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CHANGE IN ESSENTIAL OIL YIELD, CONTENT AND COMPOSITION OF CORIANDER (*CORIANDRUM SARIVUM* L.) VARIETIES, CULTIVATED FOR SEEDS

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Abstract. *Coriander essential oil is widely utilized in the food, pharmaceutical, and cosmetic industries due to its diverse applications. Extracted by steam distillation from dried Coriandrum sativum seeds, the clear or pale yellow oil has a distinctive, sweet, warm, and aromatic fragrance. In a three-year study, a field experiment was conducted in the land of the village of Voyvodinovo, where five coriander varieties (Yantar, Moroccan, Mesten Drebnoploden, Thüringen, and Marino) were tested for essential oil yield, essential oil content and chemical composition. Over 46 components were identified in coriander essential oil, representing 98.5% to 99.7% of the total composition. The oil contained a diverse array of compounds, including monoterpenoids, aldehydes, alcohols, and monoterpenes. The β-Linalool was the dominant component, with concentrations ranging from 60.3% to 71.4% across the tested cultivars. The Moroccan variety had the highest average linalool content (67.17%), while the Thüringen variety exhibited the lowest (65.73%). Geranyl acetate varied from 0.975% to 4.68%, α-pinene from 4.03% to 5.70%, and γ-terpinene from 5.81% to 8.42%. The fatty acid profile was analyzed, revealing the presence of myristic acid and palmitic acid. The Yantar variety exhibited the highest palmitic acid content (1.76%), followed by the Thüringen variety (0.89%), while the Mesten Drebnoploden variety had the lowest. myristic acid levels ranged from 0.09% to 0.43% on average. The essential oil content of the tested coriander cultivars ranged from 0.20% to 0.74%. Among them, the Yantar cultivar exhibited the highest average oil content -0.62%. The greatest essential oil yield for the period 2020-2021 was recorded in the cultivar Mesten Drebnoploden -11.4 kg ha^{-1}, whereas the lowest yield was observed in the Marino variety -5.6 kg ha^{-1}. These findings underscore the variability in coriander essential oil and composition, indicating the relevance of choosing the right cultivar in enhancing essential oil production in Bulgaria.*

Keywords*: coriander, essential oil yield, chemical composition, linalool, volatile oil*

INTRODUCTION

In recent years, there has been a growing global interest in essential oils and medicinal and aromatic plants, particularly in Europe (RIAZ et al., 2021). These plant-derived products are widely applied across the cosmetic, pharmaceutical, and food industries (BERNÀTH, 2009). A major trend involves replacing synthetic compounds with natural plant-based substances due to their structural compatibility with the human body and their lower toxicity.

Essential oils are especially valued for their antibacterial and antioxidant properties, and their use in the food industry has been well-documented (BAKKALI et al., 2008; CALO et al., 2015; FALOWO et al., 2014; JAYASENA and JO, 2013; SILVA AND DOMINGUES, 2015; POLITEO et al., 2007; DARUGHEET et al., 2012).

Relating essential oil-bearing crops, coriander (Coriandrum sativum L.) ranks among the most important globally in terms of oil yield. Modern breeding efforts have primarily focused on enhancing fruit traits for industrial essential oil extraction. Despite this, landraces still dominate global coriander production (DIEDERICHSEN et al., 2020). The ripe coriander fruits typically contain between 0.2% and 1.5% essential oil, with higher levels (up to 2.6%) reported in some regions such as Ukraine. Linalool is the major component, accounting for 64–78% of the oil content (BHAT et al., 2014; NADEEM et al., 2013). Other more important ingredients are camphor, geraniol, α-pinene, γ-terpinene, limonene, geranyl acetate, etc. (AL-KHAYRI et al., 2023; DELIBALTOVA, 2020; KUNEVA et al., 2024; PAVLIĆ et al., 2015). Over a dozen aromatic compounds with floral and citrus scents—such as rose, snowdrop, orange, lemon, violet, linden, and lily—are synthetically derived from coriander essential oil for use in the perfumery and cosmetic sectors.

