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DETERMINATION OF SUITABLE CORIANDER *(Coriandrum sativum* L.) CULTIVARS FOR EASTERN MEDITERRANEAN REGION

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ABSTRACT

Coriander, *Coriandrum sativum* L., is a major medicinal and aromatic plant having aromatic carminative, stomachic, and antispasmodic properties. There are six improved cultivars in Turkey. In the research, it was aimed to adaptability trial of the new cultivars for Eastern Mediterranean. Therefore, field experiments were carried out during 2008- 2009 and 2009- 2010 growing seasons. Plant and agronomic properties were evaluated with oil content and composition. Oil compositions were analyzed with GCMS. As a result of the research, all investigated characters were varied significantly, except linalool which is major component in coriander fruit oil. With respect to fruit yield and essential oil content, the best results were obtained from Arslan and Erbaa cultivars, respectively. Linalool contents varied between 84.60 and 90.10 %; and maximum data of the component were obtained from Gurbuz with 90%.

Key Words: *Coriandrum sativum* L., essential oil content, linalool, yield

INTRODUCTION

Coriander (*Coriandrum sativum* L.), which is a spice plants belonging to the Apiaceae (Umbelliferae) family, is well known aromatic plant and name as "aşotu" and "kişniş" in Turkish it was grown at Göller Region, Ankara, Eskişehir, Erzurum, Gaziantep and Konya in Turkey (Ayanoglu et al., 2002). Maturated fruits and leaves (fresh and dried) were used as spice and oil distillated from maturated fruit is used mainly as a flavoring agent in pharmaceutical preparations. Fruits are used as aromatic and carminative and in laxative preparations to prevent griping (Kirici et al., 1997; Leung and Foster, 2003). Coriander has been used in medicines for thousands of years, various parts of this plant such as leaves, flower, seed, and fruit, possess diuretic, sedative, anti-diabetic, anti-mutagenic, antioxidant, anti-microbial, anti-convulsant, hypnotic and anthelmintic activities (Nadeem et al., 2013). Essential oil and especially its main component, linalool is an extremely important raw material in the perfume and cosmetic products, at the same time because of its bactericidal and fungicidal effects is also used in food and pharmaceutical products as a preservative. The essential oil content of the dried fruits varies from very low (0.03 %) to a maximum report of 2.7 %. The predominant constituent of essential oil of coriander is linalool, which forms approximately two-thirds of the oil (Shahwar et al., 2012).

In general, the coriander cultivation was on the basis of population of seed. Therefore, in the agricultural policies of the region winter product and the alternative coriander plant, six varieties which have been registered very important to determine yield potential in the Eastern Mediterranean region. In this study, the content and composition of the essential oil and yield components of the registered six varieties of coriander at Eastern Mediterranean Region conditions were investigated.

MATERIALS AND METHODS

Plant material: Six improved coriander cultivar, Arslan, Erbaa, Gamze, Gürbüz, Kudret-K and Pel-Mus were used in the study. The releasing dates and organizations of registered coriander varieties were shown in Table 1.

Field experiment: The experiments were arranged in a randomized complete block design with four replications for during 2 years (2008-2009 and 2009-2010) as a winter plant at Cukurova University, Faculty of Agriculture, and Department of Field Crops, on the Research and Application area. Fruits were sown at 12th November both years. Distance between rows was 25 cm and each plot

consists of six row, plots were 4 x1.5 meters. Each plot received 40 kg ha^{-1} of nitrogen and phosphorus as basic fertilizer at planting, 20 kg ha^{-1} nitrogen fertilization at 2th April, 2009 and 30 March 2010 were done. Meteorological data for the growing seasons are shown in Table 2. Soil from a depth of 30 and 60 cm were sampled before setting the experiment, and were subjected to physicochemical analysis. Soils from depth 30 and 60 cm were total nitrogen 0.14% and 0.12 %, medium P_2O_5 (44.2 and 36.3 kg ha^{-1}), alkaline (pH of 7.68 and 7.66), salt 0.055 and 0.052 %, $CaCO_3$ 38.5 and 38.6%, respectively.

