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Research Article

Comprehensive research on Phytochemical Characterization of *Rosa webbiana* Various Parts via Advanced Spectroscopic and Chromatographic Techniques and Assessment of Their Bioactive Potential

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Abstract

Rosa webbiana, commonly known as the Himalayan Rose, is a medicinal shrub widely distributed across the high-altitude regions of the Himalaya. Traditionally, plants have been used to treat inflammatory disorders, fever, gastrointestinal issues, and cardiovascular ailments. Recent scientific studies have investigated the chemical profile of plants using advanced analytical tools such as GC–MS, HPLC, LC–MS, and FT-IR, revealing diverse classes of phytochemicals, including flavonoids, phenolic acids, fatty acids, terpenoids, tannins, and volatile oils. This study summarizes the ethnomedicinal relevance, phytochemical composition, and potential therapeutic applications of R. webbiana. The aim of this review is to provide an updated scientific overview that may support future pharmacognostic investigations and drug development research.

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Introduction

The Himalayas are one of the most important mountain systems in Asia, particularly for India, Nepal, Bangladesh, Afghanistan, Pakistan, and China. The region is exceptionally rich in biodiversity and is home to a wide variety of herbal and medicinal plants. Evergreen species dominate the landscape, and since ancient times, Himalayan communities have relied on numerous herbs and mineral-based remedies for health care. In this study, *Rosa webbiana* was selected as a key medicinal plant because of its availability in the region. Commonly known as the "jungle rose," *Rosa webbiana* is widely used in traditional medicine to treat various ailments. The plant also has ornamental value and resembles Colchicum species. The plant material used in this study was collected and authenticated at a recognized laboratory in Jammu. All parts of the plant, including leaves, stems, bark, and roots, are considered useful. Similarly, the bulbs of Allium species have been valued in traditional medicine since ancient times. Natural compounds play an important role in daily health care. Although modern medicine has gained global popularity, herbal remedies remain essential for many socioeconomic, cultural, and historical reasons. In several developing countries, large sections of the population still rely on medicinal plants as a primary health-care resource (1). Before the advent of synthetic pharmaceuticals, plants and herbs were the primary sources of medicines used to treat diseases in humans. Plant-derived compounds are often considered safer than synthetic drugs and continue to play vital roles in disease treatment and prevention (2). Notably, more than 60% of anticancer agents and approximately 75% of drugs used against infectious diseases originate from natural sources (3).

Medicinal plants have been used for healing since the earliest stages of human civilization. Ancient records from China, India, Egypt, and Greece show the extensive use of plant-based remedies long before the Common Era (4). For example, the precursor of acetylsalicylic acid (aspirin) was known as early as the 5th century BCE, when Hippocrates described the use of willow bark to reduce fever, pain, and complications during childbirth. Similar uses were documented even earlier in Egypt and Babylon. Salicylic acid derivatives occur naturally in plants such as white willow, wintergreen, and meadowsweet. This traditional knowledge later became the foundation for identifying active plant components and developing modern drugs (5).India, with its remarkable diversity of agro-climatic conditions from the temperate Himalayan zones to the tropical south and from the dry central plains to the humid regions of Assam and Kerala supports an immense variety of medicinal and aromatic plants. The country is often considered a global reservoir of herbal resource. Traditional medical systems, such as Ayurveda, Siddha, Unani, and folk medicine, have preserved and utilized thousands of plant-based formulations. It is estimated that nearly 25,000 herbal remedies are used in Indian folk medicine (6).

Medicinal plants have significantly contributed to the development of modern therapeutic agents. Between 1950 and 1970, approximately 100 new plant-based drugs were introduced into the U.S. pharmaceutical market, including desipramine, reserpine, vinblastine, and vincristine, which were derived from Rauwolfia serpentina and Vinca rosea (7). Later, numerous other plant-derived or semi-synthetic drugs emerged, such as suggestions from Commiphora weightier, etoposide and tiliroside from Podophyllum species, nabilone, plaunotol from Croton sublimates, lectin an, artemisinin from Artemisia annua, and ginkgolides from Ginkgo biloba (8). Several widely used cancer drugs, including paclitaxel, topotecan, and irinotecan, originate from plants. According to the World Health Organization, approximately 25% of modern pharmaceutical drugs are derived directly or indirectly from plants (9). The Food and Agriculture Organization (FAO) reports that approximately one-quarter of prescriptions written in the United States and Europe contain plant-derived compounds (10). More than 500,000 natural compounds are believed to be produced by plants, and over 160,000 have already been identified, with thousands more being discovered each year (11). Despite advances in synthetic chemistry, an estimated 80% of the world's population still depends on plant-based medicines for their basic health needs (12).

