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ORIGINAL PAPER

Effect of different sowing rates on the fatty oil composition of coriander grown in winter and spring in semi-arid conditions

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Abstract

Coriander is an annual herb, a member of the Umbelliferae/Apiaceae family, which often used in flavouring substances. The stem, root, leaves and fruits all have an aroma that most people consider to be pleasant. The objective of the study was to determine changes in the fatty oil composition of coriander sown at different seed rates (10, 20, 30, and 40 kg ha^{-1}) and grown in winter and summer seasons. Two coriander varieties (Mardin and Denizli) were grown under semi-arid conditions. The experiment was arranged in a split-split plot design with three replications. Sowing times composed the main plots, the subplots were varieties (population) and four different seeding rates (10, 20, 30, and 40 kg ha^{-1}) were used as sub-sub plots. The crop harvests were completed from the first half of June to the first week of July, according to the maturity of different populations. The results showed that the fatty oil ratio varied between 17.30 and 23.82%. The highest value (23.82%) was obtained from sowing 40 kg seeds per ha^{-1} of the Denizli ecotype in winter, while the lowest one (17.30%) was achieved from the seed rate of 10 kg ha^{-1} of the Mardin ecotype sown in summer. It was determined that petroselinic acid, the most important component of coriander fatty oils, was high at the seed rate of 10 kg ha^{-1} of the Mardin ecotype plants sown in summer. The GGE biplot analysis was made, demonstrating a negative relationship between petroselinic acid and linolenic acid, a positive relationship between linoleic and cis-13-octadecenoic acid, and a positive relationship between palmitic, myristic, and stearolica acids.

Keywords: *Coriandrum sativum* L., sowing time, sowing amount, oil, fatty acid, habitat

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This work does not belong to any project.

INTRODUCTION

Coriandrum sativum L. is an annual medicinal aromatic plant belonging to the Umbelliferae/Apiaceae family. Although native to the Mediterranean region, it also grows widely in Europe, Russia, Asia, and South Africa (Sahib et al. 2013 Diederichsen, Hammer 2003). In Turkey, it is cultivated in many regions, such as Mardin, the lake district, Burdur, Gaziantep, Ankara, and Konya (Uzun et al. 2010). It is sown in autumn and winter in regions with mild weather conditions, but in spring and summer in regions with harsh winters (Khah 2009). The number of plants per unit area varies depending on the amount of seed used. Seed rates are also important for plant competition and production, just like row spacing. Kırıcı (1999) reported that as the amount of seeds of coriander sown increased, the plant height increased but the number of branches, the number of umbrellas and fruit number in the umbrella decreased.

The flowers of *C.sativum* are small, umbrella-shaped, light pink or white in colour, and its seeds are small and oval-shaped, with two mericarps, and with sharp taste and smell, containing fatty oils (Yeung, Bowra 2011). Coriander has two varieties, namely *C. sativum* var. *vulgare* and *C. sativum* var. *microcarpum*. *C. sativum* var. *vulgare* has fruits with a diameter of 3 to 5 mm and is able to produce yield of essential oil of 0.1 to 0.35% (v/w), while *C. sativum* var. *microcarpum* has fruits with a diameter of 1.5 to 3 mm with a yield of essential oils 0.8 to 1.8% (v/w). *C. sativum*, var. *vulgare* is cultivated in Italy, India, China, Central, and Eastern Europe, the Netherlands, and Bangladesh. while *C. sativum* var. *microcarpum* is mostly cultivated in Canada (Burdock, Carabin 2009).

