Bulgarian Journal of Agricultural Science, 19 (No 2) 2013, 194-201
Agricultural Academy

CHANGES IN YIELD, YIELD COMPONENTS AND ESSENTIAL OIL COMPOSITION OF CUMIN (*CUMINUM CYMINUM* L.) UNDER DIFFERENT SEED AMOUNT AND INTER ROW SPACING

K. ERDEN[1], A. OZEL[1], U. DEMIREL[1] and I. KOSAR[2]
[1] *Harran University, Faculty of Agriculture, Department of Crop Sciences, 63190 Osmanbey, Sanliurfa, Turkey*
[2] *GAP Soil Water Resources and Agricultural Research Institute, 63040 Sanliurfa, Turkey*

Abstract

ERDEN, K., A. OZEL, U. DEMIREL and I. KOSAR, 2013. Changes in yield, yield components and essential oil composition of cumin (*Cuminum cyminum* L.) under different seed amount and inter row spacing. *Bulg. J. Agric. Sci.,* 19: 194-201

A field study was conducted to evaluate the agronomic response of cumin (*Cuminum cyminum* L.) on the Harran Plain (Southeastern Anatolia, Turkey) to four seed rate (5, 10, 15, 20 kg ha^{-1}) and two row spacing (15 cm and 30 cm), in the years of 2000-2003. The experiment was set up according to randomized complete block design with split plot. Seed yield, essential oil yield, essential oil ratio, 1000-seed weight, number of seed per umbel, number of branch per plant, number of umbel per plant and essential oil components ratio were significantly affected seed amount and inter row spacing. The treatment of 15 cm x 10 kg ha^{-1} in which the highest seed yield and essential oil yield were obtained, was found to be the most appropriate. *Cuminaldehyde* was determined the main component under all treatments and it was determined the highest values from the 15 cm row spacing and 10-15 kg ha^{-1} seed amounts.

Key words: Cumin (*Cuminum cyminum* L.), sowing rate, plant populations, seed yield, essential oil components

Introduction

Cumin (Cuminum cyminum L.) is a member of Apiaceae family, is one of species plants using common in the worldwide. Cumin is grown in Cyprus, Lebanon, Morocco, Malta, Turkey, Spain, Russia, India, Iran and China. Cumin seeds and essential oil extracted from seeds is used at trade and in food, perfumery, beverage and drug sectors of the industry (Beis et al., 2000).

Determination of the optimal plant population density necessary for optimal yield is a major agronomic goal. Sowing at a seed rate that result in optimal plant population density may reduce seed costs, lodging, and ameliorate disease problems. A Major factor influencing plant populations for any particular environment is seed amount and row spacing, and there is a little information concerning the study of seed amount – inter row spacing interaction. Cumin essential oil components were investigated aspects of odor and flavor by various researchers. Numerous studies have been conducted on the effect of production practices such as nutrition, harvesting time, plant densities (El-Sawi and Mohamed, 2002; Kan et al., 2007; Azizi and Kahrizi, 2008; Zolleh and et al., 2009), genotype (Martos et al., 2007), storing conditions (Jirovetz et al., 2005), and extraction method (Heravi et. al., 2007) on cumin seed yield, essential oil ratio and essential oil compositions. In addition, it is notified that major components of cumin essential oil are cuminaldehit, γ-terpinene, p-cymene, β-pinene (Beis et al., 2000; Iacobellis et al., 2005).

Plant density of cumin has an importance for plant characteristic and developing, addition to known com-

E-mail: hozel@harran.edu.tr; islimkosar@hotmail.com

petition effect. As all *Umbelliferae* family plants, in cumin, generative developing starts firstly at flower (umbel) that is on the end of the main stem, and continues towards auxiliary branches, related to plant growth. In this case, a cumin plant has seeds which have various sizes, are in different maturation stages, and are matured at various times. Therefore, the more auxiliary branch occurs, the more umbel per plant increase. One of the most important factors which determinate the branching out of cumin is plant density. Plant density can change according to amount of planted seeds, and row space.

This study was carried out to determine the effects of various seed amounts and row spaces on cumin (*Cuminum cyminum* L.) yield and essential oil composition.