Table 1. Coriander *(Coriandrum sativum* L.*)* varieties

Variety Name	Registration Date	Owner*
Kudret-K	09.04.2004	Ondokuz Mayıs Univ. Agriculture Fac.,
Pel-Mus	09.04.2004	Ondokuz Mayıs Univ. Agriculture Fac.
Gamze	09.04.2004	Blacksea Agri.Research Institute
Erbaa	09.04.2004	Blacksea Agri.Research Institute
Arslan	07.04.2005	Ankara Univ. Agriculture Fac.
Gürbüz	07.04.2005	Ankara Univ. Agriculture Fac.

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Table 2. Means temperature and precipitation values at the study area

Months	Years	Temperature (^{0}C)			Precipitation
		Min.	Max.	Mean	(mm)
November	2008	13.1	22.2	17.2	29.5
	2009	8.4	25.4	15.6	9.9
December	2008	6.4	15.7	10.6	46.7
	2009	6.0	20.6	13.3	79.5
January	2009	-2.0	18.8	9.6	144.3
	2010	-0.9	20.5	11.9	87.9
February	2009	3.8	20.1	11.0	78.0
	2010	1.3	22.3	12.6	66.3
March	2009	4.9	22.8	12.9	91.9
	2010	9.0	33.3	18.5	5.8
April	2009	9.3	29.3	17.7	29.2
	2010	15.2	35.5	23.8	58.7
May	2009	27.0	15.8	21.0	19.0
	2010	19.9	39.1	27.6	0.8
June	2009	18.9	38.4	27.2	0.0
	2010	24.8	43.1	31.1	1.5
*T.Prec. mm	2009/2010				438.6/310.4

Source:http://www.cukurova.edu.tr/Content/Asp/Turkish/cuMeteo Annual reports .asp
*T.Prec.: Total Precipitation

The soil textures were clay. The necessary observations from the germination to harvest were recorded. When the seeds had ripened, the process of harvesting started. The plots were harvested by plot harvest machine in 17 June 2009 and 16 June 2010. At harvest, plant height (cm), number of umbrella per plant and number of fruit per umbrella were recorded on ten plants randomly chosen in each plot, and thousand seed weight (g) and fruit yield (kg ha^{-1}) were obtained from the whole plot after separated side rows.

Isolation of essential oil

The fruits (40 g) of coriander that grounded in a blender separately were subjected to hydro-distillation using Clevenger-type glass apparatus for 3 hours for isolation of oils in each plot. The results are presented in ml 100 g^{-1}. The oils were stored in glass vials and kept -18ºC at the deep frozen until GC-MS analyses.

GC–MS analysis

Qualification and quantification were carried out by using a Finnigan-Trace GC–MS equipped with an auto sampler. One microlitre of sample volume was injected using split method with 50 split ratio. Chromatographic separations were accomplished with a Zebron ZB-5 capillary column (5% phenyl–95% dimethylpolysiloxane, 0.25 mm i.d.×60 m, film thickness 0.25 m). Analysis was carried out using helium as the carrier gas, flow rate 1.0 mL/min. The column temperature was programmed from 40 to 260ºC at 3ºC /min. The injection port temperature was 200ºC. The ionization voltage applied was 70eV, mass range *m*/*z* 41–400 a.m.u. The separated components were identified tentatively by matching with GC–MS results of National Institute of Standards and Technology (NIST) 05 and Wiley mass spectral library data. The

quantitative determination was carried out based on peak area integration.

Statistical Analysis

The data were analyzed by the computer MSTAT-C package program. Results of experiments were also analyzed according to the Randomized Complete Block Design. Two years' were analyzed using split-plot design: main plot was the year, sub-plot was the cultivar. Significant differences among the mean values are given separately for each year of the trial.

RESULTS AND DISCUSSION

Data of agronomical and quality (essential oil content and composition) properties in the research were subject to variance analysis and the results were summarized in Table 3.

