Journal of Carcinogenesis
Covering Genesis to Therapeutics

Journal of Carcinogenesis, ISSN: 1477-3163
2024; Vol23: Issue 1, https://carcinogenesis.com/

Gc-Ms Analysis Of Some Medicinal Plant Leaves Collecetd From Chamoli District Of Uttarakhand (India)

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ABSTRACT

The current study highlights the rich medicinal plant biodiversity of Uttarakhand valley by unveiling the pharmacological attributes of different plants belonging to this region. The study focusses on five different plant species, namely, Artemisia annua, Artemisia vulgare, Picrorhiza kurroa, Origanum vulgare and Ajuga parviflora, belonging to Uttarakhand valley. The study shows presence of primary metabolites (carbohydrates) as well as secondary metabolites (phenols, flavonoids, alkaloids and tannins) in methanolic extracts of Artemisia annua, Artemisia vulgare, Picrorhiza kutki, Origanum vulgare and Ajuga parviflora. Thereafter, the study showcases the presence of numerous bioactive secondary metabolites and phytochemicals present in these plant species by GC-MS chromatography. The results of GC-MS analysis show presence of peaks corresponding to different phytochemicals in profile of different plants, wherein, GC-MS analysis of methanolic extracts of Artemisia annua, Artemisia vulgare, Picrorhiza kutki, Origanum vulgare and Ajuga parviflora revealed presence of 27, 25, 36, 25 and 45 different phytochemicals. All these phytochemicals have been proposed to contribute to antioxidant, antimicrobial, anti-helminthic and anti-inflammatory attributes of the studied plant species.

Keywords: *Artemisia annua, Artemisia vulgare, Picrorhiza kutki, Origanum vulgare, Ajuga parviflora, GC-MS chromatography, phytochemicals*

How to Cite: Monika Basotra, Anuradha Jayaraman, and Sanjeevi Ramakrishnan, (2024) Gc-Ms Analysis Of Some Medicinal Plant Leaves Collecetd From Chamoli District Of Uttarakhand (India), *Journal of Carcinogenesis, Vol.23, No.1,* 317-328.

1. INTRODUCTION

The Uttarakhand valley, situated in the northern part of India, inhabits a huge range of plants, which are known for their medicinal attributes. The region experiences diverse climatic conditions that favour the growth of various medicinal plants. Additionally, presence of high-altitude meadows, subalpine zones as well as temperate forests harbour unique segments of medicinal plant species, whose medicinal usage is embedded in the traditional medicine systema and bear valuable pharmacological attributes. The region harbours several medicinal plants such as *Picrorhiza kurroa* (Kutki), *Rheum australe* (Himalayan Rhubarb), *Berberis aristata* (Daruharidra), *Terminalia bellirica* (Bahera), Brahmi (Bacopa monnieri), *Aconitum heterophyllum* (Atis), Himalayan Cedar *(Cedrus deodara),* Himalayan Cedar *(Cedrus deodara), Angelica glauca (*Chuanxiong*), Urtica dioica (*Nettle*), Artemisia annua, Artemisia vulgare, Origanum vulgare*, and *Ajuga parviflora.* However, *Artemisia annua, Artemisia vulgare, Origanum vulgare, Picrorhiza kurroa* and *Ajuga parviflora* stand out owing to their prominent pharmacological attributes and therapeutic applications.

Artemisia annua belonging to Asteraceae family, is popularized as potent agent combating malaria owing to presence of a phytocompound artemisinin. Furthermore, the plant possesses several pharmacological attributes and contains several bioactive phytochemicals that contribute to antioxidant, anti-inflammatory, antihelminthic and antimicrobial activity of the plant while also contributing to usage of the plant in treatment of numerous chronic maladies (Aklilu *et al*., 2023; Xu *et al*., 2024).

Artemisia vulgare also referred to as Mugwort, aids in resolution of gastrointestinal and menstrual issues while essential oil harvested from the plant acts as potent anti-inflammatory, antimicrobial, and antioxidant agent (Yu *et al.*, 2022; Kaur *et al*., 2023). Another plant species, *Picrorhiza kurroa*, commonly known as Kutki, is renowned for its unparalleled hepatoprotective and gastroprotective attributes. The plant aids in resolution of liver disorders, jaundice, as well as digestive ailments, owing to presence of bioactive compound, termed as picrosides (Patel *et al*., 2023; Singh *et al.*, 2024).

Origanum vulgare (Oregano) is renowned for its culinary uses, however its medicinal attributes extend beyond the kitchen and the plant is renowned for its antimicrobial, antioxidant, as well as anti-inflammatory effects (Batiha *et al*., 2023; Akbari *et al*., 2023). The plant is used for resolution of a number of chronic health conditions and inflammatory disorders. *Ajuga parviflora*, a herbaceous plant belonging to the Lamiaceae family, is renowned for its noteworthy ability to ameliorate chronic respiratory and digestive disorders (Kumar *et al*., 2023; Mehta *et al*., 2024; Sanjeevi *et al*., 2024a,b).

Therefore, considering the innumerable health benefits of these plants, the current study has been drafted to identify the arsenal of phytochemicals in five of these plant species, including, *Artemisia annua, Artemisia vulgare, Origanum vulgare, Picrorhiza kurroa* and *Ajuga parviflora*. All these plants are a rich storehouse of primary and secondary metabolites, which contribute to diverse pharmacological attributes of these plants. The GC-MS analysis revealed presence of several phytocompounds in these plants, which contribute to antioxidant, antimicrobial, antihelminthic and anti-inflammatory activities of these plant species.

2. MATERIAL AND METHODS

Collection and processing of plant materials

Leaves of the selected plants were collected from HRDI, Uttarakhand, India. Those were shade dried, and grinded to make fine powder. 1 gm of plant material was soaked in methanol and kept for 24 hours. Those were filtered and sent for characterization.

Gas Chromatography and Mass Spectrum analysis

The extracts and the standards were analysed by GC-MS technique of Hewlett-Packard 6890/5973 operating at 1000 eV ionization energy, equipped with utilizing Agilent 7890A/5975C GC HP-5. Capillary column (phenyl methyl siloxane, 25 m×0.25 mm i.d,) with Helium (He) gas was utilized as carrier with split ratio 1:5. Temperature of oven was set at 100 °C (for 3 minutes) to 280 °C at 1-40°C/min; detector temperature, 250 to 280°C; carrier gas, He (0.9 ml/min). Retention indices were determined by utilizing retention times of samples that were injected under the same chromatographic conditions. The substances of the standard and plant samples were identified by comparing their mass spectra and retention time with those given in literature and by comparing with the

mass spectra of the Wiley library (NIST data bank) or with the published mass spectra.

3. RESULTS

Qualitative tests for presence of primary metabolites

Fehling's test was performed to determine the presence of carbohydrates in methanolic extracts of different plant species belonging to Uttarakhand valley, including, *Artemisia annua, Artemisia vulgare, Picrorhiza kutki, Origanum vulgare* and *Ajuga parviflora*. The results showed presence of carbohydrates in methanolic extracts of all the five plant species.

