horticulturae

Article

Influence of Soil Types on the Morphology, Yield, and Essential Oil Composition of Common Sage (*Salvia officinalis* L.)

Noémi J. Valkovszki [1,*], Tímea Szalóki [1], Árpád Székely [1], Ágnes Kun [1], Ildikó Kolozsvári [1], Ildikó Szalókiné Zima [2], Szilvia Tavaszi-Sárosi [3] and Mihály Jancsó [1,*]

[1] Research Center for Irrigation and Water Management, Institute of Environmental Sciences, Hungarian University of Agriculture and Life Sciences, 5540 Szarvas, Hungary; szaloki.timea.palma@uni-mate.hu (T.S.); szekely.arpad@uni-mate.hu (Á.S.); kun.agnes@uni-mate.hu (Á.K.); kolozsvari.ildiko@uni-mate.hu (I.K.)

[2] Kinizsi 2000 Agricultural Co., Ltd., 6625 Fábiánsebestyén, Hungary; zimaildiko@gmail.com

[3] Department of Medicinal and Aromatic Plants, Institute of Horticultural Sciences, Hungarian University of Agriculture and Life Sciences, 1118 Budapest, Hungary; tavaszi-sarosi.szilvia@uni-mate.hu

* Correspondence: valkovszki.noemi.julia@uni-mate.hu (N.J.V.); jancso.mihaly@uni-mate.hu (M.J.)

Abstract: Common sage is a versatile medicinal and aromatic plant that adapts well to unfavorable soil conditions. We determined the effect of Fluvisol and Chernozem soils on sage morphology, leaf yield, essential oil content, and composition under rainfed, temperate conditions for two consecutive years. Based on the plant height, diameter, shoot length, and yield, Chernozem soil was significantly superior to Fluvisol. However, *S. officinalis* is considered a drought-tolerant plant; our results confirmed the importance of the available water capacity of the different soil types since the yield on both soil types decreased significantly after an extreme drought event in 2022. The essential oil concentration (0.67–1.10 mL/100 g DM) was higher on the Fluvisol, but the total oil content was higher in the case of Chernozem (78.64 ± 20.50 mL/m^2 DM). The ratio of essential oil components was also influenced by the soil types, but the highest amounts were analyzed for soils viridiflorol, α-humulen, and α-tujone. The essential oil yield showed a strong positive correlation with hydrocarbon sesquiterpenes (0.92) and oxygenated sesquiterpenes (0.95). Moreover, significant correlations were identified between the harvest time, seasonal precipitation patterns, soil and plant characteristics, and drug quality. On both soil types, the macronutrient content of the soils showed a strong positive correlation with the morphological parameters. The essential oil concentration was higher in the arid season of 2022 in the case of both soil types. The soil type and the seasonal effects can also change the ratio of essential oils.

Keywords: essential oil; soil type effect; seasonal effect; viridiflorol; sage leaf

Citation: Valkovszki, N.J.; Szalóki, T.; Székely, Á.; Kun, Á.; Kolozsvári, I.; Szalókiné Zima, I.; Tavaszi-Sárosi, S.; Jancsó, M. Influence of Soil Types on the Morphology, Yield, and Essential Oil Composition of Common Sage (*Salvia officinalis* L.). *Horticulturae* **2023**, *9*, 1037. https://doi.org/10.3390/horticulturae9091037

Academic Editor: Zsuzsanna Pluhár

Received: 22 August 2023
Revised: 9 September 2023
Accepted: 11 September 2023
Published: 14 September 2023

1. Introduction

Salvia officinalis L. (Dalmatian sage, common sage, or sage) is an aromatic perennial evergreen shrub that is naturally widespread in the Mediterranean areas of Europe, but nowadays, it is popular worldwide. It has been used as a medicinal plant since ancient times, while nowadays, it is cultivated in many varieties as a medicinal and ornamental plant, being one of the most important *Salvia* species [1,2].

Abiotic stresses (drought and nutrient deficiency) have significant impacts on sage plant development [3–5]. The temperature extremities [6] and the water deficit can reduce yield significantly. This negative effect may reach more than 50% in essential oil volume and concentration [7,8]. However, moderate drought stress had a positive effect on the yield and concentration of essential oil [9]. The non-optimal values of temperature, light intensity, and relative humidity not only affect the quantity and quality of the crop but also the metabolism of the plant [6]. In *Lamiaceae* species, the effects of these unfavorable factors were published by many researchers in some *Ocimum* species [10,11] and thyme [12]. Environmental effects such as altitude and pedo-climatic conditions have also been explored on the percentage of essential oil components in sage [13]. However, many other factors can also influence the oil content, like the season, geographic origin, extraction methods, plant origin, phenological stage, sampling techniques, and genetic differences [14].

In addition to these, the soil parameters such as physical structure and chemical composition are also determinant factors in secondary metabolites' amount and could also be involved in essential oil composition in the same species [15]. The use of sodium-rich volcanic tuff caused a significant decrease in total fresh leaf weight, dry weight, leaf number per plant, and total leaf area [16]. In an Ethiopian study, the influence of different soil types was examined on sage (sand clay loam (Nitosol), sandy loam (Andosol), clay soil, and red-brown clay loam (Nitosol)). The maximum plant height was observed during the cultivation under sand clay loam; however, the maximum fresh yield (14,064 kg/ha) and essential oil content (1.7%) were resulted by sandy loam [17]. Under Chernozem soil, the relative chlorophyll content (SPAD, Soil Plant Analysis Development value measured by SPAD 502 chlorophyll meter, Konica Minolta Ltd., Tokyo, Japan) of sage was 1.5 times higher, and the dry leaf weight per plant was 4 times higher than on the Fluvisol. However, there was no significant difference between the soil types in terms of essential oil content [18]. According to Rapposelli et al. (2015), the silt and sand content of soil correlated with the amount of α-pinene and sclareol in *Salvia desoleana* [15].