Coriander contains essential oils as well as fatty oils. The fatty oil content varies between 9.9 and 27.7% (Diederichsen 1996). The main component of coriander essential oils is linalool, reaching a 67.7% ratio (Emiralioglu, Yaldiz 2020). The major fatty acid is petroselinic acid (65.7% of the total fatty acid methyl esters) followed by linoleic acid, palmitoleic acid, arachidicacid, γ-linolenic acid, linolenic acid, gadoleic acid, cetoleic acid and docosahexanoic acid (Al-Snafi 2016); however, the most important fatty acid with the highest ratio is petroselinic acid. Petroselinic acid, a monounsaturated fatty acid (C18:1n-12) and a representative of octadecenoic acids, draws attention to coriander owing to its chemical structure and its uniquely high amount in this plant. Because of its different structure, petroselinic acid creates an opportunity to obtain chemical derivatives different from those obtained from other oils (Ramadan, Mörsel 2002). Research has reported that petroselinic acid is an important fatty acid with many uses in the fields of food, industry and conventional medicine (Khodadadi et al. 2016*a*). Petroselinic acid has antimicrobial properties and is also used in the perfume industry (Burdock -Carabin 2009). *C. sativum* is also used for food preparation and preservation purposes, and for the prevention of food-borne diseases and food spoilage (Mandal, Mandal 2015).

The quantitative content and quality of essential and fatty oil in coriander varies under the influence of a number of factors – temperature, water regime, variety, sowing time, seed rate, soil treatment, fertilizer, etc. (Moniruzzaman et al. 2014). Coriander is cultivated as a summer or winter annual crop according to the climatic conditions. Our previous research reported in studies that the agronomic essential oil properties of coriander may change (Kizil 2002) depending on many factors. The objective of the study was to determine the changes in fatty oil composition of two coriander varieties grown at different seed rates in winter and summer seasons under semi-arid conditions.

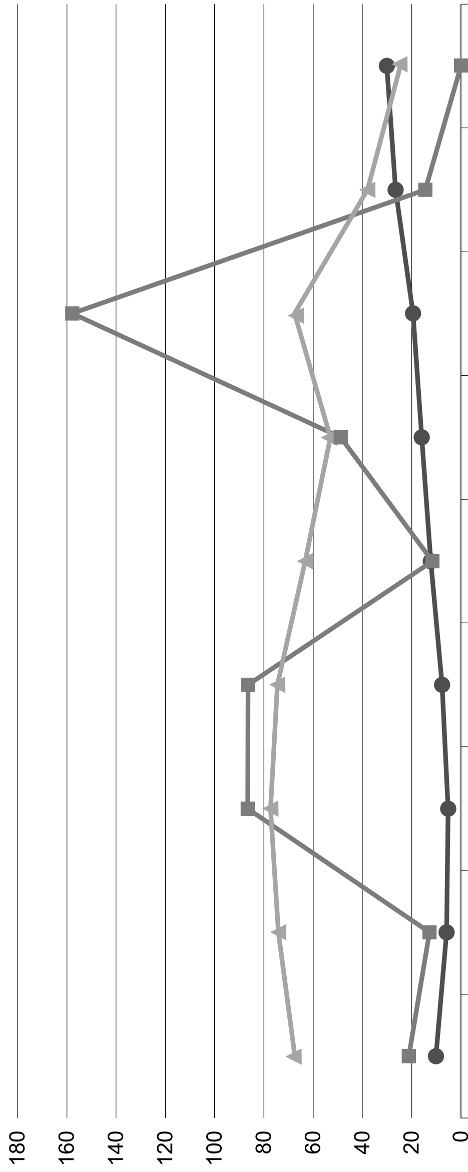
MATERIALS AND METHODS

Plant material and experimental design

The research was conducted during the 2017-2018 growing season at the experimental field of the Department of Field Crops of the Faculty of Agriculture of Dicle University (latitude 37°53′N, longitude 40°16′E, altitude 680 m above sea level). Climate data for the experimental area are given in Figure 1. Soil sample analysis was carried out at Diyarbakır GAP International Agricultural Research and Training Center. The soil of the experimental field was loamy with 0.12% salinity, 6.67% lime, a pH of 7.96, 19.60 ppm of phosphorus, and 0.23% of organic matter.