Qualitative tests for presence of secondary metabolites

Qualitative tests were performed to determine the presence of phenols, flavonoids, alkaloids and tannins in methanolic extracts of different plant species belonging to Uttarakhand valley, including, *Artemisia annua, Artemisia vulgare, Picrorhiza kutki, Origanum vulgare* and *Ajuga parviflora*. The results showed presence of phenols, flavonoids, alkaloids and tannins in methanolic extracts of all the five plant species.

Compounds identified in GC-MS study in methanolic extracts of *Artemisia annua*.

The GC-MS analysis of methanolic extracts of *Artemisia annua* identified a total of 27 phytocompounds corresponding to different peaks including Isopropyl Alcohol; 2,2-Dimethoxybutane; Glyceraldehyde; Dihydroxyacetone; 2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-on; 3-Pentanone, 2,4-dimethyl-; Maltol; Benzoic acid; Dodecane; 5-Hydroxymethylfurfural; 3,5-Diisopropoxy-1,1,1,7,7,7-hexamethyl-3,5-; 9-methylheptadecane; Sucrose; 3-Hydroxyphenylacetic acid, 2TMS derivative; Heneicosane; Octadecane, 1-chloro-; Hexadecane, 1-iodo-; Decane, 1-iodo-; Deoxypeganine; Carbonic acid, decyl nonyl ester; Benzimidazole-5-carboxamide, 1-ethyl-2-meth; Benzenepropanoic acid, 3,5-bis(1,1-dimethylet; n-Hexadecanoic acid; 1H-Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy; 9,12-Octadecadien-1-ol, (Z,Z)-; Triacontane, 1-iodo-; Octacosan-14-one. Out of the identified phytocompounds, the highest area corresponded to sucrose; Benzimidazole-5-carboxamide, 1-ethyl-2-meth and Isopropyl alcohol followed by others.

Compounds identified in GC-MS study in methanolic extracts of *Artemisia vulgare.*

The GC-MS analysis of methanolic extracts of *Artemisia vulgare* identified a total of 25 phytocompounds corresponding to different peaks including Ethyl 2-((methylamino)carbonyl)hydrazinecarboxylate; Isopropyl Alcohol; Propane, 2,2-dimethoxy-; Acetic acid; Glycerin; Dihydroxyacetone; 2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-on; 1,2-Ethanediol, monobenzoate; Phenol, 2-amino-4-[[(4-chlorophenyl)thio]methyl]; Hexane, 2,2,3,3-tetramethyl-; 1,3-Propanediol, 2-(hydroxymethyl)-2-nitro-; Oxalic acid 6-ethyloct-3-yl ethyl ester; Dichloroacetic acid, 4-pentadecyl ester; tert-Hexadecanethiol; Nonadecane; Octacosanal; IH-[1]Pyrindine-3-carbonitrile, 4-ethyl-2-oxo-; Decanoic acid, methyl ester; Benzenepropanoic acid, 3,5-bis(1,1-dimethylet); Undecanoic acid, pentyl ester; IH-Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy; Docosyl nonyl ether; Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)-; Squalene and Eicosane. Out of the identified phytocompounds, the highest area corresponded to IH-[1]Pyrindine-3-carbonitrile; Isopropyl alcohol and 1,3-Propanediol, 2-(hydroxymethyl)-2-nitro- followed by others.

Compounds identified in GC-MS study in methanolic extracts of *Picrorhiza kutki.*

The GC-MS analysis of methanolic extracts of *Picrorhiza kurroa.* identified a total of 36 phytocompounds corresponding to different peaks including Ethane, 1-chloro-1-fluoro-; Isopropyl Alcohol; Ethylene glycol, TMS derivative; Acetic acid; Ethanol, 2-(2-methoxyethoxy)-; Propanal, 2,3-dihydroxy-, (S)-; Glycerin; 2,2-Dimethoxybutane; Cyclopentane, 1-acetyl-1,2-epoxy-; Heptane, 5-ethyl-2-methyl-; Benzoic acid; Benzofuran, 2,3-dihydro-; 1,3-Propanediol, 2-(hydroxymethyl)-2-nitro-; Dodecane, 4,6-dimethyl-; Phenol, 3,5-bis(1,1-dimethylethyl)-; Eicosane; Acetic acid, 17-(4-hydroxy-5-methoxy-1,5-din); Eicosane; 1-Decanol, 2-hexyl-; 3-Eicosene, (E)-; Docosanoic acid, docosyl ester; Z-(13,14-Epoxy tetradec-11-en-1-ol acetate; Pyrimidine, 5-hydroxy-4-phenyl-; Neophytadiene; 2-Octylcyclopropene-1-heptanol; 3,7,11,15-Tetramethyl-2-hexadecen-1-ol; IH-[1]Pyrindine-3-carbonitrile, 4-ethyl-2-oxo-; Hexadecanoic acid, methyl ester; Mono(2-ethylhexyl) phthalate; IH-Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy; 9,12,15-Octadecatrienoic acid, methyl ester, (Z); Phytol; Hexadecanoic acid, 14-methyl-, methyl ester; 9,12,15-Octadecatrienoic acid, (ZZZ)-; Squalene and (2R,3R,4aR,5S,8aS)-2-Hydroxy-4a,5-dimethyl. Out of the identified phytocompounds, the highest area corresponded to Ethane, 1-chloro-1-fluoro-; Isopropyl Alcohol and IH-[1]Pyrindine-3-carbonitrile, 4-ethyl-2-oxo followed by others.

Compounds identified in GC-MS study in methanolic extracts of *Origanum vulgare*.

The GC-MS analysis of methanolic extracts of *Origanum vulgare* identified a total of 25 phytocompounds corresponding to different peaks including Isopropyl Alcohol; Ethanethiol, 2-(diethylboryloxy)-; 1,2-Ethanediamine, N-propyl; Acetic acid; 2-Propanone, 1-hydroxy-; Glycerin; 6-Ox-bicyclo[3.1.0)hexan-3-one; Cyclopentane, 1-acetyl-1,2-epoxy; Decane, 3,7-dimethyl-; 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6; 2,4-Dinitrophenylhydrazone of ribose tetrabe; Oxalic acid; isohexyl neopentyl ester; 1,3-Propanediol, 2-(hydroxymethyl)-2-nitro-;Octane, 2-methyl-;Eicosane, I-iodo-; Heptadecane, 2,6,10,15-tetramethyl-; Benzimidazole-5-carboxamide, 1-ethyl-2-meth; Tetradecanoic acid, 12-methyl methyl ester; Benzenepropanoic acid, 3,5-bis(1,1-dimethylet; n-Hexadecanoic acid; 1,6-Nonadien-3-ol, 3,7-dimethyl-; Octanoic acid, 4-dimethyl-, methyl ester, 4S; 2-Methylhexacosane and Heptadecane, 8-methyl-. Out of the identified phytocompounds, the highest area corresponded to Isopropyl alcohol; 1,3-Propanediol, 2-(hydroxymethyl)-2-nitro- and Benzimidazole-5-carboxamide, 1-ethyl-2-meth followed by others.