The nutrient content of the soil, the amount, and the quality of supplied nutrients influence the leaf and essential oil yield of sage. The total K_2O content of the soil is significantly correlated to the % amount of mono-, sesqui-, and diterpenes of essential oil [15]. According to several papers, the sage yield was improved by nutrient supply with compost, manure, fertilizers, or soil amendments [19–28]. Mona et al. (2008) published that the fertilization by 14.3 m^3/ha compost (1.40:0.47:1.21 = N:P:K, where 263 mg NH_4NO_3 is in 1 kg compost) caused better yield than the application of mineral fertilizers [28]. Govahi et al. (2016) used three different amounts of irrigation water and five different fertilizers, including biofertilizers. The highest amount of irrigation and the vermicompost (8 t/ha) with nitrogen-fixing bacteria caused the highest dry material (3.20 $\pm$ 0.33 t/ha) [9]. In another research, 150 kg/ha phosphorus supplemented by *Pseudomonas* bacteria or/and mycorrhizal inoculation without any additional nitrogen caused higher leaf yield, essential oil yield, and essential oil percentage than the chemical fertilizers [25]. In terms of essential oil content, Shukri et al. (2016) measured the maximum essential oil content (3.07%) at the treatment of 100 kg/ha diammonium phosphate (DAP) [29]. However, the maximum plant height (26.50 cm), the maximum dry plant weight (21.86 g), and the minimum essential oil content (1.68%) were resulted by 300 kg/ha DAP [29]. Similarly, the importance of the P supply was also verified by Nell et al. (2009) [30]. The total $CaCO_3$ of soil also influenced the amount of limonene and linalool in the essential oil of *Salvia fruticosa* [27].

The current study investigated the influence of soil types on sage plants' growing parameters, oil content, and essential oil compositions under rainfed temperate conditions.

2. Materials and Methods

The influences of soil types (Fluvisol and Chernozem) on common sage were investigated in two consecutive years (2021–2022). The study areas are located in the southern east part of Hungary (Szarvas 46°52′58.15″ N, 20°32′32.17″ E; Örménykút 46°50′19.23″ N, 20°43′53.60″ E). The distance of the two fields is 15 km, and 100 m^2 areas were selected from both sites for the experiments. The weather parameters were collected by an Agromet Solar automatic weather station (Boreas Ltd., Érd, Hungary). The main differences in soil parameters between the different locations are shown in Table 1. The soil samples were obtained at the same time as the second harvest. Average results represented the area as a composite sample comprising subsamples (n = 5) collected from 0 to 30 cm soil depth in 2021. In 2022, soil samples were collected directly connected to individual sage plants (n = 16).

Table 1. Laboratory analysis of the different soil types (n = 1 (2021), n = 16 (2022)).

	2021		2022	
	Chernozem	**Fluvisol**	**Chernozem**	**Fluvisol**
pH (KCl)	7.01	5.68	7.02 ± 0.02	5.46 ± 0.14
Arany-type cohesion measure (K_A)	45.0	73.0	44.4 ± 2.1	71.3 ± 3.2
Total water-soluble salts (m/m%)	0.07	0.04	0.04 ± 0.01	0.05 ± 0.01
Carbonatet lime (m/m%)	1.12	<0.50	1.23 ± 0.05	<0.50
Humus (m/m%)	4.55	4.65	3.03 ± 0.16	3.74 ± 0.65
Nitrit-Nitrate-N (KCl, mg/kg)	20.10	2.26	10.17 ± 1.70	3.33 ± 0,61
P_2O_5 (mg/kg)	4030.00	497.00	3617.50 ± 72.98	411.94 ± 94.17
K_2O (mg/kg)	1720.00	542.00	1540.00 ± 78.83	325.69 ± 85.17

Both fields were used as non-certified organic agricultural areas in the last decades. No plant protection interventions have been performed on the Chernozem and the Fluvisol fields for 17 and 22 years, respectively. In the Fluvisol, spring plowing was followed by soil melioration by an Italpollina 4-4-4 complex organic fertilizer (Hello Nature International, Biandrate, Italy) in a dose of 25 kg/100 m^2 in 2019. The previous crop was an orchard that was not cultivated for 20 years. The soil is often under the influence of water; periodically, the groundwater is close to the surface. An oxbow lake (Szarvas–Békésszentandrás) is only 300 m from the experimental area. The soil was rich in humus; however, the nitrogen supply was poor, the phosphorus content was high, and the potassium content was classified as good [31,32] (Table 1).

The pre-crop was in winter barley in the case of the Chernozem soil. Deep plowing took place in the autumn of 2018. The soil was rich in humus, the nitrogen supply was good, and the phosphorus and potassium contents were high [31,32] (Table 1).

Commercially available sage seeds were used to raise uniform plants (Pannon Flora Ltd., Budaörs, Hungary). The sowing date was 1 May 2019, with a row and plant spacing of 70 and 50 cm, respectively. During the experimental period, only mechanical weed control was used in both experimental fields. The plants were not harvested in the first growing season. However, the harvested leaf yield was high in 2020 due to higher precipitation. The two- and three-year-old sage plants were studied in 2021 and 2022, respectively.

