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EFFECTS OF DIFFERENT WATER APPLICATIONS ON YIELD AND OIL CONTENTS OF AUTUMN SOWN CORIANDER (*Coriandrum sativum* L.)

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ABSTRACT

A two-year study was conducted to determine plant biomass, plant height, seed yield, fatty acid and essential oil contents and essential oil composition of coriander (*Coriandrum sativum* L.) cultivars across different irrigation levels in a semiarid climate area of Kayseri, Turkey. The experimental design was a randomized complete block arranged in split plot arrangement with three replications. The main plots were cultivars Gurbuz and Aslan, the subplots were irrigation levels 0, 25, 50, 75 and 100%, assigned as S_0, S_1, S_2, S_3 and S_4, respectively. Growth season of autumn sowed corianders lasted about 270 days and the plant consumed water between 265-680 mm according to the applied water level. Coriander is a slightly sensitive plant to water stress since seed yield response factor of both coriander cultivars were found slightly higher than 1. Higher seed and essential oil yields were obtained with elevated water application. Water stress caused decrease in coriander biomass, plant height, seed yield and essential oil yield. Fatty acid and essential oil ratios were not changed significantly by water stress. Main essential oil component linalool was not changed with changing water amounts. Non-stable differences in essential oil components were observed between coriander varieties in both years. In coriander cultivation, timely irrigation with enough water is very crucial to obtain the highest seed yield and essential oil yield.

Key words: Coriander, water stress, yield response factor

INTRODUCTION

Coriander (*Coriandrum sativum L.*), an annual herb originated from Mediterranean and Middle East regions is used for flavoring in kitchens (Diederichsen, 1996). Although it is native to Anatolian and Caucasus, it also grew naturally in Asia and Europe. Coriander is cultivated in countries as Turkey, Russia, Hungary, Poland, Bulgaria, England, Netherlands, Morocco, Egypt. Essential oil composition of coriander has been widely studied and main component is linalool (Neffati et al., 2011). Researches recently focused on antioxidants properties of fruits, vegetables, herbs, cereals and different seeds. Antioxidant effect of coriander extracts and essential oil had been proven (Guerra et al. 2005; Singh et al. 2006).

Recent studies on coriander showed that biotic and abiotic stresses significantly affect plant growth, yield and seed quality. Fatty acid composition during maturation of coriander was studied by Lakshminarayana et al. (1981), Msaada et al. (2007) and Msaada et al. (2009a). Effects of maturing stages and growth regions on essential oil yield and composition of coriander were observed by Msaada et al. (2009b) and Telci et al. (2006). Effects of salinity as an abiotic stress on essential oil composition of coriander were reported by Neffati and Marzouk (2008, 2009). Coriander responses such as seed yield, essential oil content and composition and antioxidant efficiency were also studied in soilless culture by Neffati et al. (2011). Response of coriander to water deficiency as an abiotic stress were only studied in a pot experiment by Ghamarnia and Daichin (2013) and they stated that coriander a sensitive plant against to water stress.

In Turkey, different studies were conducted to determine coriander sowing date, sowing density, effects of growth regions, differences in coriander lines and populations but any study on coriander water consumption, effects of water stress on growth, yield and oil composition was not conducted. For example, seed yield and essential oil content according to sowing date of coriander grown in Harran plain 472-3219 $kg.ha^{-1}$ and 0.23-0.43%, respectively (Ozel et al., 2009). Seed yield differed between 551-1068 $kg.ha^{-1}$ and essential oil content between 0.19-0.44 ml/100 g seed according to sowing date and some native populations of coriander in Kazova plain, respectively (Kaya et al., 2000). Some coriander lines produced 866-1243 kg seed yield per hectare and gave 0.22-0.34% essential oil content in Konya (Kan and Ipek, 2004), 531-1688 $kg.ha^{-1}$ seed yield and 0.30-0.475% essential oil content in Aydın (Arabaci and Bayram, 2005), 985-1814 $kg.ha^{-1}$ seed yield and 0.287-0.318% essential oil content in Diyarbakır (Kizil and Ipek, 2004), 566-896 $kg.ha^{-1}$ seed yield and 0.06-0.30% essential oil content in Bornova (Avci et al., 2005).

The purpose of this study was to determine sensitivity of coriander to water stress and to determine irrigation level on growth, yield, oil and essential oil content and composition of coriander.

MATERIALS AND METHODS

To evaluate responses of growth, yield, essential oil content and composition, water consumption and sensitivity to water stress of autumn sowed coriander under grown different applied irrigation water amount, a two-year experiment were conducted at Mithatpasa research station of Erciyes University Research and Training Center in 2011-2012 and 2012-2013 growth season in Kayseri/Turkey. Semiarid experimental area is at 38° 41′ N longitude and 35°30′ E latitude 1050 m above sea level. Responses of *Coriandrum sativum* variety Aslan and *Coriandrum sativum* variety Gurbuz were evaluated under 5 different water stress conditions in the experiment. To create water stress, 100%, 75%, 50% and 25% of depleted water from field capacity were applied S_1, S_2, S_3 and S_4 treatments, respectively. This two coriander varieties in 5^{th} treatments (S_0) were only grown with precipitation. Two experiments were arranged for Aslan and Gurbuz coriander varieties in completely randomized block design in split plot arrangement with 3 replications. The main plots were cultivars Gurbuz and Aslan, the subplots were irrigation levels. Each plot had 2.4 m width and 3 m length and had six coriander rows at 40 cm space. Seed amount at sowing was 30 kg per hectare.

Di ammonium phosphates (DAP) and urea fertilizers were applied to supply 100 $kg.ha^{-1}$ nitrogen and 50 $kg.ha^{-1}$ P_2O_5. Each plot was supplied 78.3 grams DAP at sowing. Urea fertilizer (126 g/plot) was divided two portions and first portion was applied after winter dormancy and the other was applied before stem extension period.

