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GC-MS Analysis of Essential Oils from Selected Aromatic Plants of the Manang Region, Nepal

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Abstract

This study investigated the chemical composition of essential oils extracted from seven aromatic plant species collected from Manang district, Nepal; *Artemisia dubia* Wall. ex Besser, *Elsholtzia fruticosa* (D. Don) Rehder, *Tetrataenium lallii* (C.Norman) Cauwet, Carb & M.Farille, *Juniperus indica* Bertol., *Nepeta ciliaris* Benth., *Origanum vulgare* L., and *Thymus linearis* Benth. Essential oils were obtained through hydro distillation using the Clevenger apparatus and analyzed using Gas Chromatography-Mass Spectrometry (GC-MS). The analysis revealed a diverse array of terpenoid compounds, predominantly monoterpenes, sesquiterpenes, phenols and esters, in the investigated plant species. *Artemisia* and *Elsholtzia* contained γ-terpinene and terpene derivatives as the main components. Chamazulene was also found in the *Artemisia* essential oil. *Heracleum* was characterized by esters (esters of acetic acid and butanoic acid) and D-limonene, while *Juniperus* contained D-limonene, sabinene, and elemol as major constituents. *Nepeta* was rich in bergamotene, caryophyllene oxide, and sesquisabinene. *Origanum* primarily consisted of p-cymene and thymol, and *Thymus* essential oil was highly rich in thymol and carvacol. This research contributes to expanding our understanding of the chemical diversity of essential oils from high-altitude aromatic plants in the Nepalese Himalayas, providing valuable information for potential applications in various industries. The identification of novel compounds and the understanding of their biological activities could lead to the development of new natural products with potential applications in pharmaceuticals, cosmetics, and food industries.

Keywords: *Nepeta ciliaris*, *Origanum vulgarae*, Secondary metabolites, Sesquiterpenes, Terpenes, *Tetrataenium lallii, Thymus linearis*

Introduction

Essential oils are high-value, low-volume commodities primarily composed of complex mixtures of volatile, low-molecular-weight terpenoid and phenylpropanoid compounds (Mohamed & Alotaibi, 2022). These unique chemical constituents are specific to each plant, and are responsible for the oils' distinctive fragrances (Globe Newswire, 2022). Essential oils are extracted from aromatic plants. The extracted oils find diverse applications in cosmetics (Guzmán & Lucia, 2021), flavours and fragrances (Jugreet et al., 2021), spices (Cardoso-Ugarte & Sosa-Morales, 2021), repellents (Nerio et al., 2010), pesticides (Garrido-Miranda et al., 2022), herbal beverages (Christopoulou et al., 2021), aromatherapy (Ali et al., 2015), and even in radioprotection (Samarth et al., 2017).

Citrus oils, particularly lemon and orange essential oils, dominate the global market due to their exceptional functional and sensory properties. These oils are rich in a variety of compounds, including α-, β-pinene, sabinene, β-myrcene, *D*-limonene, linalool, α-humulene, and α-terpineol. These compounds belong to different chemical groups such as monoterpenes, monoterpene aldehydes/alcohols, and sesquiterpenes, and are known for their antioxidant, antimicrobial, anticancer, and anti-inflammatory properties (Bora et al., 2020). Furthermore, the European Union has legally recognized several components of plant-based volatile oils, such as carvacrol, carvone, cinnamaldehyde, citral, and p-cymene, as approved flavoring agents (*Essential Oils Market Size, Share & Growth Report 2021-2028*, n.d.).

Nepal's medicinal and aromatic plants (MAPs) sector, particularly its essential oils, is experiencing significant commercial growth. MAPs, encompassing a wide range of essential oil-bearing plants found both in natural and cultivated environments, constitute a crucial segment of non-timber forest products. These resources hold immense socio-cultural and economic value within Nepal with over 20 major essential oils demonstrating high export potential. While Nepal's initial essential oil exports were modest, they experienced remarkable growth between 2010 and 2021, surging at a compound annual growth rate (CAGR) of 11% from $974 to $7.76 million USD. This impressive trajectory established Nepal as the 52nd largest exporter of essential oils worldwide (Observatory of Economic Complexity [OEC], n.d.). Furthermore, the global essential oil market is poised for significant expansion. Valued at $21.79 billion in 2022, it is projected to grow at a CAGR of 7.9% from 2023 to 2030. This robust growth is primarily fueled by the increasing demand for essential oils across diverse sectors, including aromatherapy, the food and beverage industry, and the beauty and personal care market (*Essential Oils Market Size, Share & Trends Analysis Report By Product (Orange, Cornmint, Eucalyptus), By Application (Medical, Food & Beverages, Spa & Relaxation), By Sales Channel, By Region, And Segment Forecasts, 2023 – 2030*, n.d.; Poudel, 2022).

The global market has shown considerable interest in Nepali essential oils across three key sectors. In particular, they have garnered significant interest as premium flavours (natural health and organic foods such as timur, curcuma, ginger, cinnamon, and wintergreen), high-end beauty and personal care products (rhododendron, ginger, jatamansi, butternut, palmarosa), and pharmaceutical applications as herbal traditional medicines (*Essential Oils Market Size, Share & Trends Analysis Report By Product (Orange, Cornmint, Eucalyptus), By Application (Medical, Food & Beverages, Spa & Relaxation), By Sales Channel, By Region, And Segment Forecasts, 2023 – 2030*, n.d.). In this context, a thorough understanding of the chemical constituents of the essential oils from unexplored plant species is also crucial. Knowledge of their chemical composition is essential for assessing their quality, identifying their biological properties, and determining their appropriate applications.

