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Biomass Yield and Herb Essential Oil Characters at different Harvest Stages of Spring and Autumn Sown *Coriandrum sativum*

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Summary

Coriander green herb is popular in Eastern Turkey. Fresh herbage yield, essential oil content and essential oil composition in the vegetative parts of small-fruit coriander (*Coriandrum sativum* L. var. *microcarpum* DC.**)** grown in two different seasons (spring after autumn sowing and summer after spring sowing) and harvested at different growth stages were examined. The experimental location was at Tokat, north Anatolia, Turkey. The oil composition was identified by GC-MS. Fresh herbage yield regularly increased from the rosette stage to full flowering in both growing seasons. In the summer season (spring sowing) dry matter yield was lower as a result of a shorter vegetative period compared to the spring season (autumn sowing). Essential oil content was low in early growing periods and increased regularly in subsequent periods. (*E*)-2-decenal and decanal of aliphatic aldehydes are main components of the herb oil. (*E*)-2-decenal had higher percentages at pre-flowering stage and full flowering stage compared to the early growing stages. Considering the growing season, plants growing in the summer season had striking differences for some components such as (*E*)-2-decenal and methyl eugenol. Because of low herbage yield and high (*E*)-decenal contents, a potential irritant, spring periods is more suitable for cultivating coriander as fresh or dried herbal usage at the experimental site.

Key words. Coriander – Coriandrum sativum – sowing date – essential oil – ontogeny – aliphatic aldehydes – (*E*)-2-decenal

Introduction

Coriander (*Coriandrum sativum* L.) belongs to the parsley family (*Apiaceae* or *Umbelliferae*), and is an annual herb commonly grown in the Mediterranean region and the Near East. It has been used and cultivated since antiquity (Manniche 1989; Small 1997). The plant is grown widely all over the world for seed, as a spice or essential oil production (Diederichsen 1996). The green leaves of the immature plant are a popular culinary herb. It is used widely as fresh herb in poultry and seafood dishes and local ethnic foods of some countries (Smallfield et al. 1994). The coriander leaf and herbage is often called as Chinese parsley or cilantro. It is known as "asotu" in the Eastern Anatolian region of Turkey.

The essential oil of the herb has a different chemical composition and aroma than the essential oil of the seed. Previous research demonstrated that the composition of matured coriander seed oil is primarily made up of linalool (42–71%) (Diederichsen 1996; Telci et al. 2006a). Aldehydes dominate in the coriander leaf oil. Potter and Fagerson (1990) reported that coriander herb oil was composed mainly of (*E*)-2-decenal with 46.6 % and (*E*)-dodecanal, decanal, (*E*)-2-undecanal and (*E*)-2-tetradecanal being other main components. Eyres et al. (2005) stated coriander herb oil was composed mainly of aliphatic alcohols and (*E*)-2-decen-1-ol was the most abundant compound.

The considerable variation in the chemical composition of coriander herb oil was based on differences in genetic structure of plants, environment, growth conditions and harvest stage (ontogeny). Potter (1996) reported substantial variation in leaf oil composition between two coriander samples at the blooming stage. One of them was enriched in higher (*E*)-2-decenal (12.1 %) and 2-decen-1-ol (8.18 %), whereas the other had higher concentration of (*E*)-2-dodecenal (21.6 %), (*E*)-2-tetradecenal (20.2 %) and dodecanal (10.3 %). These researchers also reported that changes occur in the chemical composition of the herb oil as the plant matures (Lawrence 1986; Potter 1996).

Climatic conditions during vegetative periods and ontogeny have major effect on essential oil accumulation and composition in aromatic plants (Sangwan et al. 2001; Gil et al. 2002). Our previous research was based on fruit yield and seed essential oil composition of coriander as affected by different agronomical practices (Kaya et al. 2000; Telci et al. 2006a, b). Growing seasons having different rainfall, temperature and light intensity from early spring periods to late autumn influence crop yield and quality in medicinal plants. At many locations, coriander for green herbage production can be autumn sown or

spring sown, for harvest of vegetative material during spring or summer, respectively. In the present research, we investigated yield and essential oil composition in coriander herb grown in two different seasons (autumn sowing and spring sowing) and harvested at different growing stages. There are no previous reports on composition of coriander herb oil from Turkey, where we conducted our experiment. We examined coriander fresh herbage yield, essential oil content and composition at different ontogenetic stages.