We measured the plant properties as plant height (cm), plant diameter (cm), SPAD value (SPAD 502, Konica Minolta Ltd., Japan), and yield parameters: total biomass (g/plant), fresh leaves weight (g/plant), and dry leaves weight (DW; g/plant) in 16 replications. We collected the leaves of sage plants before the appearance of flowers. So, two cuttings were achieved per season. The cuts were done on the Chernozem soil on 9 May and 11 July 2021 and on 8 May and 17 July 2022. The yield was collected on the Fluvisol soil on 13 May and 18 July 2021 and on 11 May and 18 July 2022. The weight of fresh plants and dry leaves were measured with CAS 25-type and CAS MWP-1500 scales (CAS Co. Ltd., Yangju, Republic of Korea), respectively. The leaves were dried in a Memmert UFP 800 oven (Memmert Co., Schwabach, Germany) at 40 °C until the weight was found to be constant (DW).

Essential oil content was determined in three replications in the laboratory of the Department of Medicinal and Aromatic Plants of the Hungarian University of Agriculture and Life Sciences, Budapest. The essential oil of the crumbled plant material was hydrodistilled using a Clevenger-type apparatus for 2 h in four replications in each case. The amount is expressed in mL/100 g DM (dry material); the measurements were carried out after the drying of plant samples at 105 °C in a Memmert UFP 800 oven. The components of essential oil were analyzed by GC–MS in one repetition. The GC–MS analysis was carried out using an Agilent Technologies 6890N GC equipped with an Agilent Technologies MS 5975 detector using a capillary column (HP-5MS, length: 30 m, id. 250 µm, film thickness: 0.25 µm), programmed as follows: initial temperature 60 °C, ramp of 3 °C/min up to 240 °C. Injector and detector temperatures: 250 °C, carrier gas: helium (constant flow rate: 1 mL/min.); split ratio: 30:1. Ionization energy was 70 eV. The identification of the constituents was based on the comparison of the retention times with those of authentic samples, comparing the linear retention indices relative to a series of hydrocarbons (C9–C23) using the generalized equation of Van den Dool and Kratz (1963) [33], and using commercial databases (NIST and Wiley) for the mass spectra analysis [34].

To evaluate experimental data, MS Excel 2012 and IBM SPSS 25 software were used. To determine the effect of the two soil types on the physiological parameters, a two-way analysis of variance (ANOVA) was performed. Pearson's correlation was used to determine the strength of the relationship between the soil parameters and the plant properties based on the results of 2022.

3. Results

Based on the automatically recorded weather parameters, the average temperature and overall rainfall were 11.5 °C and 12.5 °C, 433.9 mm and 343.5 mm in 2021 and 2022, respectively. We can highlight the record-low precipitation of 124.3 mm between January and July 2022, which had a significant impact on the measured parameters under the rainfed conditions of the experiments.

3.1. Morphological Characteristics

The soil type, harvesting time, and seasonal variation had a significant influence on all examined parameters in $p \leq 0.05$ levels (Table 2).

Table 2. Two-way ANOVA output of soil type, harvesting time, and seasonal variation.

	Plant Height			**Plant Diameter**			**Shoot Length**		
	MS	**F**	**Sig.**	**MS**	**F**	**Sig.**	**MS**	**F**	**Sig.**
Soil	2355.26	46.40	0.00	7115.37	102.65	0.00	1972.97	65.62	0.00
Harvest	446.44	8.79	0.00	990.29	14.29	0.00	150.27	5.00	0.03
Year	2044.39	40.27	0.00	1114.80	16.08	0.00	2005.04	66.69	0.00
Error	50.77			69.32			30.06		
	Leaf DW			**SPAD**					
	MS	F	Sig.	MS	F	Sig.			
Soil	6317.84	85.02	0.00	90.37	3.91	0.05			
Harvest	412.60	5.55	0.02	378.94	16.41	0.00			
Year	2064.49	27.78	0.00	94.96	4.11	0.04			
Error	74.31			23.09					

These significant effects between Fluvisol and Chernozem were proven by detailed analyses of the agronomic factors, too. The plants on Chernozem soil were stronger in growth parameters than on the Fluvisol across the seasons. However, at the first harvesting times, the plants had similar heights in both years (Figure 1).

Comparing the harvesting times, the plants tend to be smaller at the second cutting, especially in 2022. This trend was also observed in the case of Fluvisol in 2021, but not the Chernozem. The difference between the two growing seasons was remarkable (Table 2). Because of the low precipitation in 2022, a severe drought damaged the plants, especially the second harvest. The average reduction of plant height and shoot length were similar in range in both soil types. Although the diameter and height decreased more in Chernozem than in Fluvisol, the decline of the leaf dry weight was lower (Table 3). The SPAD values decreased in the case of Chernozem because the bigger sage plants were affected more by the water shortage (Figure 1).

