Effect of different row distances on some agronomical characteristics and essential oil composition of cumin (*Cuminum cyminum* L.)

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Einfluss der Reihenweite auf agronomische Merkmale und Qualität von Kreuzkümmel (*Cuminum cyminum* L.)

1 Introduction

In recent years, interest in plant-derived food additives has grown. Plant extracts might substitute synthetic food antioxidants, because of their negative effects for human health (HINNEBURG et al., 2006). For this reason, there is at present increasing interest for spices and aromatic herbs because of their strong antioxidant and antimicrobial properties. Cumin essential oil also shows good antioxidant activity, and can be supplemented for both nutritional purposes and preservation of foods (THIPPESWAMY and NAIDU, 2005).

The seeds of cumin (*Cuminum cyminum* L.) an annual plant of the *Umbelliferae* family are one of the important spices in the world. It is indigenous to the Eastern Mediterranean Turkey, Egypt, Syria, China and India (UHL, 2000; LI and JIANG, 2004). Primary cultivation of cumin is cultivated in Europe, Asia, the Middle East, and North Africa. India and Iran are the largest cumin exporters (HORNOK, 1992). Cumin is used as a condiment and as an ingredient in many food industries (EL SAWI and MOHAMED, 2002; LEUNG and FOSTER, 2003). Cumin seed has been utilized as an antispasmodic, carminative, sedative and stimulant. Its essential oil has been reported to have antibacterial activity (FARAG et al., 1989; HORNOK, 1992; AMIN, 2000; LEUNG and FOSTER, 2003; IACOBELLIS et al., 2005), and exhibit strong larvaicidial activities (LEUNG and FOSTER, 2003). Moreover, there are some reports regarding the antidiabetic and estrogenic activities of this plant (SAYYAH et al., 2002; IACOBELLIS et al., 2005).

The distinctive odour and flavour of cumin seeds derive mainly from the essential oil with a range of 2.5 % to 4.5 % (depending on age and regional variations), which is pale to colourless and chiefly contains cuminic aldehyde (33 %), β-pinene (13 %), terpinene (29.5 %), *p*-cymene (8.5 %), *p*-menthon-1,3-dien 7-al (5.6 %), cuminyl alcohol (2.8 %) and β-farnesene (1.1 %) (UHL, 2000). Main constituents in essential oil composition vary according to sample, IACO-

Zusammenfassung

Der Beitrag behandelt die Bestimmung der optimalen Reihenweite und deren Einfluss auf agronomische Merkmale von Kreuzkümmel. Die Ergebnisse zeigen, dass die höchsten Erträge an Samen und ätherischem Öl bei Reihenweiten von 20 und 30 cm erzielt wurden. Der Gehalt an ätherischem Öl lag zwischen 2,42 und 3,20 %. Der Cuminaldehyd-Anteil betrug 16,46–27,73 %.

Schlagworte: Kreuzkümmel, Reihenweite, Samenertrag, ätherisches Öl, Cuminaldehyd.

Summary

The study reports determination of appropriate row distances and its effect on agronomical characteristics and essential oil composition of cumin. The results indicated that the highest yields in terms of seed and essential oil were obtained from 20 and 30 cm row distances. Essential oil content ranged between 2.42 and 3.20 %. *p*-mentha-1,4-dien-7-al content was determined with range of 16.46–27.73 %.

Key words: Cumin; row distances, seed yield, essential oil, *p*-mentha-1,4-dien-7-al.

BELLIS et al. (2005) reported that the main components of oil were *p*-mentha-1,4-dien-7-al (27.4 %), cuminaldehyde (16.1 %), γ-terpinene (12.8 %), β-pinene (11.4 %) and *p*-mentha-1,3-dien-7-al (8.7 %); however, GACHKAR et al. (2007) reported that *C. cuminum* contained α-pinene (29.1 %), limonene (21.5 %), 1,8 cineole (17.9 %) and linalool (10.4 %)

Although the biosynthesis of metabolites is controlled genetically, it is strongly affected by environmental influences. Agronomic practices including spacing, harvesting schedule, and harvesting time have a critical effect on quantitative and qualitative characteristics of the essential oil. The aim of the present study was to investigate the effects of different row distances on seed & oil yield and essential oil composition of cumin under the conditions of the Southeastern Anatolia Region in Turkey.