Table 3. Statistical analysis (mean of squar) for investigated characters

Source of Variance	Plant Height		Number of Umbrella per plant		Number of fruit per Umbrella		Thousand seed weight		Fruit yield		Essential oil content		Linalool Content	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Cultivar	501**	538**	1134**	47.7*	31.49*	30.00	32.18**	23.46**	2932130**	148553	0.094**	0.020*	3.71	8.38
Error	53.1	1158	8.6	11.1	9.39	13.37	0.52	0.25	483674	128187	0.012	0.007	7.33	28.14
C.V. (%)	6.0	7.8	18.2	25.0	8.95	18.31	8.76	4.37	22.47	15.82	21.6	30.6	3.06	6.18
Combined Years														
Year	1149.4		90.58		2443.88**		131.63**		8305440.05**		0.758**		83.74	
Error1	212.3		24.0		8.673		0.95		139574.8		0.016		21.26	
Cultivar	189.9**		158.9**		44.71**		54.64**		2124054.2**		0.074**		9.66	
Year x Cultivar	418.9**		23.2		16.85		1.00**		956679.96*		0.040**		2.43	
Error 2	65.1		9.8		11.38		0.38		305925.26		0.009		17.73	
C.V.(%)	6.9		21.3		12.45		6.29		20.65		25.01		4.83	

DF: Degrees of freedom, C.V.: Coefficient of variation
* indicates the significance at 0.05 probability level
** indicates the significance at 0.01 probability level

Plant Height

The effect of cultivar and years on plant height are significant statistically ($p<0.001$) with year x cultivar interaction. The highest values of plant height were obtained from Kudret-K, Gamze and Erbaa cultivars in the first year, and also combined years values (Table 4). According to the mean of years, the highest plant height value was obtained from Kudret-K with 121.9 cm while the lowest value was in Arslan with 109.2 cm in the research. Plant height varies according to the grown region's ecology and plant genotypes. Plant height values were similar to the findings of some researchers (Mert and Kirici, 1998; Kirici, 1999; Kizil and Ipek, 2004) which indicate that plant height varies between 65.5 cm and 119.4 cm.

Table 4. The means of some morphological characters and thousand seed weight, fruit yield, essential oil and linalool contents obtained from Coriander cultivars in the trial years.

	2009	2010	Com.Years*	2009	2010	Com.years	2009	2010	Com.years
Cultivars	**Plant Height (cm)**			**Number of Umbrella per Plant**			**Number of Fruit per Umbrella**		
Arslan	102.7de	115.8 bc	109.2 b	7.90 c	9.67 b	8.78 c	29.68 c	15.30	22.49 b
Erbaa	127.5 a	112.6 cde	120.1 a	20.38 ab	17.60 a	18.99 a	34.52 ab	21.72	28.13 a
Gamze	129.7 a	111.2 cde	120.4 a	15.97 b	15.30 a	15.64 b	33.85 abc	19.60	26.73 a
Gürbüz	113.2 cde	115.5 bc	114.3 ab	11.07 c	8.75 b	9.91 c	33.42 bc	22.77	28.10 a
Kudret-K	129.7 a	114.1 cd	121.9 a	17.82 b	13.65 ab	15.74 b	38.15 a	18.70	28.42 a
Pel mus	127.1 ab	101.8 e	114.5 ab	23.45 a	15.13 a	19.29 a	35.80 ab	21.70	28.75 a
LSD (5%)	11.6 (int.), 8.24 (com.year)			4.42 (1.y. cul.)	5.03 (2.y.cul.)	3.21 (com.y.)	4.61(1.y. cul.)	ns	3.44(com.y.)
	Thousand Seed Weight (g)			**Fruit Yield (kg ha^{-1})**			**Essential Oil Content (%)**		
Arslan	13.66 b	16.13 a	14.89 a	4696.2 a A	2526.2 BCDE	3611 a	0.25 c D	0.21 b D	0.23 c
Erbaa	6.70 g	10.05 de	8.37 c	2924.4 b BCD	2313.2 CDE	2685 bc	0.59 ab AB	0.40 a C	0.49 a
Gamze	7.60 f	11.50 c	9.55 b	2465.7bBCDE	2170.0 DE	2756 b	0.59 ab AB	0.21 b D	0.40 ab
Gürbüz	7.89 f	11.75 c	9.82 b	3198.1 b B	2314.7 CDE	2756 b	0.44 b C	0.24 b D	0.34 b
Kudret-K	5.41 h	9.13 e	7.36 d	2285.0 b CDE	1945.7 E	2115 c	0.69 a A	0.26 b D	0.47 a
Pel mus	8.09 de	10.50 d	9.29 b	2998.7 b BC	2306.5 CDE	2652 bc	0.53 ab BC	0.26 b D	0.40 ab
LSD (5%)	0.89 (intr.)		0.62 (com.year)	1048(1.y. cul.)	ns	564.8 (com.year)	0.16(1.y. cul.)	0.13(2.y. cul.)	0.097 (com. year)
				798.7 (intr. Capital letter)			0.14 (intr. Capital letter)		

