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COMPONENT COMPOSITION OF ESSENTIAL OIL FROM *Artemisia annua* AND *A. scoparia*

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We have continued research on the qualitative composition and quantitative content of components and the mass fraction of essential oil from *Artemisia annua* L. and *A. scoparia* Waldst. et Kit during phases of spring emergence of runners (I), budding (II), mass flowering (III), and seed ripening (IV). Essential oils from these plants were produced and their component compositions were established as before [1]. *A. annua* and *A. scoparia* were selected from the wild flora of Crimea. The mass fractions of essential oil of *A. annua* calculated per raw and dry weight were phase I, 0.17% (0.49); II, 0.12 (0.27); III, 0.88 (2.56); IV, 0.42 (0.78). The mass fractions of essential oil of *A. scoparia* calculated per raw and dry weight were phase I, 0.25% (0.61); II, 0.25 (0.67); III, 0.44 (1.13); IV, 0.26 (0.70). Tables 1 and 2 give the quantitative contents of the essential oil components of the studied plants over the whole vegetation.

We studied the qualitative composition and quantitative content of all essential oil components of these plants over the whole vegetation in Crimean Steppe soil (brown soil) and climate conditions because separate components of the essential oil of *A. scoparia* can be used in the perfume and cosmetic industry; of *A. annua*, in the medical sector. The study was performed for the first time. The results led to the conclusion that agricultural production of *A. scoparia* and *A. annua* in the AR Crimea is feasible.

Essential oil of *A. annua* is known to contain five main components including α-pinene, 1,8-cineol, ylangene, β-caryophyllene, and β-selinene in addition to a small amount of hydrocarbons camphene, β-pinene, sabinene, α- and γ-terpinenes, *p*-cymene, β-elemene, alloaromadendrene, humulene, γ- and δ-cadinenes, artemisia ketone, artemisia alcohol acetate ester, artemisia alcohol, camphor, terpineol-4, borneol, terpineol, and *cis*- and *trans*-pinocarveols. The mass fraction of essential oil in the plant material varied depending on the habitat and vegetative phase in the range 0.29–0.62% [2, 3].

Various researchers have observed in *A. annua* arteanuin A, hydroartenuin, artemisic acid [4], epoxymartenuinic acid [5], artemisitene [6], and β-amyrin acetate [7].

The mass fraction of essential oil obtained from the aerial part of *A. scoparia* collected in Turkmenistan made up 0.29–0.79% and contained anethole. Plants collected in Uzbekistan contained in leaves and inflorescences 1.28% essential oil; stems, 0.22%. They contained pinene (40%), myrcene (10%), and an insignificant amount of esters. The mass fraction of essential oil in wild *A. scoparia* collected in Kazakhstan varied from 0.08 to 1%. The oil contained phenols (up to 1.5%). The essential oil content in wild plants of the Caucases was 0.4–1.5%. Its composition included phenols, in particular, eugenol. The amount of essential oil in this same plant from Kalmykia varied from 0.1 to 0.8%. Selection of *A. scoparia* was carried out in Nikita Botanical Garden (Nikita, AR Crimea, Ukraine). Specimens were selected from the natural populations of south Ukraine, Krasnodarsk Krai, the Republic of Zakavkaz′ya, and Central Asia. The mass fraction of essential oil in them was 0.41–0.73% with a high content of eugenol [8].

Furthermore, it is known that essential oil of this plant contains aldehydes (anisic and cinnamic) and methylated phenols (thymol and *trans*-methyleugenol). The dominant component was *trans*-methyleugenol, the content of which varied from 37.2 to 89.2%. The mass fraction of essential oil was 0.73% (data are given for raw mass of one of the varieties) [9].

Our research found that the principal components of the 55 found in *A. annua* essential oil during the whole vegetation were ketones such as artemisia ketone and camphor (quantitative content by vegetation phases were I, 24.38%, 22.56; II, 47.97, 13.56; III, 46.15, 16.44; IV, 45.58, 19.13. 1,8-Cineol (13.77 and 13.92) was added to the dominant compounds during phases II and IV, respectively (Table 1).