Applied irrigation water amount to each plot was determined following equation:

$$I = (\theta_{fc} - \theta_a) \times D \times A \times C \quad (1)$$

Where, I is irrigation water amount (m^3), θ_{fc} is volumetric soil field capacity moisture ratio ($m^3\ m^{-3}$), θ_a volumetric soil actual moisture ratio ($m^3\ m^{-3}$) just before irrigation, D is effective root length (0.60 m), A is plot area (m^2) and C are 1.0, 0.75, 0.50 and 0.25 treatment coefficients for S_1, S_2, S_3 and S_4 treatments, respectively. Electrical conductivity at 25° of irrigation water was 581 $\mu S\ cm^{-1}$ and pH was 7.72.

Field capacity of the soil was determined with undisturbed soil samples taken 6 different soil depths at three points 3 days later after applying enough water to get soil moisture to near saturation point. Saturated soil plots were covered with polyethylene cover to prevent evaporation from soil surface and excess water drained from soil profile. From these soil samples, soil texture and unit mass of soil were also determined (Table 1).

Table 1. Some characters of experimental area soil

Soil layers (m)	Field capacity θ_v (%; $m^3\ m^{-3}$)	Unit mass ($g\ cm^{-3}$)	Clay (%)	Silt (%)	Sand (%)	Texture class
0-0.20	41.3	1.11	37.6	24.8	37.6	clay
0.20-0.40	42.7	1.14	49.8	15.2	35.0	clay
0.40-0.60	48.6	1.06	47.5	22.9	29.6	clay
0.60-0.80	52.2	1.17	44.1	21.5	34.4	clay
0.80-1.00	44.4	1.26	45.6	24.1	30.3	clay
1.00-1.20	47.6	1.15	40.0	17.5	42.5	clay

Soil moisture was monitored in first year by taken soil samples, gravimetrically and by neutron meter (CPN 503 DR Hydroprobe Moisture Gauge) in second year. To determine soil moisture disturbed soil samples were taken at 0.0-0.30 m, 0.30-0.60 m, 0.60-0.90 m and 0.90-1.10 soil depths with an hand auger. Weighed samples were dried 24 hours in an oven at 105°C and then soil moisture were determined from weight of evaporated water to weight of oven dried soil samples, gravimetrically. Poly vinyl chloride (PVC) pipes strength to 10 bar water pressure with 0.05 m diameter and 1.20 m length were used as axes tubes of the neutron meter (503 DR Hydroprobe). Soil moisture measurements were taken at the center of each plot at depths of 0.2 m, 0.4 m, 0.6 m, 0.8 m and 1.0 m. Because of radiation security, 0.0-0.10 m surface soil moisture was determined gravimetric method as mentioned in first year (Evett, 2007). Calibration equation was obtained at three points in the areas from neutron meter measurements as count ratio against to volumetric soil water content to determine soil moisture.

Coriander water consumption was determined with soil moisture budget equation as follows (James, 1988):

$$ET_c = I + R - DP \pm \Delta S \quad (2)$$

Where, I is applied irrigation water amount (mm), R is precipitation (mm), DP is deep percolation (mm) and ΔS is difference of stored soil water between at the sowing and at the harvest dates (mm). Effective root length was accepted 0.60 cm for each irrigation event and soil moisture increment or decrement at soil layer between 0.60-1.0 m was considered in water budget equation. Irrigations were carried out with a drip irrigation system. Lateral pipes with 0.3 m emitter space and 4 L/h emitter charge were installed 0.80 m space. Wetting percent of the drip irrigation system was 100%. Irrigation water was supplied from a well and measured in a container then applied to plots.

Plant heights were measured several times through growing season and at the harvest. Harvest was carried out after changing plant color from green to yellow and drying completely. The plant rows at two sides and 0.5 m growing zone at the head and foot of the plot were considered as side effect. Harvested plants were dried under shadow by two weeks and then plant biomass was determined. In this stage, some plant samples were dried at 65°C to stable weight and plant biomass weight adjusted to the weight at 65°C from plant moisture content. Coriander seeds were separated, weighed and 1000-seed weight was determined.

Hydro distillation methods was used to obtain essential oil content (ml/100 g) of coriander seed. Seed sample of 100 g weight was exposed to 5-hour distillation and cumulated essential oil measured as milliliter. Essential content analysis was replicated two times for each treatment. A Hewlett Packard 6890 N model GC-MS device was used for essential oil composition analysis. Fatty acid ratio was determined according to the method reported by the AOAC (1990).

Variance analysis and Duncan method to separate treatments' means were carried out with SPSS 13.0 statistical analyze software.

RESULTS AND DISCUSSION

Irrigation and Coriander Water Consumption

Differences in water consumption of coriander were significant because of different water applications (Figure 1). First year, applied water amount in S_1, S_2, S_3 and S_4 treatments for cultivar Gurbuz were 394, 339, 233 and 126 mm, and in the second year water amount in S_1, S_2, S_3 and S_4 treatments were 301, 237, 163 and 98 mm, respectively. In the first year of the study, S_2 treatment was not evaluated due to its unexpected distribution in the plots. Therefore, applied irrigation water amounts in S_1, S_3 and S_4 treatments for Aslan in the first year were 214, 114 and 55 mm, respectively, and 301, 237, 163 and 98 mm to S_1, S_2, S_3 and S_4 treatments in the second year, respectively. The precipitation rates were 296.9 mm and 336.3 mm in the first year and second year, respectively. Coriander water consumption according to water budget method (Equation 2) was showed in Figure 1. In the first and second year water consumption of S_1 treatments were 680 and 601 mm for Gurbuz and 444.5 and 619 mm for Aslan. In the first year, irrigation after sowing for Aslan was not applied due to the rainy period started after sowing. Therefore, water consumption of Aslan variety in the second year was higher than the first year's one. When water consumption of the both varieties was considered, water consumption of coriander sowed before winter would be around 630 mm in semiarid areas of Turkey. The least water consumption was naturally occurred for non-irrigated treatment (S_0). Water consumptions of the rain fed S_0 treatments of Gurbuz and Aslan were 267 and 265 mm in the first year and 369 and 324 mm in the second year, respectively. Water consumption of S_0 treatment in the second year was higher because of the higher precipitation in the growing season.

