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PHYTOCHEMICAL SCREENING OF THE VOLATILE EXTRACT FROM WHOLE ARIAL PARTS AND ROOTS OF SENECIO CHRYSANTHEMOIDES DC.

Reema Priydarshi and Anand B. Melkani

SSJDWSSS Government P.G. College, Ranikhet (Almora) Uttarakhand

Abstract: The chemical compositions of the essential oil of *Senecio chrysanthemoides* DC.was analyzed by GC, GC-MS. The percentage yield of the oil from the whole aerial parts of *S. chrysanthemoides* DC. was recorded to be 0.30% (by weight). The gas chromatogram of the oil showed more than fifty peaks. Total twenty seven constituents were identified which represented 88.4% of the oil. The oil was found to be rich in sesquiterpene hydrocarbons (63.8%). The major constituents of the essential oil were identified as germacrene D (37.7%), β-duprezianene (8.5%), camphene (6.6%) and α-humulene (5.7%). Steam distillation of roots of *S. chrysanthemoides* DC. gave 1.1 g of oil (0.04% by weight). The gas chromatogram of the oil showed more than eighty peaks. Total forty two components were identified which represented 90.4% of the oil The oil was found to be rich in sesquiterpene hydrocarbons (66.9%). Among the identified constituents, β-caryophyllene (9.7%), modhephene (9.7%), α-isocomene (8.9%) and valencene (8.0%) were found to be the principal constituents.

Key words: *Senecio chrysanthemoides* DC., essential oil composition, germacrene D, β-caryophyllene.

1. Introduction

The genus *Senecio*, which belongs to the tribe Senecioneae, is the largest and most complex genus in the family of the Asteraceae and includes more than 1500 species with a worldwide distribution that have been extensively investigated for their secondary metabolites.[1] Nineteen species of this genus have been reported to grow in Kumaon and Garhwal regions, out of which, *S. chrysanthemoides* DC., *S. nudicaulis, S. ruflnervis, S. scandens* and *S. alatus* are reported to grow in Nainital and its surroundings.[2-4]

A few herbaceous species of the genus are grown as ornamental plants.[1] Different species of *Senecio* have been used in traditional medicine as anthelmintic, diaphoretic, diuretic, for the treatment of scurvy and sickness of stomach,[5] as antipyretic and calmative, to treat against cholera and lung diseases.[6] The hexane fraction of *S. stabianus* was reported to inhibit the viability of cancer cell lines.[7] The literature on the phytochemistry of these species showed reporting on a large variety of pyrrolizidine alkaloids,[8] sesquiterpenoids,[9] diterpenoids,[10] triterpenoids,[11] shikimic acid and cacalolide derivatives.[12,13] Furthermore, biological activities such as antibacterial,[14] molluscicidal,[15] antimicrobial,[16] cytotoxic activities[17] and biosynthesis of algal pheromones[18] have also been reported for these plants.

The pyrrolizidine alkaloids and the furanoeremophilane sesquiterpenoids are the most important constituents of this genus and thought to be responsible for all pharmacological activities.[8] Pyrrolizidine alkaloids have been reported from different *Senecio* species like *S. arbotanifolius, S. adonifolius, S. alpinus, S. chrysanthemoides* DC.,[19] *S. madagascariensis,*[20] *S. nemorensis, S. aquaticus, S. vernalis*, *S. jacobaea,*[21] *S. scandens*[22] and *S. stabianus*.[7]

Various species of genus *Senecio* have been worked out for their chemical constituents. 6β-Angeloyloxy-eremophila- 1(10),7(11)-diene-12,8β-lactone, a new eremophilenolactone sesquiterpene was isolated from the roots of *S. ambraceus*.[23] β-Sitosterol, pentacosanoic acid, 19α-*H*-lupeone and sucrose were isolated from the roots of *S. scandens*.[24] Tetrahydroligularenolide, a new natural product, furanoeremophilane, ligularenolide and dehydrofukinone were reported to be isolated from *the aerial parts of S. aureus*.[25] Six flavonoid compounds; quercetin, quercetin-3-O-*β*-D-glucoside, kaempferol, kaempferol-3-O-*β*-D-glucoside, kaempferol-3-O-*α*-L-rhamnosidi-(1-6)-O-*β*-D-glucoside and ethyl caffeate were reported to be isolated from the aerial parts of *S. dianthus* Franch.[26]

The essential oil from aerial parts of *S. rowleyanus* exhibited marked cytotoxic activity against certain brain and liver human cell lines in vitro and spathulenol (22.9%), germacrene B (12.4%) and myrcene (12.8%) were reported to be the major components of its essential oil.[27]

The literature could further reveal several reports on the essential oil composition of *Senecio* species growing in various part of the world which showed great variation in their essential oil composition. Some of these reports are summarized in **table 1.**

Table 1. Chemical composition of the essential oil from different parts of *Senecio* species.

