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Ethnobotanical Knowledge and Medicinal Plant Diversity among Gujjar and Bakarwal Communities of the Pahalgam Valley, Kashmir Himalaya

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Ethnobotany; Medicinal plants; Gujjar and Bakarwal; Conservation

ABSTRACT

Pahalgam and its surrounding landscapes represent an important center of ethnobotanical knowledge and medicinal plant diversity in the Himalayan region. The present study documents traditional medicinal plant use among the Gujjar and Bakarwal communities of the Pahalgam Valley, with a focus on species diversity, indigenous healthcare practices, and emerging conservation concerns. Field surveys conducted between 2021 and 2023 across Kothpatri, Aru Valley, and Lidderwat recorded 60 medicinal plant species belonging mainly to families such as Asteraceae, Solanaceae, and Lamiaceae. The study reveals that oral administration is the dominant mode of treatment, reflecting the practicality of traditional remedies. Knowledge transmission is largely confined to older male members of the community, indicating a gradual erosion of ethnobotanical wisdom among younger generations. Rapid habitat loss, climate change, tourism pressure, and unsustainable harvesting have severely affected the distribution of several high-value medicinal species. The findings highlight the urgent need for integrated conservation strategies that combine traditional knowledge, scientific research, and community participation to ensure sustainable management of medicinal plant resources.

1. INTRODUCTION

Medicinal plants have played a fundamental role in the survival and healthcare systems of human societies since prehistoric times. According to the World Health Organization (WHO), medicinal plants

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are defined as plant species that possess therapeutic properties or contain bioactive metabolites used directly or indirectly in the preparation of medicines. Historically, human dependence on nature has extended beyond food and shelter to include plant-based remedies for disease prevention and treatment (Cragg & Newman, 2005). Across civilizations, medicinal plants have formed the backbone of traditional healthcare systems, reflecting a deep understanding of the natural environment and its healing potential.

The use of medicinal plants varies across geographical regions and cultural traditions, shaped by local biodiversity, ecological conditions, and indigenous knowledge systems (Simpson, 1995). For thousands of years, plants have been utilized in diverse crude pharmaceutical forms such as decoctions, infusions, tinctures, poultices, powders, and ointments (Balick & Cox, 1997; Samuelsson, 2004). Even today, traditional plant-based medicine remains a crucial healthcare resource for a significant portion of the global population.

In recent decades, there has been a notable global resurgence of interest in herbal and plant-based medicines. The World Health Organization estimates that nearly 80% of the world's population relies on traditional medicine for primary healthcare needs, particularly in developing and underdeveloped countries. Approximately 3.5 billion people continue to depend primarily on medicinal plants due to limited access to modern healthcare facilities and the high cost of allopathic medicines. Moreover, concerns regarding the adverse side effects of synthetic drugs have further encouraged a shift toward natural and holistic healing systems.

Traditional medical systems such as Ayurveda, Traditional Chinese Medicine (TCM), African traditional medicine, and indigenous healing practices across Asia and Latin America are deeply rooted in plant-based therapies (Ekor, 2014). Recognizing their significance, the WHO (2003) defines medicinal plants as essential biological resources containing bioactive compounds used either directly as therapeutic agents or as precursors for drug synthesis. In contemporary pharmacology, medicinal plants continue to hold a central role, with nearly 25% of all prescription drugs worldwide derived directly or indirectly from plant sources (Newman & Cragg, 2020).

The growing global interest in medicinal plants is not limited to developing nations. Industrialized countries have also witnessed increasing demand for herbal medicines as part of integrative and complementary healthcare systems (Chen et al., 2016). This renewed attention highlights the importance of scientifically validating traditional knowledge while simultaneously assessing the economic and therapeutic potential of medicinal plants. Bioactive compounds such as alkaloids, flavonoids, tannins, terpenoids, and phenolics contribute significantly to the pharmacological efficacy of medicinal plants (Kumar & Pandey, 2013). Studies have demonstrated their anti-inflammatory, antimicrobial, antioxidant, anticancer, and hepatoprotective properties (Gupta et al., 2017), reinforcing the relevance of traditional plant knowledge in modern medicine.