Two different sowing times (winter and summer) and two different varieties (Mardin and Denizli) were used in the study. The seeds of the Mardin population were obtained from farmers producing coriander in Mardin province, and the seeds of the Denizli population were obtained from farmers producing coriander in Denizli province. These were big-seeded *C. sativum* var. *macrocarpum* of the Mardin ecotype and the small-seeded *C. sativum* var. *microcarpum* of the Denizli ecotype. The previous literature has confirmed that the Mardin population belongs to *Coriandrum sativum* L. var. *vulgare* Alef., whereas the Denizli population belongs to *Coriandrum sativum* L. var. *microcarpum* DC. (Zeybek, Zeybek 1994).

Sowing times were 14 November and 14 February in the growing seasons in 2017-2018. The experiment was arranged in a split-split plot design with three replications. Sowing times consituted the main plots, the subplots were varieties (population), and four different seeding rates (10, 20, 30, and 40 kg ha^{-1}) were used as sub-sub plots. Each plot (1.40 m × 3 m) consisted of 4 rows. Sowing was done by hand into carefully opened rows. Nitrogen fertilizer was divided so that of the total of 30 kg ha^{-1}, half was given while sowing the plant, and the other half was applied during the plant rooting. Meanwhile, the whole of phosphorus fertilizer, i.e. 60 kg ha^{-1}, was applied while sowing the crop. Irrigation was not performed at either of the sowing



	November	December	January	February	March	April	May	June	July
average temperature (°C)	10.10	5.80	5.20	7.60	12.30	15.90	19.40	26.50	30.10
total precipitation (mm)	21.20	12.80	86.60	86.40	11.60	48.80	157.80	14.40	0.00
humidity (%)	67.40	74.10	77.30	74.50	63.20	53.00	67.50	37.90	24.60

Fig. 1. Diyarbakir Climate Conditions According to 2017-2018

dates, and weed control was carried out mannually, with a hoe as a tool. The crop harvests were completed from the first half of June to the first week of July, according to the maturity of different populations.

Fatty oil content (%)

The fatty oil ratio was determined using the Soxhlet method (hot extraction) on seed pulps from which essential oils were removed. 10 g of ground pulp samples were extracted for 4 hours using hexane to identify the fatty oil content (Celik, Kan 2013).

Fatty acid components (%)

Gas chromatography mass spectrometry (GC/MS) was performed to determine the chemical components of fatty oil. Gas chromatography/mass spectrometry (GC/MS) analytical settings were as follows: Shimadzu GSMS-QP2010 ULTRA system; Column Rtx-Wax; (30 m x 0.25 mm Ø, 0.25 µm film thickness); Temperature Program at 120°C with an increase of 3 min// 20°C/min; to 220°C in 42 min; Injector 240°C; Carrier Gas Helium (1.00 ml/min); Split 1:00 ; Mass Range m/z 35-500; analysis time: 50.0 min.

Statistical analysis

The composition of fatty acid components was analyzed according to the split plot experimental design split into JMP Pro 14 randomized blocks, and the data analysis was performed at a significance level of 0.05%. GGE- biplot analysis was performed using GenStat 12th Edition Program.

RESULTS AND DISCUSSION

The data obtained from different sowing times and seed rates of both varieties referred to as ecotypes are presented in Tables 1 and 2 and in Figures 2, 3 and 4. The fatty oil ratio varied between 17.30 and 23.82%. The highest value (23.82%) was obtained from sowing 40 kg ha^{-1} of the Denizli ecotype sown in winter, while the lowest level (17.30%) was obtained from sowing 10 kg ha^{-1} of the Mardin ecotype sown in summer (Fig. 2).

Nguyen et al. (2020), in their study, determined that the fatty acid ratio in various coriander species grown in Isparta conditions was between 5.8% and 24.9%; Keskin, Baydar (2016) found the oil content values that varied from 18.64 and 22.16% and from 24.62 and 25.42% in 3 different types of coriander, respectively. Nguyen et al. (2015) reported that the oil content ranged from 4.6 from 25.1% in plants harvested during successive seed development stages of coriander cultivated under organic agricultural condi-

Table 1

Fatty acid composition (% of total FAME) of two coriander varieties according to different seed rates sown in winter and summer

