6	0.6	0.7	0.7
β-Phellandrene	10.47	1034	2.8	10.9	7.3	10.6	7.7	7.5	5.6	5	5.1	7.8	7	6.9	4.2	10.1	8	7.1
γ-Terpinene	11.34	1060	1	0.6	0.4	0.8	0.9	0.8	0.1	0.3	0.8	0.6	0.4	0.7	0.6	0.9	1.2	0.7
Nonanal	12.92	1107	tr.	tr.	tr.	1.2	tr.	tr.		tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	1.2
1.3.8-p-Menthatriene	13.27	1117	1.2	5	3.4	tr.	2.5	1.9	0.7	0.5	2.6	4	1.4	0.4	1.7	0.5	1.3	1.9
Bornyl acetate	19.20	1289	0.3	1.3	0.6	0.8	1.4	1.2	0.6	0.5	0.6	0.7	1.2	0.8	0.7	0.6	1.4	0.8
Myristicin	26.96	1532	11.4	23.5	15.3	13.5	17	7.7	25.6	16.7	11.1	15.7	15.3	6.8	14.2	6.8	17.7	14.6
Elemicin	27.55	1552	2	0.9	2.8	1.1	4	0.8	1	1.1	2.4	2.2	1.4	1.2	2.4	1.2	1.4	1.7
Apiol	31.50	1689	30.6	27.6	24.6	40.5	28.8	40.1	46.7	42.5	32.4	28.8	36	41.4	30.8	34.5	31.1	34.4
3Z-Butylidene phthalide	32.68	1733	6.4	0.4	1.7	1.3	1.8	1	0.8	1.3	2	1.4	1.3	1.2	1.9	1.1	1	1.6
Z-Ligustilide	33.08	1748	4.9	2.1	3.8	3.3	4.7	4	2.4	3.5	3.5	3.4	4.1	3.4	5.1	3.5	3.6	3.7
Z-Falcarinol	40.69	2052	18.7	5.2	23.3	7.5	7.8	15.3	7.2	13.7	14.9	11.9	13.5	10.9	17.8	13.6	6	12.5
Sum			90.6	94.4	91.8	94.5	92.1	93	96.9	94.4	90.9	92.4	92.4	92.2	88.5	93.6	94	94.1

tr. Traces lower than 0.05%.

In the first cultivation season, the essential oil composition was the most abundant with β-phellandrene (13.5–40.7%) and the main component of the leaf oils: 'Aroma', 'Eagle', 'Brandenburska', 'Kinga', and 'Lenka'. The second most crucial essential oil component was 1,3,8-p-menthatriene (0.0–45.4%), and it was the dominant component of the cultivars 'Bubka', 'Hamburska', 'Kaśka', 'Vistula', and 'Ołomuńcka'. However, in 'Eagle' and 'Gazela', the relationship content was minimal, and in 'Berlińska PNE', it was not found. The third influential ingredient of the parsley leaf essential oils was β-myrcene (14.2–31.6%); it was the main ingredient of 'Gazela'. In the leaves of some cultivars, the components mentioned above were present at similar levels, e.g., in 'Alba' β-phellandrene and 1,3,8-p-menthatriene (25.1% and 25.7%), and in β-phellandrene and β-myrcene in 'Berlińska PNE' (25.4% and 28.7%) and 'Lenka' (25.4% and 20.6%). In the case of 'Omega' parsley, the content of β-phellandrene, 1,3,8-p-menthatriene, and β-myrcene was recorded at a similar level. In the 'Berlińska PNE' parsley, p-cymemene (19.5%) was also a significant component (Table 5).

Table 5. Composition of the essential oils of turnip-rooted parsley cultivar leaves in first season (in %).