Materials and Methods

Field studies

The Karaman variety of cumin (*C. cyminum* L.), obtained from local growers, was used in the study as the experimental material. The experiment was conducted at the research farm of the Agricultural Faculty of Harran University at Şanlıurfa, Turkey, during 2000-2001, 2001-2002 and 2002-2003 vegetation periods, as three years. Because of plant wilt disease (*Fusarium oxysporum* f.sp. *cumini*) at 2001-2002 growing season, the data of this year was not used. The experimental field was located in South-eastern Anatolia region (in the Harran Plain) where semi-arid climate conditions are prevail, and some climatic data for the area are showed in Figure 1.

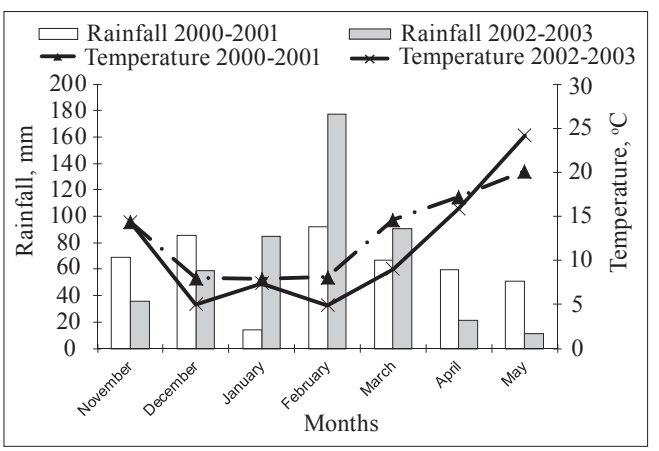

Fig. 1. Rainfall and temperature data of the study area during cumin growing season of 2000-2001 and 2002-2003

As seen in Figure 1, it was observed significant differences at climate between growing seasons, according to temperature and precipitation. In the first year of the experiment, a regular and totally 438.4 mm of precipitation and warm weather occurred. In the second year, an irregular and totally 480.1 mm precipitation and cool weather occurred. In the second year, the most precipitation was observed on January, but on April and May when grain filling period of cumin was drier than of first year (Figure 1). Relative humidity was similar at the two growing seasons.

The soil of the research field belonged to Harran I series and had A, B and C horizons, flat and/or flat-like slope, alluvial main material and a deep profile. According to soil analysis carried out prior to sowing, the soil of the research area had levels of chalk, pH, salt and organic matter of 17%, 7.84, 0.08% and 1.37%, respectively, and had a clay texture.

A split-plot design with row spaces (15 cm and 30 cm) as the main plots and four seed amounts (5, 10, 15, 20 kg ha^{-1}) as subplots was used in a randomized complete-block design with three replicates. Each experimental plot consisted of four rows and the plot length was 5.0 m long. The cumin seeds were sown by hand drill in November 2, 2000 and November 5, 2002. At the pre-sowing, nitrogen (50 kg ha^{-1}) and phosphorus (50 kg ha^{-1}) were fertilized, and at the beginning of April, nitrogen (50 kg ha^{-1}) was applied to all plots. The plant emergence was observed on November 27, 2000 and November 21, 2002, respectively, and first blooming was occurred on April 16, 2001 and April 18, 2003, respectively. From sowing until harvest, the weed control was done when needed, by hoeing. When the plants started to turn yellow and umbels turned brown, plants were harvested by hand on May 22, 2001 and May 28, 2003. Harvested plants were threshed after dried under shade conditions. The observations and plant samples were taken at random from each plot on a per unit area basis. Seed yield (kg ha^{-1}) and other plant measurements, essential oil yield (l ha^{-1}), essential oil ratio (%), 1000 seed weight (g), number of seed (number $umbel^{-1}$), number of umbel (number $plant^{-1}$) and number of branch (number $plant^{-1}$) were recorded as according to Özel et al. (2001).

Essential Oil Isolation

Plants from each plot were dried off at room temperature after harvesting. Samples taken from the blended cumin seeds were grinded and the sample (50 g) was subjected to hydrodistillation for 120 min before essential oils were measured and the resulting essential oil was subsequently analyzed. The essential oil samples were stored at 4°C until GC analysis.

