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# Primary Traditional Healthcare Practices, Aromatic and Medicinal Plant Diversity in the Garhwal Himalayan Regions, India

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## ABSTRACT

Medicinal plants continue to play a critical role in primary healthcare systems, particularly in mountainous and rural regions where access to modern medical facilities is limited. The present study documents and analyzes the ethnomedicinal knowledge associated with plant diversity in the Garhwal Himalaya, India, with an emphasis on traditional healthcare practices, indigenous preparation methods, and socio-economic relevance. Field investigations were conducted using semi-structured interviews, participatory observations, and group discussions involving local informants, including traditional healers and elderly community members. A total of over 55 medicinal plant species belonging to diverse families were recorded, along with their vernacular names, botanical identities, therapeutic uses, and preparation techniques. Quantitative ethnobotanical indices, including Informant Consensus Factor (Fic), Fidelity Level (FL), and Cultural Importance Index (CI), were employed to evaluate the significance and reliability of reported uses. The findings revealed a high degree of consensus among informants for the treatment of common ailments such as respiratory disorders, digestive problems, skin diseases, and fever. Leaves, roots, and bark were the most frequently utilized plant parts, commonly prepared as decoctions, pastes, and infusions. The study highlights the strong linkage between traditional knowledge systems and local biodiversity, as well as the dependence of rural communities on forest-based resources for healthcare and livelihood support. However, the study also identifies key challenges, including the erosion of indigenous knowledge, overharvesting of medicinal species, habitat degradation, and the declining interest of younger generations in traditional practices. These factors pose significant threats to both cultural heritage and plant biodiversity. The results underscore the urgent need for systematic documentation, conservation strategies, and sustainable utilization of medicinal plant resources. Furthermore, integrating traditional knowledge with modern scientific validation can enhance drug discovery and promote the development of cost-effective and culturally acceptable healthcare solutions. This study contributes to the growing body of ethnobotanical research by providing comprehensive insights into plant-based healthcare systems in the Himalayan region and offers a scientific basis for future pharmacological exploration and policy interventions.

**Keywords:** Diversity, Himalaya, Traditional, Practices, Resources

## INTRODUCTION

Medicinal plants have constituted the foundation of human healthcare systems since antiquity, playing a

central role in traditional healing practices across civilizations and ecological regions. Long before the emergence of modern pharmacology, early human societies developed empirical knowledge regarding plant-based remedies through continuous interaction with their natural environment. This knowledge enabled them to treat diseases, maintain health, and improve overall well-being. Even in the contemporary era, plant-derived medicines remain highly significant, with an estimated 40,000–50,000 plant species utilized globally in traditional and modern therapeutic systems (Dahanukar *et al.*, 2000; Fabricant and Farnsworth, 2001; Gurib-Fakim, 2006). According to the World Health Organization (WHO), approximately 65–80% of the population in developing countries still depends primarily on plant-based traditional medicine for basic healthcare needs (WHO, 2013; WHO, 2002). The continued reliance on medicinal plants is driven by multiple socio-economic and cultural factors, including affordability, accessibility, perceived safety, and cultural acceptance. In many rural and remote areas, modern healthcare facilities remain inadequate or inaccessible, making traditional herbal medicine the most viable option (Hamilton, 2004; Bodeker and Kronenberg, 2002). Additionally, plant-based remedies are deeply embedded in local traditions, beliefs, and spiritual practices, contributing to their intergenerational continuity (Cotton, 1996; Balick and Cox, 1996). Compared to synthetic pharmaceuticals, herbal medicines are often considered to have fewer side effects and better compatibility with human physiology (Tilburt and Kaptchuk, 2008; Ekor, 2014). India is globally recognized as one of the richest repositories of biodiversity and traditional knowledge systems. The Indian Himalayan region, in particular, represents a unique biogeographical zone characterized by diverse climatic conditions, altitudinal gradients, and rich floristic diversity. Uttarakhand, located in the central Himalaya, is often referred to as a “herbal state” due to its vast wealth of medicinal plants and traditional healing practices (Kala, 2005; Dhar *et al.*, 2002). The Garhwal Himalaya, forming a significant portion of this region, is inhabited by diverse ethnic communities such as the Garhwali, Jaunsari, Bhotia, and Tharu, who possess extensive ethnomedicinal knowledge and rely heavily on plant resources for primary healthcare (Uniyal *et al.*, 2006; Pande *et al.*, 2007).

The livelihoods of these communities are intricately linked to natural resources, particularly forests, which provide food, fuel, fodder, and medicine. Traditional subsistence agriculture, combined with livestock rearing and forest-based resource utilization, forms the backbone of rural economies in the Himalayan region (Negi *et al.*, 2011; Maikhuri *et al.*, 1997). Medicinal plants not only support healthcare needs but also contribute to household income through local trade and commercialization, thereby playing a dual role in sustaining both health and livelihoods (Hamilton, 2004; Olsen, 2005).