Compound	RT	RI	Alba	Aroma	Berlińska PNE	Brandenburska	Bubka	Cukrowa	Eagle	Gazela	Hamburska	Kaśka	Kinga	Lenka	Ołomuńcka	Omega	Vistula	Mean
α-Pinene	7.3	936	3.6	4.6	6.2	3.8	3.6	4.1	6	4.6	4.1	4.2	4.1	4.3	3.7	7.2	4.1	4.5
β-Pinene	8.6	979	1.5	1.9	2.7	1.8	1.6	2.4	3	2.4	1.8	2.1	2	1.9	1.7	3.1	2	2.1
β-Myrcene	9.0	994	16.7	24.3	28.7	22	21.8	24.9	26.1	31.6	14.2	14.3	22.1	20.6	18.2	23.1	14.5	21.5
α-Phellandrene	9.5	1008	1.7	2	0.5	1.8	1.2	1.3	0.6	0.2	1.2	1.5	1.9	1.4	1.6	1.7	1.4	1.3
p-Cymene	10.2	1028	1	1.1	4.3	1.4	1.6	0.6	2.9	2.5	1.7	3	1.2	0.9	2.7	1.9	1.2	1.9
β-Phellandrene	10.3	1032	25.1	40.7	25.4	35.9	13.7	14.4	40.5	24.1	13.5	15.9	33.3	25.4	19.9	23.2	18.1	24.6
Terpinolene	12.3	1092	0.9	0.8		0.5	1	2.1	0.1	0.1	1.7	1.2	0.6	1.3	2.2	1.1	1.2	1.1
p-Cymemene	12.4	1094	8	6.5	19.5	10.9	6	8.1	13.6	14.3	9	8.2	8	7.5	11.2	8.1	5.1	9.6
1.3.8-p-Menthatriene	13.2	1114	25.7	9.3	0	12.8	45.4	26.6	0.2	0.1	43.4	39.8	19.9	15.8	34.9	23.8	39.2	22.5
Cryptone	15.9	1182	0.1	0.2	5	0.4	0	0	1.2	1.6	tr	0	0.1	0.2	0	0.1	0	0.6
γ-Elemene	23.88	1439	0.5	0.2	0.2	0.1	0.5	1.3	0.5	0.3	1.7	1.1	0.4	1.2	0.2	0.3	0.4	0.6
Germacrene D	25.39	1488	0.7	0.6	0.1	0.9	0.3	1.3	0.4	0.7	1.4	0.8	0.9	0.8	0.4	0.3	0.6	0.7
Myristicine	26.67	1531	7.9	4.6	0.4	2.2	0.6	3.1	0.6	3.3	0.2	0.8	1.2	11.4	0.3	3.2	6.9	3.1
Elemicine	27.65	1565	1.9	0.5	1.2	0.6	0.4	2.4	1.6	2.7	0.4	0.3	0.3	1.9	0.2	0.6	1.2	1.1
Sum			95.3	97.3	94.2	95.1	97.7	92.6	97.3	88.5	94.3	93.2	96.0	94.6	97.2	97.7	95.9	95.1

tr. Traces lower than 0.05%.

The composition of the studied essential oils obtained from the leaves of various parsley cultivars in the second growing season was slightly different. The dominant component turned out to be 1,3,8-p-menthatriene (19.1–38.5%), and it was the primary compound of the leaf oils of most parsley cultivars (Table 6). Essential components were also β-myrcene (8.7–22.8%) and β-phellandrene (7.1–24.0%). The highest content of 1,3,8-p-menthatriene was recorded in 'Cukrowa' parsley at 8.5%, and the lowest (19.1%) in 'Brandenburska'. The 'Brandenburska' was characterised by the highest content of β-phellandrene (22.7%) compared to the other cultivars, and a high content of myristicin (11.3%). Myristicin was the dominant component of 'Hamburska' leaf essential oil (30.3%). In the remaining cultivars, the content was lower (2.1–15.9%) (Table 6).

Table 6. Composition of the essential oils of turnip-rooted parsley cultivar leaves in second season (in %).