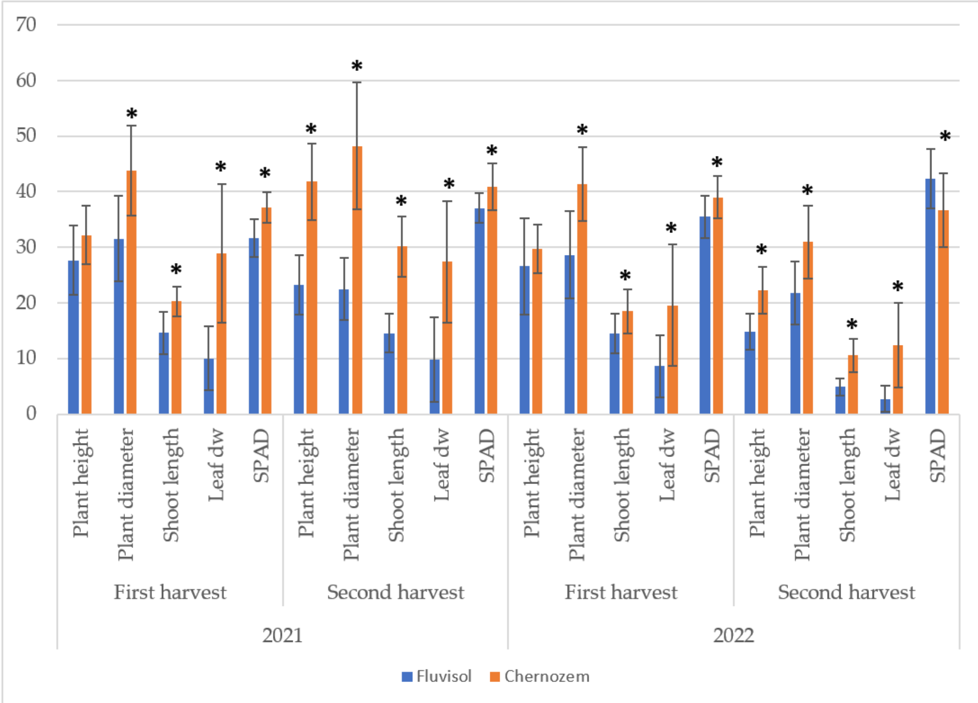

Figure 1. The differences between Fluvisol and Chernozem soil across harvest times and the two experimental years are based on the morphological parameters of common sage. The stars indicate significant differences between the two soils at $p < 0.05$.

Table 3. The average reduction (%) of growth parameters at the second cuttings from 2021 to 2022.

	Fluvisol	Chernozem
Plant height	−36.20	−46.60
Plant diameter	−3.19	−35.84
Shoot length	−66.54	−65.01
Leaf DW	−72.02	−54.70
SPAD	14.33	−10.40

Examining the total annual yields (g/m^2), the harvested dry leaves' weight on the Chernozem soil was almost three times higher than on Fluvisol in both experimental years. However, a significant yield reduction was observed in 2022 (Table 4).

Table 4. The dry leaves' weight (g/m^2) and oil production (mL/100 g DM and ml/m^2 DM) on two soil types.

	2021		2022	
	Fluvisol	Chernozem	Fluvisol	Chernozem
Dry leaves weight (DW; g/m^2)	56.48 ± 36.12 ^{a}	163.94 ± 42.75 ^{b}	32.43 ± 31.45 ^{a}	91.32 ± 47.55 ^{b}
Total oil concentration (mL/100 g DM)	0.67 ± 0.04 ^{b}	0.48 ± 0.04 ^{a}	1.10 ± 0.04 ^{b}	0.82 ± 0.04 ^{a}
Total oil content (ml/m^2 DM)	37.65 ± 24.08 ^{a}	78.64 ± 20.50 ^{b}	35.71 ± 22.88 ^{a}	74.82 ± 38.96 ^{b}

The letters (a, b) show significant differences between the two soil types at $p = 0.05$.

3.2. Essential Oil Content

Despite the lower biomass production, higher oil concentration was measured per unit mass on Fluvisol in both experimental years (Table 4). Besides the significant effect of soil type and year on leaf dry weight (g/plant, Table 2), the total oil content per one m^2 is independent of seasonal variation (MS = 115.33, F = 0.144, sig = 0.705). It only depends on the soil type (MS = 22,310.02, F = 27.95, sig < 0.001). Moreover, their interaction is also not significant (MS = 12.27, F = 0.02, sig = 0.902).

3.3. Composition of Essential Oil

Forty-seven essential oil components from sage leaves were determined by MS-GC analysis; however, sixteen compounds were found only in trace amounts. The ratio of monoterpenes was higher in plants grown in Fluvisol soil; however, in Chernozem soil, a higher amount of hydrocarbon sesquiterpenes was detected (Table 5). The following components were identified with the largest proportion per soil type in 2021 and 2022, respectively:

Table 5. Components of sage essential oil (%) on Fluvisol and Chernozem soil in 2021 and 2022.

	2021		2022	
Components of Essential Oil (%)	**Fluvisol**	**Chernozem**	**Fluvisol**	**Chernozem**
Hydrocarbon monoterpenes				
α-Pinene	1.53	0.67	2.22	0.78
Camphene	1.47	0.39	2.13	0.48
ß-Pinene	0.66	0.50	2.16	1.12
ß-Myrcene	0.27	0.16	0.49	0.26
α-Terpinene	0.09	0.08	0.15	0.11
p-Cymene	0.63	0.46	0.34	0.28
Limonene	0.97	0.68	1.13	0.59
γ-Terpinene	0.13	0.13	0.37	0.32
α-Terpinolene	0.07	0.06	0.16	0.09
Oxygenated monoterpenes				
1,8-cineol	9.66	6.95	11.04	8.56
Linalool	0.57	0.44	0.60	0.41
α-Thujone	14.69	11.89	14.14	13.67
ß-Thujone	7.78	8.04	6.01	8.47
Camphor	9.90	6.18	0.77	4.72
Isoborneol	8.08	5.42	7.87	2.94
Terpinene-4-ol	0.38	0.33	0.31	0.24
α-Terpineol	0.26	0.19	0.26	0.2
Izobornil-acetate	0.92	0.79	0.96	0.3
Hydrocarbon sesquiterpenes				
α-Copaene	0.28	0.39	0.30	0.33
ß-Caryophyllene	4.71	9.56	6.78	12.90
Aromadendrene	0.00	0.33	0.02	0.26
α-Humulene	10.59	15.57	12.49	16.34
Alloaromadendrene	0.12	0.20	0.13	0.18
γ-Muurolene	0.45	0.67	0.55	0.64
Viridiflorene	0.21	0.45	0.22	0.37
α-Muurolene	0.12	0.19	0.18	0.19
Cis-γ-Kadinene	0.15	0.23	0.19	0.21
δ-Cadinene	0.75	1.10	0.83	1.00
Oxygenated sesquiterpenes				
Caryophyllene-oxide	0.49	0.74	0.36	0.55
Viridiflorol	15.71	18.05	14.49	19.02
Humulene-oxide II	2.02	1.97	1.30	1.40