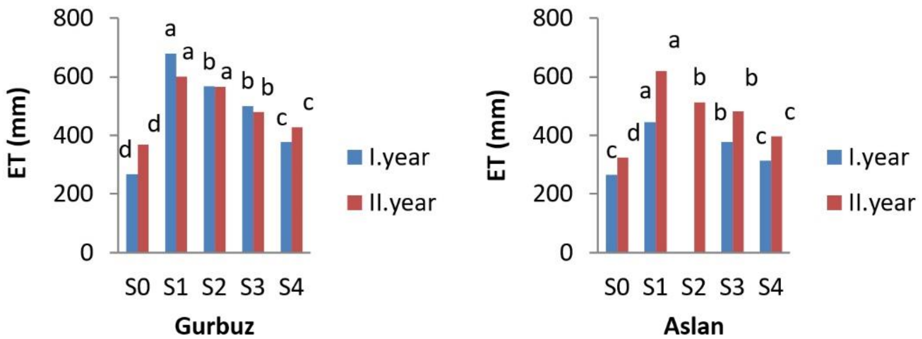

Figure 1. Water consumption and Duncan separation classes for Gurbuz and Aslan coriander varieties

Plant growth

Coriander seeds were sowed at 27 October 2011 (300th day of year or DOY= 300) and harvest was carried out at 24 July 2012 (DOY= 205) in the first year while sowing was carried out 16 October 2012 (DOY= 289) and harvest at 11 July 2013 (DOY= 192) in the second year. Therefore, total growing seasons were 270 and 268 days in first and second years, respectively. Emergence was observed on 25 March (DOY= 84) in the first year and on 3-5 November (DOY= 308) in the second year. Earlier sowing in the second year caused earlier emergence before winter. Long season of coriander sowed at 15^{th} October and the first week of November in Urfa was reported 201 days and 224 days in Diyarbakır for sowing at the middle of November (Ozel et al. 2009; Kizil and Ipek, 2004). Coriander growing seasons in both of these locations were shorter than in Kayseri because of the geographic locations.

Plant heights at harvest for Gurbuz were 0.51-0.61 m and 0.55-0.83 m in the first and second years, respectively. Harvest plant heights of Aslan cultivar were 0.46-0.56 m and 0.66-0.94 m in the first and second years, respectively. Plant heights at harvest were significantly affected by different water applications, except Gurbuz in the first year (Figure 2). Plant height of non-irrigated treatment was shorter than of irrigated treatments for Gurbuz. Plant heights of Aslan variety were aligned according to water stress severity. Water stress caused decreases in plant height for Aslan, but only severely stress caused decrease for cultivar Gurbuz. Higher plant heights were observed in the second year for both cultivars. Emergence before winter and higher precipitation in the second year may cause higher plant heights.

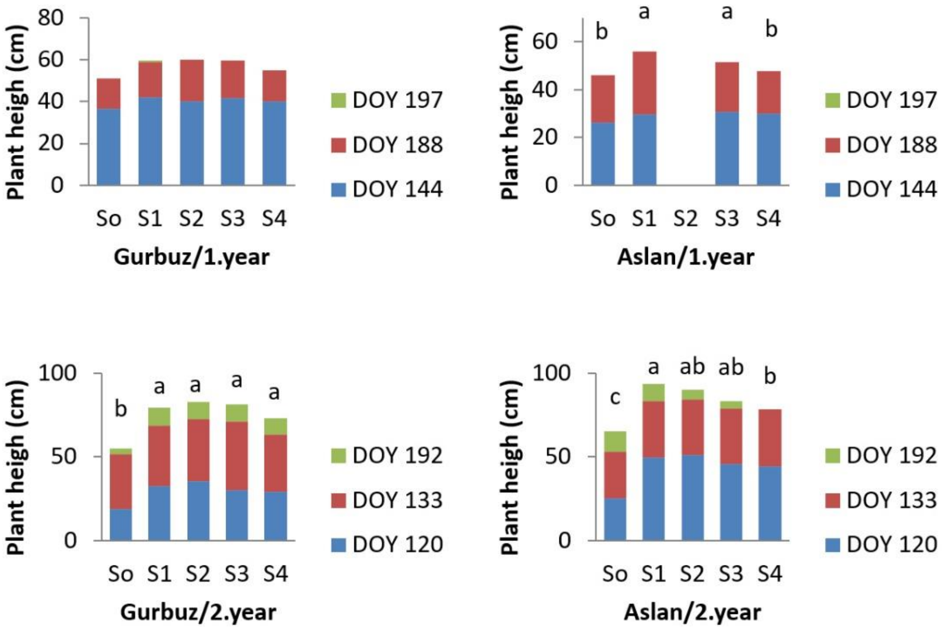

Figure 2. Effect of water stress on two coriander cultivars sowed in autumn.

Different coriander lines and populations had different plant heights (Arslan and Gurbuz, 1994; Esendal et al. 1995; Arslan et al. 1997; Mert and Kirici 1998; Kirici 1999; Kaya et al. 2000; Kizil and Ipek 2004) and sowing date also affect plant heights. Plant heights were shortened accordingly sowing from late autumn to earlier spring (Kaya et al. 2000; Ozel et al. 2009). Higher amount of seed per unit area also caused increment in coriander plant height (Arabaci and Bayram, 2005).