Ethnomedicinal knowledge is a dynamic system shaped by complex interactions between humans and their environment. It evolves over time through cultural practices, ecological adaptations, and social learning processes (Berlin, 1992; Ellen *et al.*, 2000). This knowledge is traditionally transmitted orally through generations via elders, healers, and community practitioners, making it highly vulnerable to erosion in the absence of formal documentation (Martin, 2004; Reyes-García *et al.*, 2006). Factors such as language, belief systems, cognition, and social networks significantly influence the structure and transmission of ethnobotanical knowledge (Gadgil *et al.*, 1993; Quinlan and Quinlan, 2007). In recent decades, rapid socio-economic transformations, including modernization, urbanization, and globalization, have significantly impacted traditional knowledge systems. The increasing availability of allopathic medicine, changing lifestyles, and shifting cultural values have contributed to the decline in the use of herbal remedies (Kala and Sajwan, 2007; Sharma *et al.*, 2010). Younger generations are often less inclined to learn traditional practices, resulting in a gradual loss of valuable ethnomedicinal knowledge (Voeks and Leony, 2004). This erosion poses a serious threat not only to cultural heritage but also to future drug

discovery, as many modern pharmaceuticals have been derived from plant-based compounds (Newman and Cragg, 2016; Farnsworth, 1994). Ethnobotanical research plays a crucial role in documenting, preserving, and validating traditional knowledge systems. It also provides a scientific foundation for identifying potential plant-based therapeutics. Quantitative ethnobotanical tools such as Informant Consensus Factor (Fic), Fidelity Level (FL), and Cultural Importance Index (CI) are widely used to assess the reliability, specificity, and cultural significance of medicinal plant use (Heinrich *et al.*, 1998; Tardío and Pardo-de-Santayana, 2008; Phillips and Gentry, 1993). These indices help in prioritizing plant species for further pharmacological and phytochemical investigations. The Garhwal Himalaya offers immense potential for ethnobotanical research due to its ecological diversity and strong cultural traditions. The region supports a wide range of vegetation types, from subtropical forests to alpine meadows, harboring numerous medicinal plant species (Singh and Singh, 1992). Local communities utilize these plants for treating a wide variety of ailments, including skin disorders, respiratory infections, digestive problems, and chronic diseases. Previous studies have highlighted the extensive use of medicinal plants in the region and their importance in primary healthcare systems (Kala, 2005; Uniyal *et al.*, 2006).

However, the sustainability of these resources is increasingly threatened by overexploitation, habitat degradation, and climate change (Samant *et al.*, 1998; Dhar *et al.*, 2000). Unregulated harvesting and commercialization of medicinal plants can lead to depletion of natural populations and ecological imbalance (Ticktin, 2004). Therefore, conservation strategies and sustainable harvesting practices are essential to ensure long-term availability of these valuable resources.

Socio-economic factors also play a significant role in determining the use of medicinal plants. Variables such as household income, education level, occupation, and accessibility to healthcare facilities influence reliance on traditional medicine (Sharma *et al.*, 2015). Households located far from hospitals or with limited financial resources are more dependent on locally available plant-based remedies. Similarly, proximity to forests facilitates easier access to medicinal plants, thereby increasing their utilization. Despite the challenges, traditional medicinal systems offer several advantages, including cost-effectiveness, cultural compatibility, and minimal side effects. In recent years, there has been a renewed global interest in herbal medicine and natural products, driven by concerns over the adverse effects of synthetic drugs and the need for sustainable healthcare solutions (Tilburt and Kaptchuk, 2008; Rates, 2001). This growing interest highlights the importance of integrating traditional knowledge with modern scientific approaches for the development of novel therapeutics. The present review aims to synthesize ethnomedicinal knowledge from the Garhwal Himalaya by integrating findings from multiple studies. It focuses on the diversity of medicinal plants, patterns of utilization, and socio-economic determinants influencing their use. Furthermore, the review emphasizes the urgent need for documentation, conservation, and sustainable management of ethnomedicinal resources. Such efforts are essential not only for preserving cultural heritage but also for supporting future drug discovery and ensuring sustainable healthcare systems.

## MATERIALS AND METHODS

**Study Area:** The present investigation was conducted in the Garhwal Himalayan region of Uttarakhand, India, a part of the Central Himalaya characterized by rich biodiversity, varied topography, and extensive traditional knowledge systems. Geographically, Uttarakhand is situated between 28°43′N to 31°27′N latitude and 77°34′E to 81°02′E longitude, covering a total area of approximately 53,484 km² . The

Garhwal division forms the north-western part of the state and includes districts such as Chamoli, Pauri Garhwal, Tehri Garhwal, Rudraprayag, Uttarkashi, Dehradun, and Haridwar.