Building upon our previous research on the chemical constituents of essential oils from high-altitude aromatic plants in the Langtang region of Nepal (Pradhan et al., 2023), this study is trying to further investigate and identify the components of essential oils obtained from select aromatic plants in Manang district. Located in the Central Himalayan region, Manang district is renowned for its diverse medicinal plant species (Bhattarai et al., 2006). This region's unique high-altitude environment, climatic conditions and diverse flora are likely to yield essential oils with distinct chemical compositions and potential biological activities. For this study, we selected seven aromatic plant species, *Artemisia dubia* Wall. *ex* Besser, *Elsholtzia fruticosa* (D. Don) Rehder, *Tetrataenium lallii* (C.Norman) Cauwet, Carb & M. Farille (synonym: *Heracleum lallii)*, *Juniperus indica* Bertol., *Nepeta ciliaris* Benth., *Origanum vulgare* L. and *Thymus linearis* Benth.

This study employed advanced analytical techniques such as Gas Chromatography-Mass Spectrometry (GC-MS) to comprehensively analyse the volatile compounds present in the essential oils of the selected plant species. The findings of this research will contribute to a deeper understanding of the chemical diversity of essential oils from high-altitude plants in the Nepalese Himalayas. By expanding the knowledge on the chemical constituents of essential oils from this unique ecosystem, this study aims to contribute significantly to the field of natural products chemistry and support the sustainable development of the aromatic plants from Manang region, Nepal.

Materials and Methods

Plant collection

Aerial parts of seven wild plant species, *Artemisia dubia* Wall. *ex* Besser, *Elsholtzia fruticosa* (D. Don) Rehder, *Tetrataenium lallii* (C.Norman) Cauwet, Carb & M.Farille, *Juniperus indica* Bertol., *Nepeta ciliaris* Benth., *Origanum vulgare* L., and *Thymus*

Table 1: List of plant species collected from Manang District.

S.N.	Name	Family	Parts Used for Extraction	Location	Altitude (m)
1.	*Artemisia dubia* Wall. *ex* Besser	Asteraceae	Leaves	Pisang	3260
2.	*Elsholtzia fruticosa* (D. Don) Rehder	Lamiaceae	Leaves	Chame to Timang	2657
3.	*Tetrataenium lallii* (C.Norman) Cauwet, Carb & M.Farille	Apiaceae	Seeds	Tanki to Gunsang	3781
4.	*Juniperus indica* Bertol.	Cupressaceae	Leaves	Gunsang	3918
			Berries		
5.	*Nepeta ciliaris* Benth.	Lamiaceae	Leaves	Manang to Tanki	3700
			Flowers		
6.	*Origanum vulgare* L.	Lamiaceae	Aerial part	Gunsang	3918
7.	*Thymus linearis* Benth.	Lamiaceae	Aerial part	Gunsang	3906

linearis Benth., were collected from the Manang district, Nepal, in September 2022. The collection sites ranged from 2600 m to 3900 m in altitude. The collected plant species were shade-dried for two weeks. The collection of plant species, as listed in Table 1, was identified and confirmed by the National Herbarium and Plant Laboratories (KATH), Nepal.

Reagents

All chemicals used in this study were commercially available and used without further purification. Anhydrous sodium carbonate (analytical grade) was obtained from Fisher Scientific (Mumbai, India), while dichloromethane (HPLC grade) was sourced from Merck (Mumbai, India). Eugenol, *D*-limonene, *E*-caryophyllene, *p*-cymene, α-pinene, α-phellandrene, β-pinene, thymol, δ-3-carene, and eucalyptol were purchased from Sigma Aldrich (St. Louis, MO, USA).

Extraction of essential oil

Essential oil was extracted from shade-dried plant material using the hydro-distillation method (Clevenger, 1928). Approximately 30-40 grams of plant parts were placed in a 500 mL round bottom flask and subjected to hydro-distillation using a Clevenger apparatus. The extraction process was conducted for 4 hours, and the collected oil was stored in a glass vial. Any residual moisture in the essential oil was removed using anhydrous sodium carbonate, and the oil was subsequently stored under refrigerated conditions at 4°C.

Gas Chromatography-Mass Spectrometry (GC-MS) analysis

Essential oils were analysed using a Shimadzu GC-MS-QP2010 Plus system available at the Instrument Section of the Department of Plant Resources. A capillary column (SH-RTX-5MS, 60 m × 0.32 mm × 0.25 µm) with a 5% diphenyl/95% dimethyl polysiloxane stationary phase was employed. GC analysis was performed under the following conditions: column oven temperature, 50ºC; injection temperature, 250ºC; ion source temperature, 250ºC; interface temperature, 200ºC; split injection mode with a split ratio of 80; Helium with a pressure of 53.8 kPa; total gas flow, 112.3 mL/min; column flow, 1.35 mL/min. The GC-MS system starts with an initial oven temperature of 50ºC for 1 min, then increases to 230ºC at a rate of 3ºC for 9 min. Mass spectral detection was carried out in electron ionization mode with a scan range of 40-350 m/z. The total analysis time for each sample was 70 m.

The chemical components of the essential oils were identified by comparing their mass spectral fragmentation patterns with those in the National Institute of Standards and Technology (NIST) 2017 library and the Mass spectra of Flavour and Fragrance of Natural and Synthetic Compounds (FFNSC) 4.0 library and also by comparing the retention times of the components with those of reference compounds. The percentage composition of each component in the essential oil (Area %) is reported as raw percentages based on the total ion chromatogram (TIC) without any standardization.