Numerous studies have demonstrated the oil's effectiveness against antibiotic-resistant bacteria, suggesting its potential as an alternative for treating foodborne illnesses (DELAQUIS et al., 2002; DUARTE et al., 2016; SILVA et al., 2011). Additionally, coriander fruits contain 9–24% non-volatile (fatty) oil, which is used in technical applications. A scientific opinion on the safety of coriander fruit fatty oil shows that it has the potential to be commercialized as a novel food additive for healthy individuals (AGOSTONI et al., 2013).

MATERIAL AND METHODS

Plant material

The study involved five coriander (*Coriandrum sativum* L.) cultivars with diverse geographic origins and agrobiological characteristics. The cultivar "Yantar" originates from Russia and is noted for its resistance to lodging, small fruit size, and high essential oil content. The "Morrocan" cultivar, of Italian origin, is recognized for its high yield potential and good tolerance to elevated temperatures. "Mesten Drebnoploden" is a local Bulgarian cultivar, well adapted to regional agro-climatic conditions and characterized by early maturation. The "Thüringen" cultivar comes from the Thuringia, region of Germany. Lastly, the "Marino" cultivar, developed in the Netherlands, is distinguished by its large fruit size.

Field experiment and weather conditions

Field trials were conducted in the Plovdiv region, Bulgaria, from 2020 to 2022, in a transitional-continental climate zone. Climatic conditions during the study period were generally favorable for coriander growth, with average daily temperatures either slightly above or comparable to the long-term norms. Notably, 2021 was the most favorable year due to evenly distributed rainfall and sufficient moisture during critical growth phases. A summary of monthly rainfall and temperature data during the experiment, along with long-term averages, is presented in Table 1.

Table 1

Meteorological conditions in Plovdiv region (Bulgaria) during the experiments

Month	Monthly rainfall (mm)				Mean monthly temp (°C)			
	2020	2021	2022	Long term years	2020	2021	2022	Long term years
February	48.0	25.5	24.8	32.0	4.3	5.5	4.9	2.2
March	82.0	43.3	22.3	38.0	8.9	6.4	5.4	6.0
April	88.0	69.5	55.5	45.0	14.4	11.6	13.1	12.2
May	39.5	48.5	28.3	65.0	20.1	18.5	18.8	17.2
June	63.7	88.0	86.5	63.0	23.7	22.2	24.0	20.9
July	26.5	76.3	6.8	43.0	26.3	26.5	26.0	23.2
Total	347.7	351.1	224.2	286.0				
Mean					16.28	15.12	15.37	13.62

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The experimental field consisted of alluvial-meadow soil with a pH of 6.53–7.12. Total nitrogen content ranged from 9.45 to 9.71 mg kg^{-1} (0–20 cm) and 9.20 to 19.24 mg kg^{-1} (20–40 cm). Available phosphorus (P_2O_5) ranged from 7.94 to 8.69 mg/100 g (0–20 cm) and 6.21 to 9.13 mg/100 g (20–40 cm), while available potassium (K_2O) varied from 15.40 to 29.58 mg/100 g and 25.24 to 31.79 mg/100 g in the respective layers. Humus content was low, between 1.02% and 1.37%.

The trial followed a randomized block design with four replications. Each plot covered 15 m^2 and was established after winter wheat. Soil preparation included ploughing, deep tillage (20–22 cm), and two pre-sowing cultivations with harrowing (5–6 cm), following Dallev and Ivanov (2015). Fertilization included 80 kg ha^{-1} phosphorus and 10 kg ha^{-1} nitrogen. Sowing was carried out each February at a rate of 300 seeds per m^2, with 12–15 cm row spacing and a sowing depth of 3–4 cm.