2 Materials and methods

The field experiment was carried out at the Department of Field Crops, Dicle University, Diyarbakir (latitude 37° 53' E and longitude 40° 16' E, 680 m from sea level) during winter seasons of 2003–04 and 2004–05. Cumin seeds were obtained from the Department of Field Crops, Faculty of Agriculture, University of Ankara, Turkey.

The data, taken from the State Meteorology Institute, Diyarbakir (Turkey), showed that Diyarbakir had mean temperatures of November to July period during 2003–04 and 2004–05 was 11.3 and 10.4 °C, respectively with long term mean temperature of 14.8 °C. It had mean relative humidity during November to July period during 2003–04 and 2004–05 was of 62 and 55 %, respectively with long term mean relative humidity of 64 %, and mean precipitation of 498.3 and 420.5 mm, respectively with long term mean precipitation of 432.2 mm. The soil of the experimental plot was sandy-loam having pH 7.12 and electrical conductivity 240 $S.m^{-1}$; was deficient in organic matter (1.65 %) and available P (1.25 %) (ANONYMOUS, 1999).

The treatments consisted of five row distances (20, 30, 40, 50 and 60 cm). The field experiments were laid out in randomised complete block design with three replications with sowing rate of 25 kg ha^{-1} during both years with sowing done on 05 November 2003 and 24 November 2004, respectively. A basal dose of 30 kg ha^{-1} P_2O_5 and 30 kg N ha^{-1} were applied at the time of sowing. During both years, the plots were weeded by hand when required. The unit plot sizes were 3.0, 4.5, 6.0, 7.5 and 9 m^2, respectively. Each plot comprised 5 rows. Growth and development parameters were investigated from each plot. The plots were harvested when the fruits matured after removing border effects by hand and dried on 11 July 2004 for first year and 16 July 2005 for second year.

The effect of row distances were evaluated on plant height, number of branches, number of umbel, number of seed per umbel, seed yield per plant, thousand seed weight, seed yield as agronomical characteristics, essential oil content and essential oil yield along with components of essential oil as quality characteristics.

For determining essential oil content of cumin; air-dried seeds were ground rapidly in a spice mill and 20 grams of ground seed were taken for essential oil extraction. Essential oil content was measured volumetrically, by hydrodistillation using a Clevenger's apparatus (%-v/w). The essential oil content of each plot was multiplied by seed yield (L ha^{-1}) to determine essential oil yield.

All data obtained were analysed statistically, using the MSTAT-C computer program with split-plot in randomized complete blocks (main plots as years and subplots as row distances) and mean values were grouped, using LSD values at a significance level of 5 % (FREED and EISENSMITH, 1996).

GC/MS: The essential oils were analysed by GC–MS (Hewlett Packard computerized system comprising a 6890 gas chromatograph coupled to a 5973 mass spectrometer) Chromatographic separations were accomplished with a ZB-5 capillary column (0.25 mm i.d. × 60 m, film thickness 0.25 µm) with injections in the split mode with a split ration of 40:1. The temperature was set to 60 °C for 5 min initially, and then increased to 240 °C at a rate of 3 °C per minute and maintained at 240 °C for 10 min. The injection temperature and ion source temperature were both set at 250 °C. Helium was used as a carrier gas at a flow rate of 1.0 mL/min. The ionization mode used was electronic impact at 70 eV, mass range m/z 35–550 a.m.u. The separated components were identified by matching with National Institute of Standards and Technology (NIST98) mass spectral library data and Wiley/GC/MS library. The quantitative determination was carried out based on peak area integration. Each sample was analysed three times every year.

3 Results and discussion

The agronomical results over two years for cumin are given in Table 1, 2, and 3. Row distances affected plant height, number of branches and number of umbels significantly. The maximum plant height (22.9 cm) was obtained from narrow row distances (20 cm). That difference may be aroused from competition between plants. Competition in closer distances was more than large ones (except 50 cm). Cumin plant has very low height. High plant height is desirable by producer for allowing mechanization and low harvest loses. The results of this research are in agreement with the findings of HORNOK (1992), TURAN and ARSLAN (1997), OZEL et al. (2001), SALMA et al. (2002) and TAS (2004) who emphasise that cumin has plant height in range of 19.59 to 33.5 cm.