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TABLE 1. Qualitative Composition and Quantitative Content of Essential Oil Components of *A. annua* L. During Phases I-IV in Crimean Region Brown Soils

Component	I		II		III		IV	
	w, %	t, min	w, %	t, min	w, %	t, min	w, %	t, min
Ethylisovalerate	–	–	0.30	4.68	–	–	0.32	4.68
Santolinatriene	–	–	0.56	6.13	0.33	6.22	0.16	6.12
α-Pinene	4.10	7.03	4.02	6.94	4.33	7.03	0.44	6.92
Propylisovalerate	–	–	–	–	0.23	7.44	–	–
Camphene	2.99	7.51	2.18	7.41	2.44	7.51	2.34	7.40
Sabinene	1.21	8.37	1.87	8.27	0.80	8.37	1.05	8.26
β-Pinene	0.84	8.47	0.98	8.37	0.79	8.47	0.28	8.36
Myrcene	-	–	1.23	8.91	3.59	9.01	0.40	8.91
Yomogi alcohol	0.84	9.35	0.85	9.32	1.46	9.36	1.39	9.34
3-Hexen-1-ol acetate	0.25	9.64	–	–	–	–	–	–
α-Terpinene	-	–	–	–	–	–	0.18	9.85
Limonene	0.19	10.44	0.21	10.34	0.20	10.44	0.17	10.34
1,8-Cineol	6.82	10.55	13.77	10.49	6.14	10.55	13.92	10.51
Dihydrotagetol	0.50	10.79	0.28	10.75	0.21	10.80	0.19	10.77
γ-Terpinene	0.27	11.67	0.16	11.57	0.23	11.67	0.33	11.56
Artemisia ketone	24.38	11.88	47.97	11.86	46.15	11.94	45.58	11.88
trans-Sabinenehydrate	–	–	0.35	12.04	–	–	0.18	12.06
3-Hexenylbutyrate	–	–	–	–	–	–	0.22	12.17
Artemisia alcohol	2.75	12.76	5.16	12.74	3.55	12.78	4.68	12.75
cis-Sabinenehydrate	–	–	0.15	13.34	–	–	–	–
2,8-Menthadien-1-ol	–	–	–	–	–	–	2.44	13.60
α-Thujone	0.19	13.66	–	–	–	–	–	–
2,2,3-Trimethyl-3-cyclopenten-1-aldehyde	0.33	14.55	–	–	0.38	14.54	–	–
trans-Pinocarveol	1.31	15.14	1.10	15.10	1.52	15.13	–	–
2-Methyl-6-methylen-1,7-octadien-3-one	–	–	–	–	0.56	15.25	–	–
Camphor	22.56	15.40	13.56	15.31	16.44	15.39	19.13	15.36
2,6-Dimethyl-1,5,7-octatrien-3-ol	–	–	–	–	1.01	15.96	1.44	15.98
Pinocarvone	–	–	0.55	16.17	–	–	0.17	16.07
2(10)-Pinen-3-one	1.41	16.14	–	–	1.33	16.14	–	–
Borneol	0.44	16.28	–	–	0.19	16.29	–	–
Lavandulol	0.21	16.36	0.79	16.36	0.31	16.39	–	–
Terpinen-4-ol	0.70	16.81	0.43	16.76	0.40	16.81	0.80	16.78
3,3,6-Trimethyl-1,5-heptadien-4-one	1.09	17.40	–	–	0.35	17.41	–	–
α-Terpineol	–	–	0.72	17.41	–	–	0.17	17.42
Myrtenal	–	–	0.15	17.55	–	–	0.22	17.56
Murtenol	0.41	17.65	0.21	17.68	0.44	17.64	–	–
Thymol	–	–	–	–	–	–	0.21	22.14
Carvacrol	0.41	22.37	–	–	–	–	–	–
Eugenol	–	–	–	–	0.24	24.69	–	–
α-Cubebene	0.19	25.42	–	–	–	–	0.18	25.27
Isovalerianic acid phenylmethylester	1.23	25.95	0.21	25.87	0.35	25.94	0.16	25.87
cis-Jasmone	0.28	26.46	–	–	–	–	–	–
Methyleugenol	1.01	26.74	–	–	–	–	–	–
Caryophyllene	1.18	27.24	0.66	27.10	0.75	27.23	0.47	27.08
β-Farnesene	0.35	28.86	–	–	–	–	–	–
γ-Selinene	–	–	0.20	29.41	–	–	–	–
Germacrene D	2.20	29.78	0.62	29.65	0.59	29.77	0.88	29.63
β-Selinene	0.39	29.78	0.40	29.84	–	–	0.24	29.83
Eudesma-4(14),11-diene	9.43	30.01	–	–	2.33	29.97	–	–
Elemicine	0.36	32.87	–	–	0.26	32.87	–	–
Aromadendrone epoxide	–	–	0.20	33.69	–	–	0.39	33.68
Cadinol	0.85	33.78	–	–	0.27	33.77	–	–
Caryophyllene oxide	0.78	35.10	–	–	–	–	–	–
Cubebol	1.43	35.71	–	–	–	–	–	–
Ledene oxide	0.96	37.60	–	–	0.30	37.60	0.23	37.60

w, content (%); t, retention time (min).

