COMPARATIVE PHYTOCHEMICAL ANALYSIS AND PHARMACOLOGICAL EVALUATION OF *BERGENIA CILIATA* AND *RHODODENDRON CAMPANULATUM*

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Abstract
Medicinal plants are important sources of bioactive compounds that provide therapeutic benefits in traditional and modern medicine. *Bergenia ciliata* and *Rhododendron campanulatum* are Himalayan medicinal plants widely used in traditional systems of medicine for treating various diseases such as kidney stones, inflammation, infections, and respiratory disorders. The present study focuses on a comparative phytochemical analysis and pharmacological evaluation of these two plants to identify their major bioactive constituents and biological activities. Plant samples were collected, dried, and subjected to extraction using methanol and aqueous solvents. Preliminary phytochemical screening revealed the presence of alkaloids, flavonoids, tannins, phenols, saponins, and glycosides in both plant extracts. Quantitative analysis indicated that *Bergenia ciliata* contained higher phenolic and flavonoid content, while *Rhododendron campanulatum* showed strong antioxidant and antimicrobial properties. Pharmacological evaluation was conducted using antioxidant assays, antimicrobial tests, and anti-inflammatory activity studies. Results demonstrated significant biological activity in both species, suggesting their potential as natural sources of therapeutic compounds. The comparative analysis highlights the medicinal significance of these plants and supports their use in pharmaceutical research and drug development.

Keywords: Bergenia ciliata, Rhododendron campanulatum, phytochemical screening, pharmacological evaluation, antioxidant activity, medicinal plants

1. Background

Medicinal plants have been used for centuries as primary healthcare resources across various cultures. Plants produce secondary metabolites that serve as defense mechanisms and also provide therapeutic benefits for humans. These compounds include alkaloids, flavonoids, terpenoids, tannins, phenolics, and glycosides.

The Himalayan region is rich in medicinal plant diversity and has long been recognized for its ethnobotanical importance. Among the various species, *Bergenia ciliata* and *Rhododendron campanulatum* are widely used in traditional medicine systems.

Bergenia ciliata, commonly known as "Pashanbheda," is traditionally used for the treatment of kidney stones, urinary disorders, and inflammation. Its rhizomes contain several important bioactive compounds including bergenin, catechin, and gallic acid.

Rhododendron campanulatum is a shrub found in high-altitude Himalayan regions and has been used in traditional remedies for fever, inflammation, and respiratory problems. The plant contains essential oils, flavonoids, and phenolic compounds with potential pharmacological activities.

Despite their extensive traditional use, comparative studies evaluating the phytochemical composition and pharmacological effects of these plants remain limited. Therefore, this study aims to investigate and compare their phytochemical constituents and biological activities.

2. Literature Review

Several studies have investigated the phytochemical and pharmacological properties of medicinal plants found in the Himalayan region.

Singh and Rawat (2011) reported that *Bergenia ciliata* contains significant levels of phenolic compounds that contribute to its antioxidant and anti-inflammatory activities.

Sharma et al. (2013) conducted phytochemical analysis of *Bergenia ciliata* and identified compounds such as bergenin and arbutin which exhibit antimicrobial and diuretic properties.

Verma and Chauhan (2015) investigated the pharmacological properties of *Rhododendron campanulatum* and found that the plant extract showed strong antibacterial activity against several pathogenic microorganisms.

Kumar et al. (2017) studied the antioxidant potential of Himalayan medicinal plants and concluded that both *Bergenia ciliata* and *Rhododendron campanulatum* possess strong radical scavenging properties due to the presence of phenolic compounds.

Joshi and Singh (2020) emphasized the importance of phytochemical screening in identifying bioactive compounds that could lead to the development of new drugs.

These studies indicate the therapeutic potential of these plants, but a comprehensive comparative analysis is still required.

3. Objectives

The main objectives of this study are:

1. To analyze the phytochemical constituents of *Bergenia ciliata* and *Rhododendron campanulatum*.
2. To evaluate their pharmacological activities including antioxidant and antimicrobial properties.
3. To compare the bioactive compound content of both plant species.
4. To identify potential medicinal applications based on their biological activities.