Material and Methods

Plant material

The small-fruited type of coriander, *Coriandrum sativu* L. var. *microcarpum* DC. obtained from local growers of eastern of Turkey was used in this study, because it has a larger herbage yield than the large-fruited type, *C. sativum* var. *vulgare* Alef. (synonym: *C. sativum* var. *macrocarpum* DC.), and is suitable for autumn sowing and spring sowing in many reagions such as Russia, Central Europe, the Near East (Husain et al. 1988; Small 1997) and Eastern Turkey (Telci et al. 2006a).

The experiment was carried out in Tokat (36 ° 43 ' E; 40 ° 19 ' N, 650 m above sea level) located in Central Black Sea region of north Anatolia, about 400 km east of Ankara, in Turkey.

Experiments were conducted in two different growing seasons, sown in autumn with growth in the subsequent spring season (November–June) and sown in late spring with growth in the summer season (May–July). While the autumn-sowing experiment was performed during two years (2003–2004), the spring sowing experiment was carried out only in 2004. Autumn sowing was conducted in 2002 and 2003 (8th of November and 11th of November, respectively) for assessments during the following spring growing season. Spring sowing, for assessments during the summer season, was conducted on the 18th of May, 2004. The soil of the experimental area was clay-loam soil with pH 7.80, organic carbon 1.70 %, available P (P_2O_5) 11.6 kg ha^{-1}, and available K (K_2O) 280 kg ha^{-1} in Tokat.

The experiment was laid out in "randomized block design" with three replications. Seeds were sown at 30 cm row distance in the plots, consisting of 5 rows, each row 4 m long (1.5 m x 4 m = 6 m^2). The distance of the seeds within a row was 15 cm. Whole plants were harvested at different stages of growth, from the rosette stage to full bloom. Because plants sown in autumn have a longer vegetative period, they were harvested at six different stages from the rosette stage to full bloom. Plants sown in late spring for summer growing periods had shorter vegetative periods. So, the plants were only harvested at four different times. After harvested, the plants were dried in a drying oven arrayed 35 °C until constant weigh.

Fresh herbage yield was measured for each plot and is reported as t h^{-1}. Essential oil content was measured plant material dried in the 35 °C and reported as "ml 100 g^{-1}" (%).

The extraction process was determined by Schilcher apparatus (Schilcher 1964) which is similar to the Clevenger apparatus and has two cooler. Samples of 20 g of the dried herb were watered with 200 ml distillate water (1:10 w/v). Distillation was continued for approximately 2 h. The essential oils were stored in dark glass bottles at 4 °C until analysis.

Gas chromatography and mass spectrometry analysis

Oil components were analysed by 6890 Agilant gas chromatography equipped with HP-Innowax fused silica capillary column (30 m x 0.25 mm, film thickness 0.25 μm). Oven temperature was held at 50 °C for 5 min and then increased from 50 to 220 °C at a rate of 8 °C min^{-1}. Injector and detector (FID) temperature were 250°C and 250°C respectively. Helium was used as the carrier gas at a flow rate of 1.3 ml min^{-1}. Diluted samples (1/100 in chloroform, v/v) of 2.0 μl were injected in the split/splitless (5:1 split) mode. Quantitative data were obtained electronically from FID area percent data.

The GC–MS unit consisted of a Hewlett-Packard 5973 mass selective detector operating in the electron impact mode (70 eV) coupled to a Hewlett-Packard 6890 gas chromatograph. A HP-5MS capillary column (30 m, 0.25 mm i.d., film thickness 0.25 μm) was used. The oven temperature was programmed at 70–250 °C at 3 °C min^{-1}. The injector temperature was 250 °C. MS transfer line and quadrupol temperatures were set at 280 and 150 °C, respectively. The sample was injected using the split mode (split ratio 1:60). The injection volume was 1 μl. The carrier gas was adjusted to a constant flow of 1 ml min^{-1}.