On Fluvisol soil: viridiflorol (14.48% and 15.71%), α-thujone (14.69% and 14.14%), α-humulene (10.59% and 12.49%), camphor (9.9% and 0.77%), β-thujone (7.78% and 6.01%), β-caryophyllene (4.71% and 6.78%), and isoborneol (8.08% and 7.87%).

On Chernozem soil: viridiflorol (18.50% and 19.02%), α-humulene (15.57% and 16.34%), α-thujone (11.89% and 13.67%), β-caryophyllene (9.56% and 12.90%), β-thujone (8.04% and 8.47%), camphor (6.18% and 4.72%), and isoborneol (5.42% and 2.94%) (Table 5).

3.4. The Correlation among Oil Compounds, the Examined Soil Components, and Sage Plant Properties

The Pearson correlation was performed with the entire data set in the case of the essential oil compound (Table 6) and partial data between soil and plant properties (Table 7). The correlation among oil compounds showed a strong positive relationship between viridiflorol, β-caryophyllene, and α-humulene. A negative correlation was observed between isoborneol and the other components, except α-thujone and camphor. The groups of hydrocarbon sesquiterpenes and oxygenated sesquiterpenes showed a strong positive correlation (0.86), while the groups of oxygenated monoterpenes and hydrocarbon sesquiterpenes had a negative correlation (−0.68). The essential oil yield showed a strong positive correlation with hydrocarbon sesquiterpenes (0.92) and oxygenated sesquiterpenes (0.95).

Table 6. Pearson correlation of parameters of essential oil compounds throughout two years, two soil types, based on the data in Table 5.

	Viridiflorol	α-Thujone	α-Humulene	β-Caryophyllene	Camphor	β-Thujone	Isoborneol
Viridiflorol	1.00						
α-thujone	−0.74	1.00					
α-humulene	1.00 **	−0.72	1.00				
β-caryophyllene	0.96 *	−0.71	0.96 *	1.00			
Camphor	−0.23	0.07	−0.29	−0.28	1.00		
β-thujone	0.57	−0.34	0.52	0.55	0.65	1.00	
Isoborneol	−0.93	0.46	−0.92	−0.98 *	0.09	−0.70	1.00

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Table 7. Pearson correlation of parameters of soil parameters with plant properties at the second harvest in 2022 (n = 16).

Soil Parameters	Plant Height (cm)	Plant Diameter (cm)	Shoot Length (cm)	Dry Leaves Weight (g/Plant)	SPAD
pH (KCl)	0.71 **	0.61 **	0.78 **	0.65 **	−0.46 **
Soil cohesion (K_A)	−0.69 **	−0.55 **	−0.72 **	−0.64 **	0.42 *
Total water-soluble salts (m/m%)	−0.42 *	−0.44 *	−0.42 *	−0.48 **	0.19
Carbonated lime (m/m%)	0.71 **	0.62 **	0.76 **	0.64 **	−0.44 *
Humus (m/m%)	−0.31	−0.27	−0.36 *	−0.32	0.21
Nitrite-Nitrate-N (KCl, mg/Kg)	0.74 **	0.59 **	0.79 **	0.62 **	−0.49 **
P_2O_5 (mg/kg)	0.72 **	0.62 **	0.78 **	0.67 **	−0.45 *
K_2O (mg/kg)	0.73 **	0.63 **	0.82 **	0.69 **	−0.43 *

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

The relationships regarding soil parameters and plant properties were analyzed for the second experimental year. Data show that the soil cohesion, total water-soluble salt content, and humus content correlated negatively; pH, carbonated lime, and macronutrients correlated positively to the morphological parameters of sage (Table 7).

4. Discussion

According to our results, the seasonal variation, the location with different soil types, and the harvesting time have significant impacts on the growth parameters of common sage. These confirmed the results of Kassahun et al. (2015) [17]. The morphological parameters showed the superior effect of Chernozem soil compared to the Fluvisol (Table 3). Similarly, some researchers published that the yield of sage was increased as a result of the higher available nutrient level [18–23,25–28,35–37]. The plants were smaller at the second cuttings, especially after the extreme drought in 2022, which confirms the results of Corell et al. (2012), who have highlighted the importance of water availability for the production of *S. officinalis* [7,8]. We have found a 72.02% and a 54.70% decrease in leaves DW on Fluvisol and on the Chernozem soils for the second experimental year, respectively, which shows the less favorable quality conditions and the lower available water capacity of the Fluvisol. A similar reduction was observed in several papers [6–8]. These confirmed that seasonal variation has a huge influence on sage growth under rainfed conditions. Despite this significant impact, the total amount of oil per unit m^2 is quite stable by soil type. It seems that this parameter seems constant across different meteorological years (Table 4).