GC-FID Analysis

Analytical gas chromatography was carried out on a ThermoQuest-Finnigan Trace GC gas chromatography equipped with a flame ionization detector (FID) and a AS 2000 auto sampler. A polyethylene glycol ZB-wax capillary column (30 m x 0.25 mm, 0.25 µm film thickness) was used. The flow of the carrier gas (He) was 1.5 ml min^{-1}. The split ratio was 50:1. The analysis was performed using the following temperature program; oven temps isotherm at 60°C, from 60 to 220°C at the rate of 4°C min^{-1} and from 220 to 240°C at the rate of 1°C min^{-1}. Both temperatures of injector and detector were held at 250°C. The injection volume was 0.5 µl.

Compounds Identification

Identification of the essential oil components was performed on the basis of their peak areas on wax column. The identification of the essential organic compounds was archived through retention indices and comparing the peaks of the samples with standards standards [β-Pinene (Fluka, 80607), γ-Terpinene (Fulka, 86476), p-Cymene (Fulka, 30039) α-Phellandrene (Fluka, 77429), Cuminaldehyde (Fluka, 28210)].

Statistical analysis

The data were subjected to analysis of variance (ANOVA) using randomized complete block design with split plot combined over years. The significance of differences among the treatments was determined using with the LSD Test ($P<0.005$). All statistical analysis was carried out by applying MSTAT-C© software.

Results and Discussion

Considering the parameters investigated, significant differences were noted between treatments and the growing seasons. The differences between the growing seasons may be due to the differences in average temperature and irregularity in precipitation (Figure 1). The results which were significant according to interaction between row spacing and seeds amount were illustrated in Figures 2, 3, and 4. Other characters were given in Tables 1, 2, 3, 4, and 5.

As seen in Table 1 in both years, the seed yields reached the highest level at the 15 cm row spacing and 10 kg ha^{-1} seed amount. In addition, the 15 cm and 30 cm row spacing showed differences. The highest seed yield determined in the 30 cm row spacing at 15 kg ha^{-1}

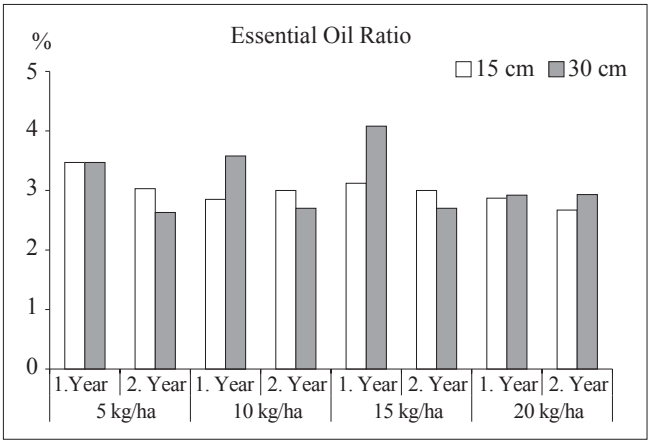

Fig. 2. The essential oil ratio of cumin under different row spacing and seed amount on during the 2000-2001 and 2002-2003 growing periods

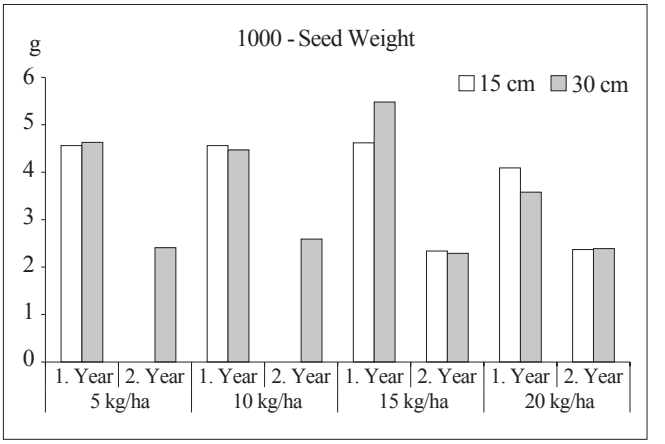

Fig. 3. The 1000-seed weight of cumin under different row spacing and seed amount on during the 2000-2001 and 2002-2003 growing periods