Identification of oil components was achieved based on their retention indices (determined by reference to a homolog series of normal alkenes), and by comparison of their mass spectral fermentation patterns (Willey and Nist database/ChemStation data system).

Statistical analysis

Numerical data for fresh herbage yield and essential oil contents were subject to analysis of variance (ANOVA) using randomized block design. The significance of differences among harvesting time of field experiments was determined using Least Significant Degree (LSD) (Gomez and Gomez 1984). All statistical analysis were classified using SPSS software (ver. 11.5).

Result and Discussion

Fresh herbage yield

Monthly rainfall and temperature during the growing seasons are shown in Fig. 1. Rainfall and temperatures of the two seasons varied considerably. Because temperature was limiting factor for plants sowed in winter, the plants started rapidly growing after March and had a long-growing period. Plants were harvested regularly in seven-day-intervals from rosette periods to full flowering stage resulting in six different harvesting dates. Fresh herbage yield increased regularly until flowering stage as a result of accumulation of photosynthesis products. Maximum yields were obtained from plants harvested at the flowering stage (6. harvest date) with 23.3 and 24.8 t h^{-1} in 2003 and 2004, respectively. The yields of the last harvesting time were significantly superior to that of other periods.

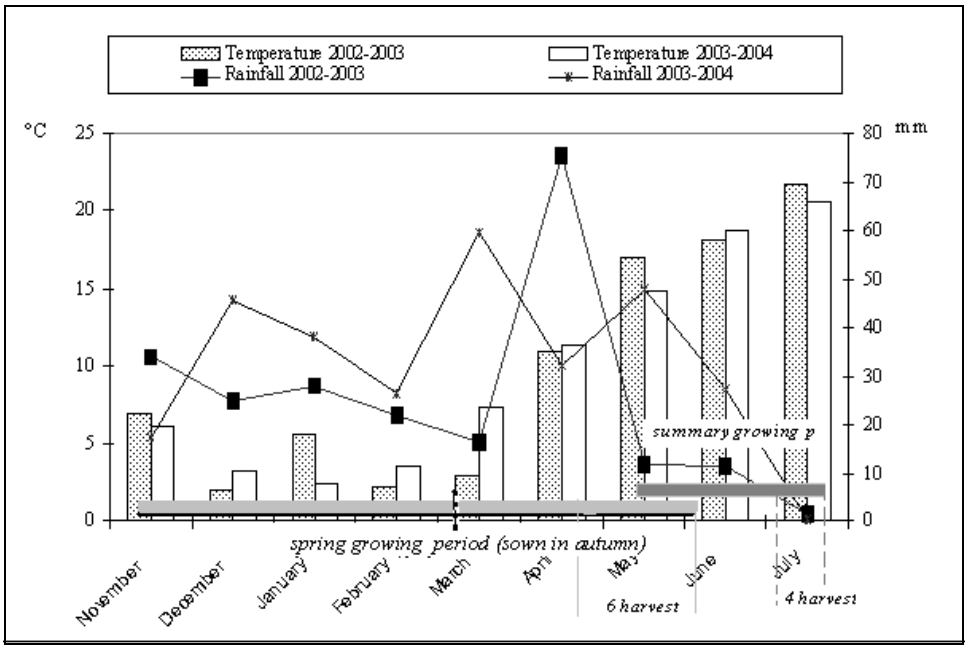

Fig. 1. Monthly rainfall and temperature of growing periods.

In the summer experiment, plants were grown between May and July of 2004. There were lower precipitation and higher temperatures with higher light intensity than during spring growing period of the same year, 2004 (Fig. 1). Plants sown in May were irrigated because of inadequate moisture. Seeds germinated 13 days after sowing. As a result of high temperature and light absorption, the plants had an accelerated ontogenesis resulting in early flowering. They were harvested in four different periods from rosette stage to full flowering. Because of short vegetation periods, fresh yields of plants were lower than that of spring experiments and large yield differences occurred between seasons (Table 1). While fresh herbage yields increased from 1.8 to 24.8 t h^{-1} in the spring season of 2004 after autumn sowing, they increased from 0.4 to 7.2 t h^{-1} in the summer of the same year after spring sowing.