Compound	RT	RI	Alba	Aroma	Berlińska PNE	Brandenburska	Bubka	Cukrowa	Eagle	Gazela	Hamburska	Kaśka	Kinga	Lenka	Ołomuńcka	Omega	Vistula	Mean
α-Pinene	7.459	935.4	2.2	3.0	2.4	2.1	2.3	1.7	2.9	2.4	1.0	1.8	2.3	2.2	1.0	2.1	3.2	2.2
β-Pinene	8.81	982.1	1.1	1.8	1.3	1.2	1.1	1.0	1.5	1.3	0.5	1.0	1.2	1.3	0.6	1.3	1.8	1.2
β-Myrcene	9.073	991.2	19.4	16.2	17.7	18.6	17.1	20.7	18.7	20.0	8.7	21.4	15.6	22.8	17.6	17.4	21.0	18.2
α-Phellandrene	9.665	1010	1.3	1.5	1.7	2.0	1.3	1.3	1.8	1.6	0.6	1.5	1.7	1.9	1.1	2.1	1.6	1.5
Limonen	10.43	1033	3.9	2.5	3.1	0.0	3.4	2.8	2.6	2.8	1.5	2.8	1.9	2.4	1.8	1.9	3.2	2.4
β-Phellandrene	10.56	1037	8.9	11.0	14.6	22.7	7.1	9.9	14.1	14.3	8.8	12.9	13.8	18.6	24.0	20.0	11.1	14.1
Terpinolene	12.3	1089	2.4	2.4	1.5	0.9	2.6	2.2	2.6	2.4	1.3	2.6	2.2	1.2	0.7	1.5	1.5	1.9
Cymenene	12.54	1096	7.3	2.7	4.8	4.0	4.6	3.4	3.5	4.2	4.3	4.1	3.0	3.8	4.8	4.1	4.3	4.2
1.3.8-p-Menthatriene	13.45	1122	28.7	36.0	33.3	19.1	35.6	38.5	33.6	27.7	25.8	26.4	32.0	27.3	20.8	27.5	34.2	29.8
Perilla aldehyde	17.11	1228	5.8	0.6	1.6	1.8	1.8	1.4	1.2	1.3	2.6	1.5	1.5	1.8	1.3	2.3	1.7	1.9
Menth-1-en-7-ol	18.97	1282	0.5	0.0	0.5	0.5	0.7	0.5	0.5	0.7	0.0	0.6	0.5	0.5	3.1	0.3	0.6	0.6
Patchenol	20.54	1329	2.0	0.0	1.4	1.6	1.6	1.5	1.3	1.3	2.3	1.4	1.4	1.5	1.2	0.0	0.0	1.2
Not identified	22.83	1398	0.9	0.3	0.8	1.0	0.8	0.7	0.6	0.7	1.0	0.8	0.7	0.8	0.2	0.8	0.9	0.7
(Z)-beta-farnesene	24.55	1453	1.2	0.3	0.6	1.1	1.3	0.9	0.5	1.2	0.6	0.7	0.4	0.8	1.2	1.3	1.0	0.9
Germacrene D	25.64	1489	1.7	0.4	0.0	2.5	1.3	0.0	1.1	1.4	1.0	1.0	0.0	0.0	0.0	2.3	1.4	0.9
Myristicin	26.93	1531	2.1	15.9	4.2	11.3	5.0	2.5	5.7	9.3	30.3	9.9	14.1	3.0	2.9	5.4	2.7	8.3
Elemicin	27.56	1552	0.2	0.1	0.8	0.3	1.7	1.0	1.2	0.1	2.8	0.9	0.2	0.6	0.1	0.6	0.2	0.7
Germacrene B	28.06	1569	1.4	0.4	0.6	0.3	0.9	0.3	0.5	1.0	1.0	1.5	0.5	0.3	1.5	0.5	1.0	0.8
Sum			91.0	95.1	90.9	91.0	90.2	90.3	93.9	93.7	94.1	92.8	93.0	90.8	83.9	91.4	91.4	91.6

Yield

The investigated parsley cultivars also differed in terms of the yield of roots, leaves, and total yield. The highest total yield was obtained from the 'Berlińska PNE' plants and 'Lenka' cultivars, and the lowest from 'Omega'. The highest yield of roots, total and marketable, was collected from plants of the 'Berlińska PNE' cultivar, and the lowest from 'Ołomuńcka' and 'Omega'. The most efficient, in terms of the yield of leaves, were 'Berlińska BCE' and 'Lenka', and the least were 'Gazela', 'Omega', and 'Vistula', but in the case of leaves, these differences were not statistically proven (Table 7).

Table 7. Effect of cultivar on the yield of turnip-rooted parsley, mean from both seasons (t ha^{-1}).

Cultivar	Yield					
	Roots		Leaves		Total	
	Total	Marketable	Total	Marketable	Total	Marketable
'Alba'	17.7 ab	12.9 ab	20.0	16.3	37.7 ab	29.2 bc
'Aroma'	17.7 ab	12.2 ab	19.6	15.9	37.3 ab	28.1 a–c
'Berlińska PNE'	19.5 b	13.7 b	21.7	17.6	41.2 b	31.3 c
'Brandenburska'	14.6 ab	9.7 ab	18.3	14.6	32.8 ab	24.3 a–c
'Bubka'	15.1 ab	10.8 ab	20.6	16.9	35.7 ab	27.6 a–c
'Cukrowa'	17.3 ab	12.8 ab	18.1	14.8	35.3 ab	27.6 a–c
'Eagle'	16.3 ab	12.0 ab	18.8	14.6	35.0 ab	26.6 a–c
'Gazela'	17.4 ab	13.0 ab	15.6	11.6	33.0 ab	24.6 a–c
'Hamburska'	14.3 a	10.3 ab	16.4	13.2	30.6 a	23.4 a–c
'Kaśka'	17.1 ab	13.1 ab	18.5	13.6	35.6 ab	26.6 a–c
'Kinga'	15.8 ab	12.0 ab	21.5	16.6	37.3 ab	28.6 a–c
'Lenka'	17.8 ab	13.1 ab	22.9	16.9	40.6 b	30.0 c
'Ołomuńcka'	13.1 a	7.7 a	16.6	12.7	29.6 a	20.3 ab
'Omega'	12.8 a	8.4 ab	15.3	10.9	28.1 a	19.3 a
'Vistula'	16.4 ab	11.9 ab	15.4	11.4	31.7 ab	23.3 a–c
Mean	16.2	11.6	18.6	14.5	34.8	26.1

Means followed by the same letter in the columns do not differ significantly by the Tukey test at 5% probability.