India is globally recognized as one of the richest reservoirs of medicinal plant diversity and is often referred to as "the land of medicinal plants." The country's wide range of climatic zones and ecological habitats has enabled the growth of more than 8,000 medicinal plant species (Kala, 2005). India's ancient

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healthcare traditions, including Ayurveda, Siddha, Unani, and Yoga, rely extensively on medicinal plants as their primary therapeutic foundation (Mukherjee & Wahile, 2006). Classical texts such as the *Charaka Samhita*, *Sushruta Samhita*, and the *Atharva Veda* provide detailed descriptions of plant-based remedies for a wide variety of ailments (Patwardhan et al., 2005).

Several Indian medicinal plants, including *Withania somnifera* (Ashwagandha), *Azadirachta indica* (Neem), *Curcuma longa* (Turmeric), and *Rauwolfia serpentina* (Sarpagandha), are widely used in both traditional and modern medicine (Singh et al., 2010). Among these, turmeric has gained global prominence due to curcumin, a bioactive compound with strong anti-inflammatory and antioxidant properties (Gupta et al., 2017). Beyond their therapeutic importance, medicinal plants contribute substantially to India's economy through herbal product manufacturing and export. The Ministry of AYUSH (2021) reports that India is one of the world's leading producers and exporters of herbal medicines.

Despite their immense value, medicinal plants in India face serious conservation challenges. Overharvesting, deforestation, urbanization, climate change, and habitat degradation have led to a rapid decline in many species (Kala, 2005). Additionally, the unregulated medicinal plant trade raises concerns regarding quality control, adulteration, and consumer safety (Ekor, 2014). To address these challenges, the Indian government has initiated several conservation programs, including the establishment of the National Medicinal Plants Board (NMPB) and Medicinal Plants Conservation Areas (MPCAs), aimed at promoting sustainable harvesting, cultivation, and biodiversity protection (Ministry of AYUSH, 2021).

Jammu and Kashmir, located in the northern Himalayan region of India, is renowned for its rich biodiversity and abundance of medicinal plants. The region's diverse climatic zones—from subtropical Jammu to temperate Kashmir Valley and alpine Ladakh—create favourable conditions for the growth of a wide range of medicinal species (Kumar & Bhau, 2016). Traditional healthcare systems such as Ayurveda, Unani, and Amchi medicine continue to play a vital role in meeting the healthcare needs of local populations (Rather et al., 2016). The Himalayan belt of Jammu and Kashmir alone hosts over 500 endemic medicinal plant species (Dar et al., 2017), including highly valued plants such as *Picrorhiza kurroa*, *Saussurea costus*, *Podophyllum hexandrum*, and *Artemisia absinthium*. These plants are known for their potent pharmacological properties, including antimicrobial, anti-inflammatory, anticancer, and hepatoprotective effects (Shinwari et al., 2011).

Medicinal plants also play a crucial role in sustaining the livelihoods of rural and tribal communities in Jammu and Kashmir. Indigenous knowledge enables local populations to harvest, process, and trade medicinal plants, contributing to household income and regional economic development (Kumar & Bhau, 2016). However, unsustainable harvesting practices, habitat destruction, and overexploitation of commercially valuable species pose serious threats to both biodiversity and community livelihoods (Sharma et al., 2021). In response, collaborative initiatives between the NMPB and the Jammu and Kashmir government have focused on conservation, controlled cultivation, and the establishment of Medicinal Plant Conservation Areas.

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Within this broader regional context, the Pahalgam area of Anantnag district holds particular ecological and ethnobotanical significance. Characterized by varied elevations, fertile soils, and favourable climatic conditions, Pahalgam supports a rich diversity of medicinal plants, including *Picrorhiza kurroa*, *Rheum emodi*, *Trillium govanianum*, and *Nardostachys jatamansi*. These species are extensively used by local communities and traditional healers and are increasingly sought after in national and international markets. However, the survival of these valuable medicinal resources is under severe threat due to climate change, habitat loss, overharvesting, pollution, and invasive species.