No	Fatty Acid Compounds	1*	2	3	4	5**	6	7	8	9***	10	11	12	13****	14	15	16
1	Myristic acid	0.04	0.04	0.04	0.04	0.05	0.05	-	-	0.07	0.09	0.08	0.08	0.05	0.04	0.04	0.04
2	Lignoceric acid	-	-	-	-	-	-	-	-	-	0.04	0.04	-	-	-	-	-
3	Pentadecanoic acid	-	0.03	0.04	0.03	-	0.04	-	-	0.04	-	0.04	-	0.03	-	-	-
4	Palmitic acid	3.83	4.04	4.04	3.80	3.58	3.58	3.51	3.50	3.95	4.16	4.05	3.98	3.62	3.59	3.54	3.5
5	Methyl palmitoleate acid	0.39	0.39	0.37	0.39	0.37	0.37	0.37	0.37	0.38	0.38	0.37	0.37	0.38	0.39	0.38	0.38
6	Palmitoleic acid	0.19	0.23	0.22	0.20	0.18	0.2	0.18	0.18	0.20	0.22	0.22	0.20	0.19	0.16	0.17	0.16
7	Heptadecanoic acid	-	0.06	0.06	-	-	-	-	-	0.05	0.07	0.06	0.06	-	-	-	-
8	cis-10-Heptadecenoic acid	-	0.09	0.09	-	-	-	-	-	0.08	0.12	0.14	0.13	-	-	-	-
9	Stearic acid	1.14	1.20	1.36	1.11	1.03	1.08	1.13	1.06	1.16	1.19	1.21	1.18	1.06	1.06	1.05	1.10
10	Petroselinic acid	79.18	78.45	77.88	78.85	78.49	78.02	78.74	78.87	78.07	77.26	77.07	77.63	78.42	78.87	78.58	78.43
11	Stearolic acid	1.18	0.24	1.19	1.20	1.08	-	0.10	0.09	0.17	1.24	1.22	1.24	1.12	1.13	1.15	0.11
12	Methyl 6,11-octadecadienoate	0.10	0.11	0.10	0.11	0.10	0.1	-	-	0.11	0.13	0.13	0.13	0.11	0.10	0.10	0.10
13	6,9-Octadecadienoic acid	0.12	0.13	0.13	0.12	-	0.08	-	-	0.12	0.15	0.16	0.15	0.12	-	0.10	-
14	Linoleic acid	13.71	14.60	14.15	13.86	14.79	15.00	14.68	14.68	14.30	14.57	14.73	14.49	14.62	14.5	14.59	14.8
15	Linolenic acid	0.14	0.15	0.15	0.13	0.14	0.20	0.13	0.15	0.14	0.18	0.28	0.18	0.11	-	0.12	0.12
16	cis-13-Octadecenoic acid	-	-	-	-	-	1.11	0.99	1.09	1.17	-	-	-	-	-	-	1.08
17	cis-13-Eicosenoic acid	-	-	-	-	-	-	0.17	-	-	0.19	0.19	0.19	-	0.17	-	-
18	cis-11-Eicosenoic acid	-	0.19	0.18	0.18	0.18	0.18	-	-	-	-	-	-	0.18	-	0.19	0.18

* 1-4: Denizli ecotype/1: winter sowing, 10 kg ha^{-1}; winter sowing, 20 kg ha^{-1}; winter sowing, 30 kg ha^{-1}; winter sowing, 40 kg ha^{-1};
** 5-8 Mardin ecotype: winter sowing, 10 kg ha^{-1}; winter sowing, 20 kg ha^{-1}; winter sowing, 30 kg ha^{-1}; winter sowing, 40 kg ha^{-1}
*** 9-12: Denizli ecotype /9- summer sowing, 10 kg ha^{-1}; summer sowing, 20 kg ha^{-1}; summer sowing, 30 kg ha^{-1}; summer sowing, 40 kg ha^{-1}
**** 13-16: Mardin ecotype summer sowing, 10 kg ha^{-1}; summer sowing, 20 kg ha^{-1}; summer sowing, 30 kg ha^{-1}; summer sowing, 40 kg ha^{-1}