seed amount, in both years. In both years, up and down amount of this seed level, the seed yield declined considerably. This may have resulted from the increases in the number of umbels with higher umbel number per plant (Figure 4) and higher seed number per umbel, although plants branched out less in 15 cm treatment than 30 cm treatment (Table 4). Aakinerdem et al. (1999) reported that there was a positive correlation between the number of umbels per plant and seed yield in cumin. Our results are similar to that is notified as it is obtained higher seed yield from sowing of narrow row spacing and small amount of seed by Chaudhary (1999). Furthermore, our values according to cumin seed yield are higher than values notified by Chaudhary (1999) and similar to values notified by Özel and Demirbilek (2000), and Özel et al. (2001).

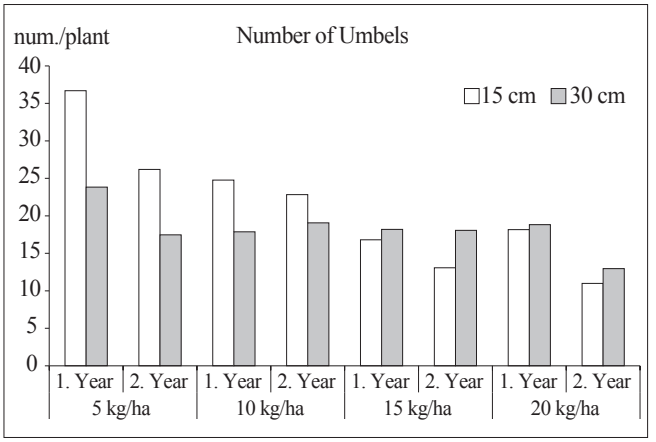

Fig. 4. The umbel number of cumin under different row spacing and seed amount on during the 2000-2001 and 2002-2003 growing periods

The trend of variation in essential oil yields showed similarities to the changes in seed yields. The essential oil yield means were ranged between 14.9 and 37.9 l ha^{-1} in first year and 9.5 and 20.5 l ha^{-1} in second year. It was obtained significantly high essential oil yield from 15 cm treatment comparing to 30 cm treatment. Essential oil yield was not changed regularly (Table 2). This resulted from the seed yield, as essential oil yield is calculated from the following formula;

Essential oil yield= seed yield x essential oil ratio.

Essential oil ratio values varied between 2.85-4.08% in the first year and 2.63-3.03% in the second year. The highest value of essential oil was obtained from 30 cm row spacing and 15 kg ha^{-1} treatments in first year and 15 cm row spacing and 5 kg ha^{-1} treatments in the second year (Figure 2). This may have resulted from that essential oil ratio is an easily changeable character by ecological conditions. Our essential oil ratio results are higher than values notified by Özel and Demirbilek (2001), similar to that notified by Doğan and Dikmen (1987), and Özel et al. (2001).

1000-seed weight of cumin varied between 3.58 and 5.48 g in the first year, and 2.26 and 2.74 g in the second year. The highest figures were noted at the 30 cm row

Table 1
The seed yield of cumin under different row spacing and seed amount on during the 2000-2001 and 2002-2003 growing periods

Seed amount, kg ha^{-1}	Seed yield, kg ha^{-1}					
	1, Year			2, Year		
	15 cm	30 cm	Mean	15 cm	30 cm	Mean
5 kg ha^{-1}	1096.7	576.3	836.5^{c}	689.0^{a}	426.8^{c}	557.9
10 kg ha^{-1}	1325	773.7	1049.3^{a}	703.7^{a}	518.5^{b}	611.1
15 kg ha^{-1}	1194	803	998.5^{ab}	671.7^{a}	564.5^{b}	618.1
20 kg ha^{-1}	1237.3	511.3	874.3^{bc}	646.5^{a}	319.8^{d}	483.2
Mean	1213.3^{a}	666.1^{b}		677.7	457.4	
Lsd (%5)						
Row Spacing (RS)		199.4			47.1	
Seed Amount (SA)		129.7			42.9	
RS*SA		ns			60.8	

Common superscripts indicate statistically indifferent groups at P > 0.05.

spacing and 15 kg ha^{-1} in the first year, and 15 cm row spacing and 15 kg ha^{-1} in second years. In general, the second year, 1000-seed weight values were not affected significantly by the treatments. Additionally, the second year 1000-seed values determined lower than the first year (Figure 3). This may have resulted from the changeable ecological conditions and plant wilt disease (Fusarium oxysporum f.sp. cumini). Our 1000 seed weight means are similar to that notified by Doğan and Dikmen (1987), Özel and Demirbilek (2000) and Özel et al. (2001).