Compounds identified in GC-MS study in methanolic extracts of *Ajuga parviflora*.

The GC-MS analysis of methanolic extracts of *Ajuga parviflora* identified a total of 45 phytocompounds corresponding to different peaks including (IR)-2,6,6-Trimethylbicyclo[3.1.1]hept-2-ene; Bicyclo[3.1.1]heptane, 6,6-dimethyl-2-methyl-; Undecane; 2-Ethyl-1-hexanol, pentafluoropropionate; D-Limonene; Eucalyptol; (+)-2-Bornanone; Dodecane; 1-Butanol, 3-methyl-, acetate; Bornyl acetate; Phenol, 2,6-dimethoxy-; Tetradecane; Caryophyllene; (IR,25,6S,75,8S)-8-Isopropyl-1-methyl-3-met; 2,4-Di-tert-butylphenol; Hexadecane; Ficosane; Hexacosane, 1-iodo-; Tetradecanoic acid; 6-Tridecanol, 3,9-diethyl-; Octadecane; EEZ-1,3,12-Nonadecatriene-5,14-diol; 1,2-Benzenedicarboxylic acid, bis(2-methylprop); Hexadecanoic acid, methyl ester; Benzenepropanoic acid, 3,5-bis(1,1-dimethylet; Noryl tetracosyl ether; n-Hexadecanoic acid; Tetracosane; Hexadecyl nonyl ether; Eicosane; E,E,Z-1,3,12-Nonadecatriene-5,14-doil; Androst-4-en-3-one,17-(1-oxo-3-phenylpropa; Stigmasta-7,16-dien-3-ol,(3.beta,5.alpha)-; Phytol; Octadecanoic acid, 3-hydroxy-2-tetradecyl-,m; 9,12-Octadecadienoic acid (Z,Z)-; 9,19-Cyclo-27-norlanstan-25-one,3-(acetylon); Octadecanoic acid; Tetratriacontyl pentaflourapropionate; Tetracontane, 1,40-diol; Tetrapentacontane, 1,54-dibromo; Octacosanol; 2-cyclopentene-1-carboxylic acid, 1,2,3-trimet and Nonadecyl heptafluorobutyrate. Out of the identified phytocompounds, the highest area corresponded to 2-cyclopentene-1-carboxylic acid, 1,2,3-trimet; 9,12-Octadecadienoic acid (Z,Z)- and n-Hexadecanoic acid followed by others.

4. DISCUSSION

The Uttarakhand valley located in Northern part of India inhabits diverse range of flora, that possess significant pharmacological implications. The plants belonging to this region have been used as ethnopharmacological agents in traditional medicine for a number of decades owing to presence of several bioactive secondary metabolites that bestow these plant species with their ‘disease combating attribute”. The current study unveils a huge range of crucial phytocompounds that contribute to pharmacological attributes of five important plant species of Uttarakhand valley

including, *Artemisia annua*, *Artemisia vulgare*, *Picrorhiza kutki*, *Origanum vulgare* and *Ajuga parviflora*. The study shows presence of carbohydrates (primary metabolites) and phenols, flavonoids, alkaloids and tannins (secondary metabolites) in methanolic extracts of all the five plant species. While carbohydrates serve as the primary energy source in plants and also act as crucial structural components apart from contributing to effective functioning of different signalling pathways in plants. Secondary metabolites perform other crucial functions in the plant related to plant defense and immunity. For instance, phenols serve as antioxidant agents, aid in plant defense and protect plant from action of UV rays. Similarly, flavonoids are also involved in plant defense and contribute to antioxidant properties and UV protection. Alkaloids and tannins protect plants against herbivory and aid in plant signalling and interaction while contributing to analgesic, anti-inflammatory and antioxidant effects.

Thereafter, the researchers performed GC-MS analysis to unveil the huge plethora of phytochemicals responsible for pharmacological attributes of different plant species. For instance, *Artemisia annua* has been used in traditional Chinese medicine as antimalarial agent to treat fever and malaria in the form of decoctions and infusions owing to presence of artemisinin. In addition, the plant acts as important anticancer, anti-inflamatory and antioxidant agent. The current study revealed presence of 27 phytocompounds in GC-MS chromatogram of methanolic extract of the plant, wherein, these phytochemicals are believed to aid to antioxidant, antihelminthic, antimicrobial and anti-inflammatory properties of the plant (Table 1).

Table 1: The Following is the table showing the results of GC-MS Analysis in five different selective medicinal plants:

S.No.	Name of the Plant	Plant part used	Results of GC-MS Analysis
1.	*Artemisia annua*	Leaves	27
2.	*Artemisia vulgare*	Leaves	25
3.	*Picrorhiza kurroa*	Leaves	36
4.	*Origanum vulgare*	Leaves	25
5.	*Ajuga parviflora*	Leaves	45

GC-MS study of methanolic extracts of *Artemisia annua*

Antioxidant Compounds: Maltol; Benzoic acid; 5-Hydroxymethylfurfural (HMF) and 3-Hydroxyphenylacetic Acid (Liu *et al*., 2023; Wang *et al*., 2023)

Antihelminthic compounds: Benzimidazole-5-carboxamide, 1-ethyl-2-meth and 1H-Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy (Sharma *et al.*, 2023; Khan *et al*., 2023)

Antimicrobial: Benzoic acid; Deoxypeganine and 3,5-Diisopropoxy-1,1,1,7,7,7-hexamethyl-3,5 (Hossain *et al.*, 2023; Kumar *et al*., 2024)

Anti-inflammatory: Maltol; Benzoic acid and 5-Hydroxymethylfurfural (HMF) (Yang *et al*., 2022; Chen *et al*., 2023)

Similarly, *Artemisia vulgare* has been used to treat ailments of the digestive system, menstrual cramps and used in form of tinctures and poultices to treat digestive issues. In addition, the plant acts as important anticancer, anti-inflammatory and antioxidant agent. The current study revealed presence of 25 phytocompounds in GC-MS chromatogram of methanolic extract of the plant, wherein, these phytochemicals are believed to aid to antioxidant, antihelminthic, antimicrobial and anti-inflammatory properties of the plant (Table 2; Figure 1)

GC-MS study of methanolic extracts of *Artemisia vulgare*

1. Antioxidant Compounds: Acetic Acid; Glycerin; 2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-on (Maltol); Dihydroxyacetone; Phenol, 2-amino-4-[[(4-chlorophenyl)thio]methyl]; Decanoic Acid, Methyl Ester and Squalene (Kim *et al.*, 2023; Liu *et al*., 2022)

2. Antihelminthic compounds: IH-Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy (Khan et *al*., 2023)

3. Antimicrobial: Hexadecanoic Acid (Palmitic Acid); Benzenepropanoic Acid, 3,5-bis(1,1-dimethylet); Decanoic Acid, Methyl Ester and Octacosanal (Wu *et al.*, 2023; Zhang *et al*., 2023)

4. Anti-inflammatory: Acetic Acid; Glycerin; Hexadecanoic Acid, 2-hydroxy-1-(hydroxymethyl); Decanoic Acid, Methyl Ester and Dichloroacetic Acid, 4-pentadecyl Ester (Kim *et al.*, 2023; Berrios *et al*., 2022).