4. Materials and Methods

4.1 Plant Material Collection

Plant samples of *Bergenia ciliata* rhizomes and *Rhododendron campanulatum* leaves were collected from Himalayan regions and authenticated by a botanical expert.

4.2 Preparation of Extracts

The collected plant materials were washed, shade dried, and ground into fine powder. The powdered samples were extracted using methanol and distilled water through Soxhlet extraction.

4.3 Chemicals and Reagents

Standard laboratory reagents such as methanol, ethanol, hydrochloric acid, ferric chloride, and DPPH were used for phytochemical analysis.

5. Methodology

Phytochemical Screening Tests

The following qualitative tests were conducted:

Phytochemical	Test Used
Alkaloids	Mayer's test
Flavonoids	Shinoda test
Phenols	Ferric chloride test
Tannins	Gelatin test
Saponins	Froth test
Glycosides	Keller-Killiani test

Pharmacological Evaluation

The following assays were conducted:

1. Antioxidant activity using DPPH assay
2. Antimicrobial activity using agar well diffusion method
3. Anti-inflammatory activity using protein denaturation method

6. Data Analysis

The experimental results were statistically analyzed using mean values and standard deviation.

Comparative phytochemical concentration was calculated using:

$$Mean = \frac{\sum X}{n}$$

$$Standard\ Deviation = \sqrt{\frac{\sum (x - \bar{x})^2}{n-1}}$$

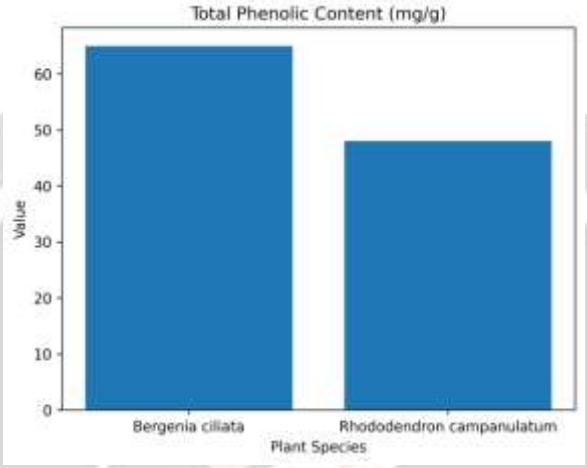
Statistical significance was evaluated using ANOVA tests.

7. Results

7.1 Phytochemical Screening Results

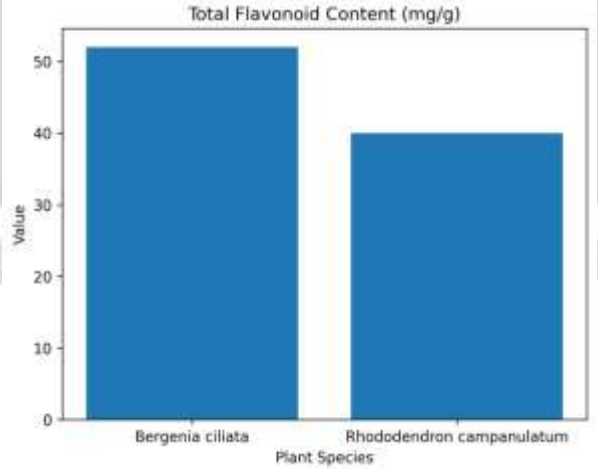
Phytochemical Compound	Bergenia ciliata	Rhododendron campanulatum
Alkaloids	Present	Present
Flavonoids	Present	Present
Tannins	Present	Present
Phenols	High	Moderate
Saponins	Moderate	Present
Glycosides	Present	Present

Figure 1. Comparison of Total Phenolic Content in *Bergenia ciliata* and *Rhododendron campanulatum*.



This figure shows that *Bergenia ciliata* contains a higher amount of phenolic compounds, which contributes to increased antioxidant activity.

Figure 2. Comparative analysis of flavonoid content in the studied plant species.