The number of umbels with seed varied between 16.80 and 36.70 number plant^{-1} in the first year and 11.00 and 26.20 number plant^{-1} in the second year. The highest values were recorded at the 15 cm x 5 kg ha^{-1} treatment in the both years. In general, the umbel numbers decreased considerably to the increasing seed amount treatment. However, it was determined higher umbel number values at the 30 cm row spacing and 15 and 20 kg ha^{-1} seed amounts, while at the 15 cm row spacing and 5 and 10 kg ha^{-1} seed amount treatments (Figure 4). This may have resulted from less competing conditions for plant growth at treatment of narrow row spacing (15 cm) according to treatment of 30 cm row spacing, because cumin is a small plants (35.00-37.60 cm, at first

Table 2
The essential oil yield of cumin under different row spacing and seed amount on during the 2000-2001 and 2002-2003 growing periods

Seed amount, kg ha^{-1}	Essential oil yield, l ha^{-1}					
	1, Year			2, Year		
	15 cm	30 cm	Mean	15 cm	30 cm	Mean
5 kg ha^{-1}	37.9^{a}	19.9^{c}	28.9	20.3	11.3	15.8^{b}
10 kg ha^{-1}	37.7^{a}	28.7^{b}	33.2	20.5	14	17.3^{ab}
15 kg ha^{-1}	37.1^{a}	32.8^{ab}	35	20.1	15.2	17.7^{a}
20 kg ha^{-1}	35.4^{a}	14.9^{c}	25.1	17.3	9.5	13.4^{c}
Mean	37	24.1		19.6^{a}	1.25^{b}	
Lsd (%5)						
Row Spacing (RS)		3.32			2.32	
Seed Amount (SA)		3.89			1.67	
RS*SA		5.5			ns	

Common superscripts indicate statistically indifferent groups at P > 0.05.

Table 3
The seed number of cumin under different row spacing and seed amount on during the 2000-2001 and 2002-2003 growing periods

Seed amount, kg ha^{-1}	Number of seed, number umbel^{-1}					
	1, Year			2, Year		
	15 cm	30 cm	Mean	15 cm	30 cm	Mean
5 kg ha^{-1}	27	20.6	23.8	24.14^{ab}	21.40^{b}	22.77
10 kg ha^{-1}	28.23	22.4	25.32	27.20^{a}	21.87^{b}	24.53
15 kg ha^{-1}	23.27	23.03	23.15	22.60^{b}	24.53^{ab}	23.57
20 kg ha^{-1}	26.87	22.47	24.67	21.13^{b}	23.73^{ab}	22.43
Mean	26.34^{a}	22.13^{b}		23.77	22.88	
Lsd (%5)						
Row Spacing (RS)		2.15			ns	
Seed Amount (SA)		ns			ns	
RS*SA		ns			3.63	

Common superscripts indicate statistically indifferent groups at P > 0.05.

year, and 23.90-27.60 cm at second year). Plants grown at 30 cm density grow closer in same row.

As seen in Table 3, the average seed number values varied between 20.60 and 28.32 number umbel^{-1} in the first year and 21.13 and 27.20 number umbel^{-1} in the second year. In both years, the highest values were recorded at the 15 cm row spacing and 10 kg ha^{-1} seed amount. Generally, it was obtained higher seed number values from treatment of narrow row spacing. This case can be evaluate as an indicator of that plants grown at 15 cm row spacing have better growing conditions than grown at 30 cm.