Different row distances affected the number of branches significantly (Table 1). The 60 cm row distance produced maximum number of branches (4.7), while the least number of branches were obtained from narrow row distances (20 cm) (Table 1). Number of branches depended on row distances; they increased by increasing row distances. TAS (2004) reported that the number of branches per plant varied between 4.0 to 4.8, in agreement with our results. However, some other researches report high number of branches in range of 5.87–8.6 (OZEL et al. 2001; EL SAWI and MOHAMED 2002).

Number of umbel is an important character for seed yield in cumin cultivation. According to results the highest number of umbels was recorded from 60 cm row distances, while the least number of umbels was recorded from the narrow row distances of 20 cm (Table 1). These results are higher than that of described by TAS (2004), who reported 3.59 to 4.64 umbels per plant. That difference may be due to different genotypes used in the studies.

The experiment years × row distance interaction affected the number of seeds per umbel significantly (Table 2). The highest number of seeds per umbel (19.3) were obtained from wide row distance (60 cm) in the first year, while the least number of seed (10.3) were obtained from the same row distance (60 cm) in the second year. The mean number of seeds per umbel (16.5) during first year were higher than

Table 1: The effect of row distances on plant height, number of branches, and number of umbels of cumin (*C. cyminum* L.)
Tabelle 1: Einfluss der Reihenweite auf die Wuchshöhe sowie die Anzahl von Seitentrieben und Fruchtständen (Dolden) pro Pflanze des Kreuzkümmels (*Cuminum cyminum* L.)

Row distances	Plant height (cm)			Number of branches per plant			Number of umbels per plant		
	2003–04	2004–05	Mean	2003–04	2004–05	Mean	2003–04	2004–05	Mean
20 cm	23.6	22.3	22.9 a*	3.6	3.3	3.4 d	12.9	13.7	13.2 c
30 cm	21.7	23.1	22.4 a	4.0	3.4	3.7 cd	14.6	16.3	15.4 bc
40 cm	19.6	20.1	19.8 b	4.1	3.9	4.0 bc	15.4	14.9	15.2 bc
50 cm	22.2	22.0	22.1 a	4.7	3.8	4.2 b	18.7	16.2	17.5 ab
60 cm	18.0	20.4	19.2 b	4.9	4.5	4.7 a	20.1	16.3	18.2 a
Mean	21.0	21.6	21.3	4.2	3.8	4.0	16.3	15.5	
LSD (0.05)	Row distances: 2.05			Row distances: 0.46			Row distances: 2.69		

*Means followed by the same letter are not significantly different (P < 0.05)

Table 2: The effect of row distances on number of seeds per umbel, seed weight per plant and thousand seed weight of cumin (*C. cyminum* L.)
Tabelle 2: Einfluss der Reihenweite auf die Anzahl Samen pro Fruchtstand (Dolde), den Samenertrag pro Pflanze und das Tausendkorngewicht von Kreuzkümmel (*Cuminum cyminum* L.)

Row distances	Number of seeds per umbel			Seed weight per plant (g plant^{-1})			1000 seed weight (g)		
	2003–04	2004–05	Mean	2003–04	2004–05	Mean	2003–04	2004–05	Mean
20 cm	14.2 bcde	14.6 bcd	14.4	0.78	1.04	0.91 c	3.59	3.72	3.66
30 cm	13.6 cde	11.3 de	12.4	0.88	1.09	0.99 bc	3.55	3.65	3.60
40 cm	17.3 abc	11.0 de	14.2	0.99	0.96	0.98 bc	3.52	3.52	3.52
50 cm	18.0 ab	11.7 de	14.8	1.12	1.19	1.15 ab	3.80	3.52	3.66
60 cm	19.3 a	10.3 e	14.7	1.41	1.27	1.34 a	3.43	3.31	3.37
Mean	16.5	11.7		1.04	1.11		3.57	3.54	
LSD (0.05)	Row distances × years int.: 4.24			Row distances: 0.19			ns**		

* Means followed by the same letter are not significantly different (P < 0.05)
** Non-significance

that of the second year (11.7) because of different climatic factors especially higher precipitation (498.3 mm), during first year compared to second year (420.5 mm). Precipitation, especially at fruiting affected the fruit yield negatively during second year.