The average yield of essential oils from the roots did not differ in both years of research. Still, in some cultivars, the changes in the yield of essential oils were significant, e.g., 'Hamburska', 'Ołomuńcka', and 'Omega'; in others, the yields were high and stable, e.g., 'Eagle' and 'Lenka'. The yield of essential oils from leaves was much higher than from roots, and in contrast to roots, higher in the warmer and drier season (second season). As in the case of roots, the yield of essential oils in the examined cultivars was very diversified, but its variability in cultivars was lower than in the roots. The highest yield of essential oil was obtained from 'Kinga' leaves in both seasons (Table 8).

Table 8. Effect of cultivar on the essential oil yield of turnip-rooted parsley (kg ha^{-1}).

Cultivar	Roots			Leaves		
	Season					
	I	II	Mean	I	II	Mean
'Alba'	4.23 a–d	5.68 d–f	4.95 b–d	14.89 e	9.85 bc	12.37 cd
'Aroma'	5.38 c–e	7.19 ef	6.28 de	18.49 f	16.12 ef	17.30 e
'Berlińska PNE'	5.65 d–f	3.54 a–d	4.60 bc	14.21 de	20.83 g	17.52 e
'Brandenburska'	3.00 a	5.32 c–f	4.16 ab	8.42 ab	14.18 de	11.30 bc
'Bubka'	5.18 b–e	6.10 d–f	5.64 b–e	14.22 de	21.41 g	17.82 e
'Cukrowa'	3.13 a	5.35 c–f	4.24 ab	11.29 b–d	16.05 ef	13.67 d
'Eagle'	6.98 fg	7.00 ef	6.99 e	13.49 de	18.81 fg	16.15 e
'Gazela'	5.50 c–e	8.20 f	6.85 e	6.56 a	9.82 bc	8.19 a

Table 8. *Cont.*

Cultivar	Roots			Leaves		
	Season					
	I	II	Mean	I	II	Mean
'Hamburska'	4.13 a–c	1.56 a	2.85 a	12.00 c–e	13.13 d	12.56 cd
'Kaśka'	6.43 e–g	5.42 c–f	5.92 c–e	11.34 b–d	12.14 cd	11.74 b–d
'Kinga'	5.45 c–e	7.02 ef	6.24 c–e	19.24 f	26.72 h	22.98 f
'Lenka'	7.52 g	6.98 ef	7.25 e	12.47 c–e	14.34 de	13.41 cd
'Ołomuńcka'	3.87 ab	1.91 ab	2.89 a	11.63 b–e	8.61 ab	10.12 ab
'Omega'	5.66 d–f	2.47 a–c	4.06 ab	9.72 a–c	6.79 a	8.26 a
'Vistula'	3.52 a	4.96 b–e	4.24 ab	11.03 b–d	12.97 d	12.00 b–d
Mean	5.04	5.25		12.60 A	14.78 B	

Means followed by the same letter in the columns do not differ significantly by the Tukey test at 5% of probability.

4. Discussion

Turnip-rooted parsley is a popular plant, the addition of which can increase both the taste and health benefits of dishes [37]. This plant's roots and leaves are used for spice purposes, mainly due to the content of valuable essential oils [11]. The content of essential oils in parsley roots and leaves depends on many factors, of which the cultivar and growing conditions are often mentioned [5,7,10,11,13–17,38]. In this experiment, the content of the essential oils in the parsley roots was from 0.013 to 0.045 mL 100 g^{-1} FW, and was within the lower limits of the content given by other authors [5,8,18]. The content of essential oils in parsley leaves (0.041–0.121 mL 100 g^{-1} FW) was higher than in the roots, and it was similar to the values reported in other publications [1,2,19,39]. The content of more oil in leaves with stems than in roots was also found by Orav et al. [8], but the differences were more minor. We also found different oil content in parsley roots and leaves depending on the cultivar. The influence of the population or cultivar on the content of essential oils in parsley roots and leaves was also found in earlier works [10,18,19]. In individual cultivars, depending on the growing season, the variability of the content of essential oils in leaves was usually smaller than in the roots. However, some cultivars were characterised by a lower variation in the content of these compounds depending on the weather conditions than others. The cultivars with a stable content of essential oils in the roots came from Polish breeding, which may indicate their adaptation to local climatic conditions, thus resulting in less variability in the content of aromatic compounds. In the case of leaves, no such relationship was observed, and the cultivars with the most stable oil content came from Europe and the US.