Similarly, *Picrorhiza kurroa* has been used to treat ailments of the digestive system, liver disorders and jaundice in form

of powders and decoctions. In addition, the plant acts as hepatoprotective, anti-allergic, anti-inflammatory and antioxidant agent. The current study revealed presence of 36 phytocompounds in GC-MS chromatogram of methanolic extract of the plant, wherein, these phytochemicals are believed to aid to antioxidant, antihelminthic, antimicrobial and anti-inflammatory properties of the plant (Table 3; Figure 2).

GC-MS study of methanolic extracts of *Picrorhiza kurroa*

1. Antioxidant Compounds: Squalene; Phytol and Hexadecanoic acid (Tanaka *et al*., 2022; Wu *et al*., 2023)

2. Antihelminthic compounds: Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy (Khan *et al*., 2023)

3. Antimicrobial: Benzoic acid; Phenol, 3,5-bis(1,1-dimethylethyl) and Phytol (Zhang *et al*., 2023; Hossain *et al.,* 2022)

4. Anti-inflammatory: Squalene; Phytol and Hexadecanoic acid (Berrios *et al*., 2022; Wu *et al*., 2023)

Similarly, *Origanum vulgare* acts as culinary herb and is used to treat digestive issues, respiratory disorders and used in the form of herbal infusions to treat cough and cold. In addition, the plant acts as important antimicrobial, anti-inflammatory and antioxidant agent. The current study revealed presence of 25 phytocompounds in GC-MS chromatogram of methanolic extract of the plant, wherein, these phytochemicals are believed to aid to antioxidant, antihelminthic, antimicrobial and anti-inflammatory properties of the plant (Table 4; Figure 3).

GC-MS study of methanolic extracts of *Origanum vulgare*

1. Antioxidant Compounds: Acetic acid; 4H-Pyran-4-one; 2,3-dihydro-3,5-dihydroxy-6-methyl and n-hexadecanoic acid (Abbasi *et al*., 2012; Liu *et al*., 2022; Wu *et a*l., 2023)

2. Antihelminthic compounds: Benzimidazole-5-carboxamide, 1-ethyl-2-meth (Sharma *et al*., 2023)

3. Antimicrobial: Benzenepropanoic Acid, 3,5-bis(1,1-dimethylethyl); Octanoic Acid, 4-dimethyl-, Methyl Ester and Cyclopentane, 1-acetyl-1,2-epoxy- (Garcia *et al*., 2023; Zhang *et al*., 2022)

4. Anti-inflammatory: n-Hexadecanoic Acid (Palmitic Acid) and Octanoic Acid, 4-dimethyl-, Methyl Ester (Wu *et al.,* 2023; Garcia *et al.,* 2023)

Similarly, *Ajuga parviflora* acts as adaptogenic and promotes overall health while also aiding in treatment of cough, cold and fever in the form of tinctures and decoctions. In addition, the plant acts as adaptogenic, antimicrobial, anti-inflammatory and antioxidant agent. The current study revealed presence of 45 phytocompounds in GC-MS chromatogram of methanolic extract of the plant, wherein, these phytochemicals are believed to aid to antioxidant, antihelminthic, antimicrobial and anti-inflammatory properties of the plant (Table 5; Figure 4).

GC-MS study of methanolic extracts of *Ajuga parviflora*

1. Antioxidant Compounds: D-limonene, Eucalyptol (1,8-Cineole), Phenol, 2,6-dimethoxy; 2,4-Di-tert-butylphenol and phytol (Russo *et al*., 2023; Choi *et al.,* 2023)

2. Antihelminthic compounds: Caryophyllene

3. Antimicrobial: D-limonene; Eucalyptol (1,8-Cineole); Bornyl acetate and 2,4-Di-tert-butylphenol (Kim *et al.,* 2023; Wu *et al*., 2022)

4. Anti-inflammatory: D-limonene; Eucalyptol (1,8-Cineole); Phytol and Phenol, 2,6-dimethoxy (Berrios *et al.,* 2022; Zhang *et al.,* 2023).

This study provides a comprehensive analysis of the methanolic extracts of different key plants of Uttarakhand valley, namely *Artemisia annua*, *Artemisia vulgaris*, *Picrorhiza kurroa*, *Origanum vulgare*, and *Ajuga parviflora*, by usage of Gas Chromatography-Mass Spectrometry (GC-MS) in order to unveil chemical profiles as well as associated pharmacological attributes of plants. However, further studies are needed to explore the modus operandi of these phytochemicals in greater details and to evaluate their efficacy for future medicinal applications (Table 6; Figure 5).

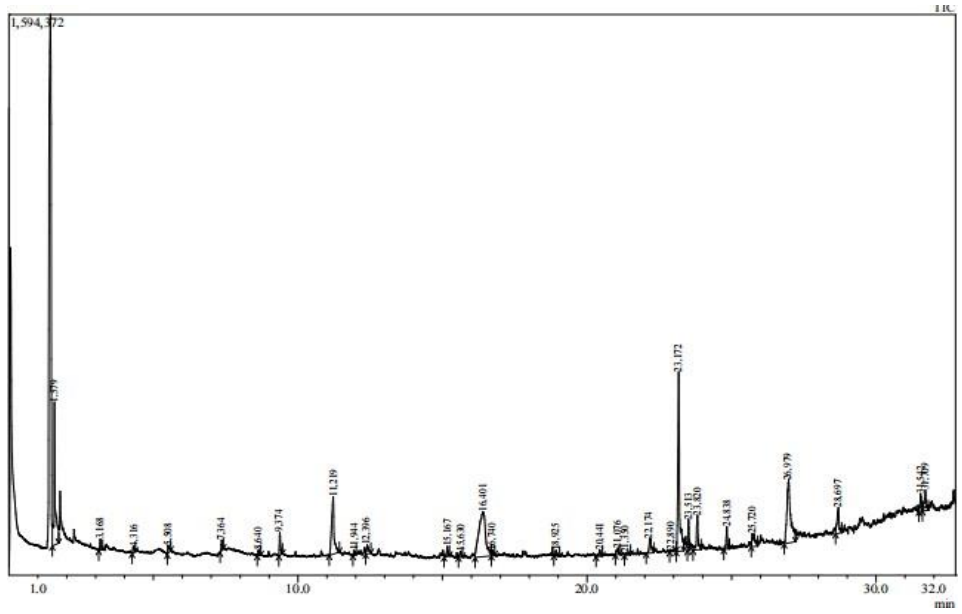

Figure 1: Chromatogram obtained in GC-MS study for methanolic extracts of *Artensia annua*.