Species	Plant part analyzed	Major constituents reported
S. pandurifolius[28]	flower, leaf and stem	α-cuprenene (30.7%), α-zingiberene (16.1%) and γ-curcumene (14.9%), respectively
S. trapezuntinus[29]	flower, leaf and stem	(*E*)-β-farnesene (26.3%, 16.9% and 31.2%, respectively)
S. vernalis Waldst. & Kit.[30,31]	aerial parts flower	spathulenol (37.1%) and 1,8-cineole (19.0%) from species growing in Iran[28] β-pinene (13.0%) and α-pinene (10.5%) from species growing in Turkey[29]
S. platyphyllus var. *platyphyllus*[31]	flower	β-caryophyllene (28.6%) and germacrene D (23.4%)
S. squalidus[32]	aerial parts	*p*-cymene (29.3%) and α-phellandrene (24.7%)
S. graveolens[16]	leaf	α-terpinene (60.0%) and *p*-cymene (14.0%)
S. farfarifolius[33]	flower	α-pinene (48.3%) and 1,8-cineole (10.3%)
S. longipenicillatus[34]	aerial parts	α-pinene (48.3%) and α-humulene (15.8%)
S. gallicus Chaix[35]	aerial parts	β-phellandrene (12.2%) and germacrene D (9.8%)
S. glacus subsp. *coronopifolius*[36]	aerial parts	myrcene (24.0%) and dehydrofukinone (I) (21.0%)

S. scandens[37]	aerial parts	α-pinene (11.9%) and n-caproaldehyde (9.0%)
S. belgaumensis[38]	flower	1-undecanol (19.5%) and *β*-caryophyllene (18.9%)
S. royleanus[39]	aerial parts, flower, leaf and stem	1,10β-Epoxy-6-oxofuranoeremophelane (39.4% to 69.2%)
S. rufinervis[40]	aerial parts	germacrene D (40.19%)
S. leucostachys[41]	leaf	sabinene (20.7%) and α-phellandrene (19.7%)
S. atacamensis Phil.[42]	leaf and stem	α-terpinene 36.05%, 20.57% and α-phellandrene 27.79%, 25.37%, respectively
S. othonnae[43]	flower	caryophyllene oxide (18.6%)
S. racemosus[43]	flower	(*E*)-β-farnesene (21.6%)
S. nemorensis[43]	flower	γ-curcumene (42.8%)
S. bombayensis[44]	flower	linalool (26.3%) and β-cedrene (14.5%)
S. flammeus[45]	aerial parts	α-farnesene (11.26 %)
S. pedunculatus[46]	leaf	caryophyllene oxide (23.28%)
S. chrysanthemoides DC.[47]	leaf	β-thujone (84.17%)
S. chrysanthemoides DC.[48]	aerial parts	(*Z*)-β-farnesene (24.80%), dihydro citronellol (13.08%), germacrene D (12.84%) and β-caryophyllene (4.39%)

Senecio chrysanthemoides DC. (synonym: *Senecio laetus* Edgew.), which is commonly known as Lhed Phool or Kunch phool in Darma, Byas and Chaudas, is endemic medicinal herb of North

Western Himalaya which has been traditionally used as medicine for inflammation of mouth and sore throat.[49] It is an erect annual herb of about 20-90 cm height. Leaves are both radical and cauline, basal leaves are ovate-lanceolate while cauline leaves are sessile. Flowers heads are numerous, yellow and arranged in dense terminal clusters, ray-florets are strap-shaped. Flowering occurs during August to October.

Previous studies on *S. chrysanthemoides* DC. showed that the essential oil from the leaves of *S. chrysanthemoides* DC. was rich in oxygenated monoterpenes (87.69%) with β-thujone (84.17%) as the major component.[47] In another report from *S. chrysanthemoides* DC., showed that the species growing in cold alpines of Himachal Pradesh, India, was found to contain (*Z*)-β-farnesene (24.80%), dihydro citronellol (13.08%), germacrene D (12.84%) and β-caryophyllene (4.39%), as the major constituents of the essential oil from aerial parts.[48]

Looking at the literature reports on *S. chrysanthemoides* DC., variation in chemical composition and our preliminary chromatographic observations, it was aimed to study the essential oil composition of whole aerial parts and roots of *S. chrysanthemoides* DC.