Dry biomass yield of coriander was affected significantly from water stress in both years except for Gurbuz in the first year (Figure 3). Total biomass yield were changed between 3122 and 4601 kg.ha^{-1} in first year and 2758 and 6458 kg.ha^{-1} in second year for Gurbuz. Total biomass yields of Aslan were 2705-3910 kg.ha-^{1} and 2694-7511 kg.ha^{-1} for two years, respectively. Total biomass yields of corianders were reported between 4429 and 5510 kg.ha^{-1} by Arslan and Gurbuz (1994), 2283 and 3473 kg.ha^{-1} according to sowing date and populations by Kaya and et al. (2000), 2078 and 4473 kg.ha^{-1} according to row spaces and seed amount per unit area by Arabaci and Bayram (2005), 5620 and 8360 kg.ha-^{1} according to coriander varieties and locations by Telci et al. (2006). The least biomass yields of this water stress study were obtained from non-irrigated treatments. Considerable biomass yield increments according to applied irrigation water amounts were determined for cultivar Aslan. Therefore, Aslan variety was more sensitive to irrigation water amounts then Gurbuz cultivar.

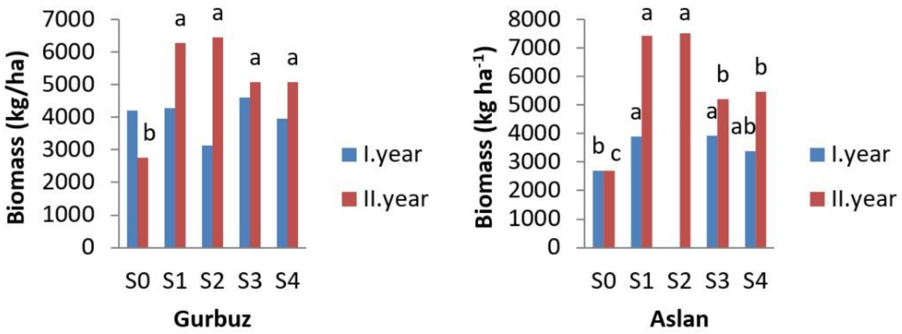

Figure 3. Effect of water stress on dry biomass of Gurbuz and Aslan sowed in autumn.

Seed yield

Seed yield of Gurbuz and Aslan were affected significantly from water stress in both years. Seed yields differed between 920 and 2355 kg.ha^{-1} in the first year and 641 and 1898 kg.ha^{-1} in the second year for Gurbuz and 975 and 1725 kg.ha^{-1} in the first year and 644-1777 kg.ha^{-1} in the second year for Aslan (Figure 4). The least seed yields for both cultivars were obtained from rain fed treatment (S_0) and the highest yields were obtained S_1 and S_2 irrigation treatments. Two-year mean seed yield of S_1, S_2, S_3 and S_4 treatments were 2.72, 2.35, 1.94 and 1.56 times higher than S_0 treatments for Gurbuz and 2.12, 2.20, 1.61, and 1.55 times higher than S_0 for Aslan, respectively. Irrigation caused important increases in seed yield up to 2.7 times. Kizil and Ipek (2004) were obtained mean seed yields from different coriander lines between 1282 and 1486 kg.ha^{-1}, Kaya et al. (2000) were obtained between 678 and 923 kg.ha^{-1} for different sowing dates. Obtained seed yield range by Karadogan and Oral (1994) was 520-663 kg.ha-^{1}, by Gul and Tansi (1997) was 1820-1840 kg.ha^{-1}, by Kirici et al. (1997) was 1420-1780 kg.ha^{-1}, by Esendal et al. (1995) was 859.5-1667 kg.ha^{-1} and by Telci et al. (2006) was 743-1102 kg.ha-^{1} .

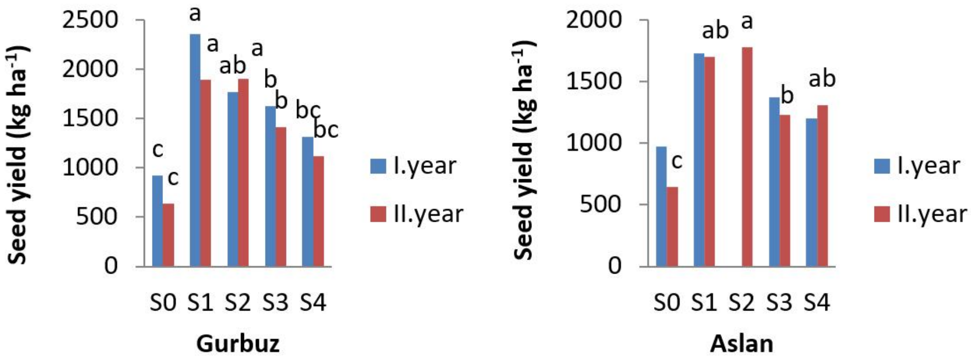

Figure 4. Coriander seed yields and Duncan separation class of Gurbuz and Aslan sowed in autumn.

Relationship between relative water consumptions ($\Delta ET/ET_m$) and relative yields represents sensitivity of plants to water (Doorenbos and Kassam, 1986) and this relationship is called yield response factor (K_y). Seed yield response factors of Gurbuz and Aslan were depicted in Figure 5. Yield response factors for the first and second years were K_y= 1.04 and K_y= 1.54 for Gurbuz and K_y= 1.09 and K_y= 1.0 for Aslan, respectively (Figure 5). Yield response factors higher than 1 means sensitivity to water deficiency. If sensitive plants are not expose to water stress, they give higher yield but if they exposed to water stress, they lost higher yield according to stress severity. Seed yield response factors of Gurbuz and Aslan were higher than 1 in both of years and they were sensitive to water. K_y coefficients of Aslan were found stable and slightly over 1 for two years. There were some differences in K_y coefficient of Gurbuz for two years but both coefficients were higher than 1 (Figure 5). When it is considered that coriander consumes 630 mm water averagely under favorable conditions. It is noticeable that coriander could give seed yield under water consumption as low as 265 mm under severe water stress conditions.