Results and Discussion

Essential oils were obtained through hydrodistillation of the aerial parts of seven plant species: *Artemisia dubia*, *Elsholtzia fruticosa*, *Tetrataenium lallii*, *Juniperus indica*, *Nepeta ciliaris*, *Origanum vulgare*, and *Thymus linearis*. Their chemical composition was subsequently determined using GC-MS analysis. Appendix 1 provides a detailed list of the identified chemical constituents present in the essential oils of these plant species and Figure 1 depicts the structure of some of the identified components. Similarly, Figure 2 to Figure 10 depict the total ion chromatograms (TICs) of each essential oil. While not all components were identified, the majority of those detected were monoterpenes and sesquiterpenes. Additionally, phenolic compounds and esters were also identified in the essential oils extracted from some of these plant species.

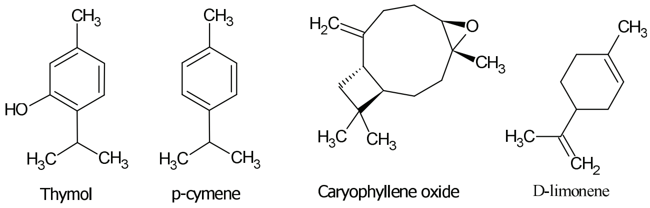

Figure 1: Structure of some of the identified terpenoid components

The essential oil extracted from the leaves of *Artemisia dubia* was dominated by terpene derivatives, including *γ*-terpinene, *α*-terpinene, *α*-terpinene geranyl, and terpinen-4-ol, collectively representing 23.8% of the oil. Minor constituents included chamazulene (6.7%), chrysanthenol (3.8%), caryophyllene derivatives (5.4%), nerolidol (3.3%), *p*-cymene (4.2%), naphthalene derivatives (8.4%), and keto derivatives such as and rostanone (2.5%). Previous studies on *Artemisia dubia* from the Langtang region at a similar altitude identified different major constituents, primarily comprising santolinatriene, *β*-cubebene, *β*-pinene, sabinene, *α*-pinene, *E*-caryophyllene, bicyclogermacrene, *α*-humulene, *E*-nerolidol, and lavandulyl acetate (Pradhan et al., 2023). These findings suggest that the chemical constituents of this plant species are influenced by climatic conditions (Alum, 2024). While both Langtang and Manang regions in Nepal are high-altitude regions with cold climates, they differ significantly in precipitation levels. Manang experiences significantly less rainfall due to the rain shadow effect, creating a considerably drier climate compared to Langtang, which receives more moisture. Essentially, Manang has a more desert-like climate compared to Langtang (Kharal et al., 2017; Steiner et al., 2021). Such differences in climatic conditions can significantly impact the vegetation in these areas and ultimately lead to variations in the chemical composition of the plant species. Similarly previous studies conducted by other researchers have also reported varying chemical compositions for the essential oil of *Artemisia dubia* from different locations. A study conducted in Kirtipur, Nepal, identified chrysanthenone, coumarin, and camphor as major components (Satyal et al., 2012). Similarly, Liang et al. (2017) reported terpinolene and limonene as major components in *Artemisia dubia* essential oil from China. These variations in chemical composition can likely be attributed to factors such as location, altitude, and the time of year plant material was collected. For instance, Satyal et al. (2012) collected their *Artemisia dubia* samples from hilly areas at an altitude of 1360 m in May, while this study utilized plant material collected in September from a mountainous region at a significantly higher altitude of approximately 3200 meters. These contrasting collection conditions likely contribute to the observed differences in the essential oil constituents.

The essential oil extracted from the leaves of Elsholtzia fruticosa primarily consisted of terpenoid compounds, including terpinen-4-ol (18.1%), *γ*-terpinene (16.5%), *α*-terpinene (8.0%), *α*-terpineol (3.8%), and *α*-terpineolene (3.8%). In addition to these terpene derivatives, other constituents such as *p*-cymene (9.6%), sabinene hydrate (4.6%), nerolidol (4.3%), and *α*-thujene (2.4%) were also identified. This chemical composition contrasts with previous studies on Elsholtzia fruticosa from the Langtang region (Pradhan et al., 2023), which, despite the similar altitude, revealed a different profile dominated by perillene, eucalyptol, *β*-pinene, and *E*-caryophyllene. This discrepancy further