On the other hand, seed weight per plant was not affected by row distances (Table 2). The seed weight per plant is probably not significant due to high interaction between row distances and years. In general, seed weights per plant increased by increasing row distances in both years. Our results are higher than those of reported by TAS (2004), who used different populations of 0.44–0.60 g.

Different row distances did not affect thousand seed weight significantly. In our study, the mean of thousand seed weight varied between 3.31–3.80 g, and are in agreement with previous studies reporting thousand seed weight of cumin in range of 1.90 and 3.48 g (HORNOK, 1992; CEYLAN, 1997; TURAN and ARSLAN, 1997; OZEL et al., 2001; TAS, 2004).

The different row distances and experiment years affected the seed yield of cumin (Table 3). The closer row distances of 20 and 30 cm gave the maximum seed yields of 666 and 663 kg ha^{-1}, respectively. Seed yield of the first year (626 kg ha^{-1}) was higher compared to the second year (427 kg ha^{-1}) (Table 3). Lower row distances produced higher seed yield compared to higher row distances, which was due to higher plant population per unit area and higher number of branches and umbels. KIZIL (2002) reported that seed yield was gradually reduced when the row distances increased in coriander. The results of seed yield are higher than those of TAS (2004) who reported seed yield of different cumin lines (*C. cyminum*) between 243.3 and 415.5 kg ha^{-1}. However, similar results (241–751.8 kg ha^{-1}) were reported by TURAN and ARSLAN (1997) and KAN and ARSLAN (1998).

Essential oil content of cumin in the experiment was not affected by row distances. However, the mean of essential oil contents of the first and second year were 3.08 % and 2.59 %, respectively. In respect of row distances, essential oil content was between 2.78 and 3.01 %. Essential oil content of cumin varied largely because it depends on regional variations, some researchers reported that essential oil of cumin varied between 2.5 and 5 % (SIMON et al., 1984; HORNOK, 1992; TURAN and ARSLAN, 1997; KAN and ARSLAN, 1998; AMIN, 2000; OZEL et al., 2001; LI and JIANG, 2004), our results are within the reported limits, except for EL SAWI and MOHAMED (2002) and TAS (2004) who reported very low essential oil contents of 1.2 and 1.8 %.

Increase of essential oil yield depends on essential oil content and seed yield. Seed yield significantly affected by year and row distances. Essential oil yield due to row distances varied between 9.7 and 20.1 L ha^{-1}. The highest oil content was recorded from 20 cm row distances. Essential oil yield and seed yield were reduced gradually when row distances increased.

Fifty-nine components were identified in the essential oil of cumin (Table 4). Important differences in terms of row distances were not observed in the oil composition of cumin. The major constituents in the mean of row distances were *p*-mentha-1,4-dien-7-al (23.69 %), cuminaldehyde (20.58 %), γ-terpinene (15.71 %), β-pinene (12.22 %), *p*-cymene (7.69 %), *p*-mentha-1,3-dien-7-al (6.95 %), in the oils of cumin. *p*-mentha-1,4-dien-7-al, cuminaldehyde (20.58 %), γ-terpinene, β-pinene, *p*-cymene, *p*-mentha-1,3-dien-7-al, a-phellandrene, b-phellandrene and β-myrcene consist of 90.76 percentage of total cumin oil.

p-mentha-1,4-dien-7-al (16.46–27.73 %) was found as major component of cumin essential oil. This component was in high content at 30 (27.02 %) and 60 cm (27.73 %) row distances, but its value (16.46 %) was low in the 20 cm

Table 3: The effect of row distances on seed yield, essential oil content and essential oil yield of cumin (*C. cyminum* L.)
Tabelle 3: Einfluss der Reihenweite auf den Samenertrag sowie den Gehalt und Ertrag an ätherischem Öl von Kreuzkümmel (*Cuminum cyminum* L.)