Given the increasing ecological pressures and the gradual erosion of traditional knowledge, there is an urgent need to document, analyze, and conserve medicinal plant knowledge in the Pahalgam region. Understanding the relationship between indigenous communities and medicinal plants is essential not only for biodiversity conservation but also for sustaining cultural heritage, healthcare security, and rural livelihoods. The present study seeks to address these concerns by examining ethnobotanical practices, conservation challenges, and ecological threats associated with medicinal plant use in Pahalgam, Jammu and Kashmir.

1.1 Rationale of Undertaking the Present Research

The survival of medicinal plants in Kashmir is increasingly threatened by a combination of anthropogenic and environmental pressures, including overgrazing, deforestation, unregulated harvesting, expanding urbanization, and the accelerating impacts of climate change. These pressures have resulted in habitat degradation, population decline of several high-value medicinal species, and the disruption of fragile Himalayan ecosystems. At the same time, the rising commercial demand for medicinal plants driven by pharmaceutical, cosmetic, and traditional healthcare industries has intensified exploitation without adequate conservation safeguards. In this context, a comprehensive scientific investigation into the ecological structure, cultural importance, and conservation status of medicinal plants in Kashmir is urgently required to support sustainable management and biodiversity preservation.

Ecological Significance of Medicinal Plants in Kashmir

Kashmir's diverse geographical and climatic conditions, encompassing temperate forests, alpine meadows, wetlands, and high-altitude zones, create numerous microhabitats that support a rich diversity of medicinal plant species. These plants play a crucial role in maintaining ecological balance by enhancing soil fertility, supporting pollinator populations, regulating nutrient cycles, and stabilizing fragile mountain ecosystems (Bisht et al., 2021). The unique climatic gradients and topographical complexity of the region allow different medicinal species to thrive across distinct ecological zones, thereby contributing significantly to regional and global biodiversity (Iqbal & Sharma, 2014). However, despite this ecological importance, only limited studies have documented the exclusive medicinal plant diversity of Kashmir and its role in global biodiversity conservation (Panday et al., 2013).

Research Gaps in Ecological Studies of Medicinal Plants

Although ethnobotanical and pharmacological studies on Kashmiri medicinal plants exist, there is a notable lack of comprehensive ecological research addressing their distribution patterns, ecosystem

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functions, population dynamics, and responses to environmental variability. The current body of research largely focuses on individual species or their pharmacological properties, while neglecting broader ecological relationships and ecosystem services. This research aims to bridge this gap by examining the spatial distribution of medicinal plants across different ecological zones of Kashmir, assessing their diversity and population structure, and analyzing their ecological roles within natural habitats. Understanding these relationships is essential for formulating effective conservation and management strategies.

Cultural and Traditional Importance of Medicinal Plants

Medicinal plants hold deep cultural and historical significance in Kashmir, where traditional knowledge related to plant-based healing has been transmitted across generations. Indigenous communities have long relied on medicinal plants to treat digestive disorders, skin ailments, respiratory diseases, and other common health problems (Zargar et al., 2013). Traditional medical systems such as Ayurveda and Unani extensively incorporate Kashmiri medicinal plants as primary therapeutic agents (Rana et al., 2020). For many rural and tribal populations, these plants continue to serve as the first line of healthcare, underscoring their importance for community well-being and cultural continuity.

Pharmaceutical and Economic Importance

Medicinal plants of Kashmir have attracted increasing attention from the pharmaceutical industry due to their bioactive compounds and therapeutic potential. Several species, including *Arnebia benthamii*, *Corydalis govaniana*, and *Gentiana kurroo*, have demonstrated significant promise for the development of novel pharmaceutical products (Dhar et al., 2016). The growing global interest in natural and plant-based medicines further emphasizes the need to protect these resources while promoting responsible bioprospecting and biotechnological research. However, excessive and unregulated harvesting, coupled with weak management frameworks, has placed many commercially valuable species at risk (Koul et al., 2020).

Conservation Challenges in Kashmir

Medicinal plants in Kashmir face multiple conservation challenges that threaten their long-term survival. Habitat fragmentation and degradation, particularly in lower elevation areas, are driven by agricultural expansion, illegal logging, and urban development (Chaudhary et al., 2016). High-altitude medicinal flora is especially vulnerable to climate change, as rising temperatures and altered precipitation patterns disrupt plant growth cycles and distribution ranges (Goswami et al., 2017). Additionally, sustained domestic and commercial demand for high-value species has resulted in declining populations, raising serious concerns about their sustainability (Mir et al., 2018).