2. EXPERIMENTAL

2.1. Plant material

The fresh plant material of *S. chrysanthemoides* DC. was collected from Rambara near Kedarnath (Uttarakhand, India) at an elevation of 2,700 m in the first week of October when the plant was in its flowering stage. The plant was identified from Botany Department, Kumaun University, Nainital and its identity was further confirmed from Botanical Survey of India, Dehradun, where a herbarium specimen was deposited for future reference.

Herbarium voucher number:

Senecio chrysanthemoides DC. (Synonym: *Senecio laetus* Edgew.) [Herbarium Acc No. BSI/(NC) 111836, BSD].

2.2. Extraction of essential oil

The oil was obtained from the fresh plant material (4 kg) by its steam distillation for about 4 hours using a copper still fitted with spiral glass condensers. The distillate was saturated with NaCl and extracted with n-hexane. The hexane extract was dried over anhydrous Na_2SO_4. The solvent was removed using a rotavap under reduced pressure at 30^0C.

2.3. Analysis of the essential oil

The GC was performed using Varian 3700 and Hewlett Packard 6980 gas chromatograph systems fitted with FI detector, an HP-5MS capillary column (30 m X 0.25 mm, film thickness 0.25 µm) and SRI model 203 Peak Simple data system was used. Helium gas was used as a Carrier gas. For GC-MS analysis AGILENT 5973 Network Mass Selective Detector Interfaced with AGILENT 6856 GC system. An HP-5MS capillary column (30m X 0.25 mm, film thickness 0.25 µm) and SRI model 203 Peak Simple data system was used. Helium gas was used as a Carrier gas. The Mass spectra were taken under EI condition at 70eV. The oven temperature was programmed at 50^0C for the first 10 min and then 3^0C/min to 240^0C, after which it was maintained at 240^0C for 5 min. The composition data taken from the computer readout were rounded off to the first decimal place, and recorded as percent area without the use of correction factors. To determine the retention indices (RI), a co-injection was made of a mixture of the oil and n-alkanes (C_8–C_{23}).

For root analysis, Shimadzu GC-2010 Plus gas chromatograph system fitted with FI detector, an Rtx-5MS capillary column capillary column (30m X 0.25 mm, film thickness 0.25µm) was used. Nitrogen gas was used as a Carrier gas. For GC-MS analysis, Shimadzu GC-2010 Plus gas chromatograph interfaced with Shimadzu GC-MS-QP-2010 Plus system. An Rtx-5MS capillary column (30m X 0.25mm, film thickness 0.25µm) was used. Helium gas was used as a Carrier gas. The Mass spectra were taken under EI condition at 70eV.

3. RESULTS AND DISCUSSION

The percentage yield of the oil from the whole aerial parts of *S. chrysanthemoides* DC. was recorded to be 0.30% (by weight). The gas chromatogram of the oil showed more than fifty peaks. Total twenty seven constituents were identified which represented 88.4% of the oil **(Figure 5.1)**. The unidentified part of the oil was made up of several minor constituents. The identification of compounds

was done by the correspondence of their observed Retention Indices as well as mass spectra with those reported in the literature[50] and by co injection where the authentic samples were available.

The oil was found to be rich in sesquiterpene hydrocarbons (63.8%). The major constituents of the essential oil were identified as germacrene D (37.7%), β-duprezianene (8.5%), camphene (6.6%) and α-humulene (5.7%). The composition of the oil showed sesquiterpene hydrocarbons (63.8%), oxygenated sesquiterpenoids (10.0%) and monoterpene hydrocarbons (14.6%).

The other compounds which have been identified in the essential oil with their percentage were; α-thujene (1.3%), sabinene (0.9%), verbenene (2.7%), *p*-cymene (0.8%), sylvestrene (0.9%), (*E*)-β-ocimene (1.4%), α-ylangene (0.4%), β-bourbonene (0.7%), *iso*-longifolene (0.7%), β-gurjunene (0.2%), 9-epi-*E*-caryophyllene (0.6%), sesquisabinene (0.7%), *cis*-β-guaiene (2.0%), γ-patchoulene (1.6%), α-muurolene (0.7%), (*Z*)-γ-bisabolene (0.5%), δ-cadinene (3.8%), guaiol (0.5%), 5-cedranone (2.9%), cubenol (1.9%), 14-hydroxy-*Z*-caryophyllene (0.3%), epi-zizanone (1.4%) and eudesm-7(11)-ene-4-ol (3.0%). The total composition of the oil along with percentage of identified constituents and their observed Retention Indices are summarized in **Table 5.2.**