Determination of Essential Oil Content by Hydrodistillation

The essential oil content was determined according to BDS ISO 6571 by hydrodistillation using Clevenger-type apparatus. Samples (50–200 g of crushed ripe coriander seeds) were distilled in 800 mL of water at ambient temperature (20 ± 2 °C). The procedure was conducted at the Rose Research Institute in Kazanlak and complied with the standard. Distillation lasted 2 hours, measured from the appearance of the first oil drop (CLEVENGER, 1928).

GC-FID/MS Analysis of Coriander Essential Oil

The chemical composition of coriander essential oil was analyzed using GC-FID/MS at the Agrobioinstitute, Sofia. The analysis was performed on an Agilent 7890A GC with a 5975C MS detector and FID, using a DB-5ms column (30 m × 0.32 mm, 0.25 µm film). The temperature program ranged from 40°C to 300°C at 5°C/min. Helium was the carrier gas (1.0 mL/min), with a split ratio of 100:1 and injection volume of 1.0 µL. Identification was based on retention indices and mass spectra, compared with NIST'08 and Adams libraries. Samples were prepared by dissolving 20 µL oil in 380 µL n-hexane.

Statistical analysis

Analysis of variance was performed on the numerical data for yields and essential oil contents (ANOVA). A correlation analysis was carried out to performed to establish the relationship between the variables (quantitative and qualitative traits) in coriander.

RESULTS AND DISCUSSIONS

Essential oil content, %

Coriander seeds' value in growing is decided by their essential oil concentration. The values of this indicator are influenced by varying climatic circumstances over time. Dry, hot weather promotes essential oil content, as does less precipitation during seed ripening (ZHELJAZKOV et al., 2008; GEORGIEVA et al., 2022; HARIZANOVA et al., 2022). The highest oil content was noted in 2022, when there was a notable drought with a temperature during ripening that was 2.8 ºC higher than average for a multi-year period and 6.75 mm of precipitation compared to a norm of 49 mm. The essential oil content of the tested varieties is 0.45 to 0.74% (Table 2). The content of essential oil in coriander seeds was influenced by weather conditions. An experiment conducted by DELIBALTOVA (2020) in Bulgaria

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corroborates this, revealing that the concentration of essential oil in coriander fruits varied significantly over three consecutive years: 0.87-1.23% in 2016, 0.61-1.08% in 2017, and 0.72-1.17% in 2018. During the period from 2020 to 2022, the cultivar Yantar exhibited the greatest essential oil concentration at 0.62%, followed by Mesten drebnoploden at 0.55%, and the variety Moroccan at 0.51%. The findings of the variance analysis regarding the influence of the parameters Variety and Year, together with their interaction, on the essential oil content in the mature seeds of coriander are presented in Table 3. The results indicated a statistically significant effect of the examined components, whereas their interaction was found to be insignificant.

Table 2

Qualitative indicators in coriander seed varieties

Variable		Essential oil content (%)	Essential oil yield (kg)	Crude (fatty) oil (%)
Years (Y)	2020	0.55	9.8	14.11
	2021	0.35	6.6	10.90
	2022	0.61	10.6	13.85
Variety (V)	Yantar	0.62	8.9	12.27
	Moroccan	0.51	10.9	12.65
	Mesten Drebnoploden	0.55	11.4	13.29
	Thüringen	0.48	8.1	13.19
	Marino	0.34	5.6	13.35
2020	Yantar	0.67	9.7	13.86
	Moroccan	0.57	12.1	13.16
	Mesten Drebnoploden	0.59	12.1	14.84
	Thüringen	0.54	9.1	14.81
	Marino	0.38	6.2	13.90
2021	Yantar	0.45	6.9	10.40
	Moroccan	0.36	8.0	10.09
	Mesten Drebnoploden	0.42	9.0	11.15
	Thüringen	0.32	5.7	11.13
	Marino	0.20	3.4	11.71
2022	Yantar	0.74	10.3	12.56
	Moroccan	0.61	12.7	14.72
	Mesten Drebnoploden	0.64	13.2	13.89
	Thüringen	0.59	9.4	13.64
	Marino	0.45	7.2	14.43
Anova	Y	**	**	**
	V	*	**	*
	YV	n.s	*	*