Row distances	Seed yield (kg ha^{-1})			Essential oil content (%)			Essential oil yield (L ha^{-1})		
	2003–04	2004–05	Mean	2003–04	2004–05	Mean	2003–04	2004–05	Mean
20 cm	684	648	666 a*	3.20	2.81	3.01	21.9	18.2	20.1 a
30 cm	804	521	663 a	3.12	2.56	2.84	24.9	13.1	19.0 a
40 cm	640	349	494 b	3.15	2.42	2.79	20.0	8.4	14.2 b
50 cm	594	326	460 bc	2.93	2.67	2.80	17.6	8.8	13.2 bc
60 cm	408	292	350 c	3.03	2.52	2.78	11.9	7.4	9.7 c
Mean	626 a	427 b		3.08 a	2.59 b		19.3 a	11.2 b	
LSD (0.05)	Row distances: 137.4; Years: 136.8			Years: 0.20			Row distances: 4.2; Years: 3.5		

* Means followed by the same letter are not significantly different ($P < 0.05$)

Table 4: Essential oil composition (%) of *C. cyminum* L. at different row distances (mean of two experiment years)
Tabelle 4: Zusammensetzung (%) des ätherischen Öls von Kreuzkümmel (*Cuminum cyminum* L.) bei unterschiedlicher Reihenweite (Mittelwerte über zwei Versuchsjahre)

Components	**Row distances**					
	20 cm	**30 cm**	**40 cm**	**50 cm**	**60 cm**	**Mean**
α-Thujen	0.36	0.37	0.41	0.37	0.33	0.37
α-Pinene	0.91	0.85	0.95	0.87	0.78	0.87
Camphene	0.02	0.02	0.01	0.02	0.02	0.02
Sabinene	0.13	0.19	0.52	0.35	0.32	0.30
β-Pinene	12.42	12.15	12.72	12.54	11.26	12.22
β-Myrcene	1.03	1.03	1.10	1.06	1.00	1.04
α-Phellandrene	1.62	1.85	2.03	1.82	1.85	1.83
γ-3-Carene	0.03	0.05	0.04	0.04	0.04	0.04
α-Terpinene	0.13	0.16	0.17	0.14	0.17	0.15
p-Menth-1-ene	0.01	0.01	0.01	0.02	0.02	0.01
p-Cymene	10.11	6.76	7.82	7.43	6.32	7.69
β-Phellandrene	1.09	1.01	1.07	1.05	1.01	1.05
1,8-Cineole	0.02	0.05	0.13	0.07	0.05	0.06
γ-Terpinene	13.66	16.51	16.39	16.03	15.95	15.71
α-Terpinolene	0.08	0.09	0.10	0.09	0.10	0.09
Linalool	0.82	0.04	0.01	0.03	0.04	0.19
Fenchyl alcohol	0.03	0.00	0.02	0.01	0.03	0.02
Terpenene-1-ol	0.04	0.05	0.02	0.03	0.05	0.04
Tarns-Pinocarveol	0.06	0.04	0.03	0.05	0.05	0.05
Pinocarvone	0.02	0.01	0.01	0.02	0.01	0.01
Pinocamphone	0.02	0.00	0.01	0.00	0.01	0.01
Terpinene-4-ol	0.28	0.37	0.33	0.34	0.37	0.34
Furfurylaldehyde	0.08	0.06	0.06	0.05	0.06	0.06
α-Terpineol	0.14	0.11	0.15	0.13	0.15	0.14
Pulegone	0.88	0.71	0.89	0.79	0.76	0.81
cis-Sabinol	0.09	0.08	0.09	0.09	0.09	0.09
cis-Piperitol	0.03	0.01	0.01	0.02	0.02	0.02
Cuminaldehyde	23.29	18.87	20.70	19.98	20.06	20.58
p-Menth 1-en-7-al	0.08	0.07	0.09	0.07	0.05	0.07
p-Mentha-1,3-dien-7-al	7.78	6.74	7.78	6.28	6.19	6.95
p-Mentha-1,4-dien-7-al	16.46	27.02	21.83	25.42	27.73	23.69
Carvacrol	0.12	0.08	0.05	0.08	0.17	0.10
2-Acetylcyclopentanone	0.05	0.06	0.05	0.08	0.08	0.06
p-Mentha-1,4-dien-7-ol	0.29	0.41	0.31	0.41	0.49	0.38
Dimethylphenol	0.03	0.04	0.03	0.05	0.05	0.04
Calarene	0.35	0.43	0.38	0.39	0.43	0.40
Germacrene D	0.06	0.06	0.06	0.05	0.07	0.06
β-Caryophyllene	0.33	0.45	0.39	0.39	0.44	0.40
Cuminic acid	0.42	0.01	0.05	0.05	0.03	0.11
α-Bergamotene	0.11	0.11	0.13	0.09	0.12	0.11
α-Humulene	0.04	0.04	0.03	0.04	0.05	0.04
β-Farnesene	0.54	0.58	0.53	0.57	0.57	0.56
γ-Cadinene	0.31	0.22	0.22	0.17	0.18	0.22
α-Cedrene	0.41	0.29	0.40	0.32	0.23	0.33
α-Zingiberene	0.06	0.01	0.00	0.00	0.01	0.02
Germacrene A	0.16	0.11	0.09	0.12	0.11	0.12
β-Bisabolene	0.13	0.09	0.10	0.10	0.11	0.11
β-Sesquiphellandrene	0.02	0.02	0.01	0.01	0.02	0.02
α-Chamigrene	0.00	0.00	0.00	0.01	0.01	0.00
γ-Bısabolene	0.01	0.01	0.00	0.01	0.01	0.01
Nerolidol	0.01	0.01	0.01	0.01	0.01	0.01
α-Caryophyllenyl alcohol	0.02	0.00	0.00	0.01	0.01	0.01
Caryophyllene oxide	0.19	0.10	0.13	0.14	0.09	0.13
Carotol	0.84	0.91	0.71	0.89	0.92	0.85
Copaene	0.00	0.03	0.00	0.00	0.01	0.01
α-Eudesmol	0.01	0.01	0.01	0.02	0.02	0.01
α-Cedrol	0.01	0.00	0.01	0.01	0.01	0.01
Sabinol	0.02	0.02	0.02	0.02	0.02	0.02
Dehydrosabinene	0.01	0.01	0.01	0.02	0.02	0.01