Steam distillation of roots of *S. chrysanthemoides* DC. gave 1.1 g of oil (0.04% by weight). The gas chromatogram of the oil showed more than eighty peaks. Total forty two components were identified which represented 90.4% of the oil (**Figure 5.2**). The identification of compounds was done by comparison of their mass spectra with those of the internal reference mass spectra library (NIST11s, WILEY8 and FFNSC2) and by comparison of their observed Retention Indices with mass spectra given in the literature.[52]

The oil was found to be rich in sesquiterpene hydrocarbons (66.9%). The composition of the oil showed sesquiterpene hydrocarbons (66.9%), oxygenated sesquiterpenoids (14.0%), oxygenated diiterpenoids (8.9%) and monoterpene hydrocarbons (0.6%). Among the identified constituents, β-caryophyllene (9.7%), modhephene (9.7%), α-isocomene (8.9%) and valencene (8.0%) were found to be the principal constituents.

The other compounds which have been identified in the essential oil with their percentage were; α-pinene (0.2%), sabinene (0.1%), β-pinene (0.2%), β- phellandrene (0.1%), 4-(2-methyl cyclohex-1-enyl)-but-2-enal (3.9%), methyl ether carvacrol (0.5%), *trans*-sabinyl acetate (0.2%), silphiperfol-5-ene (0.2%), presilphiperfol-7-ene (0.1%), 7-epi-silphiperfol-5-ene (2.6%), β-elemene (2.2%), β- isocomene (6.8%), *cis*-thujopsene (0.2%), *trans*-α-bergamotene (0.3%), epi-β-santalene (1.1%), α-humulene (5.0%), (*E*)-β-farnesene (1.6%), *cis*-eudesma-6,11-diene (0.1%), germacrene D (4.4%), indipone (trace), bicyclogermacrene (0.6%), α-muurolene (0.3%), germacrene A (1.6%), β-bisabolene (0.5%), δ-cadinene (0.5%), caryophyllene oxide (1.8%), globulol (0.2%), humulene epoxide II (0.5%), *allo*-aromadendrene epoxide (0.2%), epi-α-muurolol (0.4%), himachalol (0.5%), neo- intermedeol (2.8%), 13-hydroxy valencene (1.3%), 1,2-bis (1-methyl, 2-propenyl) benzene (2.5%), 4,4-dimethyl-3-phenyl-2,5-cyclohexadien-1-one (1.7%), tetrakis (1-methyl ethylidene)-cyclopentanone (5.5%), phytol (0.2%) and seselin (3.2%). The total composition of the oil along with percentage of identified constituents and their observed Retention Indices are summarized in **Table 5.3.**

From the results of present study, it is clear that the essential oil from aerial parts of *S. chrysanthemoides* DC. showed higher contents of sesquiterpene hydrocarbons which is similar to the previous reports of essential oil composition of some other species of *Senecio*, which reported higher contents of sesquiterpene hydrocarbons. These species are *S. pandurifolius,*[28] *S. trapezuntinus,*[29] *S. platyphyllus* var. *platyphyllus,*[31] *S. rufinervis,*[40] *S. racemosus,*[43] *S. nemorensis,*[43] and *S. flammeus.*[45]

There have been two reports on the essential oil obtained from different parts of *S. chrysanthemoides* DC. Previously, *S. chrysanthemoides* was reported to contain β-thujone (84.17%) in its essential oil from leaves.[47] The same species growing in high altitude region of Himachal Pradesh was reported to possess (*Z*)-β-farnesene (24.80%), dihydro citronellol (13.08%), germacrene D (12.84%) and β-caryophyllene (4.39%), as the major constituents in essential oil from whole aerial parts.[48]

The present investigation in the essential oil of *S. chrysanthemoides* DC. obtained from its whole aerial parts indicated that the terpenoid composition of present collection (from Rambara, Uttarakhand) was found to be different in terpenoid composition. Except germacrene D, none of the other constituents

which were earlier reported from the essential oil of *S. chrysanthemoides* DC., were detected in the essential oil of present study. Therefore, the present study indicated that the *S. chrysanthemoides* was still in a process of chemical evolution to adapt itself to different environmental factors and could be regarded as a different chemotype of *S. chrysanthemoides* DC..

The terpenoid composition of essential oil obtained from the roots of *S. chrysanthemoides* DC. are being reported for the first time.