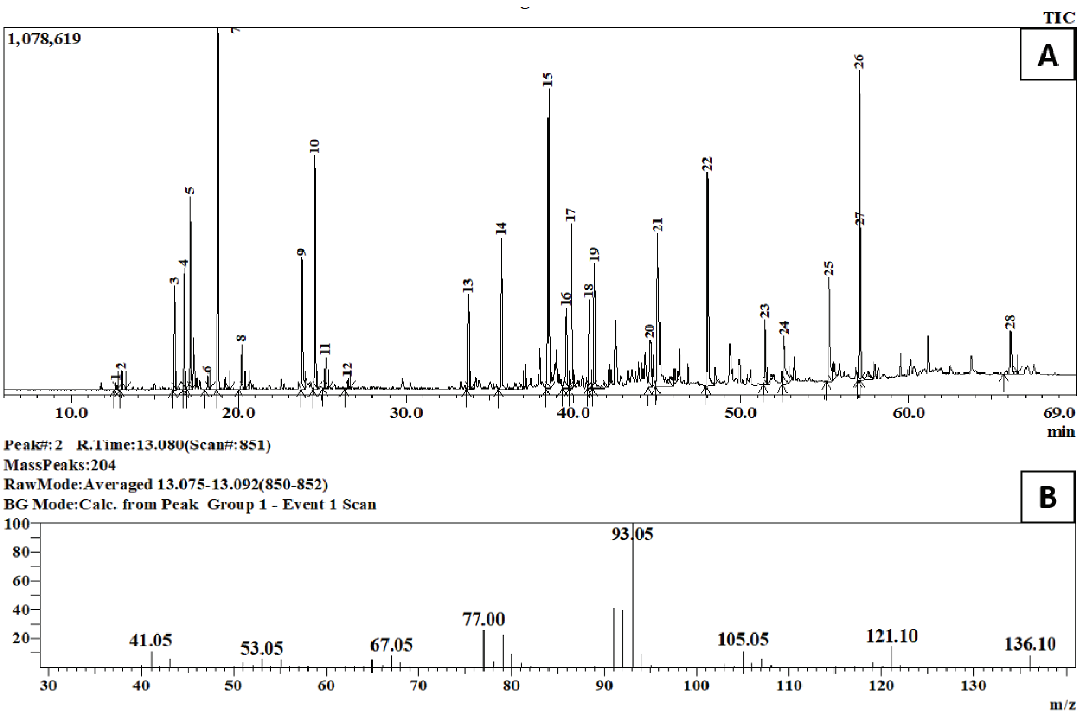

Figure 2: (A) TIC of essential oil from *Artemisia dubia*, **(B)** mass spectrum of peak #2 (α-pinene)