row distance. Cuminaldehyde is other major component of cumin and was found between 18.87 and 23.29 %. In contrast to *p*-mentha-1,4-dien-7-al, its the highest content was observed at 20 cm row distances (23.29 %). The highest content of γ-terpinene (16.51 %) was obtained from 30 cm row distance. *p*-cymene content increased at narrow row distances (20 cm) (10.11 %). In contrast to *p*-cymene, narrow row distances (20 cm) (13.66 %) led to lower γ-terpinene content. β-pinene content was 12.22 % across row distances and, it did not varied with varying row distances. These major components in *C. cyminum* were also reported by IACOBELLIS et al. (2005), but according to GACHKAR et al. (2007) they were α-pinene (29.1 %), limonene (21.5 %), 1,8 cineole (17.9 %) and linalool (10.4 %). JALALI-HERAVI et al. (2007) reported that major components of Iranian cumin essential oil are γ-terpinene (15.82 %), 2-methyl-3-phenyl-propanal (32.27 %) and myrtenal (11.64 %).

The results of γ-terpinene, *p*-cymene are close to those of LI and JIANG (2004), who reported the chemical composition of the essential oil cumin as cuminal (36.31 %), cuminic alcohol (16.92 %), γ-terpinene (11.14 %), safranal (10.87 %), *p*-cymene (9.85 %) and β-pinene (7.75 %), respectively.

The literature shows that the essential oil composition of cumin is very variable. Some researchers emphasise that the chemical composition of cumin from different origin vary (AMIN, 2000; LI and JIANG, 2004). These differences in the chemical compositions of essential oils could be attributed to climatic effects on the plants (GACHKAR et al., 2007). Our results indicated that Turkish origin cumin was rich in terms of *p*-mentha-1,4-dien-7-al, cuminaldehyde, γ-terpinene, β-pinene, *p*-cymene and *p*-mentha-1,3-dien-7-al. Moreover, BASER et al. (1992) found that Turkish cumin seed oil was characterized by high amount of cuminaldehyde, *p*-mentha-1,3-dien-7-al, *p*-mentha-1,4-dien-7-al, γ-terpinene, *p*-cymene, β-pinene and perilla aldehyde. Moreover, EL-SAWI and MOHAMED (2002) reported that the Egyptian cumin essential oil was characterized by cuminaldehyde (53.6 %).

4 Conclusions

It was concluded that, under Diyarbakir ecological conditions the cumin should be cultivated with row distances of 20 to 30 cm to get maximum seed yield. Moreover, cumin has high essential oil content, consisting of major compounds *p*-mentha-1,4-dien-7-al, cuminaldehyde, γ-terpinene, β-pinene and *p*-cymene.

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