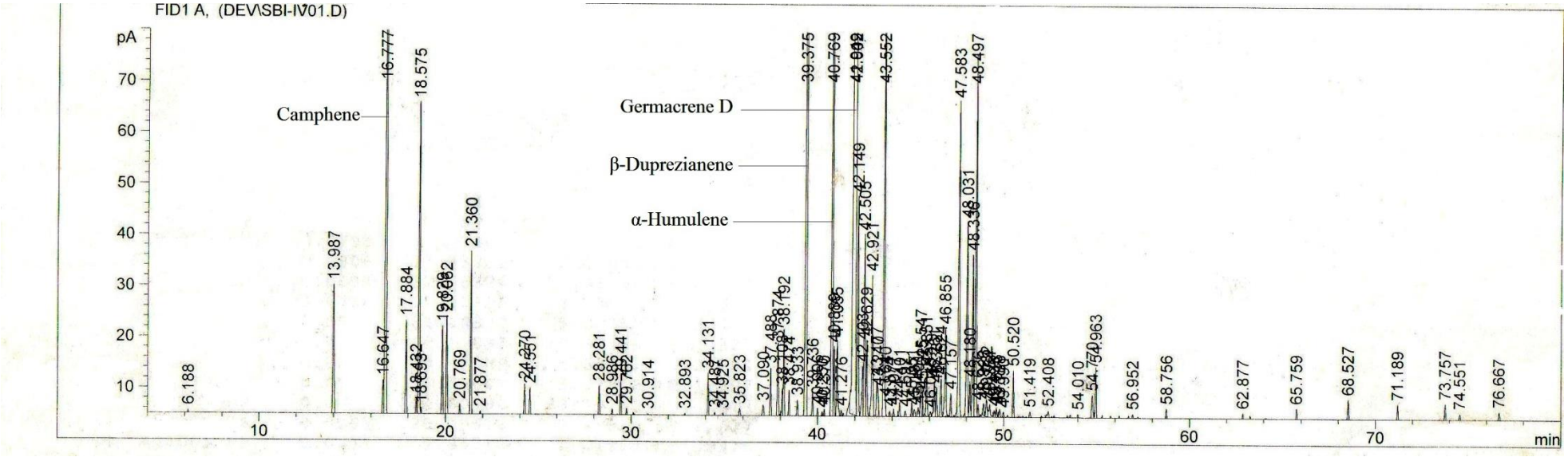

Figure 1. Gas Chromatogram of the essential oil from aerial parts of *S. chrysanthemoides* DC.