Table 2: Compounds identified in GC-MS study in methanolic extracts of *Artensia annua*.

Peak Report TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Name
1	1.579	1.500	1.725	1176382	10.51	406594	18.23	2.89	Isopropyl Alcohol
2	3.168	3.110	3.250	95808	0.86	31197	1.40	3.07	2,2-Dimethoxybutane
3	4.316	4.260	4.380	70991	0.63	17827	0.80	3.98	Glyceraldehyde
4	5.508	5.480	5.595	78043	0.70	23474	1.05	3.32	Dihydroxyacetone
5	7.364	7.305	7.420	70064	0.63	29614	1.33	2.37	2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-on
6	8.640	8.590	8.720	42990	0.38	15609	0.70	2.75	3-Pentanone, 2,4-dimethyl-
7	9.374	9.335	9.470	182633	1.63	65106	2.92	2.81	Maltol
8	11.219	11.085	11.435	957742	8.55	163856	7.35	5.85	Benzoic acid
9	11.944	11.905	12.015	42148	0.38	14221	0.64	2.96	Dodecane
10	12.396	12.340	12.520	125165	1.12	25267	1.13	4.95	5-Hydroxymethylfurfural
11	15.167	15.055	15.245	104203	0.93	29149	1.31	3.57	3,5-Diisopropoxy-1,1,1,7,7,7-hexamethyl-3,5-
12	15.630	15.555	15.690	59277	0.53	16785	0.75	3.53	9-methylheptadecane
13	16.401	16.125	16.690	2054664	18.35	127411	5.71	16.13	Sucrose
14	16.740	16.690	16.810	47607	0.43	15473	0.69	3.08	3-Hydroxyphenylacetic acid, 2TMS derivative
15	18.925	18.850	19.050	49149	0.44	14711	0.66	3.34	Heneicosane
16	20.441	20.310	20.530	81599	0.73	18997	0.85	4.30	Octadecane, 1-chloro-
17	21.076	20.980	21.120	75360	0.67	18081	0.81	4.17	Hexadecane, 1-iodo-
18	21.350	21.290	21.510	50344	0.45	6829	0.31	7.37	Decane, 1-iodo-
19	22.174	22.050	22.310	256259	2.29	41480	1.86	6.18	Deoxypeganine
20	22.890	22.860	23.090	63745	0.57	6457	0.29	9.87	Carbonic acid, decyl nonyl ester
21	23.172	23.090	23.350	1944505	17.36	496866	22.28	3.91	Benzimidazole-5-carboxamide, 1-ethyl-2-meth
22	23.513	23.470	23.550	231091	2.06	88597	3.97	2.61	Benzenepropanoic acid, 3,5-bis(1,1-dimethylet
23	23.820	23.670	23.950	408508	3.65	98065	4.40	4.17	n-Hexadecanoic acid
24	24.838	24.730	24.930	196426	1.75	62433	2.80	3.15	1H-Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy
25	25.720	25.680	25.900	261632	2.34	36929	1.66	7.08	9,12-Octadecadien-1-ol, (Z,Z)-
26	26.979	26.820	27.210	1633843	14.59	179080	8.03	9.12	
27	28.697	28.600	28.810	367692	3.28	71457	3.20	5.15	Triacontane, 1-iodo-
28	31.542	31.480	31.600	179585	1.60	49835	2.23	3.60	Octacosan-14-one

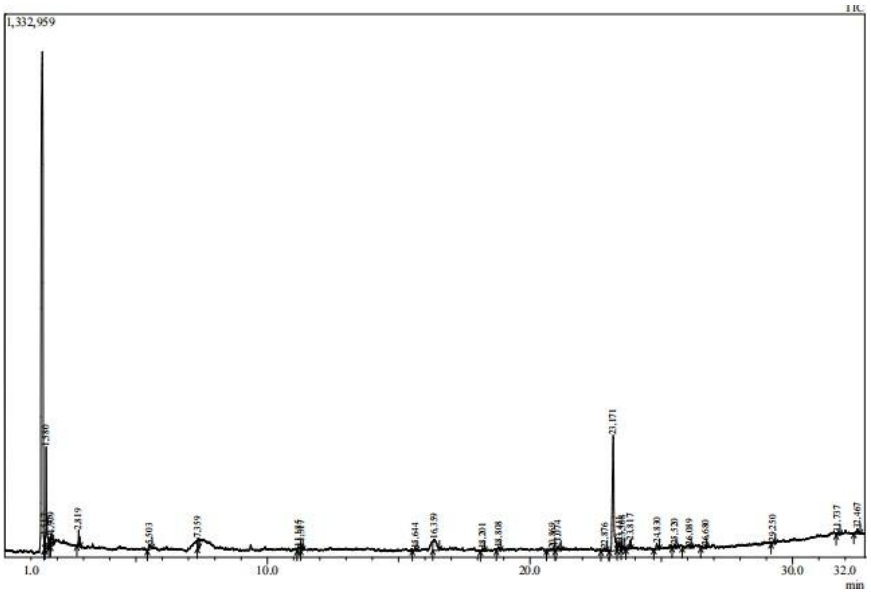

Figure 2: Chromatogram obtained in GC-MS study for methanolic extracts of *Artensia vulgare*.

Table 3: Compounds identified in GC-MS study in methanolic extracts of *Artensia vulgare.*

