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Report

Essential oil composition of sixteen elite cultivars of *Mentha* from western Himalayan region, India

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Abstract: The hydrodistilled essential oils of 16 cultivars of *Mentha*, viz. *M. arvensis* L., *M. spicata* L. and *M. citrata* Ehrh., were analysed and compared by gas chromatography and gas chromatography-mass spectrometry. Fifty-seven constituents representing 92.8-99.8% of the total essential oil composition were identified. Monoterpenoids (88.1-98.6%) are the major constituents of the essential oils. The major constituents of the oils in 9 cultivars of *M. arvensis* are menthol (73.7-85.8%), menthone (1.5-11.0%), menthyl acetate (0.5-5.3%), isomenthone (2.1-3.9%), limonene (1.2-3.3%) and neomenthol (1.9-2.5%). Carvone (51.3-65.1%), limonene (15.1-25.2%), β-pinene (1.3-3.2%) and 1,8-cineole (≤0.1-3.6%) are the major constituents in 5 cultivars of *M. spicata*, while in one cultivar (Ganga) of *M. spicata* the major constituents are piperitenone oxide (76.7%), α-terpineol (4.9%) and limonene (4.7%). Linalool (59.7%), linalyl acetate (18.4%), nerol (2.0%), *trans*-p-menth-1-en-2-ol (1.8%), α-terpineol (1.5%) and limonene (1.1%) are the major constituents of *M. citrata*.

Keywords: *Mentha arvensis*, *Mentha spicata*, *Mentha citrata*, essential oils, western Himalayan region

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INTRODUCTION

Mentha species (commonly known as mint), belonging to family Lamiaceae, constitute one of the most popular essential oil crops. They are widely distributed and cultivated in the temperate and subtemperate regions of the world [1]. Among them, *Mentha arvensis* (corn mint), *M. piperita* (peppermint), *M. citrata* (bergamot mint) and *M. spicata* (spearmint) are the main species cultivated in the temperate, Mediterranean and subtropical regions [2-4]. These species show considerable chemical diversity in the essential oil composition and are considered industrial crops as they produce a number of commercially valuable essential oils containing a complex mixture of monoterpenoids which are extensively used in pharmaceutical, food, flavour, cosmetics, beverages and allied industries [5-23]. Earlier reports on the chemical composition of oils from *Mentha* species from Himalayan region showed menthol (61.92-89.30%) and carvone (59.62-76.65%) as major constituents of oils from *M. arvensis* and *M. spicata* respectively [16-20]. Menthol (30.3-47.8%), menthone (4.5-48.6%), menthyl acetate (1.0-9.5%), menthofuran (0.1-14.6%), 1,8-cineole (4.1-8.9%), neomenthol (1.5-4.9%) and isomenthone (1.2-3.9%) were reported as major constituents of oils from *M. piperita* cultivars grown in mid- and foothills of Uttarakhand, India [21]. Piperitone, piperitenone oxide and piperitone epoxides were reported as the major oil constituents of *M. longifolia* [22]. However, another report on oil of *M. longifolia* from Himalayan region showed carvone (61.12-78.70%), dihydrocarveol (0.40-9.45%), *cis*-carvyl acetate (0.16-6.43%) and germacrene D (1.25-5.73%) as major constituents [23]. In oil of *M. citrata*, linalool (32.86-46.31%), linalyl acetate (19.27-37.72%) and α-terpineol (2.90-4.61%) were reported as major constituents at different crop stages [17]. India fulfills over 80% of the total global demand with production of more than 16,000 ton of mint oil, spreading mainly over the Indo-Gangetic plains and north-west India [21, 24, 25]. The essential oil composition of various mint species shows remarkable variation due to their hybrid nature and existence of various chemotypes, along with common climatic and geographical variations. The present study aims to assess the yield and quality performance of oils from prevalent commercial cultivars of *Mentha*. The essential oil composition of 16 cultivars of *Mentha* species, viz. *M. arvensis* L., *M. spicata* L. and *M. citrata* Ehrh., from the foothills of western Himalayas, are compared in detail.