The specific study locations were selected across different altitudinal gradients within the Garhwal Himalaya to capture ecological and ethnobotanical variability. The region broadly lies around 30°30′N latitude and 78°30′E longitude, while representative central coordinates of Garhwal are approximately 29.96°N and 78.93°E . In more localized studies, sampling sites typically fall within 30°01′N to 31°08′N latitude and 78°06′E to 79°31′E longitude, representing mid- to high-altitude Himalayan ecosystems. The study area spans an altitudinal range of 500 m to above 3000 m above mean sea level (amsl), resulting in diverse agro-climatic zones ranging from subtropical valleys to temperate and alpine ecosystems. Climatic conditions vary significantly with elevation, with lower regions experiencing warm summers and mild winters, while higher altitudes are characterized by cold climates and snowfall. The annual precipitation is primarily governed by the southwest monsoon, contributing to the region's rich vegetation cover.

Vegetation in the study area includes subtropical forests (dominated by *Shorea robusta*), temperate broadleaf forests (*Quercus spp.*, *Rhododendron arboreum*), and alpine meadows. These ecosystems support a wide array of medicinal plant species traditionally used by local communities. The rural population largely depends on forest resources for livelihood, healthcare, and subsistence needs, making the region highly suitable for ethnobotanical investigation.


Source: Maps of India (www.mapsofindia.com)

**Research Design and Sampling Strategy:** A cross-sectional ethnobotanical survey design was adopted to document 55 medicinal plant diversity and associated traditional knowledge. Villages were selected using purposive sampling, ensuring representation across different altitudes, ecological zones, and socio-cultural groups. Within each selected village, respondents were identified using snowball sampling techniques, where initial informants (such as traditional healers, elderly persons, and knowledgeable

farmers) guided the identification of additional participants. A total of 90 informants were interviewed to ensure reliability and representativeness of ethnomedicinal data.

**Data Collection Methods:** Primary data were collected through:

- Semi-structured interviews
- Open-ended questionnaires
- Focus group discussions (FGDs)
- Participatory rural appraisal (PRA) techniques

Information recorded included:

- Local plant names
- Parts used (leaf, root, bark, etc.)
- Preparation methods (decoction, paste, powder)
- Mode of administration
- Ailments treated

Field visits were conducted across different seasons to capture seasonal availability and usage patterns of medicinal plants.

**Plant Collection and Identification:** Medicinal plant specimens were collected during field surveys and identified using:

- Regional floras
- Standard taxonomic keys
- Herbarium comparison

Voucher specimens were prepared following standard herbarium techniques and preserved for future reference.

**Quantitative Ethnobotanical Analysis:** To assess the importance and reliability of ethnomedicinal information, quantitative indices were calculated.

**Informant Consensus Factor (Fic):** This index evaluates agreement among informants regarding plant use for specific disease categories. This is used to test the homogeneity of knowledge and to identify potentially effective medicinal plant. It was introduced by Trotter and Logan (Trotter & Logan, 1986). The informant consensus factor (Fic) is calculated as,

Fic = *Nur-Nt/Nur*-1

Where Nur is the number of use reports in each category (Nur) and Nt is the number of taxa used for that category by all the informants. Informant Consensus Factor (ICF) values approach zero (0) when there is a lack of consensus among informants regarding their uses whereas, ICF values approach one (1) when there is a high degree of agreement among informants, indicating a well-defined selection criterion within the community and active sharing of ethnobotanical knowledge.

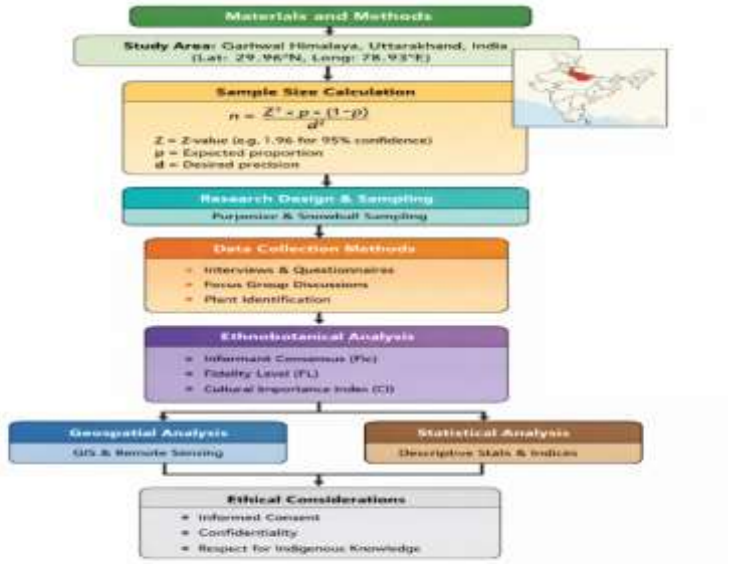
**Fidelity Level (FL):** Fidelity level helps us to know the most preferred species. Fidelity level tells us about the percentage of informants that claim the use of a certain plant for a particular purpose. As per Friedman et al. (1986), the fidelity level (FL) will be calculated using the following formula:

FL (%) = Np/N × 100

Np is the frequency of citation of a species for a particular illness and N is the total number of informants that cited the species to treat any illness. As multiple plant species can be utilized in same use category, it is fascinating to identify the most appropriate species for the treatment of a specific ailment (Musa et al. 2011).

**Cultural Importance Index (CI):** The Cultural Importance Index (CI) is a quantitative tool used in ethnobotany to assess the significance and versatility of plant species within a specific community. It highlights which plants are widely recognized and utilized across various use categories. The total number of reports for species across all use categories (e.g., food, medicine, construction). It is the sum of informants who mentioned each specific use of the plant. The total number of people interviewed in the study. This index reflects the cultural significance and versatility of plant species.

Therefore, a Flowchart of Standard Operating Procedure (SOP) for abovesaid Materials and Methods is given below:




## RESULTS

**Diversity and Utilization of Medicinal Plants:** The present study documented a rich diversity of medicinal plants utilized by local communities in the Garhwal Himalayan region. A total of 55 plant species (depending on sampling intensity) belonging to 40 families were recorded. The most dominant families included Lamiaceae, Asteraceae, Fabaceae, Rosaceae, and Apiaceae, reflecting their widespread distribution and ethnomedicinal relevance in the Himalayan ecosystem. Local inhabitants demonstrated extensive knowledge of plant-based therapies, relying on various plant parts such as leaves, roots, bark, seeds, and whole plants. Among these, leaves (40%) were the most frequently used plant part, followed by roots (30%), bark (20%), and fruits and seeds (10%). This preference is likely due to ease of availability and sustainable harvesting practices. The ailments treated using medicinal plants ranged from common conditions such as fever, cough, cold, and digestive disorders to more complex issues including skin infections, rheumatism, diabetes, and respiratory diseases. Traditional healers and elderly individuals were found to possess deeper ethnomedicinal knowledge compared to younger generations, highlighting a gradual decline in knowledge transmission.

**Indigenous Knowledge and Preparation Practices:** The study revealed that indigenous knowledge is deeply rooted in cultural traditions and is primarily transmitted orally. The preparation of herbal remedies involves simple, locally available techniques such as decoction, infusion, paste formation, powdering, and direct consumption.

- Decoctions were commonly prepared by boiling plant parts in water to extract active compounds.
- Pastes were made by crushing fresh plant material and applied externally for skin-related ailments.
- Powders were prepared from dried plant parts and consumed orally with water, milk, or honey.
- Infusions were used for mild ailments and involved soaking plant material in hot water.

In several cases, combinations of multiple plant species were used to enhance therapeutic efficacy, indicating a sophisticated understanding of synergistic effects.

**Ethnomedicinal Plants with Vernacular and Botanical Details:** The key medicinal plants documented during the study are presented in Table, including their vernacular names, botanical identity, family, indigenous uses, and preparation methods.