Peak Report TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Name
1	1.517	1.495	1.535	74320	2.24	35346	3.91	2.10	Ethyl2-((methylamino)carbonyl)hydrazinecarl
2	1.580	1.535	1.685	487431	14.69	250658	27.71	1.94	Isopropyl Alcohol
3	1.745	1.685	1.750	73486	2.22	25082	2.77	2.93	Propane, 2,2-dimethoxy-
4	1.779	1.750	1.865	126692	3.82	31332	3.46	4.04	Acetic acid
5	2.819	2.750	2.875	62965	1.90	40500	4.48	1.55	Glycerin
6	5.503	5.430	5.615	63013	1.90	13716	1.52	4.59	Dihydroxyacetone
7	7.359	7.335	7.405	85939	2.59	25148	2.78	3.42	2,4-Dihydroxy-2,5-dimethyl-3(2H)-furan-3-on
8	11.185	11.130	11.275	58581	1.77	9864	1.09	5.94	1,2-Ethanediol, monobenzoate
9	11.317	11.275	11.355	36415	1.10	9615	1.06	3.79	phenol, 2-amino-4-[[(4-chlorophenyl)thio]metl
10	15.644	15.525	15.695	26944	0.81	4768	0.53	5.65	Hexane, 2,2,3,3-tetramethyl-
11	16.359	16.300	16.550	261826	7.89	27695	3.06	9.45	1,3-Propanediol, 2-(hydroxymethyl)-2-nitro-
12	18.201	18.120	18.270	24082	0.73	5440	0.60	4.43	Oxalic acid, 6-ethyloct-3-yl ethyl ester
13	18.808	18.720	18.880	43294	1.31	7751	0.86	5.59	Dichloroacetic acid, 4-pentadecyl ester
14	20.869	20.630	20.960	52042	1.57	4815	0.53	10.81	tert-Hexadecanethiol
15	21.074	20.960	21.180	52556	1.58	8922	0.99	5.89	Nonadecane
16	22.876	22.700	22.920	40231	1.21	5251	0.58	7.66	Octacosanal
17	23.171	23.020	23.320	1202902	36.26	279680	30.92	4.30	1H-[1]Pyrindine-3-carbonitrile, 4-ethyl-2-oxo-
18	23.411	23.320	23.470	101727	3.07	20043	2.22	5.08	Decanoic acid, methyl ester
19	23.508	23.470	23.610	59900	1.81	20619	2.28	2.91	Benzenepropanoic acid, 3,5-bis(1,1-dimethylet
20	23.817	23.650	23.850	69140	2.08	19927	2.20	3.47	Undecanoic acid, pentyl ester
21	24.830	24.720	24.930	51936	1.57	14666	1.62	3.54	1H-Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy
22	25.520	25.410	25.560	29243	0.88	8045	0.89	3.63	
23	26.089	25.800	26.130	75915	2.29	7031	0.78	10.80	
24	26.680	26.500	26.720	35261	1.06	5196	0.57	6.79	Docosyl nonyl ether
25	29.250	29.180	29.340	32054	0.97	5191	0.57	6.17	Hexadecanoic acid, 2-hydroxy-1-(hydroxymetl
26	31.737	31.660	31.810	29786	0.90	6551	0.72	4.55	Squalene
27	32.467	32.330	32.580	59733	1.80	11687	1.29	5.11	Eicosane

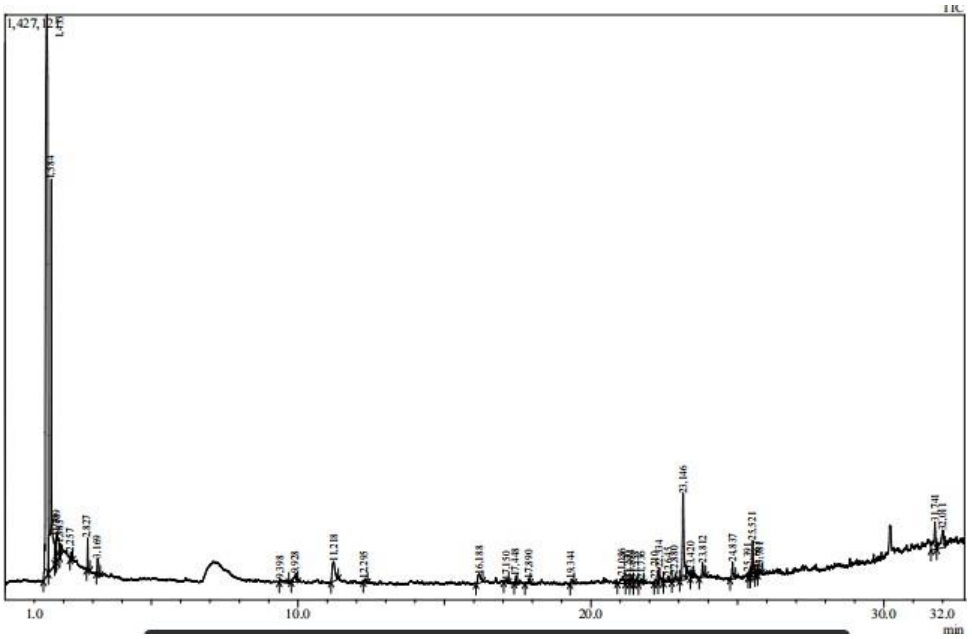

Figure 3: Chromatogram obtained in GC-MS study for methanolic extracts of *Picrorhiza kutki.*

Table 4: Compounds identified in GC-MS study in methanolic extracts of *Picrorhiza kutki.*

Peak Report TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Name
1	1.433	1.315	1.490	7167431	53.02	1368726	39.64	5.24	Ethane, 1-chloro-1-fluoro-
2	1.584	1.490	1.695	1844403	13.64	951816	27.57	1.94	Isopropyl Alcohol
3	1.745	1.695	1.760	213016	1.58	63095	1.83	3.38	Ethylene glycol, TMS derivative
4	1.789	1.760	1.870	329684	2.44	68586	1.99	4.81	Acetic acid
5	1.885	1.870	1.905	58756	0.43	31744	0.92	1.85	Ethanol, 2-(2-methoxyethoxy)-
6	2.257	2.220	2.315	37563	0.28	19163	0.55	1.96	Propanal, 2,3-dihydroxy-, (S)-
7	2.827	2.785	2.900	110787	0.82	78295	2.27	1.41	Glycerin
8	3.169	3.125	3.255	126627	0.94	38950	1.13	3.25	2,2-Dimethoxybutane
9	9.398	9.360	9.690	78449	0.58	7559	0.22	10.38	Cyclopentane, 1-acetyl-1,2-epoxy-
10	9.928	9.770	9.990	115683	0.86	20807	0.60	5.56	Heptane, 5-ethyl-2-methyl-
11	11.218	11.130	11.380	327531	2.42	47904	1.39	6.84	Benzoic acid
12	12.295	12.230	12.380	37714	0.28	8303	0.24	4.54	Benzofuran, 2,3-dihydro-
13	16.188	16.080	16.310	158451	1.17	22863	0.66	6.93	1,3-Propanediol, 2-(hydroxymethyl)-2-nitro-
14	17.150	17.020	17.190	31144	0.23	8076	0.23	3.86	Dodecane, 4,6-dimethyl-
15	17.448	17.380	17.490	41210	0.30	18403	0.53	2.24	Phenol, 3,5-bis(1,1-dimethylethyl)-
16	17.890	17.750	17.940	43614	0.32	12468	0.36	3.50	Eicosane
17	19.344	19.290	19.430	46202	0.34	10942	0.32	4.22	Acetic acid, 17-(4-hydroxy-5-methoxy-1,5-din
18	21.086	20.900	21.180	119893	0.89	16932	0.49	7.08	Eicosane
19	21.270	21.180	21.320	56879	0.42	11129	0.32	5.11	1-Decanol, 2-hexyl-
20	21.394	21.320	21.450	68213	0.50	13533	0.39	5.04	3-Eicosene, (E)-
21	21.558	21.450	21.620	75572	0.56	12871	0.37	5.87	Docosanoic acid, docosyl ester
22	21.736	21.620	21.800	69870	0.52	12067	0.35	5.79	Z-(13,14-Epoxy)tetradec-11-en-1-ol acetate
23	22.210	22.150	22.290	42733	0.32	9263	0.27	4.61	Pyrimidine, 5-hydroxy-4-phenyl-
24	22.334	22.290	22.470	128824	0.95	35420	1.03	3.64	Neophytadiene
25	22.645	22.470	22.760	80211	0.59	14449	0.42	5.55	2-Octylcyclopropene-1-heptanol
26	22.880	22.760	23.030	74845	0.55	16406	0.48	4.56	3,7,11,15-Tetramethyl-2-hexadecen-1-ol
27	23.146	23.030	23.250	787344	5.82	209309	6.06	3.76	1H-[1]Pyrindine-3-carbonitrile, 4-ethyl-2-oxo-
28	23.420	23.390	23.480	50897	0.38	19243	0.56	2.64	Hexadecanoic acid, methyl ester
29	23.812	23.690	23.910	101690	0.75	34486	1.00	2.95	Mono(2-ethylhexyl) phthalate
30	24.837	24.750	24.940	133182	0.99	38590	1.12	3.45	1H-Pyrrolo[2,1-b]quinazolin-9-one, 3-hydroxy
31	25.391	25.360	25.440	31409	0.23	14305	0.41	2.20	9,12,15-Octadecatrienoic acid, methyl ester, (Z
32	25.521	25.440	25.600	229528	1.70	85815	2.49	2.67	Phytol
33	25.663	25.600	25.690	37857	0.28	13824	0.40	2.74	Hexadecanoic acid, 14-methyl-, methyl ester
34	25.781	25.690	25.840	37599	0.28	10885	0.32	3.45	9,12,15-Octadecatrienoic acid, (Z,Z,Z)-
35	31.741	31.600	31.800	297705	2.20	65310	1.89	4.56	Squalene
36	32.011	31.800	32.090	325659	2.41	41448	1.20	7.86	(2R,3R,4aR,5S,8aS)-2-Hydroxy-4a,5-dimethyl
				13518175	100.00	3452985	100.00		