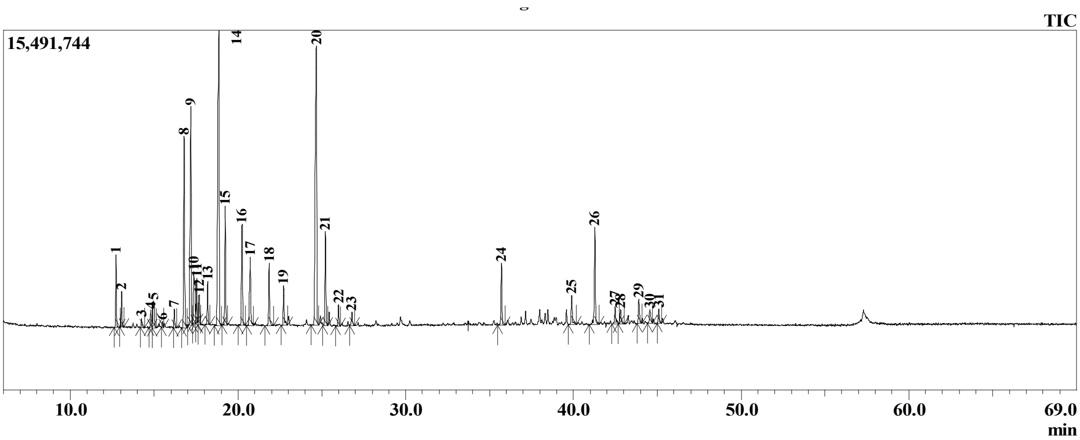

Figure 3: TIC of essential oil from *Elsholtzia fruticosa*

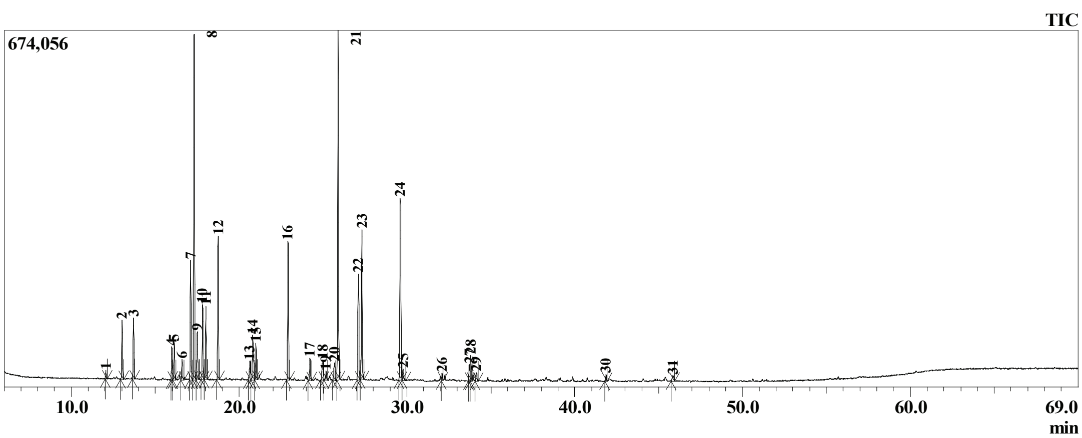

Figure 4: TIC of essential oil from *Tetrataenium lallii*

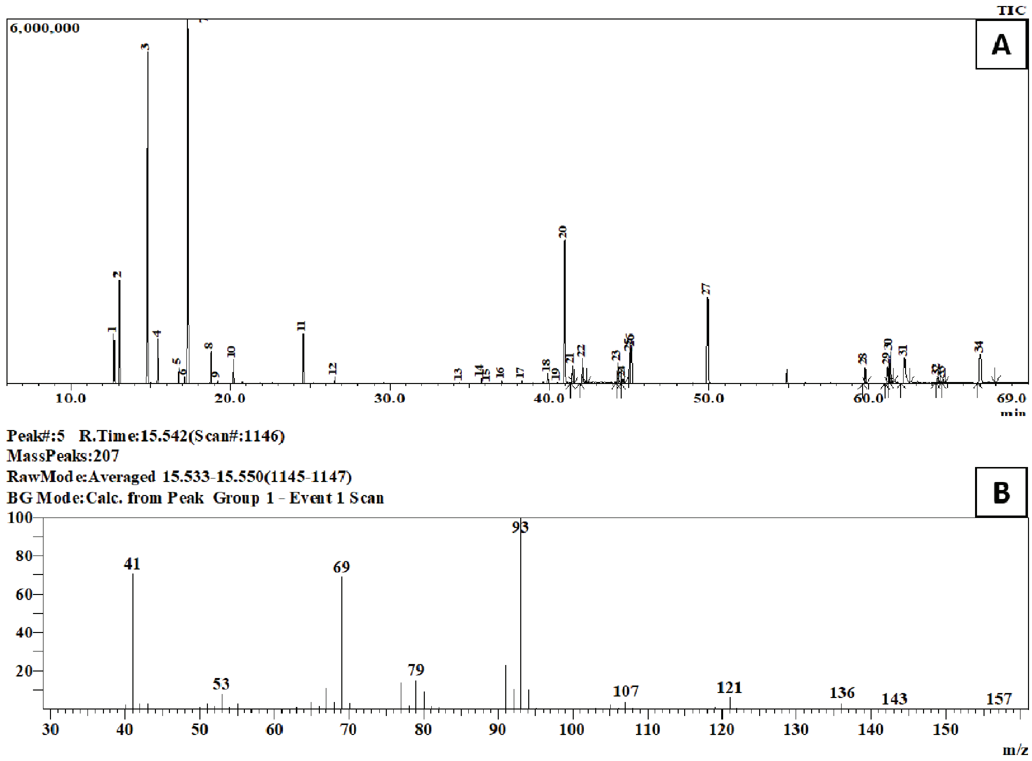

Figure 5: (A) TIC of essential oil from *Juniperus indica* berries, **(B)** mass spectrum of peak #5 (β-myrcene)

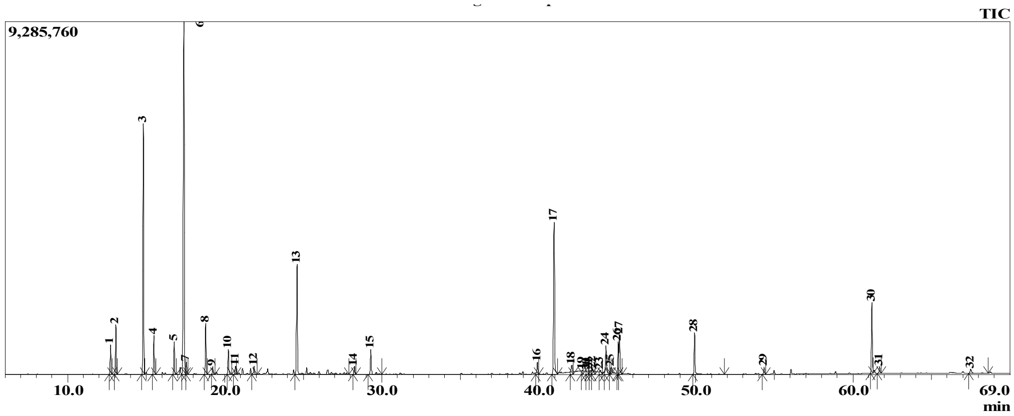

Figure 6: TIC of essential oil from *Juniperus indica* leaves

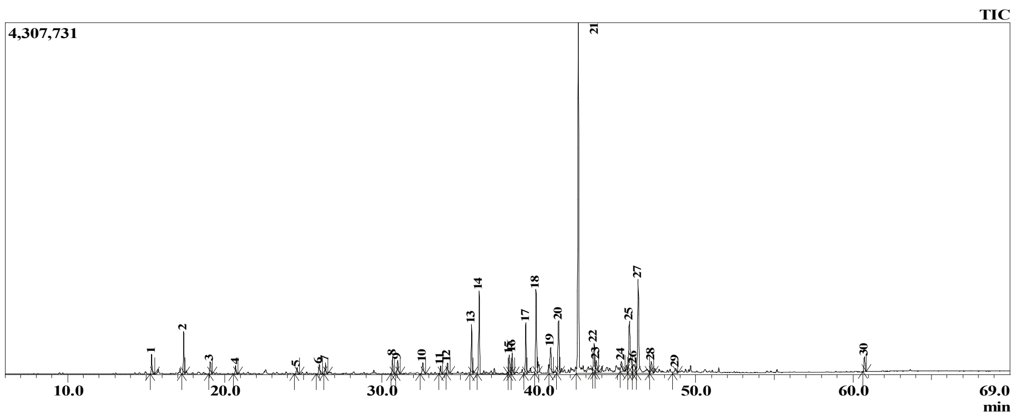

Figure 7: TIC of essential oil from *Nepeta ciliaris* (flowers)

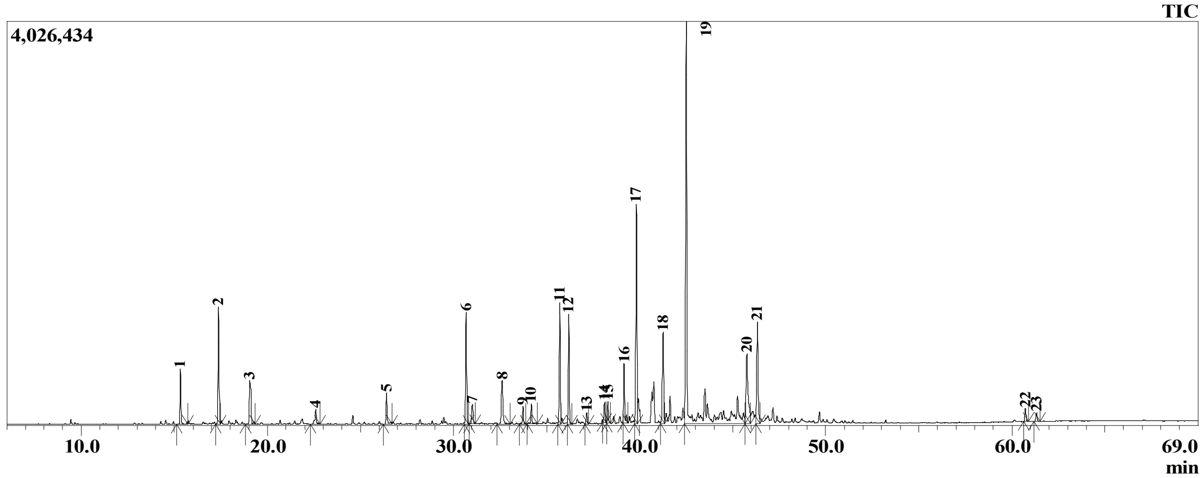

Figure 8: TIC of essential oil from *Nepeta ciliaris* (leaves)