Among the soil properties, the macronutrient, pH, and carbonated lime are correlated to the morphological parameters positively, as was reported in the study of Kassahun et al. [17]. The Chernozem soil had higher macroelement content than the Fluvisol, and there was a strong correlation between the nutrients and the plants' growing parameters, as was reported earlier by Soltanbeigi et al. [38] in a greenhouse experiment. However, the high level of nitrogen supply can boost biomass production, but it can be unfavorable for the formation of essential oil content [30]. This could be the reason for the lower oil concentration in the Chernozem soil.

The influence of low precipitation on the essential oil content can be significant in rainfed areas in both soil types. The results proved the previous results of Valkovszki et al. (2023), where irrigation could significantly modify essential oil production [39]. The main component of the essential oil component was the viridiflorol in our experiment; this is in contrast to the results of Govahi et al. [9,40], where 1,8-cineol was the main component. The proportion of the main essential oil components increased in most of the cases due to the influence of drought [7,8,13]. Our result also confirms that (Table 5).

We have found a strong positive correlation between the amount of β-thujone and camphor, and this is in contrast to the results of Menghini et al. [41], where no correlation was found between camphor and α-thujone and β-thujone. The correlation between the groups of essential oil components and the essential oil yield showed a strong positive correlation between hydrocarbon sesquiterpenes and the essential oil yield; this result is similar to the findings of Ben Taarit et al. [14]. However, it is the opposite in the case of oxygenated monoterpenes and hydrocarbon sesquiterpenes, where we calculated a strong negative correlation.

5. Conclusions

Our results indicated that *S. officinalis* can be grown effectively on different soil types, even with lower quality, such as Fluvisol. We confirmed that seasonal variation greatly influences sage production under rainfed conditions. The results indicated that water availability is an important factor regardless of the soil quality. Since sage is a medicinal and aromatic plant, where oil content is an important quality indicator, our results also indicated that a higher oil concentration could be reached on Fluvisol. However, the higher biomass production in Chernozem can counterbalance the lower oil concentration, leading to a higher oil production volume in the same area in Chernozem soil.

Furthermore, according to our study, the total essential oil volume per unit area was independent of seasonal variation; it was only influenced by soil type. However, the essential oil concentration was higher in the dryer season in the case of both soil types. The soil type and the seasonal effects can also change the ratio of essential oils.

Author Contributions: Conceptualization, N.J.V., Á.K., S.T.-S. and M.J.; methodology, N.J.V., I.S.Z. and Á.S.; formal analysis, N.J.V. and Á.S.; data curation N.J.V. and Á.S.; investigation, N.J.V., T.S., I.K., I.S.Z. and S.T.-S.; writing—original draft preparation, N.J.V., Á.K., S.T.-S. and M.J.; writing—review and editing, N.J.V., Á.S., T.S., Á.K. and M.J.; visualization, Á.S.; supervision, Á.K. and M.J.; project administration, Á.K.; funding acquisition, Á.K. and M.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Ministry of Agriculture of Hungary, grant number OD001.

Data Availability Statement: Not applicable.

Acknowledgments: The research was supported by the Doctoral School of Environmental Sciences of the Hungarian University of Agriculture and Life Sciences. The technical assistance of the "MATE ÖVKI Lysimeter Station" is gratefully acknowledged.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