**F-test significant at P<0.05; **F-test significant at P<0.01; ns non-significant.*

Essential oil yield, kg ha^{-1}

Over the years of the experiment, the factors "variety" and "year" have a statistically proven influence on the yield of essential oil in the tested varieties (Table 2). The values of this indicator in the first year of the study range from 6.2 kg ha^{-1} for the Thüringen variety to 12.1 kg ha^{-1} for the Moroccan and Mesten drebnoploden varieties (Table 2). In 2021 and 2022, the highest yield of essential oil was recorded for the Mesten drebnoploden variety, namely 9.0 kg ha^{-1} and 13.2 kg ha^{-1}, respectively. During the three years of the trial, the variety Marino produced the least amount of essential oil, ranging from 3.4 to 7.2 kg ha^{-1}. The evaluated coriander cultivars can be ranked in the following descending order based on the average values of the essential oil yield indicator: Mesten drebnoploden > Moroccan > Yantar > Thüringen > Marino.

Crude (fatty) oil, %

Both essential and crude (fatty) oil are present in coriander fruits. Its percentage is determined mainly by the genotype, but also depends on the environmental conditions and the agrotechnical units applied in plant cultivation (AKBARINIA et al., 2007; KESKIN & BAYDAR, 2016). Because of the 27.25 mm greater rainfall during ripening in 2021 than in the prior and third trial years, the crude (fatty) oil content was at its lowest levels. The investigated varieties had values ranging from 10.09 to 11.71%. In the third growing year, the crude (fatty) oil content was the highest among the tested cultivars, with the Morrocan variety leading with 14.72%, followed by the Marino variety with 14.43%. The analysis of variance demonstrates that the factor "variety" has a statistically significant impact on the indicator "crude (fatty) oil content" (Table 2).

Essential oil composition

During the three experimental years, 46 components were identified in the coriander essential oil, constituting between 98.8% and 99.8% of it. Monoterpenoids make up the majority of the oil. P-cymene, eucalyptol, cis-sabinene hydrate, β-linalool, camphor, pinocarvone, borneol, terpinen-4-ol, α-terpineol, β-citronellol, nerol, geraniol, neral, myrtenyl acetate, geranyl acetate, and viridiflorol are among the monoterpenoids' constituents.

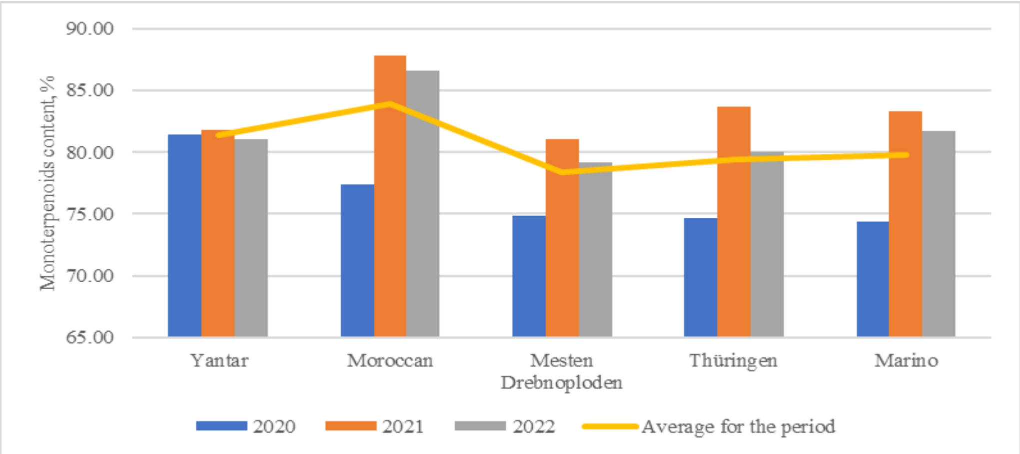

Figure 1. Monoterpenoids content, %

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Our findings are consistent with the amounts of oxygenated monoterpenes, also known as monoterpenoids, that KHALID (2015) reported. The highest monoterpenoid content was recorded in 2021 among all studied varieties, ranging from 81.05% to 87.83%. However, during the course of the experiment, the Moroccan variety exhibited the highest concentration of monoterpenoids (Figure 1).