In the case of parsley, a plant used as a spice, apart from the content of essential oils, their composition is also important, which determines the characteristic aroma of the raw material. The content of β-phellandrene, 1,3,8-p-mentatriene, apiol, and myristicin probably determines the taste and aroma of parsley [4]. The examined parsley cultivars differed in the composition of essential oils in the roots and the leaves. In the roots, a storage organ intended to survive unfavourable weather conditions (winter), apiol was the dominant ingredient in all the cultivars tested, with myristicin, β-pinene, Z-falcarinol, and β-phellandrene in smaller amounts. A similar composition of essential oils in parsley roots was obtained in other studies [7,8,11]. Moreover, Petropoulos et al. [7], in an experiment carried out in a warmer climate (Greece), showed that apiol is not always the dominant component of root essential oil. The cultivars studied showed little stability in the composition of the essential oils obtained from the roots depending on the growing season, except that the main ingredient was apiol. However, even its content changed to a large extent. Depending on the growing season, significant changes in the share were also noted in the case of the remaining components of the essential oils obtained from the roots. Gil et al. [40] showed that in some populations of coriander, weather conditions more influenced the oil composition. In others, it was less influenced by the weather conditions, but the changes in the composition of coriander essential oils were smaller than that of parsley in the presented study.

In the assimilation organs, the oil composition was more diversified, which may indicate a more individual adaptation of these plant organs to changing conditions in particular growing seasons. In the first cultivation season, with lower temperatures and higher rainfall, on average, the highest was β-phellandrene, then 1,3,8-p-menthatriene, β-myrcene, and p-cymemene. In the second, the warmer and drier season, the average content of β-phellandrene was significantly less than 1,3,8-p-menthatriene and even β-myrcene. Myristicin was a vital component of the leaf oils in the second cultivation season in some cultivars, e.g., in 'Hamburska', 30.3%. Depending on the weather conditions, changes in the essential oil composition of individual cultivars are significant; they may vary from a fraction of a percent to several dozen percent, becoming the most significant ingredient. Previous studies indicate the possibility of changing the essential oil composition of plants grown in different environmental conditions [17,34,40]. Myristicin, 1,3,8-p-menthatriene, β-phellandrene, and myrcene are often identified as the essential components of the oils obtained from parsley leaves [2–4,6–8,19,35,39,41,42]. However, Gruszecki [11] found a low content of 1,3,8-p-menthatriene in leaves harvested for the entire summer (VI–VII) and a high content of α-pinene, p-cymenene, β-myrcene, β-phellandrene, and β-pinene. According to other studies, apiol may also be an essential component of parsley leaf essential oil [41,43,44]. The varied composition of the essential oils obtained from the roots and leaves may prove that the plant can modify the essential oil components depending on the specificity of the plant's organs (storage and assimilation) and the occurrence of stress. The higher variability of essential oil composition in the leaves may be due to the fact that they were not the plant's breeding target, but only the roots. The variability of the essential oil composition, apart from the influence of weather conditions, may also result from the variability of the populations themselves, as they are not hybrid varieties.

The study showed that the yield of roots and whole plants largely depends on the cultivar. Stawiarz and Gruszecki [45] showed the effect of cultivars on the yield of parsley roots and leaves. Similarly, Gruszecki [12] found a considerable variation in the yield of five parsley cultivars harvested in bunches regarding the yield of entire plants and separate roots and leaves. On the other hand, in the presented study, the leaf yield did not differ significantly depending on the cultivar, which resulted from the variability of yields in the studied growing seasons. However, these are parsley cultivars, and were not selected regarding leaf yield. Gruszecki [12] also showed that the ratio of the yield of roots to the yield of leaves might be different for individual cultivars.

Even though the cultivars of turnip-rooted parsley were selected mainly in terms of the content of aromatic compounds in the roots, the leaves are much richer in these compounds, and the yield of essential oils from leaves is much higher than from roots. Nevertheless, it depends, to a greater extent, on the course of weather conditions. In the case of the yield of roots and leaf oils, the selection of the cultivar is crucial, as some cultivars are characterised by a high and stable yield of essential oils. In contrast, others yield a low crop with high variability depending on the course of weather conditions.

5. Conclusions

The presented work shows, for the first time, a comparison of the essential oil content in both the roots and leaves of so many turnip rooted parsley cultivars. Our research shows that the content of essential oils of turnip-rooted parsley depends on the cultivar and the weather conditions.