References

1. Papafotiou, M.; Vlachou, G.; Martini, A.N. Investigation of the Effects of the Explant Type and Different Plant Growth Regulators on Micropropagation of Five Mediterranean Salvia Spp. Native to Greece. *Horticulturae* **2023**, *9*, 96. [CrossRef]
2. Tutin, T.G.; Heywood, V.H.; Burges, N.A.; Moore, D.M.; Valentine, D.H.; Walters, S.M.; Webb, D.A. Diapensiacea to Myoporaceae. In *Flora Europaea*; Cambridge University Press: Cambridge, UK, 1972; Volume 3, ISBN 978-0-521-08489-5.
3. Toscano, S.; Franzoni, G.; Álvarez, S. Drought Stress in Horticultural Plants. *Horticulturae* **2023**, *9*, 7. [CrossRef]
4. Valkovszki, N.J.; Székely, Á.; Szalóki, T.; Kun, Á.; Kolozsvári, I.; Tavaszi-Sárosi, S.; Jancsó, M. Az öntözés hatása liziméterben nevelt orvosi zsályára (*Salvia officinalis* L.). *J. Cent. Eur. Green Innov.* **2022**, *10*, 3–20. [CrossRef]
5. Xing, Z.; Bi, G.; Li, T.; Zhang, Q.; Knight, P.R. Nitrogen Fertilization Improves Growth and Bioactive Compound Content for Salvia Miltiorrhiza Bunge. *Horticulturae* **2023**, *9*, 254. [CrossRef]
6. Ferrante, A.; Mariani, L. Agronomic Management for Enhancing Plant Tolerance to Abiotic Stresses: High and Low Values of Temperature, Light Intensity, and Relative Humidity. *Horticulturae* **2018**, *4*, 21. [CrossRef]
7. Corell, M.; Garcia, M.; Contreras, J.; Segura, M.; Cermeño, P. Effect of Water Stress on *Salvia officinalis* L. Bioproductivity and Its Bioelement Concentrations. *Commun. Soil Sci. Plant Anal.* **2012**, *43*, 419–425. [CrossRef]
8. Bettaieb, I.; Zakhama, N.; Wannes, W.A.; Kchouk, M.E.; Marzouk, B. Water Deficit Effects on *Salvia officinalis* Fatty Acids and Essential Oils Composition. *Sci. Hortic.* **2009**, *120*, 271–275. [CrossRef]
9. Govahi, M.; Ghalavand, A.; Nadjafi, F.; Sorooshzadeh, A. Effects of Different Soil Fertility Systems on Some Physiological Characteristics, Yield and Essential Oil of Sage (*Salvia officinalis* L.) under Different Irrigation Regimes. *Iran. J. Med. Arom. Plants Res.* **2016**, *32*, 333–345. [CrossRef]
10. Mulugeta, S.M.; Gosztola, B.; Radácsi, P. Morphological and Biochemical Responses of Selected Species under Drought. *Herba Pol.* **2022**, *68*, 1–10. [CrossRef]
11. Mulugeta, S.M.; Radácsi, P. Influence of Drought Stress on Growth and Essential Oil Yield of Ocimum Species. *Horticulturae* **2022**, *8*, 175. [CrossRef]
12. Szabó, K.; Zubay, P.; Németh-Zámboriné, É. What Shapes Our Knowledge of the Relationship between Water Deficiency Stress and Plant Volatiles? *Acta Physiol. Plant.* **2020**, *42*, 130. [CrossRef]
13. Russo, A.; Formisano, C.; Rigano, D.; Senatore, F.; Delfine, S.; Cardile, V.; Rosselli, S.; Bruno, M. Chemical Composition and Anticancer Activity of Essential Oils of Mediterranean Sage (*Salvia officinalis* L.) Grown in Different Environmental Conditions. *Food Chem. Toxicol.* **2013**, *55*, 42–47. [CrossRef] [PubMed]
14. Ben Taarit, M.; Msaada, K.; Hosni, K.; Hammami, M.; Kchouk, M.E.; Marzouk, B. Plant Growth, Essential Oil Yield and Composition of Sage (*Salvia officinalis* L.) Fruits Cultivated under Salt Stress Conditions. *Ind. Crops Prod.* **2009**, *30*, 333–337. [CrossRef]
15. Rapposelli, E.; Melito, S.; Barmina, G.G.; Foddai, M.; Azara, E.; Scarpa, G.M. Relationship between Soil and Essential Oil Profiles in Salvia Desoleana Populations: Preliminary Results. *Nat. Prod. Commun.* **2015**, *10*, 1615–1618. [CrossRef]
16. Owais, S.J.; Abdel-Ghani, A.H.; Ghrair, A.M.; Al-Dalain, S.A.; Almajali, N. Effect of Natural Jordanian Volcanic Tuff on Growth, Irrigation Water Saving and Leaves Mineral Content of *Salvia officinalis*. *Jord. J. Agric. Sci.* **2013**, *9*, 439–456.
17. Kassahun, B.M.; German, T.; Zigene, Z.D.; Tilahun, S.; Gebere, A.; Taddese, S.; Fikadu, D.; Miesso, B. Performance of Sage (*Salvia officinalis* L.) for Morpho-Agronomic and Chemical Traits in Different Agro-Ecologies of Ethiopia. *Int. J. Adv. Biol. Biomed. Res.* **2015**, *3*, 351–360. [CrossRef]
18. Valkovszki, N.J.; Mihály, J.; Árpád, S.; Tímea, S.; Ildikó, K.; Ágnes, K. A termőhely hatása az orvosi zsálya (*Salvia officinalis* L.) morfológiai jellemzőire és droghozamára öntözetlen körülmények között—Előzetes eredmények. *Kertgazdaság* **2021**, *53*, 54–64.
19. Al-Tabbal, J.; Alzboon, K.; Al-Zou'by, J.; Al Smadi, B.; Ammary, B. Effect of Zeolux Use on Sage (Salvia officinalis) Plant Irrigated by Fresh and RO Reject Waters. *Glob. Nest J.* **2016**, *18*, 425.
20. Amer, H.M.; Salem, S.H.; Salaheldin, S.; Hussein, M.S.; El-Fatah, A. The Growth, Chemical Composition and Evaluation of Antimicrobial Activity of *Salvia officinalis* Oil under Partial Substitution of Mineral NPK Fertilizer by Bio-Fertilizer. *Middle East J. Agric. Res.* **2019**, *08*, 457–468.
21. Dashti, M.; Kafi, M.; Astaraei, A.; Zabihi, H. Investigation of Yield and Yield Components Response of Salvia Leriifolia Benth. to the Biological and Organic Fertilizers. *Z. Arznei- Gewurzpfla.* **2018**, *22*, 84–90.
22. El-Haddad, M.E.; Zayed, M.S.; El-Sayed, G.A.M.; Abd EL-Satar, A.M. Efficiency of Compost and Vermicompost in Supporting the Growth and Chemical Constituents of *Salvia officinalis* L. Cultivated in Sand Soil. *Int. J. Recycl. Org. Waste Agric.* **2020**, *9*, 49–59. [CrossRef]