*Means followed by the same letter are not significantly different from each at 5% probability level ($p< 0.05$). ns: non significant

Number of Umbrella Per Plant

Number of umbrella per plant varied between 7.90 and 15.13 in 2009, the variation was significant statistically. The highest number of umbrella per plant (23.45) was obtained from the Pel-Mus cultivar in first year of experiment (2009). Similar to first year, there are significant statistically variation in 2010, but the highest value was obtained in Erbaa cultivar (Table 4). Rainfall of the first year was higher than that of second year (Table 2), for this reasons number of umbrellas per plant were different between the first and second years. The cultivars were statistically significant in the first and second years and combined years, but, it was not significantly different in the year x cultivar interaction (Table 3). The results for the number of umbrella per plant was an important character for seed and essential oil yield, and have been agreed with results of Kirici et al. (1997) (13.5- 16.8), Mert and Kirici (1998) (11.5- 17.7) and Kizil (2002) (11.3- 16.7).

Number of Fruit Per Umbrella

In the 2009 growing season, the highest number of fruit per umbrella (38.15) was obtained from the Kudret-K cultivar; however, results of other cultivars were similar except Arslan cultivar (Table 4). In the 2010 growing season, the highest one was recorded as 22.77 in Gürbüz cultivar. Amount of rainfall in the first year was higher than second year (Table 2), for this reasons number of fruit per umbrella was different between the first and second years. The cultivars were statistically significant in the first year and combined years, but, it was not significantly different in the second year and year x cultivar interaction (Table 3). The number of fruit per umbrella is an important yield component as much as the number of umbrella per plant. In terms of number of fruit per umbrella, Kirici et al. (1997), Mert and Kirici (1998) and Kizil (2002) reported similar results (23.5-37.1).

Thousand fruit weight

During the research, the highest thousand fruit weight was obtained from Arslan cv. as 13.66 g and 16.13 g, in 2009 and 2010 respectively (Table 4). The lowest values were detected at Kudret –K cv. as 5.41 g in the first year and 9.13 g in the second year. In general, the highest values were obtained from the second year, because of the great number of fruits per umbrella in the first year, the assimilate available for fruit filling was limited reducing fruit size (Arganosa et al., 1998). Effects of cultivars on thousand fruit weight in both years and combined year and year x cultivar interaction were found statistically significant (Table 3). The thousand fruit weight of coriander was within the range (8.52 – 11.05 g and 12.51 – 13.90 g) reported by Mert and Kirici (1998) and Kizil and İpek (2004) for Turkish coriander, the range for Canadian small-fruit cultivars (7.1- 7.3 g) and large-fruit cultivars (9.2- 9.9 g) reported by Arganosa et al. (1998). Kizil (2002) reported that thousand fruit weights of five coriander lines varied between 12.5 g and 13.6 g. According to the results, thousand fruit weight of coriander was affected by ecological conditions, fruit sizes and varieties.

