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# Fourier Transform Infrared (FTIR) Spectroscopy as a Tool for Phytochemical Characterization

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**Abstract**

The interferogram must be converted to a spectrum using Fourier analysis, which calls for a computer. Additionally, qualitative and quantitative phytochemical investigations were performed on four selected endangered medicinal plants: *Wulfenia amherstiana*, *Thalictrum foliolosum*, *Selinum tenuifolium*, and *Bergenia ligulata*. For *Bergenia ligulata*, *Thalictrum foliolosum*, *Selinum tenuifolium*, and *Wulfenia amherstiana*, an efficient and highly reproducible method was developed to enhance shoot regeneration and massive roots using leaves, nodal segments, and rhizomes as explants into complete plants. The Perkin Elmer Spectrum 400 spectrometer was utilized to get the Fourier transform infrared spectra of the bioactive component present in the plant material. Furthermore, GC-MS analysis of some plant species indicated a variety of bioactive phytoconstituents, including the functional groups, as was reported during FTIR. The roots of *Bergenia ligulata* (47.24%), *Thalictrum foliolosum* leaves (88.20%), and *Selinum tenuifolium* roots (90.6%) come next.

**Keywords:** FTIR, Interferogram, Spectrum, Medicinal and Plants

## Introduction

The process of breaking down any fluctuating signal into its individual frequency components is known as "Fourier spectroscopy." In spectroscopy, the mathematical techniques named after J.B.J. Fourier are incredibly potent. Numerous spectroscopies, including as nuclear magnetic resonance (NMR), electron spin resonance (ESR) spectroscopy, and infrared spectroscopy known as Fourier transform infrared (FT-IR), may be used using Fourier transforms. The absorption, reflection, emission, or photoacoustic spectrum produced by Fourier transforming an optical interferogram is included in FT-IR spectroscopy. The method's strength lies in its ability to analyze several frequency components at once in a single operation. The technology that results from applying Fourier concepts to different terms of spectroscopy produces a spectrometer that provides the full spectrum in the same amount of time that a traditional spectrometer (using dispersive elements like prism and grating) would need to scan across just one line in the spectrum. As a result, the number of resolvable components in the spectrum determines how much quicker Fourier spectrometers using interferometers are. Across a broad spectrum, Fourier-based techniques are employed. By choosing distinct beam splitters and detectors for the necessary ranges, FT spectroscopy may be used for a wide variety of frequencies spanning the ultraviolet, visible, near-infrared, mid-infrared, and even far-infrared areas. For such a broad range of frequencies, no other dispersive method is suitable.

Numerous spectroscopic methods have been employed to examine different materials, but FT-IR spectrometers are becoming more and more common because they provide speed, precision, and sensitivity that were previously unattainable with wavelength dispersive spectrometers. The FT-IR is a crucial tool for problem solving in many research because it enables quick examination of micro-samples that are sometimes accurate to the nanogram level. Because FT-IR spectroscopy employs interferometers in spectrometers and operates on distinct principles than dispersive spectroscopy methods, it necessitates more investigation. A sample is subjected to electromagnetic radiation in a traditional or continuous wave spectrometer, and the strength of the radiation that is transmitted is typically recorded. The response is displayed as a function of the incident radiation's frequency after the energy of the radiation is changed across the appropriate range. The radiation will be absorbed at certain resonance frequencies that are distinctive to the sample, producing a sequence of peaks in the spectrum that may be used to identify the sample. Fourier transform spectroscopy (FTS) exposes the sample to a single pulse of electromagnetic radiation made up of frequencies in a certain range rather than exposing it to various energies of electromagnetic radiation.

A quickly declining composite of all potential frequencies is present in the resultant signal. Resonant frequencies will dominate the signal due to the sample's resonance; the frequency response may be computed by performing a Fourier transform on the signal. This allows the Fourier transform spectrometer to generate the same type of spectrum as a traditional spectrometer in a significantly shorter amount of time. The Michelson, Fabry-Perot, and lamellar grating interferometers are among the interferometers used by many FT-IR spectrometers. Compared to the two beam interferometers-the Michelson and lamellar grating interferometers-the spectrometers that use Fabry-Perot interferometers have a lower resolving power. The primary distinction between the two beams is that the lamellar grating spectrometer divides the wavefront, whereas the Michelson interferometer divides the wave amplitude. Because of its simple design and operation, the Michelson interferometer is frequently preferred over the lamellar grating interferometer. The Michelson interferometer is used by the majority of FT-IR spectrometers that are sold commercially. These offer several benefits over the other methods, including multiplexing, high energy throughput, and high frequency measurement accuracy. Later sections will go into more detail about them.

## Literature Review

J., Kiran *et al*. (2020) [1]. Medicinal and other uses for compounds obtained from plants date back to antiquity. This research set out to compare and contrast eight medicinal plants with antioxidant and antibacterial capabilities that are used in traditional medicine. Applying the conventional Agar Diffusion technique, we examined the antimicrobial effects of methanolic extracts of *Centella asiatica* (leaves), *Mentha piperita* (leaves), *Calotropis gigantean* (leaves), *Vitex nigundo* (leaves), *Bauhinia racemosus* (leaves), *Emblica officinalis* (fruit), *Bauhinia purpurea* (leaves), and *Asperagus racemosus* (stem). Researchers looked examined the antioxidant properties of the aforementioned extracts by seeing how well they neutralized DPPH and ABTS radicals. Based on our findings, all of the extracts except Bauhinia purpurea were effective against E. coli, whereas Candida albicans was shown to be susceptible to just *Asperagus racemosus*. The radical scavenging activity of the studied extracts was most strongly shown by *Bauhinia racemosus*. Based on our findings, these plants might be used for their antioxidant and antibacterial properties.