Essential oil yield and ratio

Essential oil yields of different water application treatments were affected significantly for Aslan in both years but Gurbuz in the second year (Figure 6). S_1 and S_2 treatments produced the highest essential oil yields but S_0 treatment produced the lowest essential oil yield. When considering means over two years, S_0 and S_1 treatments had 1.66 and 4.56 L.ha^{-1} for Gurbuz and 1.43 and 4.35 L.ha^{-1} for Aslan, respectively. S_1, S_2, S_3 and S_4 treatments had 185%, 142%, 82% and 37% higher essential oil yield according to S_0 for Gurbuz and 203%, 195%, 94% and 73% higher essential oil yield for Aslan, respectively. Irrigation significantly increased essential oil yield for coriander.

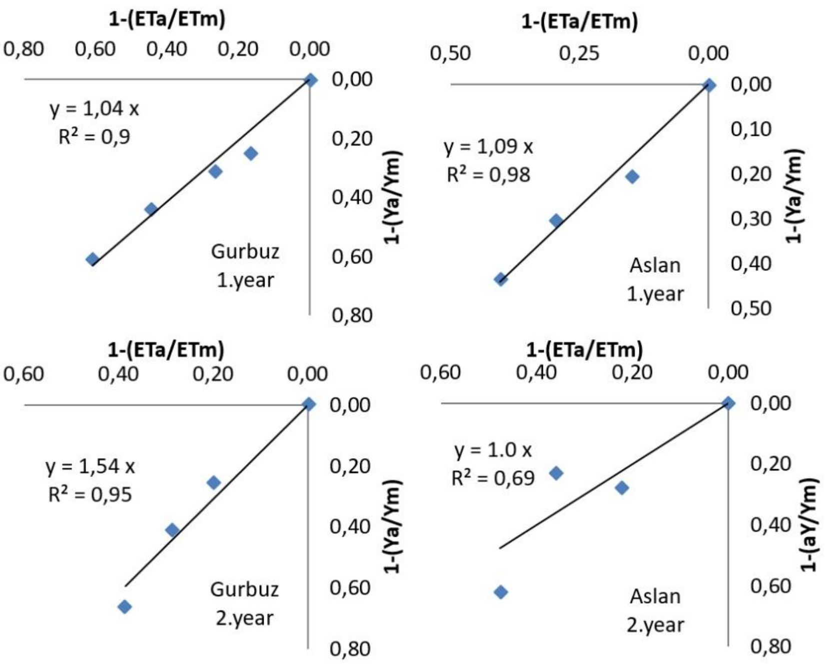

Figure 5. Seed yield response factors (K_y) of Gurbuz and Aslan coriander varieties.

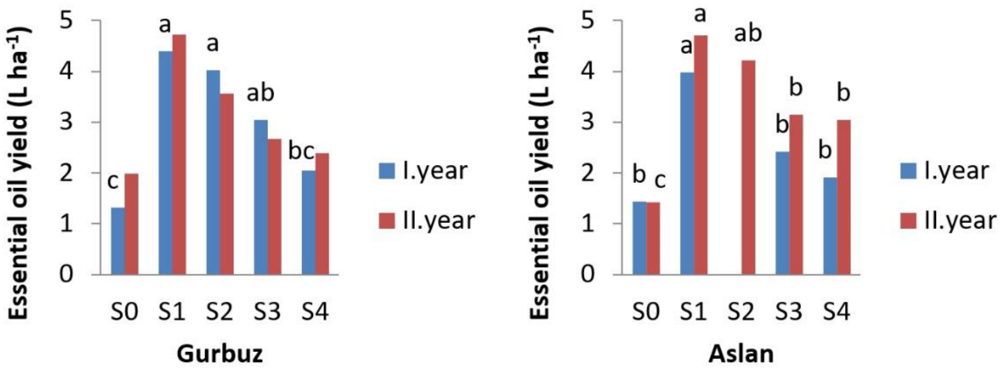

Figure 6. Effects of water stress on essential oil yield for Gurbuz and Aslan sowed in autumn.

It can be concluded that yield increment in essential oil of coriander was obtained from increasing seed yield with amount of applied irrigation water rather than increment in essential oil ratio except first year for Aslan variety, because different irrigation water amounts applications did not cause significant changes in essential oil ratio for both of cultivars. Changes in essential oil ratios of Gurbuz cultivar for treatments were not similar to changes in different applied water amounts. Essential oil ratios over two years of S_0 and S_1 treatments for Gurbuz were 0.21 and 0.22 ml/100 g seed and 0.18 and 0.25 ml/100 g seed for Aslan, respectively. Averaged essential oil ratio of the experiment over two years for Gurbuz was 0.20 ml/100 g seed and 0.21 ml/100 g seed for Aslan.

Essential oil ratios between 0.279-0.317 ml/100 g according to coriander lines and between 0.21-0.39 ml/100 g according to coriander populations were reported by Kizil and Ipek (2004) and by Kaya et al. (2000), respectively. Kaya et al. (2000) also stated that essential oil ratio changed between 0.29-0.33 ml/100 g according to sowing date. Different essential oil ratio ranges were reported as 0.3-0.4 ml/100 g by Baytop (1994), 0.3-1.1 ml/100 g by Dogan and Akgul (1987), 0.28-0.34 ml/100 g by Toncer et al. (1998), 0.30-0.60 ml/100 g by Arslan and Gurbuz (1994), 0.46-0.48 ml/100 g by Kirici et al. (1997), 0.34-0.56 ml/100 g by Mert and Kirici (1998), 0.23-0.34 ml/100 g by Beyzi and Gurbuz (2014) and 0.03-2.60% by Diederichsen (1996).