Plant-derived compounds have also significantly contributed to antiviral research. Several natural products with activity against HIV particularly

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inhibitors of reverse transcriptase and protease—have been identified through screening programs, such as those conducted by the U.S. National Cancer Institute (13). Over the past 50 years, plant secondary metabolites have revolutionized medicine, increasing human lifespan, reducing suffering, and providing essential tools against infectious and chronic diseases (14). Medicinal plants continue to play a central role in traditional health practices, especially in the Himalayan region, where communities rely heavily on native botanical resources to treat various ailments. Rosa webbing Wall. ex-Royle (family: Rosaceae) is a particularly important Himalayan shrub known for its therapeutic uses. It grows in India, Pakistan, Nepal, Afghanistan, and Tibet at altitudes of 2,000–4,000 m (15). Traditionally, plants have been used to treat digestive disorders, fever, respiratory ailments, and skin infections. The growing scientific interest in *Rosa webbiana* has led to detailed phytochemical and pharmacological investigations using modern analytical techniques (16, 17).

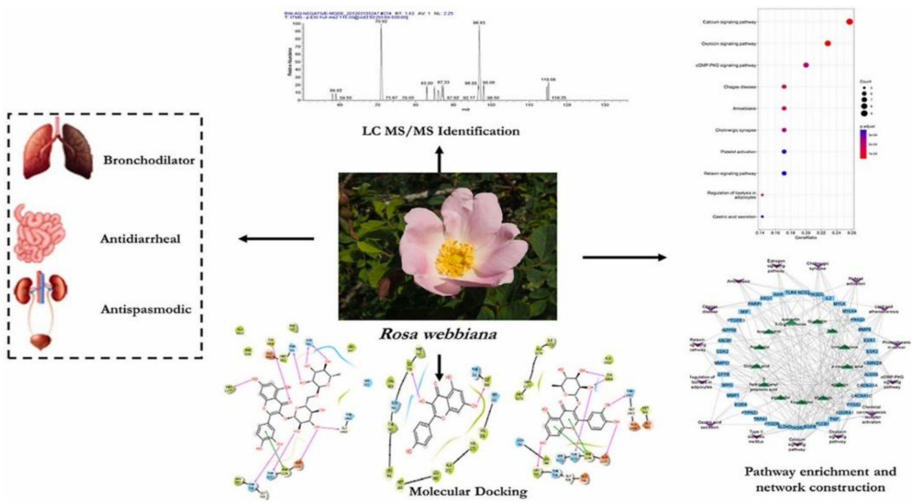

Figure: 1 Integrated workflow illustrating LC–MS/MS-based phytochemical identification of *Rosa webbiana*, molecular docking, pathway enrichment/network analysis, and predicted pharmacological activities (bronchodilator, antidiarrheal, and antispasmodic).

Kingdom: Plantae
Clade: Tracheophytes
Order: Rosales
Family: Rosaceae
Genus: Rosa
Species: R. webbiana

Pharmacological Activities (Lab Studies)

Modern pharmacological studies on *Rosa webbiana* extracts have validated many of its traditional medicinal applications.

• **Anti-inflammatory activity:** The extracts exhibit significant anti-inflammatory and hepatoprotective effects, including the ability to downregulate key inflammatory markers such as TNF-α.

• **Antispasmodic and bronchodilatory effects:** *In vitro* studies have confirmed its efficacy against diarrhea and asthma, primarily through calcium channel antagonism and anticholinergic mechanisms.

• **Neuroprotective and anti-epileptic properties:** Fruit extracts demonstrate anticonvulsant activity in animal models and provide neuroprotection by reducing neuroinflammation.