MATERIALS AND METHODS

Plant Materials and Isolation of Essential Oils

Fresh aerial parts of different cultivars of *Mentha* species were collected from the experimental field of Research Centre, Central Institute of Medicinal and Aromatic Plants, Pantnagar, Uttarakhand. The experimental site is located at the latitude of 29°N and longitude of 79.38°E, at an altitude of 243.84 metres at the foothills of the Himalayas with a hot summer and chilled winter climate. The maximum temperature ranges between 35-45°C and the minimum between 2-5°C with average rainfall of 1350 mm during the year. The soil was clay loam in texture with neutral reaction (pH 7.1). The monsoon usually breaks in mid June and continues up to September. Botanical authentication of the plant materials was carried out at the taxonomy department of CIMAP Research Centre, Pantnagar. All cultivars were planted in the month of February by their vegetative propagules (suckers and runners) at inter-row space of 50 cm and raised by following normal agricultural practices. The origins of all the cultivars studied are given in Table 1.

Table 1. Genetic origin of commercially grown elite cultivars of *Mentha*

Plant	Cultivar	Abbreviation	Origin/ Development	Reference
Mentha arvensis L. (Japanese mint)	Shivalik	I	Introduction from China	26
	Himalaya	II	Hybrid of Gomti and Kalka	26
	MAS-I	III	Somatic variant of the MA-3 accession from Thailand	26
	Damroo	IV	Selection in OPSPs* of the variety Shivalik	19
	Kalka	V	Cross-hybridisation	19
	Gomti	VI	Seedling variant of Shivalik	27
	Kushal	VII	In vitro somaclonal selection	28
	Saksham	VIII	Clonal selection	29
	Kosi	IX	Half-sib progeny selection in cv. Kalka	30
Mentha spicata L. (Spearmint)	MSS-5	X	Clonal selection	31
	Neera	XI	Induced mutagenesis	31
	Arka	XII	Induced mutagenesis	31
	Neerkalka	XIII	Interspecific hybridisation of *M. arvensis* cv. Kalka and *M. spicata* cv. Neera	32
	Supriya	XIV	Selection of superior strain in a northern Himalayan accession	33
	Ganga	XV	Clonal selection	34
Mentha citrata L. (Bergamot mint)	Kiran	XVI	Induced mutagenesis	35

* Open Pollinated Seed Progenies

Freshly harvested samples (100 g each) were hydrodistilled in a Clevenger apparatus for 3 hr. The oils were collected, dehydrated by anhydrous sodium sulphate, stored in amber vials and put in a cool and dark place prior to analysis. The extraction yield was calculated in mL of oil per 100 g of samples.

Gas Chromatographic (GC) Analysis

GC analysis of the essential oil samples was carried out on a Nucon gas chromatograph model 5765 equipped with a flame ionisation detector (FID) and CP Wax-52 CB (30 m × 0.32 i.d., 0.25 µm film thickness) fused silica capillary column. Hydrogen was used as carrier gas at 1.0 mL/min. Temperature programming was done between 70-230°C at 4°C/min. with final hold time of 10 min. Injector and detector temperatures were 210°C and 220°C respectively. Injection volume was 0.02 µL neat and split ratio was 1:40. The percentage of the individual constituent was calculated by electronic integration of the FID peak areas without response factor correction. GC analysis of a few oil samples was also carried out for cross identification of constituents by retention index (RI) on a Varian CP-3800 GC apparatus using a DB-5 column (30 m x 0.25 mm i.d., film thickness 0.25 µm) equipped with an FID. The column temperature (60-240°C) was programmed at 3°C/min. with final hold time of 10 min. using nitrogen as carrier gas at 1 mL/min.

Analysis by Gas Chromatography-Mass Spectrometry (GC-MS)

GC-MS analysis of the essential oils was performed with a Perkin-Elmer turbomass quadrupole mass spectrometer fitted with an Equity-5 fused silica capillary column (60 m × 0.32 mm i.d., film thickness 0.25 µm). The oven column temperature was 70-250°C, programmed at 3°C/min. with initial and final hold time of 2 min., using helium as carrier gas at constant pressure (10 psi). The injection volume was 0.02 µL neat with split ratio of 1:30. The injector and ion source temperature was 250°C. The ionisation energy was 70 eV (EI) with a mass scan range of 40-400 amu.