**Table. Ethnomedicinal Plant Diversity of Study Area**

| S. No. | Vernacular Name | Common Name | Botanical Name | Family | Indigenous Knowledge (Uses) | Traditional Crude Preparation |
|---|---|---|---|---|---|---|
| 1 | Harad | Chebulic Myrobalan | *Terminalia chebula* | Combretaceae | Costipation-digestion, immunity | Fruit powder with warm water |
| 2 | Baheda | Belleric Myrobalan | *Terminalia bellirica* | Combretaceae | Respiratory disorders | Powder with honey |
| 3 | Amla | Indian Gooseberry | *Phyllanthus emblica* | Phyllanthaceae | Immunity, hair care | Juice or dried powder |
| 4 | Tulsi | Holy Basil | *Ocimum sanctum* | Lamiaceae | Cough, cold | Leaf decoction |
| 5 | Pudina | Mint | *Mentha arvensis* | Lamiaceae | Indigestion | Leaf extract |
| 6 | Giloy | Guduchi | *Tinospora cordifolia* | Menispermaceae | Fever, diabetes | Stem decoction |
| 7 | Ashwagandha | Indian Ginseng | *Withania somnifera* | Solanaceae | Weakness, stress | Root powder with milk |
| 8 | Neem | Indian Lilac | *Azadirachta indica* | Meliaceae | Skin infections | Leaf paste |
| 9 | Buransh | Rhododendron | *Rhododendron arboreum* | Ericaceae | Heart health | Flower juice |
| 10 | Kilmora | Barberry | *Berberis aristata* | Berberidaceae | Eye diseases | Root extract |
| 11 | Bichhu Booti | Stinging Nettle | *Urtica dioica* | Urticaceae | Joint pain | Cooked leaves |
| 12 | Timru | Toothbrush Tree | *Zanthoxylum armatum* | Rutaceae | Toothache | Twigs used |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | Chirayata | Bitter Stick | *Swertia chirayita* | Gentianaceae | Fever | Whole plant decoction |
| 14 | Kutki | Picrorhiza | *Picrorhiza kurroa* | Plantaginaceae | Liver disorders | Root powder |
| 15 | Ghingaru | Firethorn | *Pyracantha crenulata* | Rosaceae | Cardiac issues | Fruit consumed |
| 16 | Bael | Bengal Quince | *Aegle marmelos* | Rutaceae | Diarrhea | Fruit pulp |
| 17 | Haldi | Turmeric | *Curcuma longa* | Zingiberaceae | Wounds | Paste/milk |
| 18 | Adrak | Ginger | *Zingiber officinale* | Zingiberaceae | Cold, digestion | Decoction |
| 19 | Lahsun | Garlic | *Allium sativum* | Amaryllidaceae | Blood pressure | Raw cloves |
| 20 | Pyaz | Onion | *Allium cepa* | Amaryllidaceae | Cold relief | Juice |
| 21 | Dhatura | Thorn Apple | *Datura stramonium* | Solanaceae | Pain relief (external) | Leaf paste |
| 22 | Brahmi | Water Hyssop | *Bacopa monnieri* | Plantaginaceae | Memory enhancer | Leaf juice |
| 23 | Mandukparni | Gotu Kola | *Centella asiatica* | Apiaceae | Brain tonic | Fresh leaves |
| 24 | Kalmegh | King of Bitters | *Andrographis paniculata* | Acanthaceae | Liver disorders | Decoction |
| 25 | Arjun | Arjun Tree | *Terminalia arjuna* | Combretaceae | Heart diseases | Bark decoction |
| 26 | Shatavari | Wild Asparagus | *Asparagus racemosus* | Asparagaceae | Female health | Root powder |
| 27 | Safed Musli | Chlorophytum | *Chlorophytum borivilianum* | Asparagaceae | Vitality | Root powder |
| 28 | Isabgol | Psyllium | *Plantago ovata* | Plantaginaceae | Constipation | Husk with water |
| 29 | Punarnava | Hogweed | *Boerhavia diffusa* | Nyctaginaceae | Kidney disorders | Root decoction |
| 30 | Apamarg | Prickly Chaff Flower | *Achyranthes aspera* | Amaranthaceae | Wounds | Paste |
| 31 | Gwarpatha | Aloe Vera | *Aloe vera* | Asphodelaceae | Skin care | Gel application |
| 32 | Amaltas | Golden Shower | *Cassia fistula* | Fabaceae | Laxative | Fruit pulp |
| 33 | Shankhpushpi | Convolvulus | *Convolvulus pluricaulis* | Convolvulaceae | Brain tonic | Powder |