Spectrum

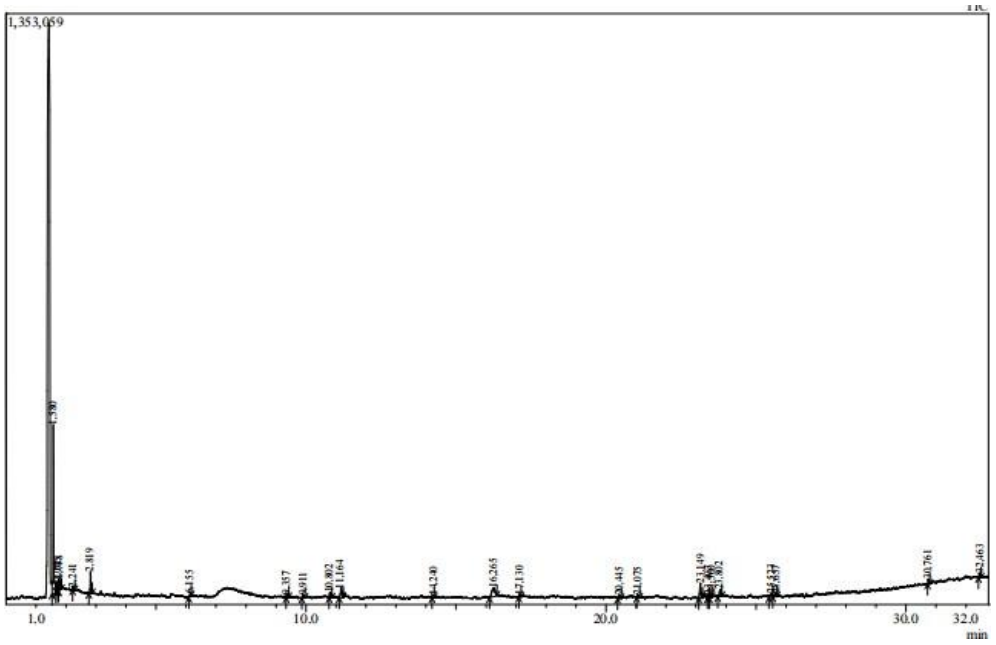

Figure 4: Chromatogram obtained in GC-MS study for methanolic extracts of *Origanium vulgare*.

Table 5: Compounds identified in GC-MS study in methanolic extracts of *Origanium vulgare*.

Peak Report TIC

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Name
1	1.580	1.535	1.670	525066	33.65	387571	53.67	1.35	Isopropyl Alcohol
2	1.712	1.670	1.735	57073	3.66	16880	2.34	3.38	Ethanethiol, 2-(diethylboryloxy)-
3	1.745	1.735	1.760	29504	1.89	23557	3.26	1.25	1,2-Ethanediamine, N-propyl-
4	1.778	1.760	1.855	82495	5.29	27115	3.75	3.04	Acetic acid
5	2.241	2.220	2.300	17662	1.13	7824	1.08	2.26	2-Propanone, 1-hydroxy-
6	2.819	2.765	2.880	71373	4.57	50953	7.06	1.40	Glycerin
7	6.155	6.095	6.180	17215	1.10	5811	0.80	2.96	6-Oxa-bicyclo[3.1.0]hexan-3-one
8	9.357	9.335	9.430	25410	1.63	7749	1.07	3.28	Cyclopentane, 1-acetyl-1,2-epoxy-
9	9.911	9.860	9.970	25657	1.64	6474	0.90	3.96	Decane, 3,7-dimethyl-
10	10.802	10.775	10.870	40842	2.62	11996	1.66	3.40	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-
11	11.164	11.105	11.245	92022	5.90	20577	2.85	4.47	2,4-Dinitrophennylhydrazone of ribose tetrabe
12	14.240	14.200	14.275	20827	1.33	6376	0.88	3.27	Oxalic acid, isohexyl neopentyl ester
13	16.265	16.115	16.365	158167	10.14	20807	2.88	7.60	1,3-Propanediol, 2-(hydroxymethyl)-2-nitro-
14	17.130	17.095	17.175	19025	1.22	6447	0.89	2.95	Octane, 2-methyl-
15	20.445	20.385	20.505	19856	1.27	7460	1.03	2.66	Eicosane, 1-iodo-
16	21.075	21.025	21.120	20087	1.29	6364	0.88	3.16	Heptadecane, 2,6,10,15-tetramethyl-
17	23.149	23.095	23.215	116874	7.49	34930	4.84	3.35	Benzimidazole-5-carboxamide, 1-ethyl-2-meth
18	23.407	23.385	23.450	19772	1.27	8643	1.20	2.29	Tetradecanoic acid, 12-methyl-, methyl ester
19	23.500	23.450	23.535	21319	1.37	8964	1.24	2.38	Benzenepropanoic acid, 3,5-bis(1,1-dimethylet
20	23.802	23.725	23.865	52688	3.38	15904	2.20	3.31	n-Hexadecanoic acid
21	25.523	25.425	25.560	39969	2.56	9174	1.27	4.36	1,6-Nonadien-3-ol, 3,7-dimethyl-
22	25.657	25.560	25.695	30491	1.95	7051	0.98	4.32	Octanoic acid, 4,6-dimethyl-, methyl ester, (4S
23	30.761	30.715	30.795	23285	1.49	11979	1.66	1.94	2-Methylhexacosane
24	32.463	32.415	32.500	33506	2.15	11557	1.60	2.90	Heptadecane, 8-methyl-
				1560185	100.00	722163	100.00		