Identification of Constituents

Identification of constituents was done on the basis of retention time, RI (determined with reference to homologous series of *n*-alkanes (C_9-C_{24}) under identical experimental condition in both polar and non polar columns), coinjection with standards, mass spectra library search (NIST/EPA/NIH version 2.1 and Wiley registry of mass spectral data, 7th edition), and by comparing RI and mass spectral data with literature [36, 37]. For quantification, the relative area percentage obtained for each constituent from the GC/FID analysis of the oils was used to calculate the mean values without using correction factors.

RESULTS AND DISCUSSION

Analysis results of the hydrodistilled essential oil of *Mentha* cultivars as well as oil yields are presented Table 2 in order of their elution on CP Wax 52 CB (0.30 m × 0.32 mm) capillary column. Fifty-seven compounds are identified, representing 92.8-99.8% of the total oil composition, which is mainly dominated by monoterpenoids (88.1-98.6%). Thirty-three constituents are identified in the essential oils of nine cultivars of *M. arvensis* accounting for 98.8-99.8% of oil composition. The major constituents of oils are monoterpenoids (97.7-98.6%), represented by 92.1-94.9% of oxygenated monoterpenes and 3.5-5.8% of hydrocarbons. Menthol (73.7-85.8%), menthone (1.5-11.0%), menthyl acetate (0.5-5.3%), isomenthone (2.1-3.9%), limonene (1.2-3.3%) and neomenthol (1.9-2.5%) are the major identified constituents. All the cultivars are rich in menthol (73.7%-85.8%) and the highest menthol content is found in MAS-1 (85.8%) followed by Kosi (78.7%), Shivalik (78.1%) and Damroo (78.0%). The menthone content varies between 1.5-11.0%, with the highest in Gomti (11.0%) followed by Kalka (7.6%), while MAS-1 contains a relatively low amount (1.5%).

Although the major characteristic constituents in all oils are the same, there are considerable variations in the quantitative make-up of the constituents of the essential oils. Earlier, menthol (61.9-82.1%), menthone (3.4-19.3%), isomenthone (2.3-6.1%), limonene (0.2-4.7%), menthyl acetate (0.5-4.4%) and neomenthol (1.3-2.4%) were reported as major constituents in different crop stages of *M. arvensis* from the mid-hills of Uttrakhand [16], while *M. arvensis* grown in foothill conditions showed high menthol content (77.5-89.3%), along with menthone, iso-menthone, menthyl acetate, neo menthol and limonene as other major constituents [19]. *M. arvensis* cv. Shivalik grown in the tropical climate of India shows menthol (53.2-82.3%), menthone (5.2-30.2%), isomenthone (2.1-3.5%) and neomenthol (0.9-2.0%) as major constituents from its flowering whole herb, flowers, leaves and stem [38]. In the present analysis menthol (73.7-85.8%) is also the major constituent in all cultivars of *M. arvensis*, with slight qualitative and quantitative variations in other individual oil constituents.

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Table 2. Comparative oil yield and chemical composition of commercially grown elite cultivars of *Mentha*