• **Antimicrobial and antioxidant activity:** The extracts show strong antioxidant potential and effectively inhibit the growth of various bacterial and fungal pathogens.

Secondary Metabolites

Plants synthesize a diverse range of organic compounds that are not directly involved in primary metabolic processes, such as growth and development. These are known as secondary metabolites, which are produced in response to external stimuli, including microbial infections, ultraviolet radiation, and other environmental stresses. Secondary metabolites play crucial roles in helping plants cope with biotic and abiotic stress, facilitating pollination, and providing competitive advantages, sometimes acting as toxins against rival species. They are broadly classified into three major groups: terpenoids, alkaloids, and phenolic compounds.

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Phenolics

Phenolic compounds are among the most widely distributed secondary metabolites in nature and play significant physiological and structural roles in plants. They are biosynthesized via the shikimic acid pathway, which utilizes pentose sugars and various metabolic intermediates to produce different phenolic structures (19). These compounds are characterized by an aromatic ring with one or more hydroxyl groups. Their structures range from simple phenols to complex, high-molecular-weight polyphenols, resulting in a wide variety of compounds found in nature. Phenolics can be categorized into numerous classes, ranging from simple phenolic molecules to complex groups such as flavonoids and tannins, including compounds such as eugenol (from clove) and catechin (20, 21). Phenolic compounds are classified into several major categories based on the number of carbon atoms and the basic structural skeleton.Dietary phenolic components include, as previously stated, phenolic acids, flavonoids, and tannins (22). The two primary subclasses of phenolic acids are hydroxybenzoic and hydroxycinnamic acids. A C6-C1 structural arrangement is typical of hydroxybenzoic acids, including gallic, p-hydroxybenzoic, protocatechuic, vanillic, and syringic acids. In contrast, hydroxycinnamic acids are aromatic molecules with a C6-C3 side chain. Four of these acids, caffeic, ferulic, p-coumaric, and sinapic, are among the most prevalent in nature (23).

Table 1 Classification of Phenolic compounds on the basis of number carbon atoms

No. of carbon atoms	Basic skeleton	Class	Examples
6	C6	Simple phenols, Benzoquinones	Catecho l, Hydroquinone, 2,6-Dimethoxy-benzo-quinone
7	C6-C1	Phenolic acids, Phenolic aldehydes	Gallic acid, salicylic acid
8	C6-C2	Acetophenones, Tyrosine derivatives,	3- Acetyl-6- methoxy benzaldehyde, Tyrosol, p- Hydroxy- phenylacetic acid
9	C6-C3	Hydroxycinnamic acids, Phenylpropenes, Coumarins, Isocoumarins, Chromones,	Caffeic,
			ferulic acids, Myristicin, Eugenol, Umbelliferon,
			Eugenin aesculet in, Bergenon,
10	C6-C4	Naphthoquinones	Juglone, Plumbagin
13	C6-C1-C6	Xanthonoids	Mangiferin
14	C6-C2-C6	Stilbenoids, Anthraquinones	Resveratrol, Emodin
15	C6-C3-C6	Chalcones, Flavonoids, Iso flavonoids, Neo flavonoids	Quercetin, cyanidin, Genistein
18	(C6-C3)2	Lignans, Neolignans	Pinoresinol, Eusiderin
30	(C6-C3C6)2	Bi flavonoids	Amento flavone

Flavonoids, which can be found either as free molecules or glycosides, are found across the plant kingdom. Flavonoids are chemical compounds with a skeleton of 15 carbon atoms, comprising two

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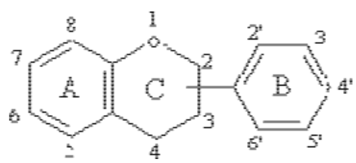
phenyl rings connected by a three-carbon bridge. Classes in which this three-carbon bridge is accessible include chalcones and dihydrochalcones. All other flavonoids have a bridge that is a component of a heterocyclic ring with a carbonyl or phenolic group. Flavones are defined by a 2-phenyl-γ-chroman structure. Although pure flavones do not have any color, their derivatives often have a yellowish hue that worsens with higher pH and more hydroxyl groups. Isoflavones differ from flavones in that the B-ring is connected to the C-ring at the C-3 position rather than the C-2 position, as observed in flavones.The conventional qualitative Shinoda test was used to identify flavonoids. These substances exhibit a wide range of biological functions. For instance, the antihepatotoxic effects of silymarin, a flavonolignan derived from milk thistle (Silybum marianum) seeds, have been extensively studied (24, 25, 26).