In Table 4, it is seen that branch number means obtained from various row spacing and seed amounts were ranged between 9.80 and 15.63 number plant^{-1} in the first year and 5.53 and 10.07 number plant^{-1} in the second year. Generally, branch number was decreased at low plant density, and the highest value was obtained from treatment of 30 cm x 5 kg ha^{-1}. Branch number obtained from the experiment was found higher than means reported by Özel and Demirbilek (2000), and Özel et al. (2001).

Distribution of essential oil components, bigger than 1% values and occurring groups were given on Table 5.

Total values of determined 7 components were ranged between 94.80 and 96.00 %. When it was examined effect of treatments on essential oil components, it was determined that seed amount treatment significantly affected the essential oil components. However, row spacing treatment was not affected components of **2.** α-*Phellandrene,* ***4.*** *p-cymene, and* ***6.*** *p-mentha-1.3-dien-7-al* in the first year, and **2.** *α-Phellandrene,* ***3.*** *γ- terpinene,* ***5.*** *Cuminaldehyde, and* **6.** *p-mentha-1 .3-dien-7-al* in the second year. Generally, distribution of essential oil components showed variation according to treatments and years. This result was supported by inventions of researchers (Beis et al., 2000; El-Sawi and Mohamed, 2002; Iacobellis at al., 2005; Jirovetz at al., 2005; Martos at al., 2007; Aziz and Kahrizi, 2008; Zolleh et al., 2009) reported that distribution of cumin essential oil components could change related to environmental factors and cultivation techniques. *β-pinene* values were ranged between 21.12 and 24.34% in the first year, 19.21 and 20.14% in the second year. The highest values for β-*pinene* were obtained from 30 cm row spacing and 10 kg ha^{-1} seed amount in the first year, while that of 15 cm and 5 kg ha^{-1} treatments in the second year. *α-Phellandrene* values were ranged between % 3.06 and 3.45, and % 5.69 and 6.14 in the first and the second year, respectively. In both years, it was reached the highest values through 10 kg ha^{-1} and 15 kg ha^{-1} treatments. *γ-terpinene* values were ranged between 13.01 and 13.68%, and 10.00 and 11.07% in the first and the second year, respectively. It was determined the highest values from seed amounts of 5 kg ha^{-1} in the first year, and 20 kg ha^{-1} in the second year. *p-cymene* values were ranged between 8.14 and 9.60% and 5.48 and 6.16% in the first and the second year, respectively. For *p-cy-*

Table 4
The branch number of cumin under different row spacing and seed amount on during the 2000-2001 and 2002-2003 growing periods

Seed amount, kg ha^{-1}	Number of branch, number plant^{-1}					
	1, Year			2, Year		
	15 cm	30 cm	Mean	15 cm	30 cm	Mean
5 kg ha^{-1}	13	15.63	14.32^{a}	10.07^{a}	9.73^{ab}	9.9
10 kg ha^{-1}	11	12.07	11.53^{b}	8.43^{c}	8.93^{bc}	8.68
15 kg ha^{-1}	10.57	12.27	11.42^{b}	6.40^{d}	8.40^{c}	7.4
20 kg ha^{-1}	9.87	9.8	9.83^{c}	5.53^{d}	5.80^{d}	5.67
Mean	11.11^{b}	12.44^{a}		7.61	8.22	
Lsd (%5)						
Row Spacing (RS)		1.14			ns	
Seed Amount (SA)		1.1			0.39	
RS*SA		ns			0.55	

Common superscripts indicate statistically indifferent groups at P > 0.05.