Compound[*]	RI[a]	RI[b]	% (FID)															
			I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*XIII*	*XIV*	*XV*	*XVI*
α-Pinene	1026	939	0.5	0.7	0.5	0.7	0.5	0.7	0.7	0.6	t	0.9	1.6	1.6	0.8	0.8	0.4	0.8
α-Thujene	1028	928	t	t	t	1.0	-	-	t	-	t	-	-	0.2	1.4	-	0.6	-
β-Pinene	1104	982	0.9	1.1	0.2	t	0.7	1.0	0.9	1.0	0.9	1.4	3.2	2.0	2.4	1.3	t	0.8
Sabinene	1116	978	t	t	t	t	-	-	t	t	t	-	-	t	-	-	t	0.3
β-Myrcene	1158	994	0.5	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6	2.3	0.2	2.8	t	1.0	0.8	0.3
α-Terpinene	1177	1022	-	-	-	-	-	-	-	-	-	t	t	0.2	-	-	t	-
Limonene	1195	1034	1.6	3.3	2.5	2.2	3.0	1.2	2.9	3.2	2.3	15.1	19.3	20.5	16.5	25.2	4.7	1.1
1,8-Cineole	1199	1038	t	t	t	t	t	0.4	-	t	-	3.0	t	3.6	3.0	t	0.4	0.9
(*Z*)-β-Ocimene	1230	1042	t	0.1	-	-	t	0.1	t	t	t	0.2	0.4	-	0.2	t	t	0.1
γ-Terpinene	1244	1065	t	t	-	-	t	t	t	t	t	0.2	-	0.5	0.2	0.2	t	0.2
(*E*)-β-Ocimene	1245	1051	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	t	0.2
p-Cymene	1271	1029	t	t	t	t	-	-	-	t	-	0.1	0.6	0.2	0.1	0.1	t	-
Terpinolene	1278	1089	-	-	-	-	-	-	-	-	-	t	0.3	t	t	t	t	0.2
3-Octyl acetate	1286	1261	-	-	-	-	-	-	-	-	-	0.2	1.0	0.4	0.2	0.9	-	-
(*Z*)-3-Hexenol	1391	841	0.1	0.2	t	0.1	0.1	t	0.1	0.1	0.1	-	-	-	-	-	-	-
3-Octanal	1428	994	0.0	0.3	0.6	0.7	0.2	1.2	0.2	0.3	0.7	0.5	1.9	0.6	0.5	0.1	0.2	-
trans-Linalool oxide	1450	1093	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3
α-Cubebene	1458	1357	-	-	-	-	-	-	-	-	-	t	0.8	t	t	0.6	-	-
Menthone	1460	1155	5.5	5.8	1.5	5.0	7.6	11.0	5.0	6.5	5.6	-	-	-	1.7	0.9	-	-
trans-Sabinene hydrate	1463	1069	t	-	t	t	-	t	t	-	t	1.7	1.1	1.5	t	0.4	0.2	-
cis-Linalool oxide	1478	1074	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6
Isomenthone	1488	1165	3.2	3.9	2.1	2.9	3.4	3.2	3.4	3.6	3.3	-	t	0.1	t	-	-	-
β-Bourbonene	1508	1386	-	-	-	-	-	-	-	-	-	t	0.8	t	t	0.2	0.3	0.9
Linalool	1535	1101	-	t	-	t	-	t	0.1	-	-	-	0.7	0.1	1.7	1.1	1.6	59.7
Linalyl acetate	1540	1256	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.4
trans-p-Menth-1-en-2-ol	1558	1140	-	-	-	-	-	-	-	-	-	t	0.9	0.5	0.1	t	-	1.8
Menthyl acetate	1560	1296	3.7	2.1	0.5	3.7	1.5	2.3	5.3	1.8	2.2	-	t	-	0.5	-	-	-
iso-Pulegol	1574	1158	0.6	0.9	0.4	0.5	0.8	0.4	0.8	0.8	0.6	-	-	-	-	-	-	-
β-Caryophyllene	1590	1420	t	t	0.5	t	0.1	0.2	0.1	0.1	0.1	1.0	1.8	1.6	1.0	0.3	0.9	t
Neomenthol	1595	1165	2.4	2.0	2.1	2.4	2.2	1.9	2.3	2.2	2.5	-	-	-	t	-	-	-
Terpinen-4-ol	1606	1180	-	t	0.1	0.1	t	0.1	t	-	-	t	0.3	0.0	t	0.7	0.7	t
(*Z*)-Dihydro carvone	1624	1193	-	-	-	-	-	-	-	-	-	0.2	1.2	0.6	0.2	0.8	-	-
Pulegone	1646	1238	0.3	0.3	0.5	0.3	0.2	0.1	0.4	0.2	0.3	-	-	-	-	0.1	-	-
Menthol	1650	1176	78.1	76.4	85.8	78.0	77.1	73.7	75.4	77.3	78.7	-	-	-	0.7	-	-	-

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Table 2. (Continued)