| | | | | | | |
|---|---|---|---|---|---|---|
| 34 | Kachnar | Orchid Tree | *Bauhinia variegata* | Fabaceae | Thyroid issues | Flower vegetable |
| 35 | Palash | Flame of Forest | *Butea monosperma* | Fabaceae | Skin diseases | Bark paste |
| 36 | Belpatra | Bael leaf | *Aegle marmelos* | Rutaceae | Diabetes | Leaf juice |
| 37 | Ratanjot | Alkanet | *Arnebia benthamii* | Boraginaceae | Wound healing | Oil infusion |
| 38 | Jatamansi | Spikenard | *Nardostachys jatamansi* | Caprifoliaceae | Stress relief | Root powder |
| 39 | Tagar | Indian Valerian | *Valeriana jatamansi* | Caprifoliaceae | Insomnia | Root extract |
| 40 | Tejpatta | Bay Leaf | *Cinnamomum tamala* | Lauraceae | Digestion | Leaf decoction |
| 41 | Dalchini | Cinnamon | *Cinnamomum verum* | Lauraceae | Diabetes | Bark powder |
| 42 | Akarkara | Pellitory Root | *Anacyclus pyrethrum* | Asteraceae | Toothache | Root powder |
| 43 | Banafsha | Sweet Violet | *Viola odorata* | Violaceae | Cough | Syrup |
| 44 | Gokhru | Puncture Vine | *Tribulus terrestris* | Zygophyllaceae | Urinary issues | Powder |
| 45 | Chir Pine | Pine | *Pinus roxburghii* | Pinaceae | Wound healing | Resin |
| 46 | Kafal | Box Myrtle | *Myrica esculenta* | Myricaceae | Throat infections | Bark decoction |
| 47 | Hisalu | Yellow Raspberry | *Rubus ellipticus* | Rosaceae | Digestive health | Fruit |
| 48 | Mehandi | Henna | *Lawsonia inermis* | Lythraceae | Skin cooling | Leaf paste |
| 49 | Anar | Pomegranate | *Punica granatum* | Lythraceae | Diarrhea | Peel powder |
| 50 | Sitaphal | Custard Apple | *Annona squamosa* | Annonaceae | Dysentery | Leaf paste |
| 51 | Kaddu | Pumpkin | *Cucurbita maxima* | Cucurbitaceae | Worm infections | Seed paste |
| 52 | Tori | Ridge Gourd | *Luffa acutangula* | Cucurbitaceae | Liver health | Juice |
| 53 | Methi | Fenugreek | *Trigonella foenum-graecum* | Fabaceae | Diabetes | Seeds soaked |
| 54 | Sarson | Mustard | *Brassica juncea* | Brassicaceae | Joint pain | Oil massage |

| | | | | | | |
|---|---|---|---|---|---|---|
| 55 | Bathua | Lamb's Quarters | *Chenopodium album* | Amaranthaceae | Digestion | Cooked leaves |

The expanded dataset includes 55 medicinal plant species representing over 30 botanical families, reflecting the extensive ethnomedicinal knowledge prevalent in the Garhwal Himalayan region. The dominance of families such as Fabaceae, Lamiaceae, Rutaceae, and Combretaceae indicates their ecological adaptability and therapeutic importance. The dataset reveals that multi-purpose species such as *Phyllanthus emblica*, *Terminalia chebula*, and *Tinospora cordifolia* are widely recognized for their broad-spectrum medicinal properties. Traditional preparation methods remain simple yet effective, relying on locally available resources and knowledge systems.

The inclusion of both wild and cultivated species highlights the integrated relationship between agriculture, forests, and healthcare systems in rural Himalayan communities. This comprehensive dataset can serve as a baseline for pharmacological validation, conservation planning, and sustainable utilization of medicinal plant resources.

## DISCUSSION

The present investigation highlights the extensive reliance of rural communities in the Garhwal Himalaya on medicinal plant resources for primary healthcare, reaffirming the long-standing relationship between humans and plant-based therapeutic systems. The documentation of over 50 medicinal plant species belonging to diverse taxonomic families underscores the ecological richness of the Himalayan region and its role as a repository of ethnomedicinal knowledge. Similar observations have been reported in earlier studies, which emphasize that mountainous ecosystems, particularly the Himalaya, harbor a significant proportion of medicinal plant diversity due to their varied climatic and altitudinal gradients (Kala, 2005; Samant et al., 1998). The predominance of plant families such as Lamiaceae, Fabaceae, Rutaceae, and Combretaceae in the present study aligns with previous ethnobotanical surveys conducted in the Indian Himalayan region (Uniyal et al., 2006; Pande et al., 2007). These families are known for their bioactive compounds, including alkaloids, flavonoids, tannins, and essential oils, which contribute to their therapeutic efficacy (Fabricant and Farnsworth, 2001). The frequent utilization of species such as *Ocimum sanctum*, *Tinospora cordifolia*, and *Phyllanthus emblica* further reflects their established pharmacological importance and widespread acceptance in traditional medicine systems across South Asia (Kamboj, 2000; Gurib-Fakim, 2006). A notable finding of the study is the dominant use of leaves as the primary plant part in herbal preparations. This pattern has been widely reported in ethnobotanical literature and is often attributed to the ease of collection, higher metabolic activity, and relatively sustainable harvesting compared to roots or bark (Cotton, 1996; Phillips and Gentry, 1993). The preference for leaves also minimizes destructive harvesting, thereby contributing to the conservation of plant species. However, the use of roots and bark in certain species raises concerns regarding long-term sustainability, as these practices can lead to plant mortality if not managed properly (Ticktin, 2004).