Mansora, Al *et al*. (2017) [2]. There is a wealth of traditional knowledge and plant life in the Al Jabal Al Akhdar area. The region's medicinal plants are its most valuable asset. There is a total of 123 species in the two areas surveyed, Al Mansora and Jarjar Oma. The Al Mansora region is home to 55 plant species, spread throughout 31 families and 53 genera. Of these, 30 are angiosperms and 1 is gymnosperm. Monocotyledons had three families, five genera, and five species, whereas dicotyledons comprised twenty-seven families, forty-seven genera, and forty-nine species. In contrast, the Jarjar oma region is home to 68 species from 33 families, 58 genera, and one gymnosperm family. The other 32 families are angiosperms. With 24 families, 44 genera, and 54 species represented among dicotyledons, and 8 families, 13 genera, and 13 species among monocotyledons. Two species each from the Ammi and Cichorium genera were found in the Al Mansora area, but only one species each from the other genera were found there. There were four species of Euphorbia, three species of Plantago, two species each of Cichorium, Herniaria, Aaparagus, Malva, and Polygonum, and one species of each of the other genera in Jarjar oma. The Jarjar oma area has thirteen more species than the Al Mansora region, according to the comparison research.

Varshney, Bhumika *et al*. (2024) [3]. A lack of understanding of correct technique and the accessibility of herbal pharmaceuticals has led to the practice of adulteration and replacement, despite the fact that herbal drugs are in high demand for the treatment of diseases nowadays. The purpose of this research was to compare the quality of *Adhatoda vasica* Nees., *Azadirachta indica* (Linn.) A. Juss., and *Calotropis procera* (Aiton) samples taken in the Haridwar District's environmentally favorable and non-eco-friendly zones. The physiochemical parameters that will be monitored in this research are total ash content, acid insoluble ash, extractive solubility in alcohol, and extractive solubility in water, among others. The results of the Eco-friendly and Non-eco-friendly zones' water-soluble and alcohol-soluble extractives were found to be significantly different. The alcohol-soluble extractive values of the *Adhatoda vasica* Nees., Azadirachta indica (Linn.) A. Juss., and *Calotropis procera* (Aiton) samples obtained from the eco-friendly zone were 9.6%, 17.6%, and 16%, respectively. In contrast, the samples obtained from the non-eco-friendly zone showed alcohol-soluble extractive values of 8%, 22.4%, and 23%, respectively. The water-soluble extractive values of the *Adhatoda vasica* Nees., *Azadirachta indica* (Linn.) A. Juss., and *Calotropis procera* (Aiton) samples obtained from the eco-friendly zone were 23.2%, 24%, and 25.6%, respectively. In contrast, the samples obtained from the non-eco-friendly zone were 16%, 18.4%, and 32% in this case.

Kamkin, Viktor *et al*. (2022) [4]. People are turning to traditional and alternative medicine cures because of the COVID-19 outbreak. The chemical make-up, pharmacological effects, and physiologically active compounds of medicinal plants allow them to halt the progression of the illness and alleviate its symptoms. The effort aims to conduct a comparative flora analysis of medicinal plants in order to determine the most promising plant for the prevention, treatment, and rehabilitation of COVID-19. Examining the literature in internet databases such as Scopus, Web of Science, Google Scholar, and PubMed, as well as official WHO media sites, allowed for the search of potential therapeutic plants. New research on COVID-19 has uncovered a plethora of therapeutic plants that may inhibit inflammation, fight viruses, and boost the immune system. To find the best medicinal plant to treat coronavirus infection, researchers compared nine different options. When compared to other medicinal plants, Chamaenerion angustifolium Seg. emerged as the most promising due to its high pharmacological impact, as shown in the comparison study. Its medicinal qualities make it possible to physiologically alleviate eighteen symptoms associated with coronavirus infection. Additional clinical studies using extracts from this plant for COVID-19 therapy and rehabilitation are recommended.

Patrick, Odile *et al*. (2025) [5]. All throughout history, medicinal plants have been an integral part of people's access to healthcare. Through a comparison of ancient and contemporary traditions in many parts of the world, including Africa, Asia, and Latin America, this study investigates the cultural importance, historical development, and practical applications of medicinal plants. The focus is on how traditional plant medicines have evolved into modern pharmaceuticals, how underprivileged populations continue to employ herbal therapies, and how industrialized countries are showing renewed interest in ethnobotanical knowledge. In addition, the study delves into the scientific and methodological obstacles to medicinal plant research, the ways in which technology might be used, and the policy implications that arise from the pursuit of long-term sustainability in global health. Ethical documentation, biodiversity protection, and controlled medicinal plant use are emphasized in a thorough review of worldwide ethnobotanical research that expose the benefits and drawbacks of traditional medicine. To guarantee accessible, safe, and effective healthcare solutions globally, the research promotes a synergistic approach, combining traditional knowledge with scientific innovation.

## Research Methodology

These include the following species: *Thalictrum foliolosum* (Ranunculaceae), *Selinum tenuifolium* (Apiaceae) (Syns. *Ligusticopsis wallichiana* DC), *Wulfenia amherstiana* (Plantaginaceae), *Bergenia ligulata* Engl. (Bergenia pacumbis) (Saxifragaceae), and *Selinum tenuifolium* (Wall. ex C.B. Clarke) (Syns. *Ligusticopsis amherstiana*).