Reports by the Jammu and Kashmir Forest Department (2019) highlight that conservation initiatives for medicinal plants remain inadequate due to insufficient community participation, limited awareness programs, and weak coordination between policymakers and local stakeholders. The increasing exploitation of medicinal plants for both domestic use and international trade has further intensified conservation challenges, necessitating immediate scientific and policy-level interventions.

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Need for an Integrated Ecological and Conservation Approach

A major limitation of existing research on Kashmiri medicinal plants is the lack of integration between ecological studies, cultural dimensions, and conservation planning. While some studies have focused on the pharmacological properties of selected species (Dhar et al., 2002), detailed ecological assessments of their ecosystem roles, adaptive responses to environmental change, and patterns of exploitation remain scarce. Most studies concentrate on individual plant species, overlooking the broader ecological systems and biodiversity frameworks essential for effective conservation (Panday et al., 2013).

The present research seeks to address these gaps through a systematic ecological investigation of medicinal plants in Kashmir, emphasizing their diversity, distribution, ecological functions, and conservation status. By integrating ecological data with socio-economic and cultural perspectives, this study aims to develop sustainable conservation strategies that balance environmental protection with local livelihoods and market demands. Given the central role of medicinal plants in healthcare, culture, and ecosystem stability, this research responds to an urgent need to document, conserve, and sustainably manage Kashmir's medicinal plant wealth for present and future generations.

2. LITERATURE REVIEW

A literature review constitutes a fundamental component of any scientific investigation, as it provides the theoretical foundation, contextual background, and critical synthesis of prior research relevant to the study. It enables researchers to identify research gaps, understand methodological trends, and establish the relevance of the present inquiry. In ethnobotanical research, literature reviews are particularly important because they document traditional healthcare knowledge, support scientific validation of indigenous practices, and contribute to conservation planning and sustainable development.

Medicinal Plants, Traditional Knowledge, and Conservation

Author(s) / Year	Area / Focus of Study	Key Findings / Contributions	Significance to Present Study
Ancient Civilizations (2500 BC–600 BC)	Egypt, China, Greece, India	Early civilizations relied heavily on plant-based medicines; texts like *Pun-Tsao*, *Yellow Emperor's Classic*, Vedas and Ayurveda documented herbal therapeutics.	Establishes historical foundation of medicinal plant use and traditional knowledge systems.
Kirtikar & Basu (1918)	Indian Medicinal Plants	Provided systematic botanical descriptions and medicinal uses of Indian flora.	Considered a foundational reference for Indian medicinal plant research.

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Nadkarni (1926)	Indian Materia Medica	Detailed pharmacological properties and therapeutic uses of medicinal plants.	Strengthened scientific documentation of traditional medicine.
Chopra (1933)	Indigenous Drugs of India	Emphasized indigenous plant-based drugs and their medicinal value.	Linked traditional knowledge with scientific validation.
Satyavati et al. (1976)	Indian medicinal flora	Highlighted need for cultivation of medicinal plants for sustainable use.	Supports conservation and cultivation approaches.
Atal & Kapur (1982)	Economic importance	Discussed economic potential and conservation significance of medicinal plants.	Demonstrates livelihood relevance of medicinal flora.
Jain (1985)	Ethnobotany of India	Extensive documentation of traditional plant uses by ethnic communities.	Provides ethnobotanical framework for present study.
Jain & De Filipps (1991)	Indian medicinal species	Described about 1,850 medicinal plant species with uses.	Strengthened systematic classification of medicinal plants.
Lawrence (1895)	Kashmir Valley	Documented medicinal herbs used by Hakims in indigenous systems.	Early regional documentation of Kashmir medicinal flora.
K.N. Koul (1924)	Gurais Valley, Kashmir	Pioneer collector of medicinal plant species.	Initiated botanical exploration in Kashmir region.
Kaul (1928)	Jammu & Kashmir forests	Listed 19 medicinal plant species from forest regions.	Provided baseline regional data.
Bal (1939); Kapoor (1951)	Kashmir region	Reported medicinal plant diversity of the region.	Strengthened early regional ethnobotanical records.
Botanical Survey of India (1960)	India-wide	Published list of 1,097 medicinal plants with distribution.	Important national-level reference.