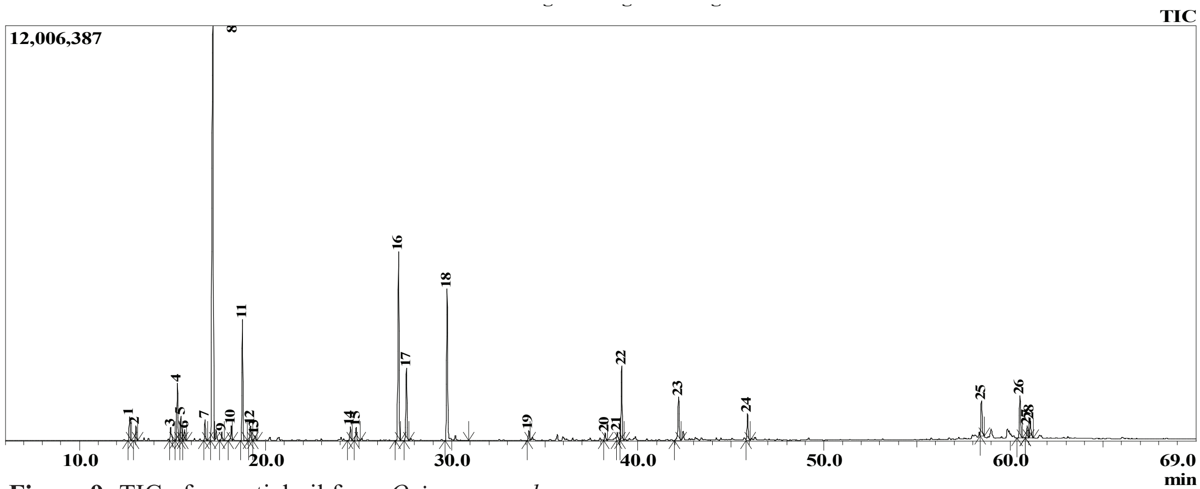

Figure 9: TIC of essential oil from *Origanum vulgare*

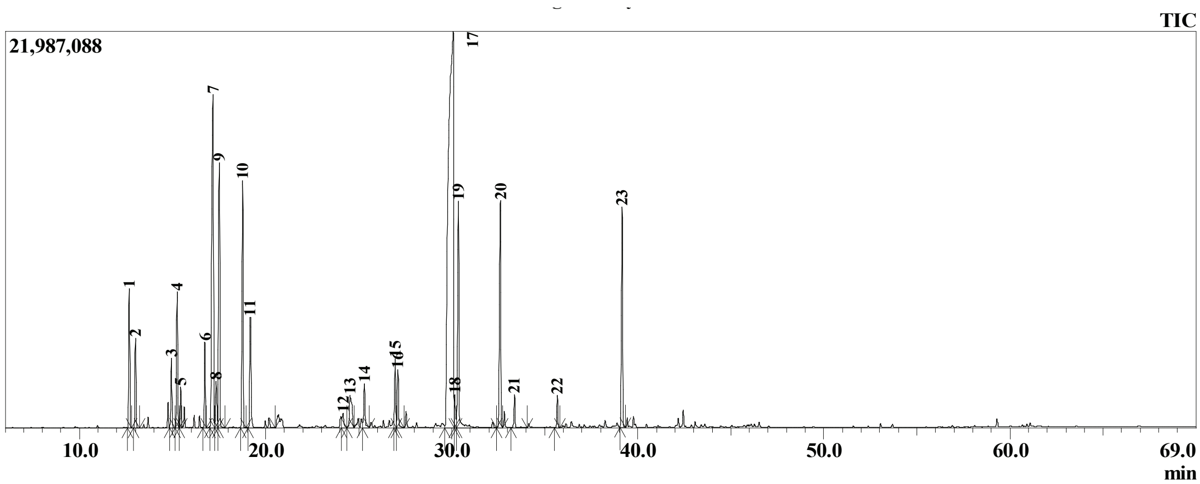

Figure 10: TIC of essential oil from *Thymus linearis*

emphasizes the significant influence of climatic variations on the chemical composition of plant species, even within the same region at similar altitudes. However, the constituents of the essential oil from the seeds of *Tetrataenium lallii* (synonym: *Heracleum lallii)* closely resembled those reported in the literature for other *Heracleum* species. Mustafavi et al. (2022) identified the essential oil from Iranian populations of *Heracleum persicum* as being highly rich in hexyl butyrate and octyl acetate. Similarly, Jagannath et al. (2012) identified bornyl acetate, α-pinene, limonene, and octyl acetate as the major constituents in the seeds of the Indian species, *Heracleum rigens*. While the specific constituents may vary between species, these studies consistently demonstrate that ester derivatives are major components of the essential oils extracted from the seeds of *Heracleum* species. Our findings from *T. lallii* support this observation. The seeds of *T. lallii* predominantly contained ester derivatives, including butanoic acid esters (15.9%), acetic acid octyl ester (15.7%), bornyl acetate (8.6%), *p*-cymene (5.3%), isobutyrates (6.5%), butyrates (6.1%), butyl isovalerate (3.1%), along with *D*-limonene (15.4%).