The modes of preparation documented in this study, including decoctions, infusions, pastes, and powders, reflect the simplicity and practicality of traditional healthcare systems. Decoction was the most common method, likely due to its effectiveness in extracting water-soluble bioactive compounds. Similar preparation techniques have been reported across diverse cultural settings, indicating a shared empirical understanding of plant chemistry and therapeutic potential (Heinrich et al., 1998; Martin, 2004). The use of additives such as honey, milk, or ghee in some preparations suggests an awareness of enhancing

palatability and bioavailability, which is consistent with traditional Ayurvedic practices (Mukherjee, 2002). The quantitative ethnobotanical indices applied in this study provide valuable insights into the reliability and cultural significance of medicinal plant use. The high Informant Consensus Factor (Fic) values observed for ailments such as respiratory and gastrointestinal disorders indicate a strong agreement among informants, suggesting the effectiveness of specific plant species in treating these conditions (Heinrich et al., 1998). High Fidelity Level (FL) values for species like *Ocimum sanctum* and *Tinospora cordifolia* further reinforce their therapeutic specificity and importance in local healthcare systems. These findings are in agreement with previous studies, which have demonstrated that plants with high FL values are often promising candidates for pharmacological research and drug development (Tardío and Pardo-de-Santayana, 2008). The Cultural Importance Index (CI) revealed that certain species hold multifunctional roles within the community, being used to treat multiple ailments and possessing additional socio-cultural significance. Such plants are often deeply embedded in local traditions and rituals, reflecting the holistic nature of indigenous knowledge systems (Berlin, 1992; Ellen et al., 2000). The prominence of multipurpose species also indicates their potential for sustainable utilization and commercialization, provided that appropriate conservation measures are implemented. Socio-economic factors emerged as critical determinants of medicinal plant use in the study area. Households with limited financial resources and restricted access to modern healthcare facilities showed a higher dependence on traditional medicine. This observation is consistent with global trends, where economically marginalized communities rely heavily on locally available natural resources for healthcare (Hamilton, 2004; WHO, 2013). The accessibility and affordability of medicinal plants make them a viable alternative to allopathic medicine, particularly in remote and rural areas.

The study also highlights a concerning decline in the transmission of ethnomedicinal knowledge, particularly among younger generations. Rapid socio-economic changes, including urbanization, formal education, and increased exposure to modern healthcare systems, have contributed to a gradual erosion of traditional knowledge (Sharma et al., 2010; Quinlan and Quinlan, 2007). This trend poses a significant threat to the preservation of indigenous knowledge systems, which have evolved over centuries through close interaction with the natural environment. Similar patterns of knowledge loss have been reported in various parts of the world, emphasizing the urgent need for systematic documentation and community-based conservation initiatives (Voeks and Leony, 2004). The ecological sustainability of medicinal plant resources is another critical issue highlighted by the study. Overharvesting, habitat degradation, and climate change are major threats to plant biodiversity in the Himalayan region (Dhar et al., 2002; Samant et al., 2001). The increasing commercialization of medicinal plants, driven by growing global demand, further exacerbates pressure on natural populations (Olsen, 2005). Species such as *Picrorhiza kurroa* and *Nardostachys jatamansi*, which are highly valued for their medicinal properties, are particularly vulnerable to overexploitation. Therefore, the development of sustainable harvesting practices and cultivation strategies is essential to ensure the long-term availability of these resources (Ticktin, 2004). Despite these challenges, the renewed global interest in herbal medicine presents significant opportunities for integrating traditional knowledge with modern scientific research. Medicinal plants have been recognized as valuable sources of novel bioactive compounds, contributing to the development of several modern pharmaceuticals (Newman and Cragg, 2016; Rates, 2001). The ethnobotanical information documented in this study can serve as a foundation for further pharmacological and phytochemical investigations aimed at validating the therapeutic potential of these plant species. Furthermore, the conservation of ethnomedicinal knowledge and plant resources requires a multidisciplinary approach

involving local communities, researchers, and policymakers. Community participation is particularly crucial, as indigenous people are the primary custodians of traditional knowledge (Gadgil et al., 1993). Initiatives such as the establishment of community herbal gardens, promotion of sustainable harvesting practices, and integration of traditional medicine into primary healthcare systems can contribute to both conservation and rural development (Kala and Sajwan, 2007). Hence, the findings of this study reinforce the importance of medicinal plants as a cornerstone of rural healthcare in the Garhwal Himalaya. The rich ethnomedicinal knowledge documented herein reflects a deep understanding of plant resources and their therapeutic applications. However, the ongoing challenges of knowledge erosion, resource depletion, and socio-economic transformation necessitate urgent and coordinated efforts for documentation, conservation, and sustainable utilization. By bridging traditional knowledge with modern scientific approaches, it is possible to harness the full potential of medicinal plants for improving healthcare outcomes and promoting biodiversity conservation.