To get the Fourier transform infrared spectra of the bioactive component found in the plant material, The Perkin Elmer Spectrum 400 spectrometer was employed. Several functional groups were detected using root powder. The first phytochemical findings have been validated by this test. In order to conduct the analysis, a little amount of dried powdered plant extract was mixed with potassium bromide (KBr) to form small tablets, and then a thin film was formed by applying pressure.

## Data Analysis

The FTIR examined many possible functional groups of the extract's active constituents based on the peak values in the infrared radiation band.

## FTIR Analysis of *Bergenia ligulata*

FTIR spectroscopy investigations revealed that various functional chemicals had distinct typical peak values. Alkenes, carboxylic acids, aldehydes, alcohols, amides, phenols, primary amines, aromatic esters, ethers, and alkyl halides are among the functional groups that are confirmed to exist in The *Bergenia ligulata* root extract by the FTIR spectrum produced by the current investigation (Table 1).

By comparing the frequency range using the Sigma-Aldrich Table as a guide, the functional group was determined.

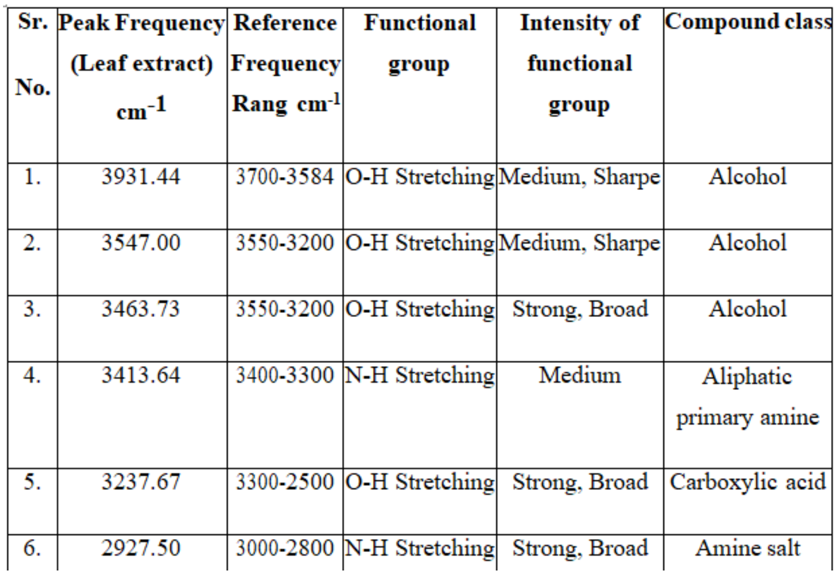
The following data relates to different functional groups of B. ligulata plant extract:

The existence of an alcohol functional group was established by the O-H stretching-corresponding absorption peak at 3931.44 cm$^{-1}$, 3547.00 cm$^{-1}$, and 3463.73 cm$^{-1}$.

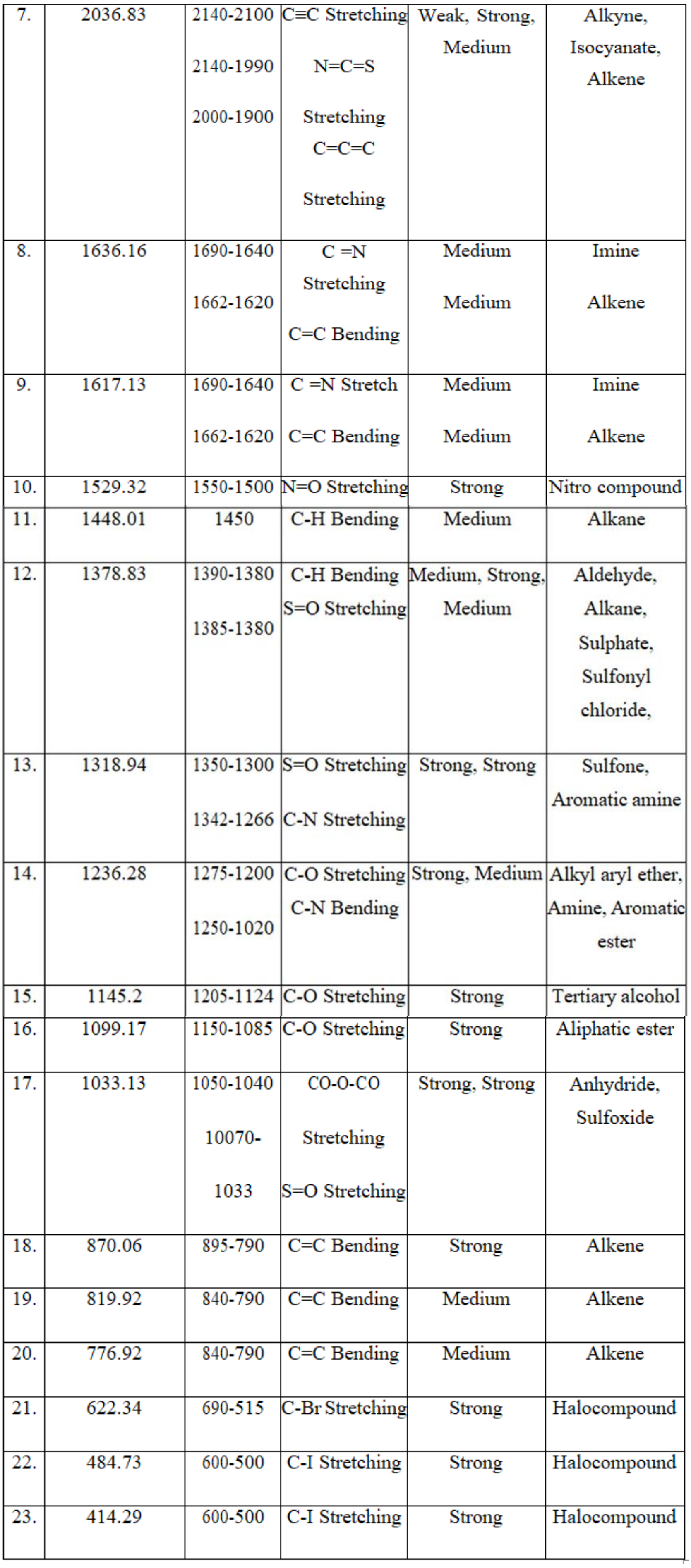
The existence of an aliphatic primary amine was shown by the N-H stretching absorption band at 3413.64 cm$^{-1}$.