Essential oil composition

The main component of coriander essential oil is linalool and different water applications did not affect linalool significantly (Table 2, 3, 4 and 5). Linalool percent over two years for Gurbuz and Aslan was 87%. Wanger and Bladt (1996) stated that main essential oil component of coriander changes between 50-70%. Beyzi and Gurbuz (2014) found a range between 78.94 and

85.66%. Linalool percent changed between 50.5-92.5% according to coriander populations but sowing date did not affect it (Kaya et al., 2000).

Alpha-pinene, limonene, terpinolene, camphor, alpha terpineol and geraniol components of coriander essential oil significantly changed in the first year for Gurbuz, but any significant changes in any of the essential oil component were not observed in the second year (Table 2 and 3). In the first year, alpha pinene, camphor and 4 carvomenthol were the coriander components for Aslan in which significant differences were observed (Table 4). In the second year, only limonene and gamma terpinene were the components for Aslan in which significant differences were observed (Table 5). From these results it can be concluded that water stress did not cause any stable differences for both coriander cultivars in both years. Changes in essential oil components may be more complex phenomenon that required evaluation with other variables such as plant characters, weather and soil conditions, biotic and abiotic stresses.

Table 2. Differences in essential oil composition of *Coriandrum sativum* var. *Gurbuz* for different irrigation water applications in first year (%).

Essential oil component	S_0	S_1	S_2	S_3	S_4	Mean
Alpha-pinene	0.703 c	1.36 a	1.407 a	0.857 bc	1.130 ab	1.091
Camphene	0.090	0.137	0.140		0.063	0.111
Sabinene	-	0.163	0.163	0.120	0.097	0.139
Beta-pinene	0.413	0.160	0.160	0.157	0.187	0.215
Myrcene	0.217	0.237	0.293	0.253	0.363	0.273
P-cymene	0.467	0.630	0.657	0.540	0.627	0.584
Limonene	0.323 b	0.560 a	0.570 a	0.440 ab	0.580 a	0.495 a
Gamma-terpinene	2.587	2.203	2.523	2.233	2.340	2.377
Terpinolene	0.120 b	0.157 b	0.167 b	0.273 a	0.097 b	0.163
Linalol	88.96	87.41	88.04	88.13	88.82	88.27
Camphor	1.820 c	2.233 a	2.123 a	2.157 a	2.030 a	2.073
4-carvomenthol	0.190	0.170	0.170	0.150	0.120	0.160
Alpha-terpineol	0.293 a	0.247 ab	0.230 bc	0.190 c	0.237 bc	0.239
Geraniol	1.867 a	1.660 a	1.577 ab	1.230 b	1.583 ab	1.583
Nerol	1.423	1.520	1.357	0.930	1.293	1.305

Table 3. Differences in essential oil composition of *Coriandrum sativum* var. *Gurbuz* for different irrigation water applications in second year (%).

Essential oil component	S_0	S_1	S_2	S_3	S_4	Mean
Alpha-pinene	1.427	1.670	1.550	1.817	1.207	1.534
Camphene	0.160	0.187	0.163	0.173	0.140	0.167
Sabinene	0.135	0.150	0.137	0.195	0.125	0.147
Beta-pinene	0.193	0.203	0.183	0.227	0.170	0.195
P-cymene	0.673	0.923	0.747	0.880	0.670	0.779
Limonene	0.583	0.653	0.540	0.643	0.480	0.580
Gamma-terpinene	2.477	3.427	2.807	3.530	2.320	2.912
Terpinolene	0.227	0.175	0.160	0.170	0.163	0.181
Linalol	84.80	85.05	87.13	84.76	87.30	85.81
Camphor	2.160	2.420	2.310	2.153	2.077	2.224
4-carvomenthol	0.183	0.213	0.223	0.207	0.180	0.201
Alpha-terpineol	0.213	0.227	0.217	0.197	0.220	0.215
Ndecanal	0.433	0.200	0.130	0.163	0.210	0.246
Geraniol	2.180	1.713	1.633	1.530	1.840	1.779
Nerol	2.270	2.003	1.683	2.643	2.213	2.163

Table 4. Differences in essential oil composition of *Coriandrum sativum* var. Aslan for different irrigation water applications in the first year (%).

Essential oil component	S_0	S_1	S_2	S_3	S_4	Mean
Alpha-pinene	0.797 c	1.437 a	-	1.093 b	1.153 b	1.120
Camphene	-	-	-	0.110	-	0.110
Sabinene	-	-	-	0.117	0.090	0.110
Beta-pinene	0.150	0.153	-	0.150	0.133	0.147
Myrcene	0.240	0.273	-	0.200	0.253	0.242
P-cymene	0.570	0.627	-	0.650	0.683	0.633
Limonene	0.423	0.477	-	0.593	0.557	0.513
Gamma-terpinene	2.040	2.497	-	2.587	2.230	2.338
Terpinolene	0.140	0.123	-	0.120	0.093	0.119
Linalol	88.33	87.15	-	86.78	87.30	87.39
Camphor	2.107 b	2.520 a	-	2.480 a	2.173 b	2.320
4-carvomenthol	0.167 a	0.150 a	-	0.193 a	0.067 b	0.144
Alpha-terpineol	0.303 a	0.213 b	-	0.207 b	0.173 b	0.224
Geraniol	1.860	1.820	-	2.140	1.980	1.950
Nerol	1.500	1.310	-	1.607	1.747	1.541

Table 5. Differences in essential oil composition of *Coriandrum sativum* var. Aslan for different irrigation water applications in the second year (%).