Table 2

Mean Comparison of Major Fatty Oil Components of Coriander

Sowing Time	Ecotype	Seed rate (kg ha^{-1})	Palmitic acid	Stearic acid	Petroselinic acid	Linoleic acid
Winter	Denizli	10	3.83 *d*	1.14 *ef*	78.42	13.71
		20	4.04 *b*	1.20 *bc*	78.87	14.60
		30	4.04 *b*	1.37 *a*	78.58	14.15
		40	3.80 *d*	1.11 *gh*	78.43	13.86
	Mardin	10	3.58 *f*	1.03 *l*	78.49	14.79
		20	3.58 *f*	1.08 *ıj*	78.02	15.00
		30	3.51 *gh*	1.13 *fg*	78.74	14.68
		40	3.50 *h*	1.06 *jk*	78.87	14.68
Summer	Denizli	10	3.95 *c*	1.16 *de*	78.07	14.30
		20	4.16 *a*	1.19 *bc*	77.26	14.57
		30	4.05 *b*	1.21 *b*	77.07	14.73
		40	3.98 *c*	1.18 *cd*	77.63	14.49
	Mardin	10	3.62 *e*	1.06 *jk*	79.18	14.62
		20	3.59 *ef*	1.06 *jk*	78.45	14.50
		30	3.54 *g*	1.05 *kl*	77.88	14.59
		40	3.50 *h*	1.10 *hı*	78.85	14.80
			**	**	**	**
Ecotype x Sowing Time						
Denizli	Winter		3.92 *b*	3.92 *b*	1.20 *a*	78.59
Mardin	Winter		3.54 *d*	3.54 *d*	1.07*c*	78.53
Denizli	Summer		4.03*a*	4.03*a*	1.18 *b*	77.50
Mardin	Summer		3.56*c*	3.56*c*	1.06 *c*	78.57
Probability			**	**	ns	ns

** $p<0.05$, * $p<0.01$, abbreviation: ns – not significant

tions. Sriti et al. (2010) identified the oil content of coriander seeds (*Coriandrum sativum* L.) as 9.30-22.65%, while Ramadan, Mörsel (2002) found the fatty oil ratio to be 28.4%.

Variation in the seeds' fatty oil content reported previously might have been due to differences between the research locations, ecologies, and treatments (Kiralan et al. 2009, Amiripour et al. 2021). In addition, it is reported that the effect of a genotype on changes in the composition of fatty acids in different varieties and at different sowing times is greater than the effect of the environment (Samanci, Ozkaynak, 2003).

According to the data presented in Table 2, sowing time, variety and seed rate had different, statistically non-significant effects on the petroselinic and linoleic acid amounts in unsaturated fatty acids. In contrast, palmitic

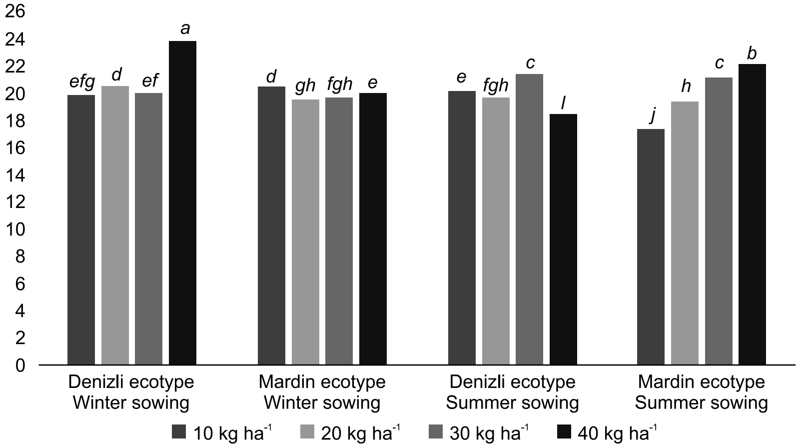


Fig. 2. Fatty oil ratios (%) of two coriander varieties according to different seed rate sown as winter and spring