The primary ingredient in matured fruits' essential oil was linalool, an oxygenated monoterpene. The matured fruits of all tested varieties had comparatively larger linalool concentrations during the second year. Climate conditions like cloudy days, low temperatures during maturation, and heavy precipitation have been shown to have a negative impact on the accumulation of linalool levels (SANGWAN et al. 2001). All evaluated cultivars had linalool contents ranging from 60.3% to 71.4% during the testing period, while reference values for the indicator ranged from 65.0% to 78.0% (Table 3).

Table 3

The chemical composition of the essential oil (%) of coriander varieties

Name	RT	Yantar			Mesten drebnoploden			Thüringen			Morrocan			Marino		
		2020	2021	2022	2020	2021	2022	2020	2021	2022	2020	2021	2022	2020	2021	2022
α-Pinene	10.02	6.10	3.23	3.56	6.91	4.14	4.55	7.47	3.91	5.71	6.92	2.46	2.70	7.20	4.27	4.70
Camphene	10.53	0.75	0.34	0.37	0.83	0.40	0.44	0.95	0.31	0.35	0.71	0.24	0.27	0.86	0.43	0.47
β-Pinene	11.45	0.32	0.33	0.37	0.53	0.40	0.44	0.53	0.36	0.39	0.44	0.28	0.30	0.60	0.41	0.45
β-Myrcene	11.87	0.65	0.46	0.51	0.80	0.46	0.50	0.78	0.42	0.46	0.64	0.37	0.41	0.83	0.53	0.59
p-Cymene	13.00	2.33	2.97	3.27	1.94	1.46	1.61	1.87	2.17	2.39	1.87	3.58	3.94	1.98	2.13	2.34
Limonene	13.16	2.37	1.05	1.16	2.43	0.72	0.79	2.66	0.60	0.66	2.56	0.54	0.59	2.54	0.80	0.88
Eucalyptol	13.21	0.02	0.40	0.44	0.05	0.60	0.66	0.02	0.32	0.35	0.03	0.28	0.31	0.05	0.46	0.51
γ-Terpinene	14.12	5.92	6.64	7.30	11.48	6.56	7.21	10.67	5.82	6.40	8.71	4.16	4.57	10.53	6.40	7.07
Terpinolene	14.96	0.61	0.35	0.38	0.63	0.40	0.44	0.69	0.27	0.30	0.70	0.27	0.22	0.67	0.39	0.43
β-Linalool	**15.69**	**62.9**	**68.3**	**66.2**	**60.4**	**70.8**	**67.8**	**60.3**	**70.9**	**65.9**	**61.6**	**71.4**	**68.5**	**61.9**	**69.5**	**66.5**
Camphor	17.18	6.12	3.10	3.41	4.60	3.36	3.69	4.84	2.58	2.83	6.06	2.85	3.14	4.60	2.88	3.17
Borneol	17.77	0.18	0.20	0.22	0.13	0.071	0.08	0.11	0.28	0.31	0.03	0.12	0.13	0.14	0.14	0.16
α-Terpineol	18.39	0.63	0.41	0.45	0.44	0.43	0.47	0.42	0.37	0.41	0.30	0.49	0.53	0.49	0.45	0.49
Decanal	18.70	0.32	0.38	0.42	0.14	0.71	0.78	0.08	0.87	0.96	0.40	0.54	0.59	0.17	0.49	0.54
Citronellol	19.22	0.08	0.21	0.23	0.17	0.11	0.12	0.09	0.35	0.39	0.12	0.10	0.11	0.13	0.11	0.12
Geraniol	19.94	3.46	3.75	4.13	3.81	2.84	3.12	2.80	3.63	3.99	3.65	2.66	2.93	2.59	2.88	3.17
Geranyl acetate	23.42	5.01	1.38	1.52	2.69	0.12	0.12	3.67	1.19	1.31	3.16	5.18	5.69	1.93	4.16	4.57
Myristic acid	32.57	nd	0.41	0.45	nd	0.24	0.26	nd	0.26	0.28	nd	0.12	0.13	nd	0.09	0.10
Palmitic acid	36.76	nd	1.67	1.84	nd	0.39	0.43	nd	0.84	0.92	nd	0.39	0.43	nd	0.56	0.61