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Gupta (1962)	Western Himalaya	Identified 22 medicinal plant species native to Kashmir.	Highlights Himalayan medicinal richness.
Dhar & Bhat (1977)	*Atropa* species	Studied pharmaceutical importance of Belladonna.	Demonstrates medicinal chemistry relevance.
Bhat & Pandita (1977)	*Digitalis* species	Documented cardiac medicinal applications.	Links ethnobotany with modern medicine.
Sarin & Atal (1977)	*Dioscorea deltoidea*	Identified diosgenin for steroid drug synthesis.	Shows industrial pharmaceutical importance.
Kapur & Sarin (1977)	Medicinal ferns	Documented medicinal ferns of J&K.	Expands plant group diversity studies.
Kak (1981–83)	Kashmir flora	Documented ~500 plant species and economic aquatic plants.	Highlights biodiversity and economic potential.
Kapur (1983)	Endangered plants	Reported endangered medicinal species of J&K.	Emphasizes conservation urgency.
Navchoo & Buth (1994, 1996)	Gujar, Bakarwal & Zanskar	Documented 86 medicinal species used by tribal communities.	Important ethnomedicinal evidence.
Hussain (1996)	Unani medicine, Kashmir	Elaborated plant-based Unani practices.	Demonstrates integration of traditional systems.
Dar et al. (2000)	Kashmir Himalaya	Documented 106 medicinal plant species with ecology.	Provides conservation baseline data.
Dar & Naqshi (2001)	Plant resources of Kashmir	Discussed medicinal importance, economic value, and conservation.	Supports sustainable utilization framework.
Sharma (1991); Ara et al. (1992); Naqshi et al. (1992)	Jehlum Valley	Recorded 129 species from 57 families.	Highlights rich regional ethnobotanical diversity.
Nawchoo et al. (1994); Singh (1994)	*Ocimum sanctum*	Documented folklore, pharmacology and clinical value.	Validates medicinal efficacy of sacred plants.

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Kaul (1997)	Kashmir & Ladakh	Comprehensive documentation of temperate and cold arid medicinal flora.	Major reference for Himalayan medicinal plants.
Chaurasia et al. (1999)	Ethno-veterinary	Reported plant-based animal healthcare practices.	Expands medicinal use beyond humans.
Kirn et al. (1999)	Poonch District	Documented multipurpose plant uses.	Highlights livelihood and utility values.
Baba et al. (2012); Mir et al. (2018)	India-wide	Reported use of >75,000 plant species by ethnic communities.	Shows magnitude of traditional knowledge systems.
Gupta et al. (1992); Bhadula et al. (1996)	Conservation	Reported overexploitation and species decline.	Identifies threats to medicinal plant survival.
Verma et al. (2007)	Varanasi	Documented 72 medicinal plant species.	Demonstrates urban ethnomedicine relevance.
Bhattacharyya & Borah (2008)	Assam	Studied medicinal weeds used by rural women.	Highlights role of women and common weeds.
Kalita & Phukan (2010)	Tai Ahom community	Documented plant remedies for 17 ailments.	Reinforces indigenous healthcare knowledge.
Rahmatullah et al. (2010)	Bangladesh	Recorded 50 medicinal plant species used by Kavirajes.	Regional South Asian comparison.
Engler (2008)	Overexploitation	Identified fuelwood and fodder pressure as major threats.	Explains anthropogenic causes of decline.
Jain (2000)	Biodiversity loss	Reported impact of urbanization, grazing and pollution.	Supports need for conservation planning.
WHO–IUCN–WWF (1993); IUCN (2011)	Global conservation	Issued guidelines for medicinal plant conservation.	Provides international conservation framework.
Kala (2000)	Trans-Himalaya	Assessed rare and endangered medicinal plants.	Important for Himalayan conservation focus.