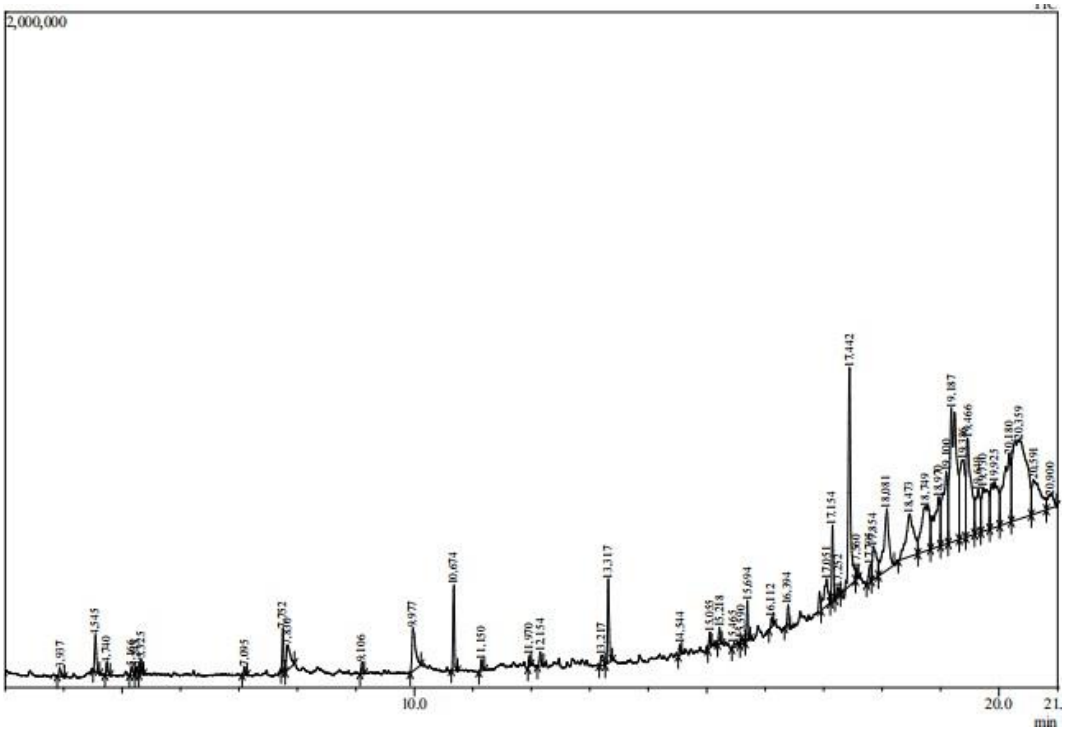

Figure 5: Chromatogram obtained in GC-MS study for methanolic extracts of *Ajuga parviflora* .

Table 6: Compounds identified in GC-MS study in methanolic extracts of *Ajuga parviflora*.

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Name
29	17.442	17.290	17.545	1785765	6.08	646366	11.74	2.76	n-Hexadecanoic acid
30	17.560	17.545	17.595	63220	0.22	36286	0.66	1.74	Tetracosane
31	17.795	17.735	17.820	164542	0.56	49919	0.91	3.30	Hexadecyl nonyl ether
32	17.854	17.820	17.935	483343	1.64	98092	1.78	4.93	Eicosane
33	18.081	17.935	18.205	1136373	3.87	181739	3.30	6.25	E,E,Z-1,3,12-Nonadecatriene-5,14-diol
34	18.473	18.275	18.610	1179650	4.01	125671	2.28	9.39	Androst-4-en-3-one, 17-(1-oxo-3-phenylpropo
35	18.749	18.610	18.830	1305251	4.44	132174	2.40	9.88	Stigmasta-7,16-dien-3-ol, (3.beta.,5.alpha.)-
36	18.970	18.830	19.000	1101119	3.75	145827	2.65	7.55	Phytol
37	19.100	19.000	19.130	1297104	4.41	211983	3.85	6.12	Octadecanoic acid, 3-hydroxy-2-tetradecyl-, m
38	19.187	19.130	19.320	3201355	10.90	390676	7.10	8.19	9,12-Octadecadienoic acid (Z,Z)-
39	19.386	19.320	19.430	1404744	4.78	231654	4.21	6.06	9,19-Cyclo-27-norlanostan-25-one, 3-(acetylo
40	19.466	19.430	19.580	1630773	5.55	286150	5.20	5.70	Octadecanoic acid
41	19.649	19.580	19.690	724508	2.47	128138	2.33	5.65	Tetratriacontyl pentafluoropropionate
42	19.730	19.690	19.840	1034637	3.52	130263	2.37	7.94	Tetracontane-1,40-diol
43	19.925	19.840	20.010	1202031	4.09	133057	2.42	9.03	Tetrapentacontane, 1,54-dibromo-
44	20.180	20.010	20.210	1795518	6.11	202887	3.69	8.85	Octacosanol
45	20.359	20.210	20.550	3884986	13.22	235459	4.28	16.50	2-Cyclopentene-1-carboxylic acid, 1,2,3-trimet
46	20.591	20.550	20.810	1030525	3.51	102270	1.86	10.08	Nonadecyl heptafluorobutyrate
47	20.900	20.810	20.990	291804	0.99	39994	0.73	7.30	
				29383295	100.00	5504062	100.00		

Spectrum

5. CONCLUSION

The present study comprehensively highlights the phytochemical diversity and pharmacological potential of five medicinally significant plants from the Uttarakhand valley — Artemisia annua, Artemisia vulgare, Picrorhiza kurroa, Origanum vulgare, and Ajuga parviflora. Qualitative screening confirmed the presence of primary metabolites such as carbohydrates and secondary metabolites including phenols, flavonoids, alkaloids, and tannins, all of which play vital roles in plant defense and contribute to their medicinal properties. The GC-MS analysis revealed a wide array of bioactive phytocompounds that collectively exhibit antioxidant, antimicrobial, anti-inflammatory, and antihelminthic activities.

Compounds such as artemisinin, squalene, phytol, benzoic acid, hexadecanoic acid, and D-limonene are of particular pharmacological relevance and align with the traditional uses of these plants in herbal medicine. These findings underscore the immense potential of the Uttarakhand flora as a reservoir of therapeutic agents that could be harnessed for modern drug development. Nonetheless, detailed pharmacodynamic, pharmacokinetic, and toxicological investigations are essential to elucidate the mechanisms of action and validate the clinical efficacy of these phytochemicals. Overall, the study reinforces the importance of conserving Himalayan medicinal biodiversity and encourages further research into its sustainable utilization for pharmaceutical and nutraceutical applications

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