Flavonoids have been extensively studied for their anti-ulcer, antioxidant, and analgesic properties. They are also recognized as potent free radical scavengers (27, 28, 29). Free radicals play a crucial role in the development of ulcerative and erosive lesions in the gastrointestinal tract, making flavonoids particularly valuable in gastroprotective therapies.
Some important flavonoids and related phenolic molecules are described below.

1. Quercetin
Quercetin is one of the most abundant flavonoids found in medicinal plants, such as *Thea sinensis*, *Glycyrrhiza glabra*, *Hypericum perforatum*, and *Ginkgo biloba*. It protects the stomach mucosa against the damaging effects of ethanol, acidified ethanol, cold-restraint stress, pylorus ligation, and other similar procedures. One reason it protects the digestive system is its powerful antioxidant and membrane-stabilizing capabilities.

2. Genistein
Genistein is a well-known isoflavone commonly found in soybeans and soy-based products, such as tofu and textured vegetable protein. It exhibits multiple pharmacological properties, including antioxidant, antiulcer, and anticancer activities. Genistein also modulates estrogen receptors and inhibits tyrosine kinase enzymes.

3. Lignans
Among the many phenolic compounds found in plants, lignans are the most significant. High cholesterol, menopausal symptoms, blood clotting issues, cancer, and impaired kidney function due to lupus are some of the ailments that these herbs are used to treat in herbal therapy. Steganacin, pinoresinol, and podophyllotoxin are examples of these compounds.
Clinically, chemotherapeutic medicines for a variety of malignancies include semisynthetic derivatives of podophyllotoxin, particularly etoposide and teniposide.

4. Anthraquinones
Anthraquinones are an important group of medicinally relevant compounds found in herbs, such as senna, aloe, and rhubarb, which are widely used for treating constipation and related gastrointestinal disorders. These compounds constitute a major class of glycosides. The aglycone portion of anthraquinone glycosides is believed to be synthesized through the head-to-tail condensation of acetate units. Various structural forms exist within this group, including anthraquinone, anthrone, anthranol, dianthranol, oxanthrone and dianthrone.

- Anthrone is pale yellow and insoluble in alkali; therefore, it does not fluoresce under alkaline conditions.
- Anthranol is brownish-yellow, soluble in alkali, and exhibits blue fluorescence when treated with an alkaline solution.

Catechins
Catechins are a class of flavonoids characterized by the presence of a 3-hydroxy group and are also referred to as flavan-3-ols or simply flavanols. Chemically, flavan-3-ols possess a 2-phenyl-3,4-dihydro-2H-chromen-3-ol skeleton. This group includes both catechins and gallate esters.
Catechins and Their Epimers
Catechins exist as epimers, with (-)-epicatechin and (+)-catechin being the most common optical isomers found in nature. Catechin was first isolated from the extract of *Acacia catechu*, from which it derives its name. Related substances like gallocatechin and epigallocatechin have a higher antioxidant potential than epicatechin and catechin because they have an extra phenolic hydroxyl group.
Catechin Gallates

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Catechin gallates are gallic acid esters of catechins, including compounds such as epigallocatechin gallate (EGCG) and epicatechin gallate (ECG). These compounds are abundantly present in teas derived from *Camellia sinensis*, including white, green, black, and oolong teas, with EGCG being the most abundant catechin in tea. Catechins are also present in the human diet through chocolate, fruits, vegetables, and wine, as well as in other plant species

Biological Activities

According to Katiyar et al. (30), epigallocatechin-3-gallate (EGCG) is a potent antioxidant that protects the skin from UV radiation-induced damage and tumor formation. Additionally, green tea catechins exhibit antimicrobial properties by interfering with specific stages of bacterial DNA replication, thereby inhibiting their growth (31).