Essential oil contents

The differences in essential oil yield sowed a similar pattern for autumn and spring sowed coriander. Essential oil content was low in early growing periods and increased regularly at subsequent stages. Maximum essential oil contents were found at full flowering periods with 0.50 and 0.45% in plants of spring season in 2003 and 2004, respectively and 0.55% in plants of summer season in 2004. Literature pointed out that essential oil accumulation depended on developmental phase of the plants (SANGWAN et al. 2001). Interactions between ontogeny and oil accumulation were reported in many aromatic plants. Our data confirm to other reports about maximum essential oil contents at the full flowering stage in many aromatic plants, e.g. mint (MAROTTI et al. 1993).

Essential oil composition

The result revealed that aliphatic aldehydes constituted the major quantity of essential oil in the plants. (*E*)-2-decenal and decanal are main components of herb oil in coriander (Table 2). (*E*)-2-decenal varied between 17.13 and 35.36 % in autumn-sown plants (spring period) and between 10.59 and 50.80 % in summer-season-plants. Decanal was another major components detected in the

Table 1. Variation of fresh herb yield and herb essential oil content of coriander.

Harvesting date	Fresh herbage yield (t ha^{-1})			Essential oil contents (ml $100g^{-1}$)		
	2003 winter	2004 winter	2004 summer	2003 winter	2004 winter	2004 summer
1	1.2 e	1.8 e	0.4 c	0.15 d	0.20 c	0.13 b
2	4.4 d	5.2 de	1.8 bc	0.15 d	0.18 c	0.18 b
3	8.7 cd	9.1 cd	3.3 b	0.18 cd	0.20 c	0.43 a
4	10.0 c	11.6 c	7.2 a	0.20 c	0.23 bc	0.55 a
5	18.3 b	18.6 b	–	0.30 b	0.29 b	–
6	23.3 a	24.8 a	–	0.50 a	0.45 a	–
LSD	4.3 **	4.8 **	1.6 *	0.04 **	0.08 *	0.12 **

*: P>0.05, **: P>0.01

Table 2. Variation of essential oil composition in coriander herb grown during two different seasons (spring after autumns sowing and summer after spring sowing) (% of all components).