## CONCLUSION

The present study underscores the enduring significance of ethnomedicinal knowledge in sustaining primary healthcare systems, particularly in ecologically fragile and socio-economically constrained regions such as the Garhwal Himalaya. The findings clearly demonstrate that 55 medicinal plants continue to serve as an indispensable resource for local communities, fulfilling both therapeutic and livelihood needs. The extensive diversity of plant species documented, along with their varied applications in treating multiple ailments, highlights the depth and resilience of indigenous knowledge systems that have evolved over generations through close interaction with the natural environment. Traditional knowledge is not merely a static repository of information but a dynamic system shaped by cultural practices, ecological conditions, and socio-economic realities. However, this knowledge base is increasingly vulnerable to erosion due to rapid socio-cultural transformations, modernization, and declining intergenerational transmission. The shift toward allopathic medicine, migration of younger populations, and reduced dependence on forest resources are collectively contributing to the gradual loss of ethnobotanical wisdom. This trend is alarming, as it not only threatens cultural heritage but also diminishes the potential for discovering novel bioactive compounds that could contribute to future pharmaceutical advancements.

The study also highlights the strong relationship between socio-economic factors and the reliance on medicinal plants. Households with limited access to formal healthcare facilities, lower income levels, and closer proximity to forest ecosystems exhibit a higher dependence on traditional remedies. This reinforces the notion that ethnomedicinal practices are deeply intertwined with issues of accessibility, affordability, and sustainability. In this context, medicinal plants represent a cost-effective and culturally acceptable healthcare alternative, particularly in remote and underserved areas. Another important observation is the ecological vulnerability of medicinal plant resources. Unsustainable harvesting practices, habitat degradation, overexploitation, and the impacts of climate change pose serious threats to plant biodiversity in the Himalayan region. The increasing commercialization of medicinal plants, if not managed properly, may further exacerbate resource depletion and disrupt ecological balance. Therefore, conservation of medicinal plant diversity must be prioritized alongside efforts to document and validate traditional knowledge. Hence, the application of quantitative ethnobotanical indices such as Informant Consensus Factor (Fic), Fidelity Level (FL), and Cultural Importance Index (CI) in this study has provided a robust framework for identifying culturally significant and therapeutically valuable plant species. These tools

enhance the scientific credibility of ethnobotanical research and facilitate the prioritization of species for pharmacological investigation and conservation planning.

There is an urgent need for systematic documentation and digital archiving of traditional knowledge. Ethnomedicinal information should be recorded through participatory approaches involving local communities, traditional healers, and researchers. Establishing regional databases and integrating indigenous knowledge into national biodiversity information systems can help safeguard this valuable heritage from irreversible loss. The conservation strategies must be strengthened through both in situ and ex situ approaches. Community-based conservation models, including the establishment of medicinal plant conservation areas (MPCAs) and sacred groves, should be promoted. Additionally, cultivation of high-demand medicinal species in agroforestry systems and home gardens can reduce pressure on wild populations while providing economic benefits to local communities. The sustainable harvesting protocols should be developed and implemented to ensure long-term availability of medicinal plant resources. Training programs and awareness campaigns for local collectors and traders can play a crucial role in promoting responsible harvesting practices. Certification schemes and value-chain development can further enhance the economic viability of sustainably sourced medicinal plants. There is a need to integrate traditional medicine with modern healthcare systems. Scientific validation of medicinal plants through phytochemical, pharmacological, and clinical studies should be encouraged to ensure safety, efficacy, and standardization. Collaborative efforts between traditional healers and biomedical researchers can facilitate the development of evidence-based herbal formulations and promote their acceptance in mainstream healthcare. Policy interventions are essential to support the conservation and sustainable use of medicinal plants. Governments and regulatory bodies should formulate clear guidelines for access, benefit-sharing, and intellectual property rights associated with traditional knowledge, in line with international frameworks such as the Convention on Biological Diversity (CBD). Financial incentives, subsidies, and capacity-building programs should be provided to encourage community participation in conservation and cultivation initiatives. Educational and awareness programs should be designed to promote the value of ethnomedicinal knowledge among younger generations. Incorporating traditional knowledge into academic curricula and organizing community workshops can help revive interest and ensure its transmission across generations. Therefore, future research should adopt interdisciplinary approaches that combine ethnobotany, ecology, pharmacology, and socio-economics to develop a holistic understanding of medicinal plant systems. Long-term monitoring studies are needed to assess the impacts of environmental and socio-economic changes on plant diversity and traditional knowledge systems.

Hence, medicinal plants and ethnomedicinal knowledge represent a vital link between biodiversity, culture, and healthcare. Their conservation and sustainable utilization are not only essential for supporting rural livelihoods and primary healthcare but also for advancing global efforts toward sustainable development and bioprospecting. Protecting this invaluable resource requires coordinated efforts from researchers, policymakers, and local communities to ensure that the rich legacy of traditional medicine continues to benefit present and future generations.

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