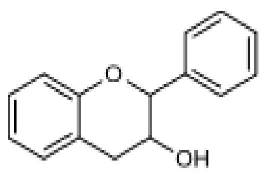

Figure: 2

RESULTS & DISCUSSION

The total polyphenol, catechin, and flavonoid contents of *Rosa webbiana* were estimated using spectrophotometric methods. To the best of our knowledge, the phenolic content, catechins, flavonoids, and antioxidant activity of *R. webbiana* have not been previously reported. The Folin-Ciocalteu technique was used to quantify the total phenolic content, which was expressed as gallic acid equivalents (GAE) using measurements obtained with a UV-Vis spectrophotometer. Following the procedures outlined in the Materials and Methods section, the concentration of catechin was determined by observing the intensity of the yellow complex generated at 425 nm. Based on the yellow color produced and measured using UV-Vis spectrophotometry, flavonols were calculated using the technique of Ghasemi et al. When comparing polyphenol, catechin, and flavonoid contents to standard calibration curves made using gallic acid, catechin, and quercetin, respectively, the units used were milligrams per gram of dry weight.

Various vegetative parts of *R. webbiana* (roots, leaves, and stems) were analyzed for their polyphenol, catechin, and flavonol content. The results indicated that the phenolic content was highest in the leaves, catechins were most abundant in the stems, and flavonoids were concentrated in the leaves (Table). Specifically, the leaves contained 7.7% phenolics, followed by stems (5.65%) and roots (5.56%).

The variations in polyphenol, catechin, and flavonoid contents across different plant parts of *R. webbiana* are illustrated.

Table 2 Distribution of major phytochemicals (% DW) in different plant parts (root, leaf, and stem) of *Rosa webbiana*

Chemical (% DW)	Plant part		
	Root	Leaf	Stem
Polyphenols	5.56	7.7	5.65
Catechines	1.61	1.01	1.9
Flavonols	0.49	0.89	0.6

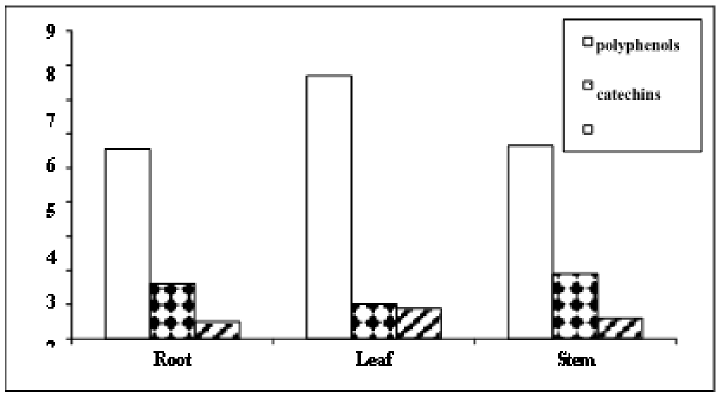

Figure: 3 Polyphenol, Catechines & flavonoids of various parts of *Rosa webbiana*

Identification & Quantification Of Catechines by High Performance Liquid Chromatography (HPLC)

Catechin Analysis by RP-HPLC

Catechins, including EGC, CAT, EGCG, EC, GCG, CG, and ECG, were quantified using reverse-phase high-performance liquid chromatography (RP-HPLC). A gradient elution-based RP-HPLC protocol was employed for the analysis and quantitation of phenolic compounds present in different extracts of the roots, leaves, and stems of *Rosa webbiana*. *Catechins* in each extract were identified using

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retention time comparisons with reference standards under the same chromatographic conditions. Standard calibration curves were produced for each catechin separately under the same experimental conditions and used for quantification. The HPLC catechin profiles of the root, leaf, and stem extracts of *R. webbiana* are presented in Figures, showing the variation in catechin composition among the different plant parts.