Essential oil component	S_0	S_1	S_2	S_3	S_4	Mean
Alpha-pinene	0.690	1.777	1.587	1.590	1.323	1.393
Camphene		0.187	0.167	0.163	0.183	0.175
Sabinene		0.120	0.123	0.155	0.135	0.134
Beta-pinene	0.170	0.210	0.187	0.200	0.200	0.197
Myrcene	0.210	0.357	0.320	0.357	0.310	0.311
P-cymene	0.583	0.827	0.740	0.783	0.730	0.733
Limonene	0.243 b	0.613 a	0.590 a	0.653 a	0.547 a	0.529
Gamma-terpinene	1.587 b	3.200 a	2.997 a	3.213 a	2.447 ab	2.687
Terpinolene		0.170	0.170	0.180	0.165	0.172
Linalol	88.50	86.16	85.98	85.52	86.87	86.61
Camphor	2.277	2.500	2.577	2.710	2.467	2.506
4-carvomenthol	0.210	0.215	0.217	0.260	0.217	0.225
Alpha-terpineol	0.223	0.237	0.250	0.257	0.257	0.245
Ndecanal	0.447	0.100	0.130	0.170	0.213	0.251
Geraniol	2.090	1.683	1.790	1.840	1.933	1.867
Nerol	2.110	1.743	1.633	1.717	1.643	1.769

Fatty oil

Different amount of irrigation water applications caused significant changes in fatty oil yield for Gurbuz and Aslan in the second year, but did not in fatty oil ratio in both years. Although the lowest fatty oil yield obtained from severe water stress treatments of S_0 and S_4, these yields were not significantly different than the other treatments in the first year. S_0 treatments of Gurbuz and Aslan yielded 48.6 and 56.9 $L.ha^{-1}$ fatty oil, respectively in the second year. The highest fatty oil yield was 212.4 $L.ha^{-1}$ for Gurbuz from S_1 treatment and 171 $L.ha^{-1}$ for Aslan from S_2 treatment (Figure 7).

No significantly differed fatty oil ratios were 11 and 8.6% in both year for Gurbuz and 10.9 and 8.1% for Aslan, respectively. Msaada et al. (2009a) found significant changes in fatty acid ratio from 9.6% to 26.4% during fruit maturation in Tunusia.

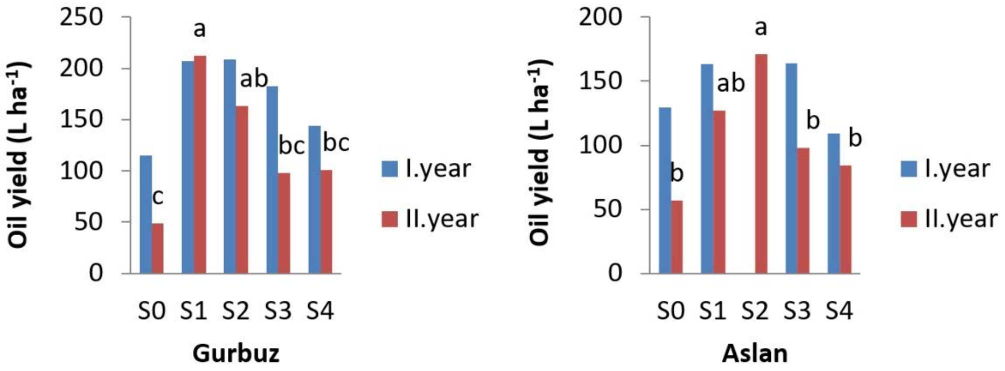

Figure 7. Effects of different irrigation water applications on fatty oil yields of Gurbuz and Aslan sowed in autumn.

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LITERATURE CITED

AOAC. 1990. Official Methods of Analysis (15th edition). Association of Official Analytical Chemists, Inc., Arlington, Virginia, USA.

Arabaci, O., and E. Bayram. 2005. The Determination of Some Morphological and Technological Properties of Coriander (*Coriandrum sativum* L.) at Different Row Spacing and Seeding Rate. Turkey VI.Field Crops Congress, 5-9 September, Antalya, (1): 535-540 pp (in Turkish).

Arslan, N., and B. Gurbuz. 1994. A Research on Yield and Some Chracters of Coriander (*Coriandrum sativum* L.) Populations Derived From Different Locations. Field Crop Congress, 25-29 April, İzmir, (1): 132-136 (in Turkish).

Arslan, N., B. Gurbuz and A. Gumuscu. 1997. A Research on Winter Resistance of Some Coriander (*Coriandrum sativum* L.) Populations in Ankara Conditions. Proceedings of The XIth Symposium on Plant Originated Crude Drugs, 22-24 May 1996 Ankara, 491-498 (in Turkish).

Avci, A.B., R. Amir Nia and E. Bayram. 2005. The Yield and Quality Characteristics of *Coriandrum sativum* var. *vulgare* of Persian Origin Under Bornova Conditions. Turkey VI.Field Crops Congress, 5-9 September, Antalya, (1): 477-482 pp (in Turkish).

Baytop, T. 1994. Dictionary of Turkish Plant Names. Turkish Language Institute Publications No. 578, Ankara. 508 p. (in Turkish).

Beyzi, E., and B. Gurbuz. 2014. Effect of Different Fruit Sizes on Essential Oil Ratio and Components of Coriander. TEOP 17 (6): 1175-1180.

Diederichsen, A. 1996. Coriander (*Coriandrum sativum* L.). Promoting the conservation and use of underutilized and neglected crops 3; Institute of olant genetics and crop plant research. Rome, Italy: Gatersleben/International Plant Genetic Resources Institute.

Dogan, A., and A. Akgul. 1987. Production, composition and using areas of coriander. Journal of Nature Turkish Agriculture and Forestry , 11 (2): 326-333 (in Turkish).

Doorenbos, J., and A.H. Kassam. 1986. Yield response to water. FAO Irrigation and Drainage Paper No.33, Rome. 193 pp.

Esendal, E., K. Kevseroglu and G. Yalcintas. 1995. Effects of different sowing date and row spacing on some morphological characters and seed yields of coriander (*Coriandrum sativum* L.). Workshop on Medicinal and Flavour Plants, 25-26 Mayıs, Izmir (in Turkish).

Evett, S.R. 2007. Soil Water and Monitoring Technology. In: Lascano R.J., Sojka R.E. (eds.) , Irrigation of Agricultural Crops. ASA, CSSA, SSSA Agronomy Monograph No. 30, Madison, Wisconsin, USA. 25-84 pp.