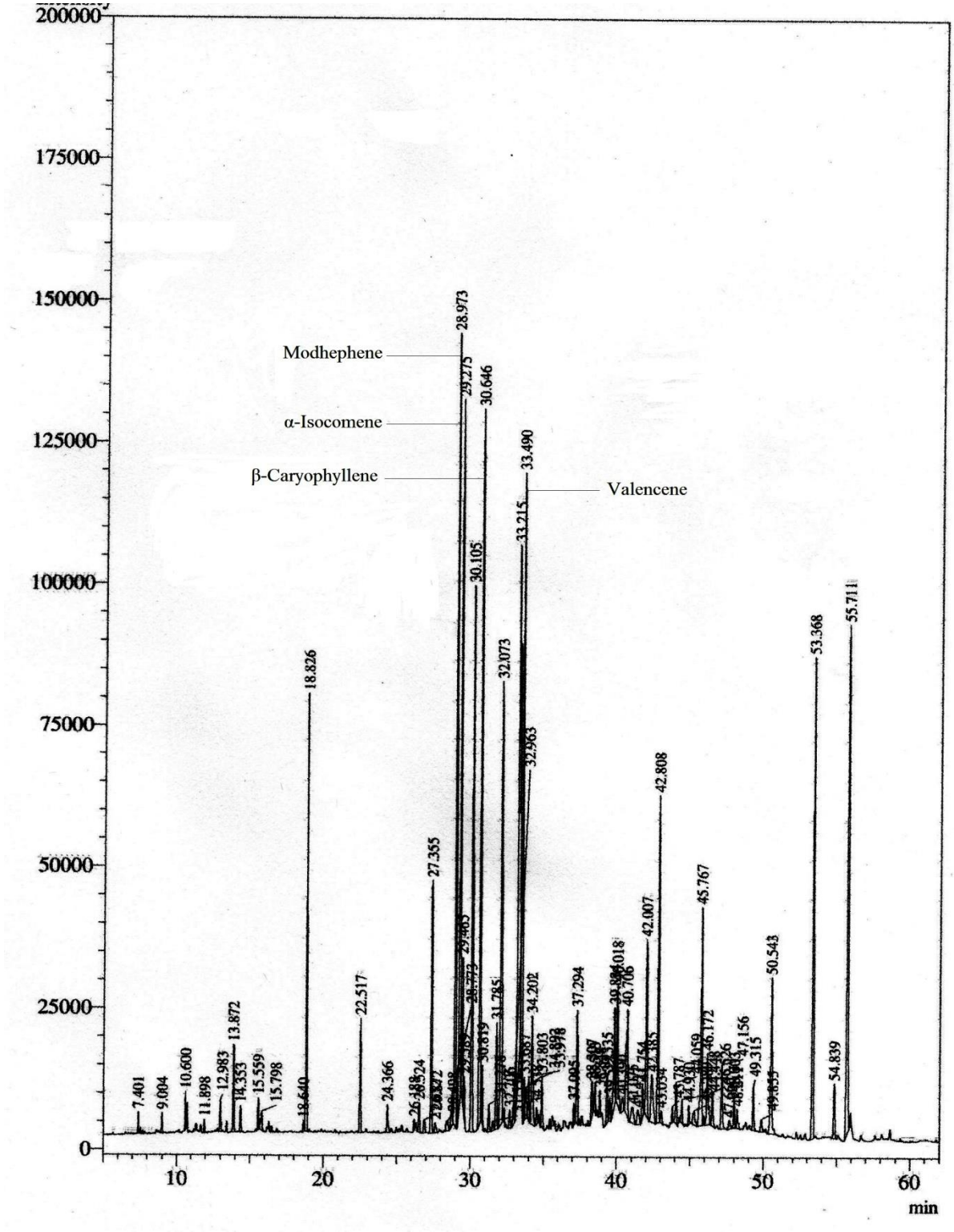

Figure 2. Gas Chromatogram of the essential oil from roots of *S. chrysanthemoides* DC.

Table: 2. Chemical composition of the essential oil from aerial parts of *S. chrysanthemoides* DC.

Compound	Percentage in the oil	Methods of Identification		
		RI (observed)	RI (reported)	Source*
α-thujene	1.3	929	930	A
camphene	**6.6**	**963**	**954**	**A**
sabinene	0.9	977	975	A
verbenene	2.7	979	967	A
p-cymene	0.8	1026	1025	A
sylvestrene	0.9	1030	1030	A
(*E*)-β-ocimene	1.4	1054	1050	A
α-ylangene	0.4	1378	1375	A
β-bourbonene	0.7	1386	1388	A
iso-longifolene	0.7	1393	1390	A
β-duprezianene	**8.5**	**1422**	**1423**	**A**
β-gurjunene	0.2	1431	1433	A
α-humulene	**5.7**	**1457**	**1454**	**A**
9-epi-*E*-caryophyllene	0.6	1460	1466	A
sesquisabinene	0.7	1464	1459	A
germacrene D	**37.7**	**1487**	**1485**	**A,B**
cis-β-guaiene	2.0	1495	1493	A
γ-patchoulene	1.6	1498	1502	A
α-muurolene	0.7	1507	1500	A
(*Z*)-γ-bisabolene	0.5	1517	1515	A

δ-cadinene	3.8	1526	1523	A
guaiol	0.5	1579	1600	A
5-cedranone	2.9	1635	1630	A
cubenol	1.9	1651	1646	A
14-hydroxy-*Z*-caryophyllene	0.3	1659	1667	A
epi-zizanone	1.4	1661	1670	A
eudesm-7(11)-ene-4-ol	3.0	1674	1700	A
sesquiterpene hydrocarbons	**63.8%**			
oxygenated sesquiterpenoids	**10.0%**			
monoterpene hydrocarbons	**14.6%**			
Total identified	**88.4%**			

***A:** Mass Spectral data (R. P. Adams, 2007);[50] **B:** Co-injection with authentic sample; **trace:** less than 0.1 percent.

Table: 3. Chemical composition of the essential oil from roots of *S. chrysanthemoides* DC.