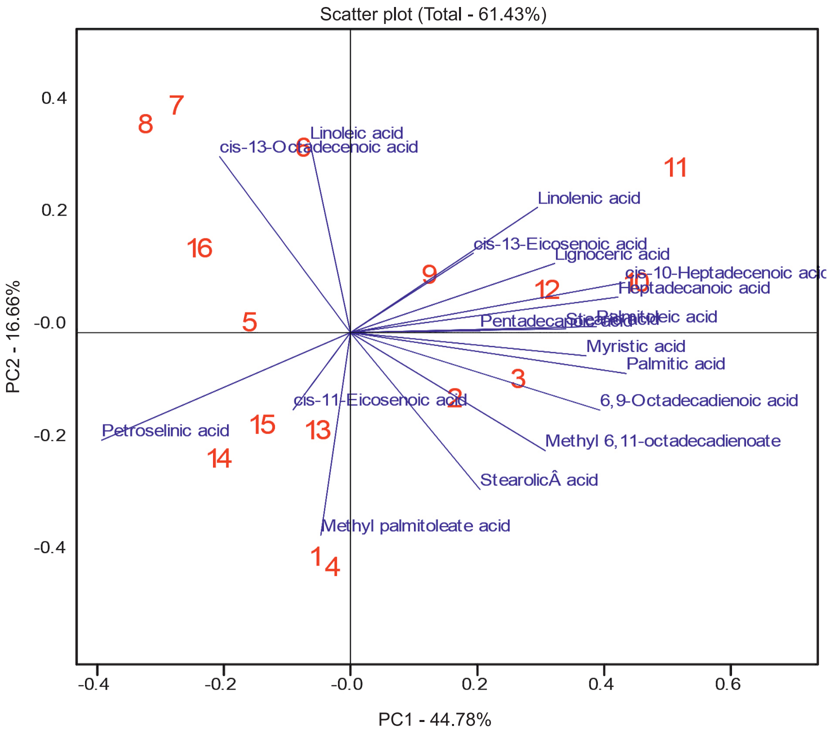


Fig. 3. GGE-biplot for 16 Applications and fatty Acids (%).

* 1-4: Denizli ecotype/1: winter sowing, 10 kg ha^{-1}; winter sowing, 20 kg ha^{-1}; winter sowing, 30 kg ha^{-1}; winter sowing, 40 kg ha^{-1}; ** 5-8 Mardin ecotype: winter sowing, 10 kg ha^{-1}; winter sowing, 20 kg ha^{-1}; winter sowing, 30 kg ha^{-1}; winter sowing, 40 kg ha^{-1}; *** 9-12: Denizli ecotype /9- summer sowing, 10 kg ha^{-1}; summer sowing, 20 kg ha^{-1}; summer sowing, 30 kg ha^{-1}; summer sowing, 40 kg ha^{-1}; **** 13-16: Mardin ecotype summer sowing, 10 kg ha^{-1}; summer sowing, 20 kg ha^{-1}; summer sowing, 30 kg ha^{-1}; summer sowing, 40 kg ha^{-1}