Ghamarnia, H., and S. Daichin. 2013. Effect of different water stress regimes on different Coriander (*Coriandrum sativum* L.) Parameters in a semi-arid climate. International Journal of Agronomy and Plant Production, 4 (4): 822-832.

Guerra, N.B., E.D.A. Melo, and J.M. Filho. 2005. Antioxidant compounds from coriander (*Coriandrum sativum* L.) etheric extract. Journal of Food Composition and Analysis 18: 193-199.

Gul, O., and S. Tansi. 1997. Effect of different sowing density of coriander (*Coriandrum sativum* L.) on yield and essential oil ratio. Journal of Agricultural Faculty of Cukurova University, 12 (2): 155-162.

James, G.L. 1988. Principles of Farm Irrigation System Design. John Wiley and Sons, New York. 512 pp.

Kan, Y., and A. Ipek. 2004. Yield and Some Properties of Different Coriander (*Coriander sativum* L.) Lines. Proceedings of The XIVth Symposium on Plant Originated Crude Drugs, 29-31 May 2002, Eskisehir/Turkey (in Turkish).

Karadogan, T., and E. Oral. 1994. Effect of Different Row Spacings on Yields, Yield Compenents and Quality of Coriander Varieties. Journal of The Faculty of Agriculture of Ataturk University 25 (3): 311-318.

Kaya, N., G. Yilmaz, G. and I. Telci. 2000. Agronomic and Technological Properties of Coriander (*Coriandrum sativum* L) Populations Planted on Different Dates. Turkish Journal of Agriculture and Forestry. 24 (2000), 355-364 (in Turkish).

Kirici, S. 1999. Adaptation of corianders (*Coriandrum sativum* L.) derived from different regions and determination of proper seeding density: Effect of seeding density on morphological properties of corianders. Cukurova University Journal of Agricultural Faculty, 14 (1): 33-40 (in Turkish).

Kirici, S., A. Mert, F. Ayanoglu. 1997. The effect of nitrogen and phosphorus on essential oil content and yield values of coriander (*Coriandrum sativum L.*) at Hatay ecology, 2nd Field Crops Congress of Turkey, September, 22-25, 1997, Samsun/Turkey Proceedings 347-351.

Kizil, S., and A. Ipek. 2004. The Effects of Different Row Spacing on Yield, Yield Components and Essential Oil Content of Some Coriander (*Coriandrum sativum* L.) Lines.

Journal of Agricultural Science, 10 (3): 237-244 (in Turkish).

Lakshminarayana, G., K.V.S.A. Rao, K. Sita Devri and T.N.B. Kaimal. 1981. Changes in fatty acids during maturation of *Coriandrum sativum* seeds. Journal of American Oil Chemists'Society, 58 (8): 838-839.

Mert, A., and S. Kirici. 1998. Determination of yield and yield characters of coriander (*Coriandrum sativum* L.) populations. Proceedins of XIIth International Symposium on Plant Originated Crude Drugs, New Trends and Methods in Natural Products Research. 20-22 May, Ankara (in Turkish).

Msaada, K., K. Hosni, M. Ben Taarit, T. Chahed, M.E. Kchouk and B. Marzouk. 2007. Changes on essential oil composion of coriander (*Coriandrum sativum* L.) fruits during three stages of maturity. Food Chemistry, 102: 1131-1134.

Msaada, K., K. Hosni, M. B. Taarit, M. Hammami and B. Marzouk. 2009a. Effects of growing region and maturity stages on oil yield and fatty acid composition of coriander (*Coriandrum sativum* L.) fruit. Scientia Horticulturae, 120: 525-531.

Msaada, K., M. B. Taarit, K. Hosni, M. Hammami and B. Marzouk. 2009b. Regional and maturational effects on essential oils yields and composition of coriander (*Coriandrum sativum* L.) fruits. Scientia Horticulturae, 122: 116-124.

Neffati, M., and B. Marzouk. 2008. Changes in essential oil and fatty acid composition in coriander (*Coriandrum sativum* L.) leaves under saline conditions. Industrial Crops and Product, 28: 137-142.

Neffati, M., and B. Marzouk. 2009. Roots volatiles and fatty acids of coriander (*Coriandrum sativum* L.) grown in saline medium. Acta physiologiae Plantarum, 31: 455-461.

Neffati, M., J. Sriti,G. Hamdaoui,M.E. Kchouk and B. Marzouk. 2011. Salinity impact on fruit yield, essential oil composition and antioxidant activities of *Coriandrum sativum* fruit extracts. Food Chemistry , 124: 221-225.

Ozel, A., I. Guler and K. Erden. 2009. Effect of Different Sowing Time on Yield and Some Plant Characters of Coriander (*Coriandrum sativum* L.) under The Harran Plain Conditions. Journal of Agricultural Faculty of Harran University, 13 (4): 41-48.

Singh, G., S. Maurya, M.P. de Lampasona and C.A.N. Catalan. 2006. Studies on essential oils, Part 41. Chemical composition, antifungal, antioxidant and sprout suppressant activities of coriander (*Coriandrum sativum*) essential oil and its oleoresin. Flavour and Fragrance Journal 21: 472-479.

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Telci, I., O.G. Toncer and N. Sahbaz. 2006. Yield, Essential Oil Content and Composition of *Coriandrum sativum* Varieties (var. vulgare Alef and var. microcarpum DC.) Grown in Two Different Locations. Journal of Essential Oil Research, 18: 189-193.

Toncer, O., S. Tansi and S. Kizil. 1998. The effect of different sowing time on essential oil of coriander in gap region. Anadolu Journal of AARI, 8 (2): 101-105.

Wanger, H., and S. Bladt. 1996. Plant Drug Analysis. A Thin Layer Chromatography Atlas. Springer-Verlag, Berlin.