Alkyne, alkane, aldehyde, imine, sulfate, sulfonyl chloride, alcohol, phenol, sulfoxide, and aliphatic ester are indicated by the following measurements: 2927.50 cm$^{-1}$, 2036.83 cm$^{-1}$, 1636.16 cm$^{-1}$, 1617.13 cm$^{-1}$, 1529.32 cm$^{-1}$, 1448.01 cm$^{-1}$, 1378.83 cm$^{-1}$, 1318.94 cm$^{-1}$, 1236.28 cm$^{-1}$, 1145.2 cm$^{-1}$, 1099.17 cm$^{-1}$, 870.06 cm$^{-1}$, 819.92 cm-1, 819.92 cm$^{-1}$, 819.92 cm$^{-1}$, and 776.92 cm$^{-1}$.

**Table 1:** FTIR peak assignment of analyzed of methanolic root extract fraction of *Bergenia ligulata* compared with standard chart



| Sr. No. | Peak Frequency (Leaf extract) cm$^{-1}$ | Reference Frequency Rang cm$^{-1}$ | Functional group | Intensity of functional group | Compound class |
|---|---|---|---|---|---|
| 1. | 3931.44 | 3700-3584 | O-H Stretching | Medium, Sharpe | Alcohol |
| 2. | 3547.00 | 3550-3200 | O-H Stretching | Medium, Sharpe | Alcohol |
| 3. | 3463.73 | 3550-3200 | O-H Stretching | Strong, Broad | Alcohol |
| 4. | 3413.64 | 3400-3300 | N-H Stretching | Medium | Aliphatic primary amine |
| 5. | 3237.67 | 3300-2500 | O-H Stretching | Strong, Broad | Carboxylic acid |
| 6. | 2927.50 | 3000-2800 | N-H Stretching | Strong, Broad | Amine salt |



| | | | | | |
|---|---|---|---|---|---|
| 7. | 2036.83 | 2140-2100<br>2140-1990<br>2000-1900 | C≡C Stretching<br>N=C=S Stretching<br>C=C=C Stretching | Weak, Strong, Medium | Alkyne, Isocyanate, Alkene |
| 8. | 1636.16 | 1690-1640<br>1662-1620 | C =N Stretching<br>C=C Bending | Medium<br>Medium | Imine<br>Alkene |
| 9. | 1617.13 | 1690-1640<br>1662-1620 | C =N Stretch<br>C=C Bending | Medium<br>Medium | Imine<br>Alkene |
| 10. | 1529.32 | 1550-1500 | N=O Stretching | Strong | Nitro compound |
| 11. | 1448.01 | 1450 | C-H Bending | Medium | Alkane |
| 12. | 1378.83 | 1390-1380<br>1385-1380 | C-H Bending<br>S=O Stretching | Medium, Strong, Medium | Aldehyde, Alkane, Sulphate, Sulfonyl chloride, |
| 13. | 1318.94 | 1350-1300<br>1342-1266 | S=O Stretching<br>C-N Stretching | Strong, Strong | Sulfone, Aromatic amine |
| 14. | 1236.28 | 1275-1200<br>1250-1020 | C-O Stretching<br>C-N Bending | Strong, Medium | Alkyl aryl ether, Amine, Aromatic ester |
| 15. | 1145.2 | 1205-1124 | C-O Stretching | Strong | Tertiary alcohol |
| 16. | 1099.17 | 1150-1085 | C-O Stretching | Strong | Aliphatic ester |
| 17. | 1033.13 | 1050-1040<br>10070-1033 | CO-O-CO Stretching<br>S=O Stretching | Strong, Strong | Anhydride, Sulfoxide |
| 18. | 870.06 | 895-790 | C=C Bending | Strong | Alkene |
| 19. | 819.92 | 840-790 | C=C Bending | Medium | Alkene |
| 20. | 776.92 | 840-790 | C=C Bending | Medium | Alkene |
| 21. | 622.34 | 690-515 | C-Br Stretching | Strong | Halocompound |
| 22. | 484.73 | 600-500 | C-I Stretching | Strong | Halocompound |
| 23. | 414.29 | 600-500 | C-I Stretching | Strong | Halocompound |

### FTIR Analysis of *Thalictrum foliolosum*

FTIR spectroscopy investigations revealed that various functional chemicals had distinct typical peak values. Alkenes, carboxylic acids, aldehydes, alcohols, amides, phenols, primary amines, aromatic esters, ethers, and alkyl halides are among the functional groups that are confirmed to exist in the leaf extract of *Thalictrum foliolosum* by the FTIR spectrum produced by the current research (Table 2). By comparing the frequency range with the Sigma-Aldrich Table, the functional group was determined.