Compound*	RI[a]	RI[b]	% (FID)															
			I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*XIII*	*XIV*	*XV*	*XVI*
(*E*)-β-Farnesene	1670	1188	0.4	0.1	0.1	0.2	t	0.3	t	t	0.2	0.7	t	0.1	-	0.7	t	t
Isomenthol	1673	1459	0.1	0.4	0.3	0.2	0.4	0.4	0.4	0.3	0.2	-	-	-	-	-	-	-
α-Humulene	1675	1454	-	-	-	-	-	-	-	-	-	t	0.4	0.6	-	t	t	0.2
α-Terpineol	1682	1192	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	t	0.7	0.1	t	0.1	4.9	1.5
Germacrene D	1701	1481	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	1.1	t	0.2	1.1	0.2	0.4	0.1
Piperitone	1748	1255	0.5	0.4	0.6	0.5	0.5	0.5	0.5	0.5	0.5	-	-	0.2	t	0.1	0.5	-
Carvone	1755	1242	t	t	0.1	0.1	t	t	0.1	t	t	64.8	54.0	51.3	65.1	58.3	t	-
Bicyclogermacrene	1756	1495	-	-	-	-	-	-	-	-	-	0.3	0.2	0.3	t	0.4	-	-
Geranyl acetate	1765	1380	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7
Citronellol	1772	1225	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2
Nerol	1804	1226	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0
trans-Carveol	1845	1218	-	-	-	-	-	-	-	-	-	0.9	1.0	0.1	0.1	0.4	-	-
Geraniol	1857	1254	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	t
cis-Carveol	1882	1230	-	-	-	-	-	-	-	-	-	0.3	1.4	0.3	0.9	1.1	-	-
Myrtanol	1889	1194	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-
cis-Dihydrocarveol	1912	1190	-	-	-	-	-	-	-	-	-	0.2	0.9	0.4	0.1	0.3	-	-
cis-Carvyl acetate	1930	1360	-	-	-	-	-	-	-	-	-	0.1	0.8	1.1	0.2	0.2	-	-
Piperitenone oxide	1984	1363	-	-	-	-	-	-	-	-	-	t	0.6	0.2	0.1	t	76.7	-
Caryophyllene oxide	1989	1584	t	t	-	t	t	t	t	-	-	0.3	0.8	0.4	0.3	0.2	t	0.9
Germacrene D-4-ol	2069	1578	0.1	0.1	0.4	0.1	t	t	0.1	0.1	0.1	-	-	-	-	t	t	-
Viridiflorol	2104	1592	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	0.2	-
Spathulenol	2143	1579	t	0.1	-	t	0.1	0.1	0.1	0.1	t	t	0.1	0.7	-	0.6	t	0.3
β-Eudesmol	2154	1650	-	-	-	-	-	-	-	-	-	t	0.2	0.2	-	0.1	t	0.3
Aliphatic compounds			0.1	0.5	0.6	0.8	0.3	1.2	0.3	0.4	0.8	0.7	2.9	1.0	0.7	1.0	0.2	-
Monoterpene hydrocarbons			3.5	5.8	3.7	4.5	4.8	3.6	5.1	5.4	3.8	20.2	25.6	28.0	21.6	28.8	6.5	4.0
Oxygenated monoterpenes			94.9	92.1	94.1	93.9	93.5	94.1	93.5	93.1	94.1	71.2	64.4	60.1	74.4	64.5	85.7	86.1
Sesquiterpene hydrocarbons			0.2	0.5	1.0	0.3	0.6	0.7	0.6	0.5	0.4	3.1	3.2	2.8	2.1	1.8	1.6	1.2
Oxygenated sesquiterpenes			0.1	0.2	0.4	0.1	0.1	0.1	0.2	0.2	0.1	0.3	1.1	1.3	0.3	1.0	0.2	1.5
Total identified			98.8	99.1	99.8	99.6	99.3	99.7	99.7	99.6	99.2	95.5	97.2	93.2	99.1	97.7	94.2	92.8
Oil yield (%, v/w)			1.0	0.9	0.8	1.1	1.0	1.2	1.1	0.9	1.3	0.8	0.6	0.7	0.7	0.5	0.4	0.6

*Mode of identification: retention index (RI), coinjection with standard/peak enrichment with known oil constituent, MS (GC-MS), [a]RI: retention index on CP Wax 52 CB (30 m × 0.32 mm); [b]RI: retention index on DB-5 fused silica capillary column (30 m × 0.25 mm); t = trace (<0.1%), (-) = not detected; for plant abbreviations (I-XVI), see Table 1.