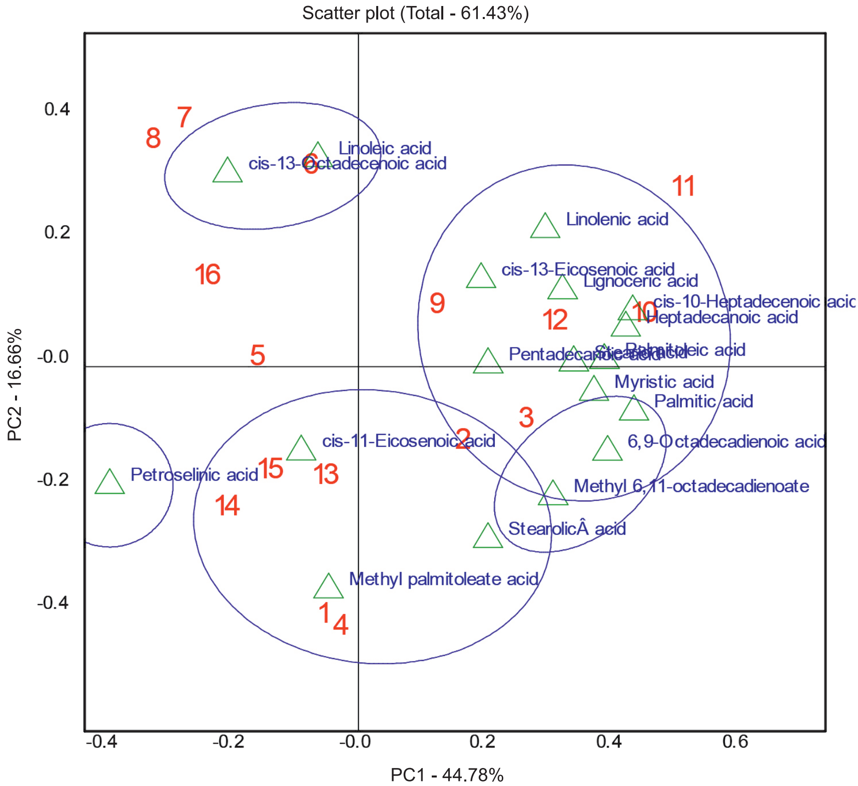


Fig. 4. 16 treatments and fatty acids (%) Mega-environment relationship graph
* 1-4: Denizli ecotype/1: winter sowing, 10 kg ha^{-1}; winter sowing, 20 kg ha^{-1}; winter sowing, 30 kg ha^{-1}; winter sowing, 40 kg ha^{-1}; ** 5-8 Mardin ecotype: winter sowing, 10 kg ha^{-1}; winter sowing, 20 kg ha^{-1}; winter sowing, 30 kg ha^{-1}; winter sowing, 40 kg ha^{-1}; *** 9-12: Denizli ecotype /9- summer sowing, 10 kg ha^{-1}; summer sowing, 20 kg ha^{-1}; summer sowing, 30 kg ha^{-1}; summer sowing, 40 kg ha^{-1}; **** 13-16: Mardin ecotype summer sowing, 10 kg ha^{-1}; summer sowing, 20 kg ha^{-1}; summer sowing, 30 kg ha^{-1}; summer sowing, 40 kg ha^{-1}

and stearic acid contents were significantly affected by all of these factors. The main components of the oils were: petroselinic acid (77.07-79.18%), linoleic acid (13.71-15%), palmitic acid (3.50-4.16%), and stearic acid (1.03-1.21%) – Table 1. Diederichsen (1996) reported that the fatty acids in coriander oil are comprised of 68.8% of petroselenic acid (C18:1), 16.6% of linoleic acid (C 18:2), 7.5% oleic acid (C18:1), 3.8% of palmitic acid (C 16:0) and trace amounts of stearic acid, vaccenic acid and myristic acid. Momin et al. (2012) reported that the fatty oil composition of ripe coriander fruits mainly includes petroselinic acid (68.8%), linoleic acid (16.6%), oleic acid (7.5%) and palmitic acid (3.8%).

Although it was not statistically significant, the highest petroselinic acid content (79.18%) was found from the sowing rate of 10 kg ha^{-1} of the Mardin ecotype sown in summer, while the lowest (77.07%) was obtained from the sowing rate of 30 kg ha^{-1} of the Denizli ecotype sown in summer. The highest linoleic acid content (15.00%) was obtained at the seed rate of 20 kg ha^{-1} of the Mardin ecotype sown in winter, and the lowest (13.71%) was obtained at the seed rate of 10 kg ha^{-1} of the Denizli ecotype sown in winter. The palmitic acid content was high (4.16%) in the seed rate of 20 kg ha^{-1} of the Denizli ecotype sown in summer, but low (3.50%) at the seed rate of 40 kg ha^{-1} of the Mardin ecotype in both growing seasons. The highest stearic acid ratio (1.37%) was found at the seed rate of 30 kg ha^{-1} of the Denizli ecotype sown in winter, while the lowest (1.03%) was found at the seed rate of 10 kg ha^{-1} of the Mardin ecotype sown in winter (Table 2).