nd *– „no data”*

The highest linalool content in all varieties was recorded in 2021, reaching 71.4% in Moroccan cultivar. This experimental year in terms of climatic factors comes closest to the values of the multi-year period.

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The soapy or pungent aroma of the essential oil is largely due to several aldehydes present in coriander (ERIKSSON et al., 2012). The group of aldehydes identified by chromatographic analysis of the essential oil from the five coriander varieties tested includes the chemical components hexanal, decanal, 2E-decenal, udecanal, dodecenal (Table 3).

Geraniol is a monoterpenoid with concentrations varying from 2.59% to 4.13% during the experiment. A water-insoluble monoterpene, geranyl acetate has a nice fruity or floral rose aroma. From 0.12% in the Mesten drebnoploden variety to 5.69% in the Moroccan variety, the data from the chromatographic studies conducted over the period of the three years show a wide range of variations.

In the second and third years, the presence of myristic and palmitic acids was found in all experimental varieties. The highest levels of palmitic acid (1.67-1.84%) and myristic acid (0.41-0.45%) are found in the Yantar cultivar.

Finally, we can conclude that the main component for the five tested coriander varieties over the trial period was linalool with average values from 65.71 % to 67.17%, followed by γ-terpinene (5.81-8.42%), α-pinene (4.02-5.70%), camphor (3.42-4.2%), limonene (1.23-1.52%) and geranyl acetate (0.97-4.68%), while other compounds (camphene, p-cymene, β-pinene, myrcene and sabinene) were present in less than 1%. MILICA et al. (2016) observed similar results (Table 3).

To establish the relationship between the variables (quantitative and qualitative characteristics) in coriander, a correlation analysis was performed. The correlation coefficients expressing the relationship between the studied indicators are expressed in the correlation matrix. With a correlation value of r = 0.962 and a significance level of α = 0.001, Table 4 demonstrates the highest correlation between the chemical component γ-terpinene and the indicators of crude fatty oil. With correlation coefficients of r = 0.744 and a level of statistical significance of α = 0.05, respectively, the indicators Essential Oil and Oil Yield have a powerful and statistically relevant relationship.

Table 4

Correlation matrix of quantitative and qualitative parameters

	Essential Oil	Oil Yield	Crude Fatty Oil	β-Linalool	Palmitic acid	γ-Terpinene
Essential Oil	1					
Oil Yield	0.744*	1				
Crude Fatty Oil	-0.466	-0.354	1			
β-Linalool	0.022	0.577	-0.468	1		
Palmitic acid	0.527	-0.170	-0.326	-0.632	1	
γ-Terpinene	-0.360	-0.295	0.962**	-0.547	-0.259	1

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

CONCLUSIONS

The study shows that the cultivar's genetics, the annual weather conditions, and most importantly, the amount and distribution of vegetative precipitation all have a substantial impact on the production and quality traits of the assessed coriander varieties.

In the five tested coriander varieties through the year with the lowest average daily temperatures during the growing season, the quality indicators of essential oil content, oil yield, and crude (fatty) oil content are understated. The cultivar Mesten drebnoploden exhibits the highest average crude (fatty) oil content at 13.29%, whereas the variety Yantar demonstrates the greatest average essential oil content at 0.62%. Crude fatty oil and the chemical component of the essential oil γ-terpinene had a highly significant and positive correlation. The findings of the study could help recommend coriander cultivars for this region.

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