23. Greco, C.; Comparetti, A.; Febo, P.; La Placa, G.; Mammano, M.M.; Orlando, S. Sustainable Valorisation of Biowaste for Soilless Cultivation of *Salvia officinalis* in a Circular Bioeconomy. *Agronomy* **2020**, *10*, 1158. [CrossRef]
24. Greco, C.; Comparetti, A.; Fascella, G.; Febo, P.; La Placa, G.; Saiano, F.; Mammano, M.M.; Orlando, S.; Laudicina, V.A. Effects of Vermicompost, Compost and Digestate as Commercial Alternative Peat-Based Substrates on Qualitative Parameters of *Salvia officinalis*. *Agronomy* **2021**, *11*, 98. [CrossRef]
25. Jafari, G.M.; Abbaszadeh, B.; Oraei, M. Effects of Chemical and Biological Fertilizers on Growth, Yield and Essential Oil of *Salvia officinalis*. *J. Med. Plant By-Prod.* **2015**, *4*, 31–37. [CrossRef]
26. Khammar, A.A.; Moghaddam, M.; Asgharzade, A.; Sourestani, M.M. Nutritive Composition, Growth, Biochemical Traits, Essential Oil Content and Compositions of *Salvia officinalis* L. Grown in Different Nitrogen Levels in Soilless Culture. *J. Soil Sci. Plant Nutr.* **2021**, *21*, 3320–3332. [CrossRef]
27. Kocabas, I.; Kaplan, M.; Kurkcuoglu, M.; Baser, K.H.C. Effects of Different Organic Manure Applications on the Essential Oil Components of Turkish Sage (*Salvia fruticosa* Mill.). *Asian J. Chem.* **2010**, *22*, 1599–1605.
28. Mona, Y.; Kandil, A.M.; Swaefy, H. Effect of Three Different Compost Levels on Fennel and Salvia Growth Character and Their Essential Oils. *Res. J. Agric. Biol. Sci.* **2008**, *4*, 34–39.
29. Shukri, H.M. Effect of Diammonium Phosphate (DAP) Fertilization on Growth of Sage Plant (*Salvia officinalis* L.) and Concentration of Volatile Oil *Salvia officinalis* L. *J. Biotechmol. Res. Cent.* **2016**, *10*, 31–36. [CrossRef]
30. Nell, M.; Vötsch, M.; Vierheilig, H.; Steinkellner, S.; Zitterl-Eglseer, K.; Franz, C.; Novak, J. Effect of Phosphorus Uptake on Growth and Secondary Metabolites of Garden Sage (*Salvia officinalis* L.). *J. Sci. Food Agric.* **2009**, *89*, 1090–1096. [CrossRef]
31. Michéli, E.; Fuchs, M.; Láng, V.; Szegi, T.; Dobos, E.; Szabóné Kele, G. Javaslat Talajosztályozási Rendszerünk Megújítására: Alapelvek, Módszerek, Alapegységek. *Agrokémia Talajt.* **2015**, *64*, 285–297. [CrossRef]
32. Schad, P. The International Soil Classification System WRB, Third Edition, 2014. In *Novel Methods for Monitoring and Managing Land and Water Resources in Siberia*; Mueller, L., Sheudshen, A.K., Eulenstein, F., Eds.; Springer International Publishing: Cham, Switzerland, 2016; pp. 563–571. ISBN 978-3-319-24409-9. [CrossRef]
33. van Den Dool, H.; Kratz, P.D. A Generalization of the Retention Index System Including Linear Temperature Programmed Gas—Liquid Partition Chromatography. *J. Chromatogr. A* **1963**, *11*, 463–471. [CrossRef]
34. Sárosi, S.; Sipos, L.; Kókai, Z.; Pluhár, Z.; Szilvássy, B.; Novák, I. Effect of Different Drying Techniques on the Aroma Profile of Thymus vulgaris Analyzed by GC-MS and Sensory Profile Methods. *Ind. Crops Prod.* **2013**, *46*, 210–216. [CrossRef]
35. Sonmez, C.; Bayram, E. The Influence of Different Water and Nitrogen Applications on Some Yield Parameters and Antioxidant Activity in Sage (*Salvia officinalis* L.). *Turk. J. Field Crops* **2017**, *22*, 96–103. [CrossRef]
36. Doda, Q.; Bardhi, N.; Teqja, Z.; Mero, G.; Kallço, I.; Zeka, B. Effects of Different Limestone Rates on Yield and Yield Indicators of a Sage (*Salvia officinalis* L.) Ecotype. *Online Int. Interdiscip. Res. J.* **2014**, *4*, 7–16.
37. Yaldiz, G.; Camlica, M. Assessing the effect of various doses of organic manures on herbage yield, essential oil, and compositions of sage grown under climate chamber and field conditions. *Org. Agric.* **2023**, *13*, 377–397. [CrossRef]
38. Soltanbeigi, A. Qualitative Variations of Lavandin Essential Oil under Various Storage Conditions. *J. Essent. Oil Bear. Plants* **2020**, *23*, 1237–1252. [CrossRef]
39. Valkovszki, N.; Jancsó, M.; Székely, Á.; Szalóki, T.; Kolozsvári, I.; Tavaszi-Sárosi, S.; Kun, Á. The effect of application of effluent water on sage (*Salvia officinalis* L.) yield and quality in lysimeters. *Folia Hortic.* **2023**, *35*, 163–177. [CrossRef]
40. Govahi, M.; Ghalavand, A.; Nadjafi, F.; Sorooshzadeh, A. Comparing different soil fertility systems in Sage (*Salvia officinalis*) under water deficiency. *Ind. Crops Prod.* **2015**, *74*, 20–27. [CrossRef]
41. Menghini, L.; Leporini, L.; Pintore, G.; Chessa, M.; Tirillini, B. Essential oil content and composition of three sage varieties grown in Central Italy. *J. Med. Plants Res.* **2013**, *7*, 480–489. Available online: https://academicjournals.org/journal/JMPR/article-full-text-pdf/CD5317220911 (accessed on 22 August 2023).