Fruit Yield

The highest fruit yields both experimental years were obtained from Arslan cv. as 4696.2 kg ha^{-1} and 2526.2 kg ha^{-1}, respectively (Table 4). The lowest values were detected at Kudret-K as 2285.0 kg ha^{-1} in the first year and 1945.7 kg ha^{-1} in the second year. Effects of cultivar in both years, in the combined years, cultivar and year x cultivar interaction on dry leaf yield were found statistically significant (Table 3). The highest yield values were obtained from first year in the all coriander cultivars. Therefore, the climatic differences between years could also explain the responses of all coriander cultivars were obtained high fruit yield to the conditions that prevailed during the 2009 growing season. Kirici et al. (1997) and Mert and Kirici (1998) found that fruit yields of coriander varied 965 – 1780 kg ha^{-1} in the similar ecological conditions. Kizil and Ipek (2004) reported that fruits yield changed between 1568 – 2145 kg ha^{-1} and 1282 – 1486 kg ha^{-1}, respectively. Arganosa et al. (1998) reported that yield varied according to large (1915- 2061 kg ha^{-1}) and small sizes (1602- 1715 kg ha^{-1}) seed coriander. In terms of fruit yields our results are higher than the finding of the above-mentioned researches. The reason for this, plantations which have done during the winter, longer duration of vegetation and growing regions have played an important role in these differences.

Essential Oil Content

The content of essential oils of coriander fruits from different varieties were varied from 0.21- 0.69 % in both years (Table 4). In the experiment years, the highest values were obtained from Kudret-K (0.69 %) and Erbaa and Gamze (0.59 %) and the lowest values were obtained from Aslan (0.25 %) cv. According to the two-year averages the highest essential oil was obtained in Kudret-K variety (0.47 %) while the lowest essential oil content was obtained in Arslan cv. (0.23 %). Shahwar et al. (2012) reported that content of essential oil of coriander fruits varies from 0.03–2.6 %. According to pharmacopoeia; coriander fruits contained essential oil less than 0.5 % (Wagner et al., 1984). Some researchers reported that essential oil varied between 0.22 – 1.1 % (Mert and Kirici, 1998). The seed of Tunisian coriander had the highest essential oil yield with 0.68 % (Sriti et al., 2009). These essential oils variations can be attributed to some factors like climatic conditions, species and growing conditions (Shahwar et al., 2012).

Essential Oil Components

The essential oils from fruits of coriander cultivars analyzed by GC-MS, 22 compounds were identified. Both two years and all varieties as main component was linalool content ranged between 84.60 and 90.10 %. During two years, the highest mean values of linalool content (90.10 % and 87.80 %) were obtained from Gürbüz cultivar (Table 5). The lowest ones were obtained from Pel-Mus cv. (87.36 %) at the first year and Arslan cv. (84.60 %) at the second year. In regard to mean values of year content of linalool was over 86 %. In both years, all cultivars had similar contents of linalool, because there were no significant difference among mean values of cultivar and year and year x cultivar interaction. The other major components were γ-terpinene 1.37- 2.94 %, camphor 1.59- 2.97 %, nerol acetate 0.51- 2.87 % nerol 0.60- 1.98 % and α-pinene 0.85- 1.84 %. Composition of coriander seed essential oil was found to be varied at different researches. Shahwar et al. (2012) studied the chemical composition of coriander, and they found that the major volatile compounds in coriander seed were linalool (55.59 %), γ-terpinene (7.47 %), α-pinene (7.14 %), camphor (5.59 %), decanal (4.69 %), geranyl acetate (4.24 %), limonene (3.10 %), geraniol (2.23 %), camphene (1.78 %), and D-limonene (1.36 %). Leung and Foster (2003) reported that coriander fruits contain 0.2-2.6 % (usually 0.4- 1.0 %) volatile oil, the major component of the oil is d-linalool, which is present in 55-74 %, depending on the ripeness of the fruits, geographical locations and other factors. Similarly,

Msaada et al. (2007) reported that the mature fruits essential oil was composed mainly of linalool (87.54 %). Bhuiyan et al. (2009), for fruits of coriander plants which collected from Bangladesh for a period of two years, have reported that essential oil was 0.42 % and the main components were linalool (37.65 %), geranyl acetate (17.57 %) and γ-terpinene (14.42 %). Gil et al. (2002) reported that oil composition was sensitive to the year variation in weather conditions as well as in soil environment. However, in our results; linalool content of coriander cultivars both years were stable.

Table 5. The means of essential oil components (%) obtained from fruits of coriander cultivars in the trial years*.