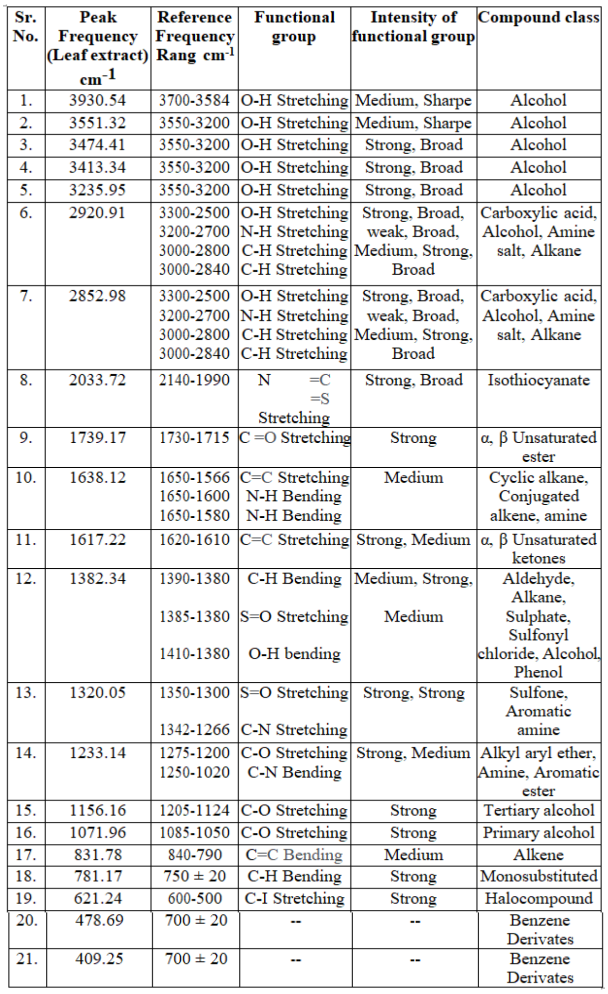
The following details relate to different functional categories of T. foliolosum plant extract:

The existence of an alcohol functional group was established by the O-H stretching-corresponding peak absorption at 3930.54 cm$^{-1}$, 3551.32 cm$^{-1}$, 3474.41 cm$^{-1}$, and 3235.95 cm$^{-1}$.

The existence of O-H, N-H, and C-H stretching revealed carboxylic acid, alcohol, amine salt, and alkane. Absorption bands at 2852.98 cm$^{-1}$.

The following values indicate Alcohol, phenol, sulfone, aromatic amine, cyclic alkane, conjugated alkene, amine, aldehyde, sulfate, sulfonyl chloride, and α, β unsaturated ester: 2852.98 cm$^{-1}$, 2033.1739, 72 cm$^{-1}$.17 cm$^{-1}$, 1638.12 cm$^{-1}$, 1617.22 cm$^{-1}$, 1382.34 cm$^{-1}$, 1320.05 cm$^{-1}$, 1233.14 cm$^{-1}$, 1156.16 cm$^{-1}$, 1071.96 cm$^{-1}$, 831.78 cm$^{-1}$, 781.4,78.69 cm$^{-1}$, 409.25 cm$^{-1}$, 621.24 cm$^{-1}$, and 17 cm$^{-1}$.

**Table 2:** FTIR peak assignment of analyzed of methanolic root extract fraction of *Thalictrum foliolosum* compared with standard chart



| Sr. No. | Peak Frequency (Leaf extract) cm$^{-1}$ | Reference Frequency Rang cm$^{-1}$ | Functional group | Intensity of functional group | Compound class |
|---|---|---|---|---|---|
| 1. | 3930.54 | 3700-3584 | O-H Stretching | Medium, Sharpe | Alcohol |
| 2. | 3551.32 | 3550-3200 | O-H Stretching | Medium, Sharpe | Alcohol |
| 3. | 3474.41 | 3550-3200 | O-H Stretching | Strong, Broad | Alcohol |
| 4. | 3413.34 | 3550-3200 | O-H Stretching | Strong, Broad | Alcohol |
| 5. | 3235.95 | 3550-3200 | O-H Stretching | Strong, Broad | Alcohol |
| 6. | 2920.91 | 3300-2500<br>3200-2700<br>3000-2800<br>3000-2840 | O-H Stretching<br>N-H Stretching<br>C-H Stretching<br>C-H Stretching | Strong, Broad, weak, Broad, Medium, Strong, Broad | Carboxylic acid, Alcohol, Amine salt, Alkane |
| 7. | 2852.98 | 3300-2500<br>3200-2700<br>3000-2800<br>3000-2840 | O-H Stretching<br>N-H Stretching<br>C-H Stretching<br>C-H Stretching | Strong, Broad, weak, Broad, Medium, Strong, Broad | Carboxylic acid, Alcohol, Amine salt, Alkane |
| 8. | 2033.72 | 2140-1990 | N =C =S Stretching | Strong, Broad | Isothiocyanate |
| 9. | 1739.17 | 1730-1715 | C =O Stretching | Strong | α, β Unsaturated ester |
| 10. | 1638.12 | 1650-1566<br>1650-1600<br>1650-1580 | C=C Stretching<br>N-H Bending<br>N-H Bending | Medium | Cyclic alkane, Conjugated alkene, amine |
| 11. | 1617.22 | 1620-1610 | C=C Stretching | Strong, Medium | α, β Unsaturated ketones |
| 12. | 1382.34 | 1390-1380<br>1385-1380<br>1410-1380 | C-H Bending<br>S=O Stretching<br>O-H bending | Medium, Strong,<br>Medium | Aldehyde, Alkane, Sulphate, Sulfonyl chloride, Alcohol, Phenol |
| 13. | 1320.05 | 1350-1300<br>1342-1266 | S=O Stretching<br>C-N Stretching | Strong, Strong | Sulfone, Aromatic amine |
| 14. | 1233.14 | 1275-1200<br>1250-1020 | C-O Stretching<br>C-N Bending | Strong, Medium | Alkyl aryl ether, Amine, Aromatic ester |
| 15. | 1156.16 | 1205-1124 | C-O Stretching | Strong | Tertiary alcohol |
| 16. | 1071.96 | 1085-1050 | C-O Stretching | Strong | Primary alcohol |
| 17. | 831.78 | 840-790 | C=C Bending | Medium | Alkene |
| 18. | 781.17 | 750 ± 20 | C-H Bending | Strong | Monosubstituted |
| 19. | 621.24 | 600-500 | C-I Stretching | Strong | Halocompound |
| 20. | 478.69 | 700 ± 20 | -- | -- | Benzene Derivates |
| 21. | 409.25 | 700 ± 20 | -- | -- | Benzene Derivates |