Compound	Percentage in the oil	Methods of Identification		
		RI (observed)	RI (reported)	Source*
α-pinene	0.2	937	939	A,B
sabinene	0.1	966	975	A,B
β-pinene	0.2	976	979	A,B
β-phellandrene	0.1	1021	1029	A,B
4-(2-methyl cyclohex-1-enyl)-but-2-enal	3.9	1159	-	B

carvacrol methyl ether	0.5	1238	1244	A,B
trans-sabinyl acetate	0.2	1279	1290	A,B
silphiperfol-5-ene	0.2	1319	1328	A,B
presilphiperfol-7-ene	0.1	1329	1336	A,B
7-epi-silphiperfol-5-ene	2.6	1347	1348	A,B
modhephene	**9.7**	**1373**	**1383**	**A,B**
α-isocomene	**8.9**	**1378**	**1388**	**A,B**
β-elemene	2.2	1389	1390	A,B
β-isocomene	6.8	1396	1408	A,B
β-caryophyllene	**9.7**	**1409**	**1419**	**A,B**
cis-thujopsene	0.2	1422	1431	A,B
trans-α-bergamotene	0.3	1438	1434	A,B
epi-β-santalene	1.1	1445	1447	A,B
α-humulene	5.0	1450	1454	A,B
(*E*)-β-farnesene	1.6	1457	1456	A,B
cis-eudesma-6,11-diene	0.1	1472	1489	A,B
germacrene D	4.4	1478	1485	A,B
valencene	**8.0**	**1491**	**1496**	**A,B**
indipone	trace	1495	1497	A,B
bicyclogermacrene	0.6	1498	1500	A,B
α-muurolene	0.3	1502	1500	A,B
germacrene A	1.6	1508	1509	A,B
β-bisabolene	0.5	1510	1505	A,B
δ-cadinene	0.5	1527	1523	A,B

caryophyllene oxide	1.8	1583	1583	A,B
globulol	0.2	1588	1590	A,B
humulene epoxide II	0.5	1614	1608	A,B
allo-aromadendrene epoxide	0.2	1643	1641	A,B
epi-α-muurolol	0.4	1648	1642	A,B
himachalol	0.5	1656	1653	A,B
neo-intermedeol	2.8	1661	1660	A,B
13-hydroxy valencene	1.3	1767	1768	A,B
1,2-bis (1-methyl, 2-propenyl) benzene	2.5	1786	-	B
4,4-dimethyl-3-phenyl-2,5-cyclohexadien-1-one	1.7	1822	-	B
tetrakis (1-methyl ethylidene)-cyclopentanone	5.5	1857	-	B
phytol	0.2	1932	1943	A,B
seselin	3.2	1992	1998	A,B
sesquiterpene hydrocarbons		**66.9%**		
oxygenated sesquiterpenoids		**14.0%**		
oxygenated diterpenoids		**8.9%**		
monoterpene hydrocarbons		**0.6%**		
Total identified		**90.4%**		

***A:** Retention Indices and Mass Spectral data (R. P. Adams, 2007);[50] **B:** Mass Spectral data from bibliography (NIST11s, WILEY8 and FFNSC2 libraries); **trace:** less than 0.1 percent.

4. CONCLUSION

The steam distillation of 4 kg fresh plant material (aerial parts) of *S. chrysanthemoides* DC. was recorded to be 1.6 g (0.30% by weight). The gas chromatogram of the oil showed more than fifty peaks. Total twenty seven constituents were identified which represented 88.4% of the oil. The unidentified part of the oil was made up of several minor constituents. The identification of compounds was done by the correspondence of their observed Retention Indices as well as mass spectra with those reported in the literature[50] and by co injection where the authentic samples were available.

The oil was found to be rich in sesquiterpene hydrocarbons (63.8%). The major constituents of the essential oil were identified as germacrene D (37.7%), β-duprezianene (8.5%), camphene (6.6%) and α-humulene (5.7%). The composition of the oil showed sesquiterpene hydrocarbons (63.8%), oxygenated sesquiterpenoids (10.0%) and monoterpene hydrocarbons (14.6%).

The other compounds which have been identified in the essential oil with their percentage were; α-thujene (1.3%), sabinene (0.9%), verbenene (2.7%), *p*-cymene (0.8%), sylvestrene (0.9%), (*E*)-β-ocimene (1.4%), α-ylangene (0.4%), β-bourbonene (0.7%), *iso*-longifolene (0.7%), β-gurjunene (0.2%), 9-epi-*E*-caryophyllene (0.6%), sesquisabinene (0.7%), *cis*-β-guaiene (2.0%), γ-patchoulene (1.6%), α-muurolene (0.7%), (*Z*)-γ-bisabolene (0.5%), δ-cadinene (3.8%), guaiol (0.5%), 5-cedranone (2.9%), cubenol (1.9%), 14-hydroxy-*Z*-caryophyllene (0.3%), epi-zizanone (1.4%) and eudesm-7(11)-ene-4-ol (3.0%).