mene, it was determined the highest values from treatment of row spacing of 15 cm in both years, and treatments of seed amounts of 10 kg ha^{-1} and 15 kg ha^{-1} in the first and the second year, respectively. *Cuminaldehyde* values were ranged between 27.78 and 30.57% in the first year and 23.22 and 24.65% in the second year. For c*uminaldehyde*, it was determined the highest values from treatment of row spacing of 15 cm in both years, and treatments of seed amounts of 20 kg ha^{-1} and 15 kg ha^{-1} in the first and the second year, respectively. *p-mentha-1.3-dien-7-al* values were ranged between 7.74 and 8.88% in the first year and 8.04 and 8.43% in the second year. For *p-mentha-1.3-dien-7-al*, it was determined the highest values from treatments of seed amounts of 10 kg ha^{-1} and 20 kg ha^{-1} in the first and the second year, respectively. *p-mentha-1.4-dien-7-al* values were ranged between 6.24 and 13.02% in the first year and 20.38 and 21.74% in the second year. It was determined the highest values from treatment of row spacing of 15 cm in both years, and treatment of seed amounts of 15 kg ha^{-1} and 20 kg ha^{-1} in the first and the second year, respectively. It was determined *Cuminaldehyde* as the main component of cumin essential oil under all treatments in both year. It was followed by *β-pinene, γ-terpinene, p-mentha-1.4-dien-7-al, p-cymene*, *p-mentha-1.3-dien-7-al,* and *α-Phellandrene* in the first year and year *p-mentha-1.4-dien-7-al*, *β-pinene, γ-terpinene*, *p-mentha-1.3-dien-7-al, α-Phellandrene*, and *p-cymene* in the second. This change between years could be resulted from differences of growth conditions and especially from precipitation. High precipitation in February and March of the second year caused occurring of plant wilt disease (*Fusarium oxysporum* f.sp. *cumini*) again, that was epidemic at previous year. As result of that, differences in yield and essential oil components occurred. In result of previous researches, *Cuminaldehyde* (Beis

Table 5
The components of cumin essential oils under different row spacing and seed amounts

Row spacing	1. Year							Mean
	Components							
	1*	2	3	4	5	6	7	
15 cm	21.12^{b}	3.15	13.84a	8.97	30.35^{a}	8.88	9.40^{b}	95.71
30 cm	23.09^{a}	3.25	12.91b	8.84	27.78^{b}	8.55	11.44^{a}	95.86
Seed amount								
5 kg/ha	21.37b	3.18ab	13.68a	8.14c	28.02c	8.82b	12.78a	95.99
10 kg/ha	24.34a	3.45a	13.01b	9.60a	29.53b	9.67a	6.24c	96
15 kg/ha	21.15b	3.06b	13.54a	8.70b	28.14c	7.74c	13.02a	95.35
20 kg/ha	21.57b	3.12b	13.27ab	9.18a	30.57a	8.62a	9.63b	95.96
Mean	22.11	3.2	13.38	8.91	29.07	8.71	10.42	94.8
Lsd (%5)	0.75	0.28	0.49	0.43	0.8	0.64	0.74	
	2. Year							
Row spacing	1*	2	3	4	5	6	7	Mean
15 cm	20.11a	5.92	10.04	6.16a	24.23	8.21	20.38b	95.05
30 cm	19.21b	5.95	10.89	5.65b	23.71	8.25	21.59a	95.25
Seed amount								
5 kg/ha	20.14a	6.06a	10.00c	6.01a	23.81b	8.23b	20.61b	94.86
10 kg/ha	19.39c	5.85b	10.54b	6.05a	24.21ab	8.20b	21.02b	95.26
15 kg/ha	19.73b	6.14a	10.26bc	6.08a	24.65a	8.04b	20.57b	95.47
20 kg/ha	19.39c	5.69b	11.07a	5.48b	23.22c	8.43a	21.74a	95.02
Mean	19.66	5.93	10.47	5.9	23.97	8.23	20.99	95.12
Lsd (%5)	0.17	0.19	0.48	0.2	0.48	0.19	0.49	

Common superscripts indicate statistically indifferent groups at P > 0.05.
***1**. *β-pinene,* **2.** *α-Phellandrene*, **3.** *γ- terpinene*, **4.** *p-cymene*, **5.** *Cuminaldehyde*, **6.** *p-mentha-1,3-dien-7-al*, **7.** *p-mentha-1,4-dien-7-al*

et al., 2000; El-Sawi and Mohamed, 2002; Jirovetz et al., 2005; Heravi et. al., 2007), *γ-terpinen* (Martos et al. 2007), and *p-mentha-1.4-dien-7-al* (Iacobelis et al., 2005) were reported as the main component of cumin.

Conclusions

Result of this study showed that 15 cm row spacing and 10 kg ha-1 seed amount were found preferable for the Southeast Anatolia of Turkey. Because of the highest seed and essential oil yields, they are considered more promising than other treatments. Also, *Cuminaldehyde* was determined the main component of cumin essential oils under all treatments and it was determined the highest values from the 15 cm row spacing and 10-15 kg ha-1 seed amount treatments.