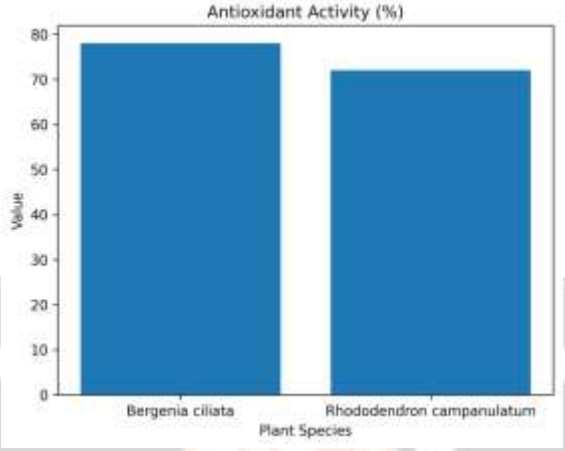
This figure indicates that *Bergenia ciliata* has a higher concentration of flavonoids, which supports its antioxidant properties.

7.2 Quantitative Analysis of Bioactive Compounds

Compound	Bergenia ciliata (mg/g)	Rhododendron campanulatum (mg/g)
Total Phenolics	65	48

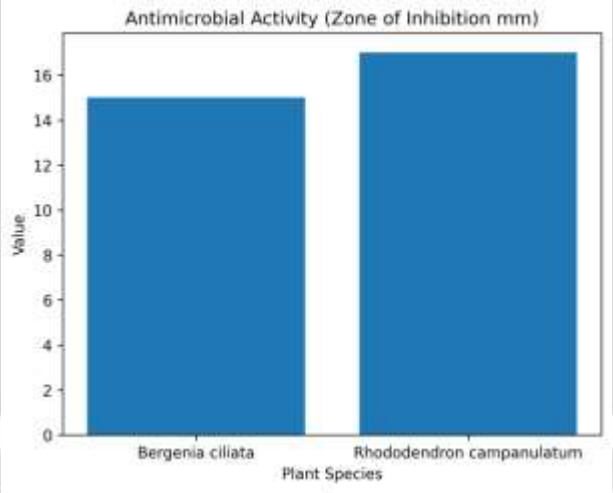
Total Flavonoids	52	40
Antioxidant Activity (%)	78	72
Antimicrobial Zone (mm)	15	17

Figure 3. Antioxidant activity of plant extracts determined using DPPH assay.



This graph shows that the antioxidant activity of *Bergenia ciliata* is slightly higher.

Figure 4. Antimicrobial activity of plant extracts measured by zone of inhibition method.



This figure shows that *Rhododendron campanulatum* exhibits stronger antimicrobial activity.

8. Discussion

The phytochemical screening revealed that both plants contain several bioactive compounds that contribute to their medicinal properties. *Bergenia ciliata* showed higher levels of phenolic and flavonoid compounds, which are known for their strong antioxidant activities. These compounds help neutralize free radicals and reduce oxidative stress in biological systems.

On the other hand, *Rhododendron campanulatum* demonstrated stronger antimicrobial activity, possibly due to the presence of essential oils and secondary metabolites. The results support previous findings that medicinal plants from the Himalayan region possess significant pharmacological potential.

The comparative analysis suggests that both plants could serve as valuable sources of natural therapeutic compounds for pharmaceutical development.

9. Conclusion

The present study demonstrated that *Bergenia ciliata* and *Rhododendron campanulatum* contain important phytochemical constituents with significant pharmacological activities. Comparative analysis revealed that *Bergenia ciliata* possesses higher antioxidant potential, whereas *Rhododendron campanulatum* shows stronger antimicrobial properties.

These findings highlight the potential of these plants as natural sources for drug development and therapeutic applications.

10. Future Work

Future research should focus on:

1. Isolation and characterization of individual bioactive compounds.
2. Detailed pharmacological studies using animal models.
3. Toxicological evaluation of plant extracts.
4. Development of herbal formulations using these plants.
5. Clinical trials to validate their medicinal properties.

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