### FTIR Analysis of *Selinum tenuifolium*

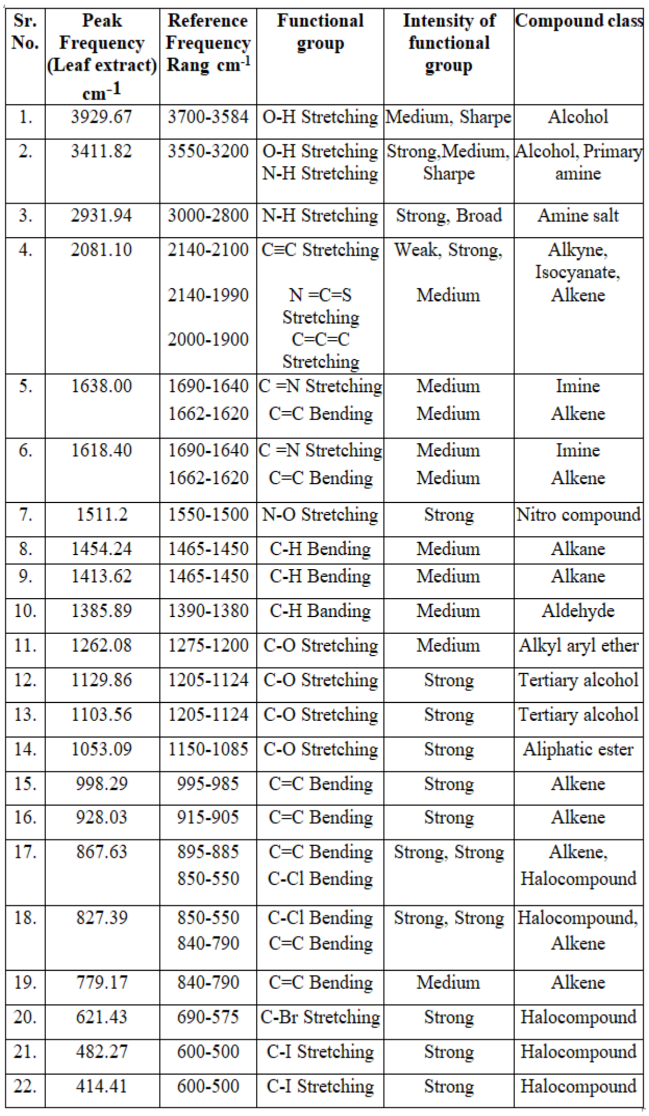
FTIR spectroscopy investigations revealed that various functional chemicals had distinct typical peak values. Alkenes, carboxylic acids, aldehydes, alcohols, amides, phenols, primary amines, aromatic esters, ethers, and alkyl halides are among the functional groups that are confirmed to exist in the root extract of *Selinum tenuifolium* by the FTIR spectrum produced by the current research (Table 3). By comparing the frequency range using the Sigma-Aldrich Table as a reference, the functional group was determined.

The following details relate to different functional categories of S. tenuifolium plant extract:

The existence of an alcohol functional group was determined by the O-H stretching-corresponding absorption peak at 3929.67 cm$^{-1}$ and 3411.82 cm$^{-1}$.

The O-H, N-H, and C-H stretching absorptions showed the existence of alkane, carboxylic acid, 3°alcohols, and amine salt. Bands at 2931.94 cm$^{-1}$, 2081.10 cm$^{-1}$, 1638.00 cm$^{-1}$, and 1618.40 cm$^{-1}$. The incidence of alkene, amine, aldehyde, alcohol, phenol, and halo compound is indicated by the absorption bands at 1413.62 cm$^{-1}$, 1385.89 cm$^{-1}$, 1262.08 cm$^{-1}$, 1053.09 cm$^{-1}$, 998.29 cm$^{-1}$, and 867.63 cm$^{-1}$.

**Table 3:** FTIR peak assignment of analyzed of methanolic root extract fraction of *Selinum tenuifolium* compared with standard chart