	Arslan		**Erbaa**		**Gamze**		**Gürbüz**		**Kudret-K**		**Pel-Mus**	
Components	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
α-pinene	1.24	0.85	1.84	1.38	1.10	1.73	0.99	1.12	1.01	1.57	1.17	1.17
camphene	-	0.12	0.18	0.10	0.16	0.19	0.09	0.07	0.04	0.16	1.16	0.13
sabinene	-	0.13	0.14	0.09	0.06	0.13	0.07	0.06	0.02	0.10	0.17	0.10
β-pinene	-	0.06	-	0.04	-	0.13	-	0.08	-	0.13	-	0.11
β-myrcene	-	0.34	0.49	0.41	0.36	0.41	0.30	0.27	0.32	0.32	0.38	0.56
cymol	1.04	0.59	0.67	0.57	0.50	0.75	0.58	0.68	0.32	0.66	0.78	0.77
limonene	0.23	0.56	0.41	0.55	0.35	0.76	0.29	0.62	0.35	0.66	0.42	0.70
Cis-ocimene	-	-	-	0.07	-	0.06	-	0.13	-	0.03	-	0.12
γ-terpinene	2.86	3.53	2.69	2.47	2.44	2.94	2.11	2.30	1.37	2.19	2.65	2.39
α-terpinolene	-	0.04	-	0.06	-	0.13	-	0.08	-	0.11	-	0.13
linalool	**88.18**	**84.60**	**88.05**	**85.17**	**89.13**	**85.46**	**90.10**	**87.80**	**88.25**	**87.59**	**87.36**	**84.67**
cis-sabinene hydrate	-	0.03	-	0.11	-	0.02	-	0.09	-	0.06	-	0.11
camphor	2.02	2.35	1.59	2.80	1.89	2.61	1.78	2.14	2.97	2.68	2.10	2.79
1-borneol	-	0.03	-	0.06	-	0.10	-	0.07	-	-	-	0.06
4-terpineol	-	0.05	0.3	0.21	-	0.10	0.10	0.13	0.09	0.10	0.14	0.17
p-menth-1-en-8-ol	-	0.07	0.09	0.18	-	0.17	0.14	0.18	0.32	0.21	0.33	0.27
n-decanal	-	0.02	-	0.15	-	0.08	-	0.03	-	0.11	-	0.15
nerol	1.52	1.56	1.11	1.85	0.60	1.29	1.13	1.35	1.52	1.06	1.40	1.98
thymol	0.47	1.80	-	0.15	1.97	0.03		-	-	-	-	-
nerol acetate	0.51	1.34	2.29	1.91	1.04	1.80	2.09	1.32	2.87	1.36	1.71	1.76
caryophyllene	-	0.20	-	-	0.29	-	-	-	-	-	-	-
2-dodecenal	-	0.03	0.14	0.34	0.04	0.23	0.09	0.10	0.28	0.15	0.41	0.32
total	**98.07**	**98.30**	**99.72**	**98.64**	**99.93**	**99.12**	**99.86**	**98.62**	**99.73**	**99.25**	**99.97**	**97.31**

*Values are mean of four replications

In our research, it was observed that the amount of linalool was 84-90%, which is higher than those of the previous studies as mentioned above. This might be due to the environmental conditions, locations and cultivars. Msaada et al. (2009) reported that linalool increase was concomitant with daily temperature. In the coriander essential oil must be contained linalool over 50-70% (Wagner et al., 1984). Indeed, linalool has a potential use as antisposmadic, immunostimulatory and antinociceptive, and is also used in the perfumery and liquor industries. For this reason, it suggests the exploitation of coriander seed as a low-cost renewable source of bioactive compounds for industrial processing in the fields of cosmetics, perfumes and nutraceuticals (Sriti et al., 2009).

CONCLUSION

In this study, Turkish coriander varieties were evaluated in climatic conditions of Eastern Mediterranean Region. As a results of studies, the maximum fruit yield was observed from Arslan cv. while oil content in Erbaa and Kudret-K varieties. All varieties in the studies have high linalool contents over 85% and the component had similar variation according to varieties and years. Because Aslan variety has high fruit yields, the variety is recommended for grower's commercial productions.

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