No	Components	Spring			Summer		
		Range	Mean	SD	Range	Mean	SD
	Alkan and Alkens						
1	Nonane	0.27 – 3.63	2.42	1.90	0.00 – 0.74	0.32	0.07
2	Undecene				0.00 – 6.35	4.33	1.92
3	1-pentadecene	0.00 – 0.76	0.63	0.31			
4	1-hexadecene	0.00 – 0.49	0.39	0.21			
5	1-heptadecene	0.39 – 0.41	0.40	0.20			
6	1-hexadecene	0.00 – 0.24	0.16	0.12			
	Aliphatic alcohols						
7	Nonanol (1-nonanol)	0.00 – 0.60	0.47	0.21	0.49 – 0.96	0.72	0.23
8	Decanol	4.78 – 7.87	5.82	1.26			
9	1-undecanol	1.23 – 4.64	2.20	1.26	0.58 – 2.76	1.33	1.01
10	2-tridecen-1-ol						
	Aliphatic aldehydes						
11	Heptanal	0.00 – 0.19	0.15	0.07			
12	Octanal	0.00 – 2.11	1.42	0.68	0.57 – 1.53	0.95	0.41
13	Nonanal	0.88 – 1.74	1.31	0.30	0.44 – 0.97	0.72	0.26
14	Decanal	19.00 – 22.88	20.69	1.37	9.67 – 17.52	13.82	3.21
15	Undecanal	2.15 – 6.00	4.13	1.58	1.41 – 3.14	2.26	0.97
16	Undecenal	4.61 – 6.71	5.63	0.83	3.04 – 5.13	4.15	0.98
17	Dodecanal	2.23 – 7.81	4.16	2.07	0.72 – 1.75	1.29	0.52
18	Tetradecenal	0.00 – 0.83	0.37	0.26	–		
19	Tetradecanal	0.82 – 2.51	1.58	0.60	0.63 – 1.41	1.07	0.40
20	2-undecenal	0.00 – 0.42	0.32	0.17			
21	(*E*)-2-decenal	17.13 – 35.36	25.36	7.32	10.59 – 50.80	28.78	17.62
22	2-dodecen 1-al	7.26 – 10.15	8.50	1.71	6.30 – 9.28	8.08	1.36
23	3-dodecen-1-al	2.54 – 8.23	4.51	2.34	3.57 – 5.68	4.45	0.97
	Others						
24	2-oxo-N-pentadecanlactam	0.00 – 1.18	1.01	0.48			
25	Elaidinic acid				0.00 – 1.07	0.80	0.53
26	α-pinene	0.00 – 0.31	0.25	0.12			
27	Trans, trans-2,4-decadienal	0.00 – 0.25	0.20	0.10			
28	Linalool	0.65 – 0.69	0.67	0.02	1.54 – 1.93	1.74	0.19
29	9-Octadecenoic acid (Z)	–					
30	Methyl-eugenol	–			2.39 – 18.11	10.57	7.88
31	α-bergomotene	–			6.10 – 8.92	7.51	1.99
32	Decanoic acid	2.33 – 5.07	3.21	1.00	2.02 – 11.56	6.79	6.74
33	Cis-α-bisabolene	–			0.00 – 0.59	0.44	0.29
34	Trans-β-farmasene	–			0.00 – 0.83	0.62	0.41
35	β-ionone	0.00 – 0.46	0.30	0.26			
36	9-octadeconoic acid (Z)	0.00 – 1.29	0.86	0.74			
37	α-amorphane	–			2.00 – 2.72	2.18	0.36
38	Undecanoic acid	0.24 – 0.45	0.36	0.10	0.00 – 0.84	1.38	0.92
39	Dodecanoic acid	–			0.00 – 1.43	1.07	0.71
40	Bicyclo [4,4,0] dec-1-en	0.00 – 1.17	0.79	0.17	0.00 – 3.15	2.28	1.52
41	Cadinol ?				0.00 – 2.04	1.51	1.00
42	Cyclodecane	0.00 – 0.25	0.20	0.01			
43	Methyl dihydromalvate	0.00 – 0.27	0.20	0.03			
44	5-eicosene	0.00 – 0.13	0.08	0.06			

Table 2. Continue

No	Components	Spring			Summer		
		Range	Mean	SD	Range	Mean	SD
45	Koiganal	0.00 – 0.59	1.48	0.26	0.49 – 0.97	0.71	0.24
46	3-eicosene	0.00 – 0.12	0.09	0.04			
47	Neophytadiene	0.12 – 1.66	0.74	0.61	0.00 – 0.58	0.43	0.25
48	Hexadecanoic acid	0.00 – 0.50	0.34	0.20			
49	1-eicosene	0.00 – 0.12	0.10	0.04			
50	9-octadecanoic acid	0.22 – 0.74	0.40	0.29			
51	Phytol	0.54 – 1.62	1.01	0.46	0.74 – 0.92	0.82	0.05
52	9-octadecenal	0.00 – 1.06	0.70	0.54			
53	9-octadeconoic acid	0.00 – 3.73	2.48	0.92			

coriander herb oil. It was between 19.00 and 22.88 % in autumn sown plants, between 9.67 and 17.52 % in summer-season-plants. 2-dodecen-1-al, 3-dodecen-1-al, dodecanal, undecenal and undecanal were also identified as major components in coriander herb oil.