| Sr. No. | Peak Frequency (Leaf extract) cm$^{-1}$ | Reference Frequency Rang cm$^{-1}$ | Functional group | Intensity of functional group | Compound class |
|---|---|---|---|---|---|
| 1. | 3929.67 | 3700-3584 | O-H Stretching | Medium, Sharpe | Alcohol |
| 2. | 3411.82 | 3550-3200 | O-H Stretching<br>N-H Stretching | Strong,Medium, Sharpe | Alcohol, Primary amine |
| 3. | 2931.94 | 3000-2800 | N-H Stretching | Strong, Broad | Amine salt |
| 4. | 2081.10 | 2140-2100<br>2140-1990<br>2000-1900 | C≡C Stretching<br>N =C=S Stretching<br>C=C=C Stretching | Weak, Strong,<br>Medium | Alkyne, Isocyanate, Alkene |
| 5. | 1638.00 | 1690-1640<br>1662-1620 | C =N Stretching<br>C=C Bending | Medium<br>Medium | Imine<br>Alkene |
| 6. | 1618.40 | 1690-1640<br>1662-1620 | C =N Stretching<br>C=C Bending | Medium<br>Medium | Imine<br>Alkene |
| 7. | 1511.2 | 1550-1500 | N-O Stretching | Strong | Nitro compound |
| 8. | 1454.24 | 1465-1450 | C-H Bending | Medium | Alkane |
| 9. | 1413.62 | 1465-1450 | C-H Bending | Medium | Alkane |
| 10. | 1385.89 | 1390-1380 | C-H Banding | Medium | Aldehyde |
| 11. | 1262.08 | 1275-1200 | C-O Stretching | Medium | Alkyl aryl ether |
| 12. | 1129.86 | 1205-1124 | C-O Stretching | Strong | Tertiary alcohol |
| 13. | 1103.56 | 1205-1124 | C-O Stretching | Strong | Tertiary alcohol |
| 14. | 1053.09 | 1150-1085 | C-O Stretching | Strong | Aliphatic ester |
| 15. | 998.29 | 995-985 | C=C Bending | Strong | Alkene |
| 16. | 928.03 | 915-905 | C=C Bending | Strong | Alkene |
| 17. | 867.63 | 895-885<br>850-550 | C=C Bending<br>C-Cl Bending | Strong, Strong | Alkene, Halocompound |
| 18. | 827.39 | 850-550<br>840-790 | C-Cl Bending<br>C=C Bending | Strong, Strong | Halocompound, Alkene |
| 19. | 779.17 | 840-790 | C=C Bending | Medium | Alkene |
| 20. | 621.43 | 690-575 | C-Br Stretching | Strong | Halocompound |
| 21. | 482.27 | 600-500 | C-I Stretching | Strong | Halocompound |
| 22. | 414.41 | 600-500 | C-I Stretching | Strong | Halocompound |

## FTIR Analysis of *Wulfenia amherstiana*

FTIR spectroscopy investigations revealed that various functional chemicals had distinct typical peak values. The FTIR spectrum of the root extract of *Wulfenia amherstiana*, which was produced by the current investigation, validates Alkenes, carboxylic acids, aldehydes, alcohols, amides, phenols, primary amines, aromatic esters, ethers, and alkyl halides are among the functional groups that are present (Table 4). The functional group was identified by comparing the frequency range with the Sigma-Aldrich Table.

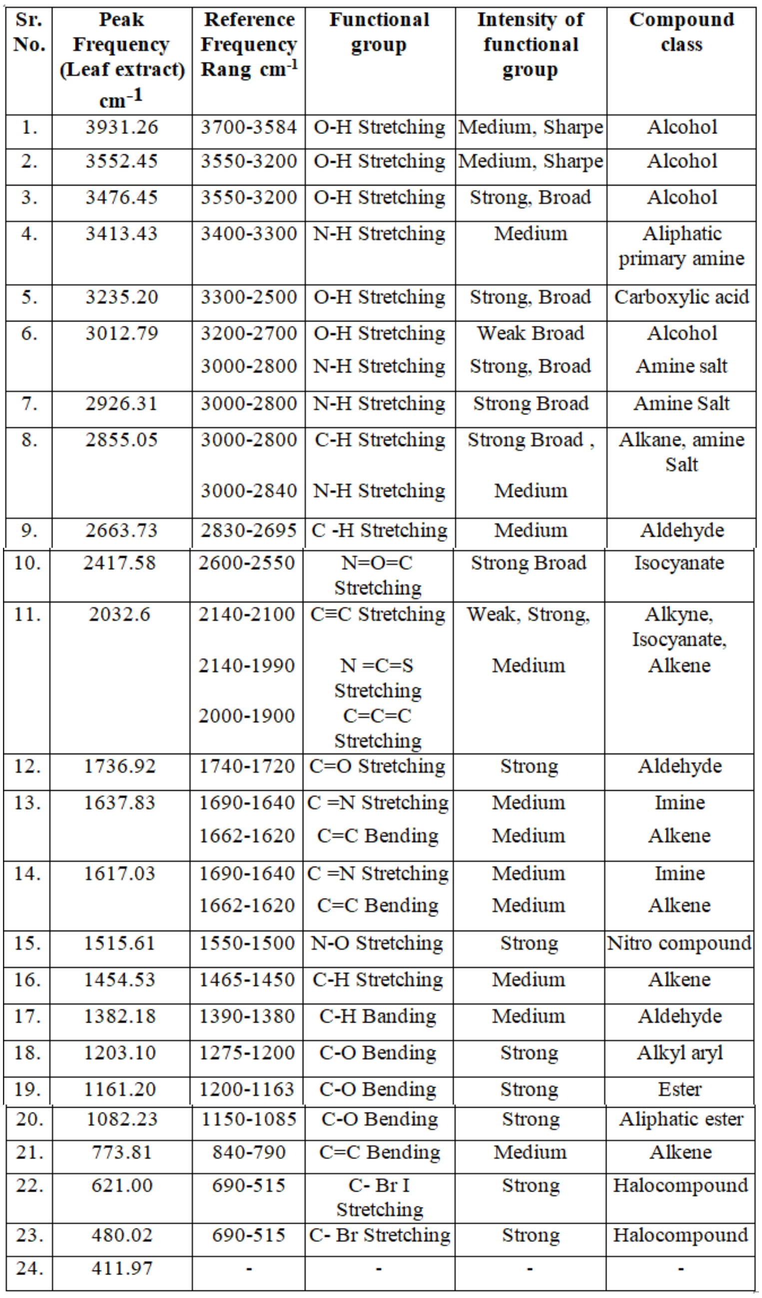
The following details relate to different functional categories of W. amherstiana plant extract:

The O-H stretching that corresponded to the absorption peaks at 3931.26 $cm^{-1}$, 3552.45 $cm^{-1}$, 3476.45 $cm^{-1}$, and 3413.43 $cm^{-1}$ demonstrated the existence of an alcohol functional group.