In our study, the ecotype ×sowing time interaction for palmitic acid and stearic acid was found to be significant, but it was not statistically significant with respect to petroselinic acid and linoleic acid. The highest share of palmitic acid (4.03 %) was obtained from the Denizli ecotype sown in summer, and the lowest one was obtained from the Mardin ecotype sown in winter. The percentage of stearic acid was high in the Denizli ecotype, but low in Mardin ecotype sown in summer.

The percentage of petroselinic acid was found to be 79.16-79.89% by Keskin, Baydar (2016), and 79.79% by Kaufmann et al. (2022). According to the results of this research, the share of petroselinic acid obtained was similar to the results reported by Keskin, Baydar (2016) and by Kaufmann et al. (2022), but higher than determined by Nguyen et al. (2020) and Reiter et al. (1998).

In the study, a GGE Biplot (figure: 3-4) was created to determine the multivariate relationships between the fatty acid composition of different genotypes and the different seed rates sown in summer and winter, and the genotype – application – sowing time relationships. In the study, the PC1 value, which forms the GGE Biplot graph, is 44.78% and the PC2 value is 16.66%, and these two components constituted 61.43% of the total variation. In a GGE Biplot graph, if the angle between vectors is less than 90°, it shows that the performance of that genotype is better than the average; if the angle between vectors is greater than 90˚, the performance of the genotype is lower than the average, and if the angle is equal to 90˚, it is close to the average (Yan, Tinker, 2006). There was a negative relationship between petroselinic acid and linolenic acid, a positive relationship between linoleic and cis-13-octadecenoic acid, and a positive relationship between palmitic, myristic, and stearolic acids. When Figure 4 is examined, the GGE biplot analysis clustered 16 different fatty acids in 5 mega-environments. Cis-13-octadecenoic acid and linoleic acid are in one group, and the remaining fatty acids, except petroselinic acid, are gathered into 3 different groups. However, it was determined that petroselinic acid is independent from the other fatty acids and the tested treatments. No coriander ecotype x environmental treatments were grouped with petroselinic acid. Cis-13-octadecenoic acid and linoleic acid were prevalent fatty acids in the Mega group Mardin ecotype winter sowing, 20 kg ha^{-1}. Winter-Mardin 10, 30, 40 kg ha^{-1}, Summer Mardin 40 kg ha^{-1}, Summer Denizli 30 kg ha^{-1} variants were not grouped in the above mega circle. Many studies have been carried out with the GGE biplot analysis method to evaluate the performance of different Coriander genotypes (Dyulgerov, Dyulgerov 2013, Khodadadi et al. 2016*b*, Gholizadeh et al. 2022).

CONCLUSIONS

The effect of different sowing rates (10, 20, 30, and 40 kg ha^{-1}) of the Mardin and Denizli coriander ecotypes planted in winter and summer was investigated. , was investigated The ratio of petroselinic acid, which is the most important component in coriander fatty oil content, was investigated relative to the winter and summer sowing times. It was concluded that the highest petroselinic acid ratio was obtained from winter sowing time (79.18%), and the lowest petroselinic acid ratio was obtained from summer sowing time (77.07%). In the study, it was determined that the fatty oil content ratios obtained from different sowing dates were similar to each other. Fatty oil percentages were found to be between 17.30-23.82%, the highest fatty oil rate (23.82%) was in the Denizli ecotype sown in winter at the seed rate of 40 kg ha^{-1}; the lowest fatty oil ratio (17.30%) was detected in the Mardin ecotype sown in summer at the seed rate of 10 kg ha^{-1}. In conclusion, it was determined that petroselinic acid, the most important component of coriander fatty oil, was high at the seed rate of 10 kg ha^{-1} of the Mardin ecotype plants sown in summer. Various studies have been carried out and put into practice to increase the production of coriander, which is an important medicinal plant. It has been concluded that the ecological characteristics of these plants have a greater effect when compared to cultivation, and since yield and quality are as important as production in plant breeding, the cultivation of coriander should be carried out in appropriate environment and with the right cultivation technique.

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