Acknowledgements

This manuscript is based part of work supported by Republic Of Turkey Ministry of Development Southeastern Anatolia Project Regional Development Administration agreement no. 3-5-2007. Special thanks to Dr. Barbaros Ozer who helped and checked the English review of the manuscript.

References

Akınerdem, F., Y. Kan and B. Sade, 1997. The effects of different nitrogen and phosphorus doses on grain yield of cumin populations fallow year on Konya-Sarayönü dry conditions. *The 2nd National Field Crops Congress of Turkey*, (Proceedings of Industry Plant, University of Ondokuz Mayis, Faculty of Agriculture, Department of Field Crops, Samsun-Turkey. September 22-25, 1997) 2: 381-385 (Tr).

Azizi, K. and D. Kahrizi, 2008. Effect of nitrogen levels, plant density and climate on yield and quality in cumin (*Cuminum cyminum* L.) under the conditions of Iran. *Asian Journal of Plant Sciences*, **7** (8): 710-716.

Beis, S.H., N. Azcan, T. Özek, M. Kara and K.H.C. Başer, 2000. Production of essential oil from cumin seeds. *Chemistry of Natural Compounds*, **36** (3): 265-268.

Chaudhary, G. R., 1999. Response of cumin to row spacing and seed rate. *Journal of Spices and Aromatic Crops*, **8** (2): 159-162.

El-Sawi, S. A. and M.A . Mohamed, 2002. Cumin herb as a new source of essential oils and its response to foliar spray with some micro-elements. *Food Chemistry*, **77** (1): 75–80.

Heravi, M. J., B. Zekavat and H. Sereshti, 2007. Use of gas chromatography–mass spectrometry combined with resolution methods to characterize the essential oil components of Iranian cumin and caraway. *Journal of Chromatography A*, **1143** (1-2): 215–226.

Iacobellis, N. S., P. Lo Cantore, F. Capasso and F. Senatore, 2005. Antibacterial activity of Cuminum cyminum L. and Carum carvi L. essential oils. *J. Agric. Food Chem.*, **53** (1): 57-61.

Jirovetz, L., G. Buchbauer, A. S. Stoyanova, E. V. Georgiev and S. T. Damianova, 2005. Composition, quality control and antimicrobial activity of the essential oil of cumin (Cuminum cyminum L.) seeds from Bulgaria that had been stored for up to 36 years. *International Journal of Food Science and Technology*, **40** (3): 305–310

Kan, Y., M. Kartal, T. Özek, S. Aslan and K. H. C. Başer, 2007. Composition of essential oil of *Cuminum cyminum* L. according to harvesting times. *Turkish Journal of Pharmaceutical Sciences*, **4** (1): 25-29.

Martos, M. V., Y. R. Navajas, J. F. López and J. A. P. Álvarez, 2007. Chemical composition of the essential oils obtained from some spices widely used in Mediterranean Region. *Acta Chimica Slovenica*, **54** (4): 921–926.

Özel, A. and T. Demirbilek, 2000. Determination of yield and some agronomic characters of some annual spice plants under the Harran Plain arid conditions. *Journal of the Faculty of Agriculture*, Harran University, **4**(3-4): 21-32.

Özel, A., T. Demirbilek and O. Çopur, 2001. Determination of the yield and agronomic characters of some annual spice plants under the Harran Plain conditions. *Workshop on Agricultural and Quality Aspects of Medicinal and Aromatic Plants*, May 29-June 01, 2001, pp. 151-158, Adana/Türkiye.

Tunçtürk, R. and M. Tunçtürk, 2006. Effects of different phosphorus levels on the yield and quality components of cumin (*Cuminum cyminum* L.). *Research Journal of Agriculture and Biological Sciences*, **2** (6): 336-340.

Zolleh, H. H., S. Bahraminejad, G. Maleki and A. H. Papzan, 2009. Response of cumin (*Cuminum cyminum* L.) to soving date and plant density. *Research Journal of Agriculture and Biological Sciences*, **5** (4): 597-602.

Received June, 2, 2012; accepted for printing January, 12, 2013.