The presented study also shows that cultivars of parsley differ in terms of the composition of essential oils, which varies yearly. Apiol was the primary component of the essential oils of each variety in the roots, a storage organ intended to survive unfavorable weather conditions. This may indicate that the composition of the root oil depends on the place of cultivation, and that the climatic conditions of Central and Eastern Europe favour the accumulation of this component in the roots. In the assimilation organs, the oil compositions were more diversified, suggesting a more active and individual adaptation of plants to changing conditions in particular growing seasons.

Root parsley is mainly grown to obtain aromatic roots, and the leaves are often a waste product. The research shows that this approach is inappropriate because the leaves are a full-fledged spice, and the essential oil content in them and their yield per unit area is higher than that of the roots. In addition, the varied response of cultivars depending on weather conditions, regarding the content of oils, may indicate the possibility of selecting cultivars suitable for given weather conditions in crops.

Author Contributions: Conceptualization, R.G. and M.W.-J.; methodology, R.G.; software, R.G.; validation, R.G. and M.W.-J.; formal analysis, R.G.; investigation, R.G.; resources, R.G. and M.W.-J.; data curation, R.G. and M.W.-J.; writing—original draft preparation, R.G.; writing—review and editing, R.G. and M.W.-J.; visualization, R.G. and M.W.-J.; supervision, R.G. and M.W.-J.; project administration, R.G.; funding acquisition, R.G. and M.W.-J. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Atta-Aly, M.A. Effect of nickel addition on the yield and quality of parsley leaves. *Sci. Hortic.* **1999**, *82*, 9–24. [CrossRef]
2. Hashem, F.A.E.; Sahab, A.F. Chemical response of parsley and mentha herbs to certain stress agents. *Food Chem.* **1999**, *65*, 29–33. [CrossRef]
3. Diaz-Maroto, M.C.; Pérez-Coello, M.S.; Cabezudo, M.D. Effect of different drying methods on the volatile components of parsley (*Petroselinum crispum* L.). *Eur. Food Res. Technol.* **2002**, *215*, 227–230. [CrossRef]
4. Petropoulos, S.A.; Daferera, D.; Polissiou, M.G.; Passam, H.C. Effect of freezing, drying and the duration of storage on the composition of essential oils of plain-leafed parsley [*Petroselinum crispum* (Mill.) Nym. ssp. *neapolitanum* Danert] and turnip-rooted parsley [*Petroselinum crispum* (Mill.) Nym. ssp. *tuberosum* (Bernh.) Crov.]. *Flavour Fragr. J.* **2010**, *25*, 28–34. [CrossRef]
5. Zderkiewicz, T.; Dyduch, J. Dynamika gromadzenia się kwasu L-askorbinowego i olejku eterycznego w różnych fazach wegetacji pietruszki. *Acta Agrobot.* **1972**, *25*, 179–184. [CrossRef]
6. Żukowska, E.; Michalik, B.; Simon, P.W.; Senalik, D. Zawartość związków zapachowych w różnych częściach roślin pietruszki korzeniowej. *Hod. Rośl. Nasien.* **1990**, *2–3*, 33–37.
7. Petropoulos, S.A.; Daferera, D.; Akoumianakis, C.A.; Passam, H.C.; Polissiou, M.G. The effect of sowing date and growth stage on the essential oil composition of three types of parsley (*Petroselinum crispum*). *J. Sci. Food Agric.* **2004**, *84*, 1606–1610. [CrossRef]
8. Orav, A.; Kailas, T.; Jegorowa, A. Composition of the essential oil of dill, celery, and parsley from Estonia. *Proc. Estonian Acad. Sci. Chem.* **2003**, *52*, 147–154.
9. Azeez, S.; Parthaserathy, V.A. Parsley. In *Chemistry of Spices*; Parthasarathy, V.A., Chempakam, B., Zachariah, T.J., Eds.; CABI: London, UK, 2008; pp. 376–400.
10. Oile, M.; Bender, I. The content of oils in umbeliferous crops and its formation. *Agron. Res.* **2010**, *8*, 687–696.
11. Gruszecki, R. The effect of growth stage on essentials oil composition of Hamburg parsley. *Acta Hort.* **2009**, *826*, 391–395. [CrossRef]
12. Gruszecki, R. Effect of cultivar on early yield of parsley grown from the late summer sowing. *Folia Hort.* **2004**, *16*, 27–32.
13. Mackiewicz, H.O. Metoda fluorescencyjna oceny intensywności aromatu pietruszki korzeniowej—*Petroselinum sativum* Hoffm. var. *tuberosum* Thellung f. breve Alef. *Biul. Warz.* **1987**, *30*, 269–282.
14. Habegger, R.; Müller, B.; Hanke, A.; Schnitzler, W.H. Geruchsgebende Inhaltsstoffe im ätherischen Öl von verschiedenen Mőhrensorten. *Gartenbauwissenschaft* **1996**, *61*, 225–229.
15. Zheljazkow, V.D.; Pickett, K.M.; Caldwell, C.D.; Pinock, J.A.; Roberts, J.C.; Mapplebeck, L. Cultivar and sowing date effects on seed yield and oil composition of coriander in Atlantic Canada. *Indus. Crops Prod.* **2008**, *28*, 88–94. [CrossRef]
16. Petropoulos, S.A.; Daferera, D.; Polissiou, M.G.; Passam, H.C. Effect of nitrogen-application rate on the biomass, concentration, and composition of essential oils in the leaves and roots of three types of parsley. *J. Plant Nutr. Soil. Sci.* **2009**, *172*, 210–215. [CrossRef]
17. Petropoulos, S.A.; Daferera, D.; Polissiou, M.G.; Passam, H.C. Effect of salinity on the growth, yield and essential oils of turnip-rooted and leaf parsley cultivated within the Mediterranean region. *J. Sci. Food Agric.* **2009**, *89*, 1534–1542. [CrossRef]
18. Ejsmond, J. Porównanie wartości aromatycznej odmian pietruszki. *Biul. Warz.* **1979**, *23*, 405–417.
19. Simon, J.E.; Quinn, J. Characterization of essential oil of parsley. *J. Agric. Food Chem.* **1988**, *36*, 467–472. [CrossRef]