The essential oil extracted from the berries and leaves of *Juniperus indica* was rich in monoterpenoids, predominantly limonene and sabinene, and the sesquiterpenoid, α-elemol. Minor components included α-pinene, α-terpinene, α-thujene, myrcene, eudesmol, and cadinene. The chemical composition of the essential oils from berries and leaves exhibited some similarities. While both contained limonene, the leaf oil had a higher concentration (28.5%) compared to the berry oil (23.9%). Conversely, the berry oil was significantly richer in sabinene (20.2%) than the leaf oil (15.8%). Notably, α-elemol was present at approximately 10% in both cases. These findings differ from our previous studies on the essential oil of *Juniperus recurva* from the Langtang region, which primarily comprised δ-3-carene, β-pinene, cadina-1(6), 4-diene, δ-cadinene, and α-terpinolene. Another study conducted on the leaves and berries of *J. indica* from Uttarakhand at an altitude of 3800 meters revealed a somewhat similar profile, with sabinene, terpinen-4-ol, α-pinene, and γ-terpinene as the major components (Lohani et al., 2010). Essential oils extracted from *Nepeta* species have been primarily reported to be rich in caryophyllene, sesquiphellandrene, and caryophyllene oxide, along with trace amounts of other sesquiterpenoid compounds (Baranauskiene et al., 2019; Kumar & Mathela, 2018; Kumar et al., 2019). Similarly, the essential oils extracted from both the leaves and flowers of *Nepeta* were found to be predominantly composed of caryophyllene oxide (29.0% in leaves, 34.4% in flowers), sesquisabinene (10.8% in leaves, 5.8% in flowers), caryophyllene (6.0% in leaves, 3.5% in flowers), and bergamotene (6.2% in leaves, 7.2% in flowers), which aligns well with previous literature. In addition to these major sesquiterpenes, cyclohexenone derivatives were also identified as minor constituents (5.9% in leaves, 8.9% in flowers).

Oreganum vulgare and *Thymus linearis* are primarily used as culinary herbs. The essential oils extracted from the aerial parts of both plant species were rich in oxygenated compounds. *Oreganum vulgare* primarily consisted of *p*-cymene (34.1%), thymol methyl ether (12.1%), thymol (10.1%), terpinene (6.9%), bisabolene (4.5%), and carvacryl methyl ether (4.5%). *Thymus linearis* was notably rich in thymol (41.3%), alongside *p*-cymene (12.1%), thymol acetate (6.7%), carvacrol (6.2%), bisabolene (5.8%), eucalyptol (5.6%), and thujene (2.5%). Both plant species exhibited similar essential oil profiles, with variations in the relative abundance of carvacrol, *p*-cymene, thymol, and terpinene, along with other minor constituents (Firdous et al., 2023; Han et al., 2017; Kabdal et al., 2022; Teixeira et al., 2013).

Conclusion

This study provides valuable insights into the chemical composition of essential oils extracted from seven aromatic plant species collected from Manang district, Nepal. The GC-MS analysis revealed a diverse array of chemical constituents, with terpenoids, particularly monoterpenes and sesquiterpenes, being the predominant compounds. Key findings include the identification of compound, chamazulene, in *Artemisia dubia* and the characterization of the essential oil of *Nepeta ciliaris* essential oil, which was found to be primarily composed of sesquisabinene, caryophyllene oxide, and bergamotene. Furthermore, this study highlights the significant influence of factors such as altitude and climate on the chemical composition of essential oils. This is evidenced by comparing the composition of *Artemisis dubia* and *Elsholtzia fruticosa essential oils* with previous studies on similar species from different locations. These findings contribute to a deeper understanding of the chemical diversity of essential oils from high-altitude aromatic plants in the Nepalese Himalayas. This knowledge has potential applications in various fields, including pharmaceuticals, cosmetics, and the food industry. Further research is warranted to investigate the biological activities and potential therapeutic applications of these unique essential oil compositions.

Author Contributions

S Pradhan and D R Kandel collected the plant materials from Manang region; S Pradhan and R Maharjan dried the plant materials, extracted and analysed the essential oil; S Pradhan conducted literature survey and prepared the manuscript; D R Kandel prepared the herbarium and identified the collected plant materials; D R Kandel and R Maharjan reviewed the manuscript. All authors have read and agreed to the final version of the manuscript.

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Appendix 1 : Qualitative composition (area %) of monoterpenes in the essential oils from the aromatic plant species of the Manang region