The existence of alkane, amine salt, carboxylic acid, 3°alcohols, and isocyanate was shown by the O-H, N-H, C≡C, N = C=S, and C-H stretching absorption bands at 3235.20 $cm^{-1}$, 3012.79 $cm^{-1}$, 2926.31 $cm^{-1}$, 2855.05 $cm^{-1}$, and 2032.69 $cm^{-1}$.

The following values: 1736.92 cm-1, 1637.83 $cm^{-1}$, 1617.03 $cm^{-1}$, 1454.53 $cm^{-1}$, 1382.18 $cm^{-1}$, and 1203.10 $cm^{-1}$, show the presence of alcohol, phenol, halo compound, aliphatic ester, alkyl aryl, alkene, amine, and aldehyde.

**Table 4:** FTIR peak assignment of analyzed of methanolic root extract fraction of *Wulfenia amherstiana* compared with standard chart



| Sr. No. | Peak Frequency (Leaf extract) $cm^{-1}$ | Reference Frequency Rang $cm^{-1}$ | Functional group | Intensity of functional group | Compound class |
|---|---|---|---|---|---|
| 1. | 3931.26 | 3700-3584 | O-H Stretching | Medium, Sharpe | Alcohol |
| 2. | 3552.45 | 3550-3200 | O-H Stretching | Medium, Sharpe | Alcohol |
| 3. | 3476.45 | 3550-3200 | O-H Stretching | Strong, Broad | Alcohol |
| 4. | 3413.43 | 3400-3300 | N-H Stretching | Medium | Aliphatic primary amine |
| 5. | 3235.20 | 3300-2500 | O-H Stretching | Strong, Broad | Carboxylic acid |
| 6. | 3012.79 | 3200-2700<br>3000-2800 | O-H Stretching<br>N-H Stretching | Weak Broad<br>Strong, Broad | Alcohol<br>Amine salt |
| 7. | 2926.31 | 3000-2800 | N-H Stretching | Strong Broad | Amine Salt |
| 8. | 2855.05 | 3000-2800<br>3000-2840 | C-H Stretching<br>N-H Stretching | Strong Broad ,<br>Medium | Alkane, amine Salt |
| 9. | 2663.73 | 2830-2695 | C -H Stretching | Medium | Aldehyde |
| 10. | 2417.58 | 2600-2550 | N=O=C Stretching | Strong Broad | Isocyanate |
| 11. | 2032.6 | 2140-2100<br>2140-1990<br>2000-1900 | C≡C Stretching<br>N =C=S Stretching<br>C=C=C Stretching | Weak, Strong,<br>Medium | Alkyne, Isocyanate, Alkene |
| 12. | 1736.92 | 1740-1720 | C=O Stretching | Strong | Aldehyde |
| 13. | 1637.83 | 1690-1640<br>1662-1620 | C =N Stretching<br>C=C Bending | Medium<br>Medium | Imine<br>Alkene |
| 14. | 1617.03 | 1690-1640<br>1662-1620 | C =N Stretching<br>C=C Bending | Medium<br>Medium | Imine<br>Alkene |
| 15. | 1515.61 | 1550-1500 | N-O Stretching | Strong | Nitro compound |
| 16. | 1454.53 | 1465-1450 | C-H Stretching | Medium | Alkene |
| 17. | 1382.18 | 1390-1380 | C-H Banding | Medium | Aldehyde |
| 18. | 1203.10 | 1275-1200 | C-O Bending | Strong | Alkyl aryl |
| 19. | 1161.20 | 1200-1163 | C-O Bending | Strong | Ester |
| 20. | 1082.23 | 1150-1085 | C-O Bending | Strong | Aliphatic ester |
| 21. | 773.81 | 840-790 | C=C Bending | Medium | Alkene |
| 22. | 621.00 | 690-515 | C- Br I Stretching | Strong | Halocompound |
| 23. | 480.02 | 690-515 | C- Br Stretching | Strong | Halocompound |
| 24. | 411.97 | - | - | - | - |

## Conclusion

FTIR spectroscopy showed that different functional compounds had different typical peak values. Analysis of several plant species revealed a range of bioactive phytoconstituents, including the functional groups, as reported during FTIR. The roots of *Selinum tenuifolium* (90.6%), *Bergenia ligulata* (47.24%), and *Thalictrum foliolosum* leaves (88.20%) come next. This paper investigated and micro propagated the medicinal potential of four endangered plants: *Wulfenia amherstiana*, *Thalictrum foliolosum*, *Selinum tenuifolium*, and *Bergenia ligulata*. The interferogram must be converted to a spectrum using Fourier analysis, which requires a computer. Numerous spectroscopies, including nuclear magnetic resonance (NMR), electron spin resonance (ESR), and infrared spectroscopy, also referred to as Fourier transform infrared (FT-IR), can make use of Fourier transforms. FT-IR spectroscopy requires extensive research since it uses interferometers in spectrometers and functions differently from dispersive spectroscopy techniques.

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