Steam distillation of roots of *S. chrysanthemoides* DC. gave 1.1 g of oil (0.04% by weight). The gas chromatogram of the oil showed more than eighty peaks. Total forty two components were identified which represented 90.4% of the oil. The identification of compounds was done by comparison of their

mass spectra with those of the internal reference mass spectra library (NIST11s, WILEY8 and FFNSC2) and by comparison of their observed Retention Indices with mass spectra given in the literature.[52]

The oil was found rich in sesquiterpene hydrocarbons (66.9%). The composition of the oil showed sesquiterpene hydrocarbons (66.9%), oxygenated sesquiterpenoids (14.0%) and oxygenated diiterpenoids (8.9%). Monoterpene hydrocarbons constituted only (0.6%) of the oil. Among the identified constituents, β-caryophyllene (9.7%), modhephene (9.7%), α-isocomene (8.9%) and valencene (8.0%) were found to be the principal constituents.

The other compounds which have been identified in the essential oil with their percentage were; α-pinene (0.2%), sabinene (0.1%), β-pinene (0.2%), β- phellandrene (0.1%), 4-(2-methyl cyclohex-1-enyl)-but-2-enal (3.9%), methyl ether carvacrol (0.5%), *trans*-sabinyl acetate (0.2%), silphiperfol-5-ene (0.2%), presilphiperfol-7-ene (0.1%), 7-epi-silphiperfol-5-ene (2.6%), β-elemene (2.2%), β- isocomene (6.8%), *cis*-thujopsene (0.2%), *trans*-α-bergamotene (0.3%), epi-β-santalene (1.1%), α-humulene (5.0%), (*E*)-β-farnesene (1.6%), *cis*-eudesma-6,11-diene (0.1%), germacrene D (4.4%), indipone (trace), bicyclogermacrene (0.6%), α-muurolene (0.3%), germacrene A (1.6%), β-bisabolene (0.5%), δ-cadinene (0.5%), caryophyllene oxide (1.8%), globulol (0.2%), humulene epoxide II (0.5%), *allo*-aromadendrene epoxide (0.2%), epi-α-muurolol (0.4%), himachalol (0.5%), *neo*- intermedeol (2.8%), 13-hydroxy valencene (1.3%), 1,2-bis (1-methyl, 2-propenyl) benzene (2.5%), 4,4-dimethyl-3-phenyl-2,5-cyclohexadien-1-one (1.7%), tetrakis (1-methyl ethylidene)-cyclopentanone (5.5%), phytol (0.2%) and seselin (3.2%). This is the first report on the terpenoid composition of root oil from *S. chrysanthemoides* DC.

The literature search revealed that the terpenoid composition of essential oil from aerial parts of *S. chrysanthemoides* DC. and the results of present study varied from location to location. A comparison between the essential oil compositions found in present study with those reported previously, is summarized in the **Table 4.**

Table 4. Biochemical marker (major constituents) of the essential oil from aerial parts of *Senecio chrysanthemoides* DC.

Plant part analyzed	Major constituents reported
leaf[47]	β-thujone (84.17%)
whole aerial parts[48]	(*Z*)-β-farnesene (24.80%), dihydro citronellol (13.08%), germacrene D (12.84%) and β-caryophyllene (4.39%)
whole aerial parts (Present study)	germacrene D (37.7%), β-duprezianene (8.5%), camphene (6.6%) and α-humulene (5.7%)

There have been two reports on the essential oil obtained from different parts of *S. chrysanthemoides* DC. Previously, *S. chrysanthemoides* was reported to contain β-thujone (84.17%) in its essential oil from leaves.[47] The same species growing in high altitude region of Himachal Pradesh was reported to possess (*Z*)-β-farnesene (24.80%), dihydro citronellol (13.08%), germacrene D (12.84%) and β-caryophyllene (4.39%), as the major constituents in essential oil from whole aerial parts.[48]

The present investigation in the essential oil of *S. chrysanthemoides* DC. obtained from its whole aerial parts indicated that the terpenoid composition of present collection (from Rambara, Uttarakhand) was found to be entirely different. Except germacrene D, none of the other constituents which were earlier reported from the essential oil of *S. chrysanthemoides* DC., were detected in the essential oil of present study. Therefore, the present study indicated that the *S. chrysanthemoides* was still in a process of chemical evolution to adopt itself to different environmental factors and could be regarded as a different chemotype of *S. chrysanthemoides* DC..

The terpenoid composition of essential oil obtained from the roots of *S. chrysanthemoides* DC. are being reported for the first time.

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