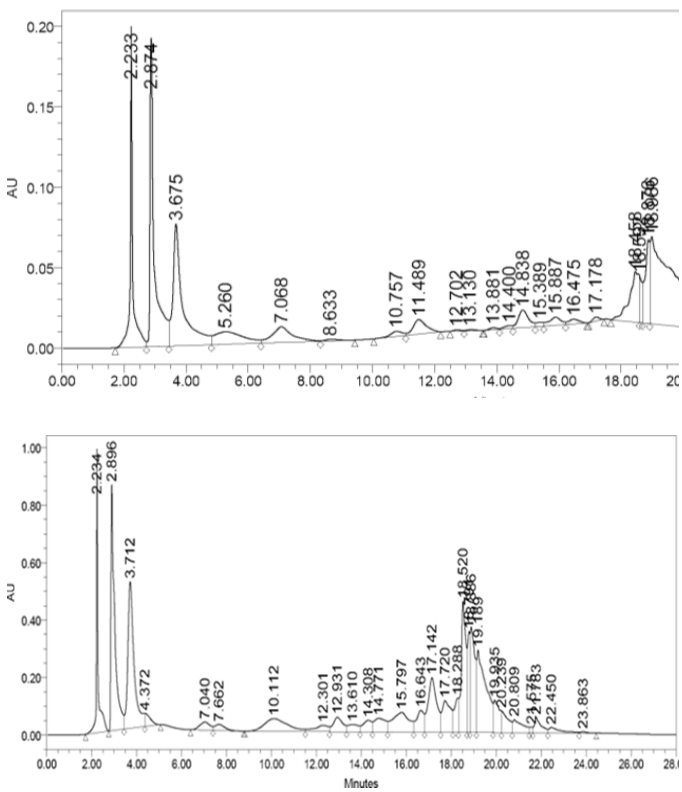

Figure: 4 HPLC profile of catechins in different parts of R. webbiana. a: root, b: leaves & c: stem. 1: Gallic acid, 2: EGC, 3: cat, 4: EGCG, 5: GCG, 6: ECG, 7: CG

HPLC Catechin Profile of *Rosa webbiana*

RP-HPLC analysis of catechins in *R. webbiana* revealed that epigallocatechin (EGC) was most abundant in the leaves (1.7%), followed by the stems and roots.

Other catechins, including epicatechin gallate (ECG), gallocatechin (GC), and gallocatechin gallate (GCG), were also found at higher concentrations in the leaves, followed by the stems and roots.

Catechin (CAT), gallic acid, and epicatechin (EC) were present at slightly higher levels in the stem compared to the leaves and roots; however, the variation among plant parts was relatively small.

The roots consistently showed the lowest catechin content among the three plant parts analyzed, highlighting the leaves as the richest source of catechins in *R. webbiana*.

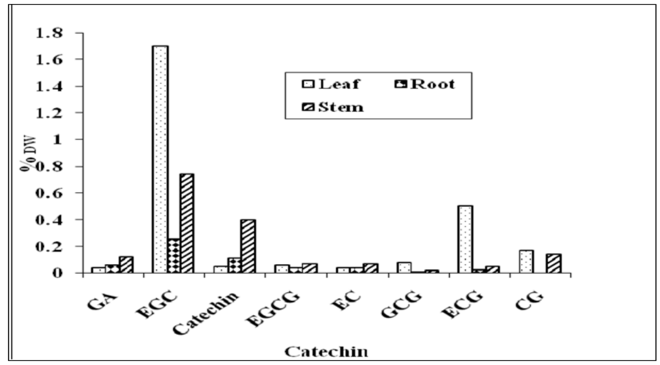

Figure: 5 HPLC profile showing catechin content (% DW) in leaf, stem, and root of *Rosa webbiana*

Table 3 Variations in the Catechine profile of various parts of *Rosa webbiana* as estimated by HPLC

Catechine (% DW)	Plant part			Total content
	Leaf	Root	Stem	
GA	0.04	0.06	0.12	**0.22**
EGC	1.7	0.25	0.74	**2.69**
Catechine	0.05	0.11	0.4	**0.56**
EGCG	0.06	0.04	0.07	**0.17**
EC	0.04	0.038	0.07	**0.148**
GCG	0.08	0.009	0.02	**0.109**
EG	0.5	0.025	0.05	**0.575**
CG	0.17	0.001	0.14	**0.311**

Identification and Quantification of Flavonoids by HPLC

The flavonoid profiles of the roots, leaves, and bulbs of *Allium carolinianum* were analyzed using high-performance liquid chromatography (HPLC). Flavonoids were detected exclusively in the leaves, with quercetin being the only flavonoid identified in this plant part. Figure shows the results of HPLC

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analysis of *Rosa webbiana* root, leaf, and stem extracts for flavonoids.