20. Gruchała, L. Aromaty pietruszki i selerów. *Biul. Branż. Hod. Rośl. Nas.* **1987**, *4*, 26–30.
21. Jung, H.P.; Sen, A.; Grosch, W. Evaluation of potent odorants in parsley leaves (*Petroselinum crispum* (Mill.) Nym. ssp. *crispum)* by aroma extract dilution analysis. *Lebensm. Wiss. Technol.* **1992**, *25*, 55–60.
22. Masanetz, C.; Grosch, W. Hay-like off flavor of dry parsley. *Z. Lebensm. Unters. Forsch. A* **1998**, *206*, 114–120. [CrossRef]
23. Masanetz, C.; Grosch, W. Key odorants of parsley leaves (*Petroselinum crispum* (Mill.) Nym. ssp. *crispum*) by odour-activity values. *Flavour Fragr. J.* **1998**, *13*, 115–124. [CrossRef]
24. Zheng, G.Q.; Kenney, P.M.; Lam, L.K.T. Myristicin: A potential cancer chemopreventive agent from parsley leaf oil. *J. Agric. Food Chem.* **1992**, *40*, 107–110. [CrossRef]
25. Choi, H.S.; Song, H.S.; Ukeda, H.; Sawamura, M. Radical-scavenging activities of citrus essential oils and their components: Detection using 1,1-diphenyl-2-picrylhydrazyl. *J. Agric. Food Chem.* **2000**, *48*, 4156–4161. [CrossRef]
26. Takahashi, Y.; Inaba, N.; Kuwahara, S.; Kuki, W. Antioxidative effect of citrus essential oil components on human low-density lipoprotein *in vitro*. *Biosci. Biotechnol. Biochem.* **2003**, *67*, 195–197. [CrossRef]
27. Kim, H.J.; Chen, F.; Wu, C.; Wang, X.; Chung, H.Y.; Jin, Z. Evaluation of antioxidant activity of australian tea tree (*Melaleuca alternifolia*) oil and its components. *J. Agric. Food Chem.* **2004**, *52*, 2849–2854. [CrossRef]
28. Ruberto, G.; Baratta, M.T. Antioxidant activity of selected essential oil components in two lipid model systems. *Food Chem.* **2000**, *69*, 167–174. [CrossRef]
29. Zhang, H.; Chen, F.; Wang, X.; Yao, H.-Y. Evaluation of antioxidant activity of parsley (*Petroselinum crispum*) essential oil identification of its antioxidant constituents. *Food Res. Int.* **2006**, *39*, 833–839. [CrossRef]
30. Brandt, K.; Lietz, G.; Kobaek-Larsen, M.; Christensen, L.P. A systematic approach for identifying plant components with impact on Human Health. *Acta Hort.* **2007**, *744*, 93–100. [CrossRef]
31. Nitz, S.; Spraul, M.H.; Drawert, F. C17 polyacetylenic alcohols as the major constituents in roots of *Petroselinum crispum* Mill. ssp. *tuberosum*. *J. Agric. Food Chem.* **1990**, *38*, 1445–1447. [CrossRef]
32. Jabłońska-Ryś, E. Wpływ blanszowania na zawartość związków terpenowych w wybranych odmianach pietruszki korzeniowej (*Petroselinum crispum*). *Ann. UMCS Sect. E* **2004**, *59*, 2039–2044.
33. Kohlmünzer, S. *Farmakognozja*; PZWL: Warszawa, Poland, 2007.
34. Vokk, R.; Lõugas, T.; Mets, K.; Kravets, M. Dill (*Anethum graveolens* L.) and Parsley (*Petroselinum crispum* (Mill.) Fuss) from Estonia: Seasonal Differences in Essential Oil Composition. *Agron. Res.* **2011**, *9*, 515–520.
35. Boutsika, A.; Sarrou, E.; Cook, C.M.; Mellidou, I.; Avramidou, E.; Angeli, A.; Martens, S.; Ralli, P.; Letsiou, S.; Selini, A.; et al. Evaluation of parsley (*Petroselinum crispum*) germplasm diversity from the Greek Gene Bank using morphological, molecular and metabolic markers. *Ind. Crops Prod.* **2021**, *170*, 113767. [CrossRef]