S.N.	Compound Name	Composition Area (%)								
		Artemisia dubia	*Elsholtzia fruticosa*	*Tetrataenium lallii*	*Juniperus indica*		*Nepata ciliaris*		*Origanum vulgare*	*Thymus linearis*
					Berry	Leaves	Leaves	Flower		
1	(-) - Globulol		0.8							
2	(-)-β-bourbonene			0.4					0.6	
3	(+)-epi-Bicyclosesquiphellandrene	1.3								
4	1-octen-3-ol		1.7						0.9	
5	2-((2R, 4aR,8aS)-4a-Methyl-8-methylenedecane	1.9								
6	2(1H) Naphthalenone,3,5,6,7,8,8a-hexahydro	1.5								
7	2-(4a,8-Dimethyl-2,3,4,5,6,8a-hexahydro-1H)	1.4								
8	3-carene				0.5					
9	4-(1,5-Dimethylhex-4-enyl) cyclohex-2-enone						5.9	8.9		
10	Abietadiene				1.1					
11	Abietal <4-epi->				2.6					
12	Acetic acid, octyl ester			15.7						
13	Acetoxyelemol <8-α->					2.8				
14	Androstan-17-one, 3-ethyl-3-hydroxy	2.5								
15	Benzaldehyde		0.3							
16	Bergamotene <α-, cis>						5.2	5.8		
17	Bergamotene <β-, trans>						1.0	1.4		
18	Bornyl acetate			8.6						
19	Butanoate <hexyl-, 3-methyl->			6.6						
20	Butanoic acid, 2-methyl-, 2-methylbutyl ester			2.5						
21	Butanoic acid, 2-methyl-, hexyl ester			4.8						
22	Butanoic acid, 3-methyl-, 3-methylbutyl ester			1.6						
23	Butyrate <butyl-, 2-methyl->			3.2						
24	Butyrate <hexyl>			1.4						
25	Butyrate <isobutyl-, 2-methyl->			1.5						
26	Cadin-4-en-10-ol		0.6							
27	Carvacrol									6.2
28	Carvacryl methyl ether								4.5	
29	Caryophyllene oxide	1.9					29.0	34.4		
30	Chamazulene	6.7								
31	Cis-chrysanthenol	3.8								
32	Citronellate <methyl->					0.5				
33	Copaene	1.9								
34	Curcumen-15-al <ar->							1.1		
35	Decanal <n->			0.9						
36	D-Limonene	2.7	2.9	15.4	23.9	28.5				

S.N.	Compound Name	Composition Area (%)								
		Artemisia dubia	*Elsholtzia fruticosa*	*Tetrataenium lallii*	*Juniperus indica*		*Nepata ciliaris*		*Origanum vulgare*	*Thymus linearis*
					Berry	Leaves	Leaves	Flower		
37	E-Caryophyllene	3.5	2.6		0.4		6.0	3.5		0.5
38	E-Nerolidol	3.3	4.3							
39	Ethanone, 1-(1-cyclohexen-1-yl)-						5.3	2.8		
40	Eucalyptol		1.4	2.2		0.6				5.6
41	Eugenol									0.2
42	E-*β*-ocimene		1.5						0.9	
43	Germacrene B				0.1					
44	Germacrene B				1.2					
45	Germacrene D	1.2			0.2				0.5	0.1
46	Hexacosane									
47	Hexanoic acid, hexyl ester			1.2						
48	Hexanoic acid, octyl ester			0.4						
49	Humulene epoxide II							2.4		
50	Isobutyl isovalerate			1.6						
51	Isobutyrate <hexyl->			6.1						
52	Isobutyrate <isobutyl>			0.4						
53	Isopimara-9(11),15-diene					0.5				
54	Isovalerate <butyl>			3.1						
55	Linalool oxide <cis>								0.3	
56	Linalyl anthranilate	2.9		1.1		0.5		0.5		
57	Naphthalene, decahydro-4a-methyl-1-methyl	6.9								
58	Napth-1-ol < 1,2,3,4,4a,7,8,8a-octahydro-,4				0.5					
59	Norbornane < 2,2-dimethyl-,5-methylene->									0.1
60	n-pentacosane									
61	Octan-3-ol								0.6	0.3
62	Octan-3-one								2.9	2.1
63	p-cymen-8-ol								0.8	
64	p-cymene	4.2	9.6	5.3	0.4				34.1	12.4
65	Pregeijerene B					1.6				
66	Propionic acid, 2-methyl-, 3-methylbutyl ester			0.9						
67	Sabinene		0.6		20.2	15.8				0.3
68	Sabinene hydrate <trans>		4.6							2.0
69	Santolina triene									
70	Sesquisabinene						10.8	5.8		0.2
71	Terpinen-4-ol	6.0	18.1		3.1	7.3		0.4	0.8	1.0
72	Terpinolene	1.2								
73	Thymol			0.6					10.4	41.3
74	Thymol acetate									6.7

S.N.	Compound Name	Composition Area (%)								
		Artemisia dubia	*Elsholtzia fruticosa*	*Tetrataenium lallii*	*Juniperus indica*		*Nepata ciliaris*		*Origanum vulgare*	*Thymus linearis*
					Berry	**Leaves**	**Leaves**	**Flower**		
75	Thymol methyl ether								12.1	0.9
76	Totarol <trans>					0.4				
77	Valeranone								1.8	
78	Z-α-bisabolene									0.1
79	Z-β-ocimene		1.0						0.5	
80	α - epi Muurolol	2.1								
81	α - phellandrene	2.9	0.7							0.2
82	α - terpniene geranyl	4.0								
83	α -pinene		1.1	2.4	5.6	2.6			0.7	1.5
84	α -terpinene	3.3	8.0		1.0	1.8			1.1	1.4
85	α -terpineol		3.8	0.5						1.0
86	α -terpinolene		3.8		1.5	1.5				0.2
87	α-copaene	2.4					0.9	0.5		
88	α-curcumene						0.9	1.3		
89	α-elemol	2.1			9.5	10.9				
90	α-humulene						0.6			
91	α-muurolene	1.2								
92	α-thujene		2.4		2.5	1.5			1.1	2.5
93	β - oplopenone					0.7				
94	β-bisabolene						3.0	3.5	4.5	5.8
95	β-elemene				0.2					
96	β-eudesmol	3.8			2.0					
97	β-myrcene		0.2		2.4	2.0			1.2	0.5
98	β-pinene									1.1
99	β-selinene									
100	γ- epi Eudesmol					0.5				
101	γ-eudesmol		1.3		2.5	2.2				
103	γ-terpinene	9.3	16.5	6.4	1.9	2.9			6.9	5.9
104	δ-3-carene									0.2
105	δ-cadinene	3.2	1.3		0.7	0.8				
106	τ-cadinol		0.8							
	Total	88.9	89.8	94.7	86.3	88.0	68.6	72.2	87.1	100.0