TABLE 2. Qualitative Composition and Quantitative Content of Essential-Oil Components of *Artemisia scoparia* Waldst. et Kit During Phases I-IV in Crimean Region Brown Soils

Component	I		II		III		IV	
	w, %	t, min	w, %	t, min	w, %	t, min	w, %	t, min
α-Pinene	–	–	0.16	6.94	0.11	6.93	0.80	6.92
Sabinene	–	–	–	–	–	–	0.18	8.27
β-Pinene	0.13	8.36	0.92	8.37	0.91	8.37	8.51	8.38
Myrcene	0.12	8.85	0.18	8.91	0.06	8.90	0.39	8.90
Limonene	0.18	10.30	0.42	10.34	0.29	10.33	1.93	10.33
1,8-Cineol	–	–	–	–	0.12	10.48	0.27	10.48
trans-Ocimene	–	–	0.16	10.75	0.50	10.74	4.11	10.75
cis-Ocimene	–	–	–	–	0.12	11.15	0.53	11.14
Linalool	–	–	–	–	–	–	0.24	13.24
Scoparene	1.04	21.30	1.46	21.52	2.46	21.52	1.27	21.50
Thymol	–	–	0.25	22.14	–	–	–	–
Eugenol	–	–	2.28	24.70	2.58	24.70	3.24	24.68
Agropyrene	0.58	25.64	0.53	25.92	0.43	25.91	0.50	25.90
Methyleugenol	0.12	26.75	–	–	–	–	–	–
Caryophyllene	–	–	1.06	27.11	0.09	27.10	1.51	27.09
β-Farnesene	–	–	–	–	–	–	0.23	28.70
β-Himachalene	–	–	0.51	29.62	0.15	29.62	1.55	29.61
Germacrene B	–	–	1.22	30.27	–	–	–	–
ap-Curcumene	–	–	–	–	–	–	0.13	29.75
Bicyclogermacrene	–	–	–	–	–	–	1.00	30.25
Capillene	96.72	30.35	90.09	30.77	89.37	30.77	73.38	30.66
Spatulenol	0.56	33.45	0.17	33.56	–	–	0.23	33.53
Caryophyllene oxide	0.15	33.61	–	–	–	–	–	
Capillin	0.40	35.84	–	–	–	–	–	–
Eugenol acetate	–	–	0.39	40.32	0.98	40.31	–	–

w, content (%); t, retention time (min).

Essential oil of *A. annua* contained groups of components, the content of which was from 2 to 10% (medium values), that were present either during the whole vegetation or in its separate phases or in one of the phases. The first group included camphene, artemisia alcohol (by vegetation phases I, 2.99%, 2.75; II, 2.18, 5.16; III, 2.44, 3.55; IV, 2.34, 4.68). The second group included α-pinene and eudesma-4(14),11-diene (by vegetation phases I, 4.10%, 9.43; II, 4.02, not observed; III, 4.33, 2.33; IV, 0.44, not observed). The third group included myrcene and germacrene D (by vegetation phases I, not observed, 2.20%; II, 1.23, 0.62; III, 3.59, 0.59; IV, 0.40, 0.88) (Table 1).

Most of the essential oil components were minor. We divided them into two groups, those always present and those sporadically appearing. The first group included sabinene, β-pinene, yomogi alcohol, limonene, dihydrotagetol, etc.; the second, ethylisovalerate, 3-hexen-1-ol acetate, α-terpinene, etc. (Table 1).

The slight discrepancy in the qualitative composition and quantitative content of the separate essential oil components between our results and those in the literature [2, 3] was obviously due to the different soil, climate, and ecobiological conditions under which the *A. annua* plants grew.

We found 25 components in essential oil of *A. scoparia* (Table 2). The predominant one over the whole vegetation was capillene. Its content by vegetation phases was I, 96.72%; II, 90.09; III, 89.37; IV, 73.38. It can be seen that the capillene concentration in the essential oil was greatest during phase I. The other components in this phase were minor (up to 2%). The capillene content gradually decreased as the vegetation approached seed ripening (Table 2). However, the concentration of the minor compounds increased (from 2 to 10%). Thus, phase II showed eugenol (2.28%); phase III, an increased content of scoparene (2.46) and eugenol (2.58); phase IV, β-pinene (8.51), *trans*-ocimene (4.11), and eugenol (3.24). Thus, the quality of the essential oil and its mass fraction varied during the vegetation. The mass fraction of essential oil of *A. scoparia* calculated per fresh and dry weight was greatest during phase III, 0.44 (1.13).

The discrepancy in the dominant component of essential oil between our data (dominant capillene) and those published (dominant *trans*-methyleugenol) [9] was obviously due to the different origins of the studied *A. scoparia* plants (soil and climate conditions, directed selection).

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