36. Thangavelua, S.; Balasubramanianb, B.; Palanisamyc, S.; Shanmugamd, V.; Natchiappane, S.; Kalibullaf, S.I.; Rathinasamyg, B.; Arumugama, V.A. Characterization and phytoconstituents of *Petroselinum crispum* (Mill) and *Coriandrum sativum* (Linn) and their impacts on inflammation—An in vitro analysis against human adenocarcinoma cells with molecular docking. *S. Afr. J. Bot.* **2022**, *146*, 776–788. [CrossRef]
37. Ferreiraa, F.S.; Oliveira, V.S.; Chávez, D.W.H.; Chaves, D.S.; Riger, C.J.; Sawaya, A.C.H.F.; Guizellini, G.M.; Sampaio, G.R.; da Silva Torres, E.A.F.; Saldanha, T. Bioactive compounds of parsley (*Petroselinum crispum*), chives (*Allium schoenoprasum* L) and their mixture (*Brazilian cheiro-verde*) as promising antioxidant and anti-cholesterol oxidation agents in a food system. *Food Res. Int.* **2022**, *151*, 110864. [CrossRef]
38. Proz, M.D.M.Á.; da Silva, M.A.S.; Rodrigues, E.; Bender, R.J.; Rios, A.D.O. Effects of indoor, greenhouse, and field cultivation on bioactive compounds from parsley and basil. *J. Sci. Food Agric.* **2021**, *101*, 6320–6330. [CrossRef]
39. Gil, A.; de la Fuente, E.B.; Lenardis, A.E.; Lopez Pereira, M.; Suarez, S.A.; Bandoni, A.; van Baren, C.; Di Leo Lira, P.; Ghersa, C.M. Coriander essential oil composition from two genotypes grown in different environmental conditions. *J. Agric. Food Chem.* **2002**, *50*, 2870–2877. [CrossRef]
40. Petropoulos, S.A.; Daferera, D.; Polissiou, M.G.; Passam, H.C. The effect of water deficit on the growth, yield and composition of essential oil of parsley. *Sci. Hort.* **2008**, *115*, 393–397. [CrossRef]
41. Craft, J.D.; Setzer, W.N. The volatile components of parsley, *Petroselinum crispum* (Mill.) Fuss. *Am. J. Essent. Oils Nat. Prod.* **2017**, *5*, 27–32.
42. Jugreet, B.S.; Ibrahime, S.K.; Zengin, G.; Abdallah, H.H.; Mahomoodally, M.F. GC/MS Profiling, in vitro and in silico pharmacological screening and principal component analysis of essential oils from three exotic and two endemic plants from Mauritius. *Chem. Biodivers.* **2021**, *18*, e2000921. [CrossRef]
43. Braglia, B.; Costa, P.; Di Marco, G.; D'Agostino, A.; Redi, E.L.; Scuderi, F.; Gismondi, A.; Canini, A. Phytochemicals and quality level of food plants grown in an aquaponics system. *J. Sci. Food Agric.* **2022**, *102*, 844–850. [CrossRef] [PubMed]
44. Rattan, S.; Partap, M.; Kanika; Kumar, S.; Warghat, S.R. Nutrient feeding approach enhances the vegetative growth biomass, volatile oil composition, and myristicin content in hydroponically cultivated *Petroselinum crispum* (Mill.) Nyman. *J. Appl. Res. Med. Aromat. Plants* **2022**, *26*, 100359. [CrossRef]
45. Stawiarz, A.; Gruszecki, R. Wpływ zastosowania preparatu Calcorium Liquide na wielkość i jakość plonu pietruszki korzeniowej (*Petroselinum crispum* ssp. *tuberosum*). *Ann. Hortic.* **2016**, *26*, 13–21.