Of the 6 cultivars of *M. spicata* (spearmint), carvone (51.3-65.1%) is the main constituent in 5 cultivars followed by limonene (15.1-25.2%), 1,8-cineole (≤0.1-3.6%), β-pinene (1.3-3.2%), β-myrcene (≤0.1-2.8%) and β-caryophyllene (0.3-1.8%). The oil of Neerkalka contains the highest concentration of carvone (65.1%) followed by MSS-5 (64.8%), Supriya (58.3%), Neera (54.0%) and Arka (51.3%). Neerkalka also contains menthone (1.7%), menthol (0.7%) and menthyl acetate (0.5%), which are not noticed in other cultivars of *M. spicata* except Supriya (0.9% menthone). The presence of lower concentrations of menthone, menthyl acetate and menthol in cv. Neerkalka is due to the hybrid nature of this cultivar [32]. In contrast, cv. Ganga of *M. spicata* has a different oil composition characterised by piperitenone oxide (76.7%), α-terpineol (4.9%), limonene (4.7%) and linalool (1.6%) as major constituents.

Carvone-rich spearmint has been investigated earlier in India as well as other countries. Earlier study showed carvone (59.6-72.4%) and limonene (10.7-24.8%) as major constituents of oil of *M. spicata* from the mid-hills of Himalayan region of India at different crop stages [17], while *M. spicata* collected from different subtropical and temperate zones of north-west Himalayan region of India showed carvone (49.6-76.6%) followed by limonene (9.5-22.3%), 1,8-cineole (1.3-2.6%) and *trans*-carveol (0.3-1.5%) in its oils [20]. In north Indian plains carvone content varies between 45.9-77.1% [18]. The percentage of carvone also varies in oil of spearmint grown in different countries, e.g. Egypt (46.4-68.5%) [39-40], Canada (59.0-74.0%) [41], Turkey (78.3-82.2%) [42, 43] and China (55.4-74.6%) [44]. *M. spicata* grown in other countries also contains carvone as one of the major constituents of its essential oil, e.g. Bangladesh (73.2 %) [45], Algeria (59.4%) [46] and Morocco (29.0%) [47]. Spearmint grown in Iran was found to contain less amount of carvone (22.4%) [48]. However, the essential oil of *M. spicata* chemotype from Tunisia shows a entirely different oil composition with menthone (32.7%) and pulegone (26.6%) as major constituents [49]. Linalool-rich (82.8%) chemotype of *M. spicata* was also reported from Turkey [43]. In another report on *M. spicata* grown in Iran, α-terpinene (19.7%), piperitenone oxide (19.3%), isomenthone (10.3%) and β-caryophyllene (7.6%) were reported as major constituents [50].

In the oil of *M. citrata* cv. Kiran, 28 components are identified, representing about 92.8% of the whole oil. The major constituents are linalool (59.7%), linalyl acetate (18.4%), nerol (2.0%), *trans*-p-menth-1-en-2-ol (1.8%), α-terpineol (1.5%) and limonene (1.1%). Nerol (2.0%), geranyl acetate (0.7%), citronellol (0.2%) and geraniol (≤0.1%) are the characteristic constituents which have not been reported in other cultivars of *Mentha* species.

CONCLUSIONS

The essential oil profile of 16 cultivars of *Mentha* are useful for commercial purpose as they possess a range of aroma chemicals used in perfumery, flavour, pharmaceutical and other allied industries. Moreover, the major/marker constituents in their essential oils may be utilised as an important tool in oil authentication. All the cultivars of *M. arvensis* yield oils rich in menthol (73.7-85.8%) while the five cultivars of *M. spicata* are a very good source of carvone (51.6-65.1%) and cultivar Ganga of *M. spicata* is a good source of piperitenone oxide (76.7%). The essential oil of cultivar Kiran of *M. citrata* is an excellent source of linalool and linalyl acetate.

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