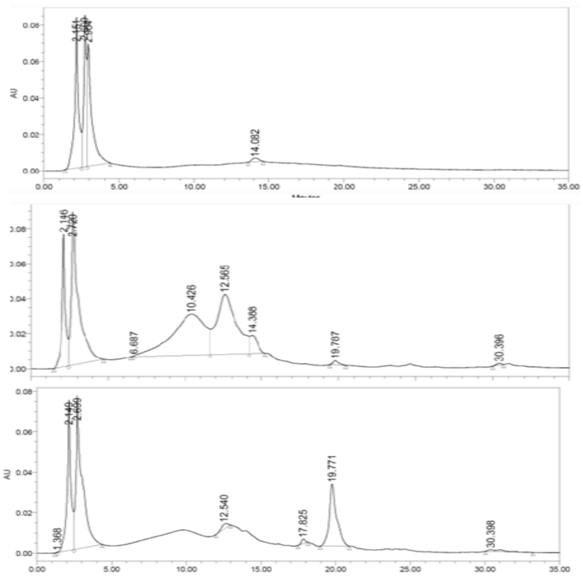

Figure: 6 HPLC profiles of flavonoids in different parts of *Rosa webbiana*. a: leaf, b: root & c: stem. 1: chlorogenic acid, 2: rutin, 3: quercetin, 4: myrcetin, 5: kaempferol, 6: quercetin-3-O-galactoside, 7: iso-rhamnetin.

Flavonoid Content in *Rosa webbiana*

As shown in Table, a considerable number of flavonoids were found in R. webbiana stems, roots, and leaves. The plant tissues examined all contained quercetin, with the following concentrations: stems (1.36%), leaves (1.23%), and roots (0.11%). None of the tested extracts contained kaempferol.

Table. Flavonoid Profiles of different vegetative parts of R. webbiana by HPLC

Flavonoids (% dry wt.)	Plant part		
	Leaf	Stem	Root
Chlorogenic acid	0.01	ND	0.016
Rutin	0.03	0.08	0.02
Quercetin	1.23	1.36	0.11
Myrecetin	ND	0.03	ND
Kaempferol	ND	ND	ND
Quercitn-3-O-galactoside	0.03	0.03	ND
Iso-rhamnetin	ND	0.003	ND

Conclusion

The presence of diverse phytochemicals in *Rosa webbiana* supports its medicinal value. Flavonoids and phenolic compounds contribute to its antioxidant and anti-inflammatory activities, while the identified fatty acids and sterols possess known antimicrobial and cardioprotective properties. GC–MS analysis further revealed the presence of bioactive compounds with potential therapeutic effects, providing scientific validation for its traditional uses. This study demonstrates that *Rosa webbiana* from the Himalayan region contains significant phytochemical constituents with promising pharmacological applications. The integration of complementary analytical techniques offers a comprehensive chemical profile, supporting future research in drug discovery and the development of plant-based therapeutic agents.

Submission Declaration:

This manuscript has not been published previously and is not under consideration for publication elsewhere. The authors confirm that the work is original and have read and approved the final manuscript for submission.

Conflict of Interest:

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

Declaration Of Competing Interest:

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethics Statement:

This review paper, "**Comprehensive research on Phytochemical Characterization of *Rosa webbiana* Various Parts via Advanced Spectroscopic and Chromatographic Techniques and Assessment of Their Bioactive Potential**'', involves no experimental research, human subjects, or animal studies that need ethical approval; instead, it is based entirely on publicly available literature. For academic openness and integrity, all acknowledged sources were appropriately referenced. I have done all in my power to provide an objective, accurate, and thorough literature review free from any conflicts of interest that could affect how the data are interpreted. The development of this study did not involve any instances of scientific misconduct, data manipulation, or plagiarism. Let me know if you need refinement.

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