There are considerable differences in essential oil composition of coriander herb oil reported in previous studies (SMALLFIELD et al. 1994). POTTER (1996) explained that coriander herb oil consisted mainly of aldehydes with 50 % 2-alkenals. The 2-alkenals found were (*E*)-2-decenal (12.1%), (*E*)-2-dodecenal (15.6–21.6 %) and (*E*)-2-tetradecenal (12.7–20.2 %). The research also explained that decanal (9.25–9.45 %) and dodecanal (4.96–10.3 %) are other major components in the coriander herb. POTTER and FAGERSON (1990) also reported that major components of coriander herb oil were (*E*)-2-decenal (46 %), (*E*)-2-dodecanal (10 %), 2-decen-1-ol (9 %). Although there are quantitative differences between components, our qualitative results are similar to those of POTTER and FAGERSON (1990), SMALLFIELD et al. (1994) and POTTER (1996), all stating that aldehydes sucah as (*E*)-2-decenal, decanal, dodecanal, undecanal are major components. However, the chemical composition of coriander herb oil reported by EYRES et al. (2005) differs considerably from our records. EYRES et al. (2005) reported that (*E*)-2-decen-1-ol was the most abundant components with 26 %. In our research, 2-dodecen-1-al and 3-dodecen-1-al were identified and was 7.26–10.15 % and 2.54–8.23 % in plants of spring periods, 6.30–9.28 % and 3.57–5.68 % in plants of summary period, respectively (Table 2). The variations are based on differences in genotype, climate, agronomical procedure, ontogeny and post harvest treatments (SMALLFIELD et al. 1994; POTTER 1996; EYRES et al. 2005).

Ontogenetic variability:

There were qualitatively and quantitative variations of most essential oil components depending on the growing season. While 42 components were identified in plants of spring season, 29 components were identified in plants of summer seasons (Table 2). The main component (*E*)-2-decenal had a high plasticity depending on harvest stages and seasons, whereas the other major component, decanal, showed less variation. POTTER (1996) reported that (*E*)-2-decanal content increased from the vegetative to bud formation stage, while decanal contents decreased. LAWRENCE (1986) also examined essential oil variation of coriander plants from blooming stage to full fruit maturity stage. He stated that (*E*)-2-decenal first increased and then decreased, whereas decanal exhibited a steady decrease.

The differences observed in the essential oil composition were related to both ontogeny and environmental differences Because the main component, (*E*)-2-decenal, is a potential irritant and had higher percentages in pre-flowering (3. harvesting stage of plants in summary period and 4–5 harvesting stage of plants in spring periods) and full flowering (4. harvest in summary period and 6. harvest in spring periods), it is better to harvest prior to flowering periods for herbal consume in spite of lower herbage yields. Regarding the seasons, plants had striking differences in some components such as (*E*)-2-decenal, methyl eugenol, etc. (Table 1 and Fig. 1). The variation may be based on higher temperature and light intensity in the summer season. It is known that environmental conditions such as photoperiods, temperature and light intensity have major effect in accumulation and composition of essential oil (SANGWAN et al. 2001).

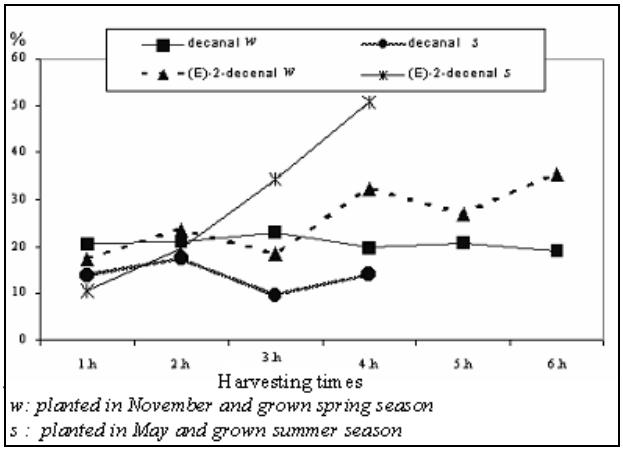

Fig. 2. Variation of decanal and (*E*)-2-decenal (% of all essential oil) in coriander herb harvested at different growth stages after autumn sowing and spring sowing.

In conclusion, the spring period (autumn sowing) was more suitable to cultivate coriander for fresh or dried herbal usage at the experimental location, because the shorter growing period in summer after spring sowing caused low herbage yield and the plants had high contents of (*E*)-decenal, which is a potential irritant.

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