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Sarin (2003)	Conservation strategies	Suggested inventory, cultivation and standardization.	Guides sustainable management methods.
Chaudhury (2007)	Endangered species	Detailed threatened medicinal plants.	Key reference for conservation status.
Semwal et al. (2007)	Population ecology	Studied density and diversity patterns.	Supports ecological assessment methods.
Abida Bano et al. (2013)	Azad Kashmir	Assessed 140 species using IUCN criteria.	Demonstrates severity of extinction risk.
Ashish Kumar et al. (2016)	Agro-techniques	Developed cultivation methods for rare species.	Supports domestication-based conservation.
Morya et al. (2016)	Plant diversity	Emphasized ecological balance and management.	Reinforces integrated conservation approach.

3. STUDY AREA

Geographic Location and Environmental Setting of Jammu and Kashmir

Jammu and Kashmir occupies the northernmost position of India and is distinguished by its extraordinary geographical setting, ecological richness, and cultural heterogeneity. The region covers an approximate area of 55,673 square kilometers and lies between 32°17′ to 37°05′ North latitude and 73°26′ to 80°30′ East longitude. Its strategic location at the junction of South Asia, Central Asia, and East Asia has historically shaped its environmental character, biodiversity composition, and socio-cultural evolution. The region is bordered by Pakistan on the western side, China on the northern and eastern margins, and the Indian states of Punjab and Himachal Pradesh to the south. This unique geographical placement has made Jammu and Kashmir not only geopolitically significant but also ecologically distinct.

The physical landscape of Jammu and Kashmir is marked by dramatic variations in altitude, relief, and landforms. The region encompasses fertile plains, deep river valleys, dense forests, snow-clad mountain ranges, alpine pastures, and vast glacier systems of the Himalayan mountain complex. The presence of major mountain systems such as the Shivaliks, Lesser Himalayas, Pir Panjal Range, Greater Himalayas, and the Karakoram Range has resulted in extreme environmental heterogeneity within a relatively small geographical area. Altitudes vary from below 300 meters above mean sea level in the Jammu plains to over 7,000 meters in the high Himalayan and Karakoram ranges. Such altitudinal gradients have created diverse microclimates and ecological niches, enabling the coexistence of subtropical, temperate, alpine, and cold desert ecosystems within the same region.

This geographical diversity plays a crucial role in shaping vegetation patterns, soil characteristics, hydrological regimes, and biodiversity distribution. The region’s glaciers serve as major freshwater reserves and give rise to important rivers such as the Jhelum, Chenab, Tawi, Indus, and their tributaries,

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which support agriculture, horticulture, and human settlements. Consequently, Jammu and Kashmir holds exceptional ecological importance and functions as one of the most environmentally sensitive regions of the Indian subcontinent.

Physiographic Divisions

Jammu and Kashmir exhibits remarkable physiographic diversity, transitioning from fertile plains to some of the world's highest mountain landscapes. Based on relief, geological structure, and ecological characteristics, the region is broadly divided into three major physiographic units: the Jammu region, the Kashmir Valley, and Ladakh.

Jammu Region

The Jammu region constitutes the southern part of the Union Territory and includes the Shivalik foothills, outer Himalayan ranges, and adjoining plains. This region represents a transitional zone between the Indo-Gangetic plains and the Himalayan highlands. The Shivalik hills, composed mainly of unconsolidated sediments, are prone to soil erosion and landslides, while the plains support fertile alluvial soils suitable for intensive agriculture.

The Tawi River and its tributaries form the principal drainage system of the region, playing a vital role in irrigation and settlement development. The landscape supports extensive cultivation of crops such as wheat, rice, maize, and pulses, along with horticultural produce including mango, citrus fruits, and guava. Due to comparatively lower altitude and warmer climate, the Jammu region exhibits vegetation typical of subtropical ecosystems, including sal forests, scrub forests, and grasslands.

Kashmir Valley

The Kashmir Valley is one of the most prominent physiographic features of the region. It lies between the Pir Panjal Range in the southwest and the Greater Himalayan Range in the northeast, forming a fertile, bowl-shaped intermontane basin. The valley is approximately 135 kilometers long and 32 kilometers wide and is drained primarily by the Jhelum River.

The valley is characterized by flat alluvial plains, wetlands, karewa plateaus, and surrounding forested mountain slopes. Karewas—lacustrine deposits formed by ancient lakes—are particularly significant as they support horticulture, especially saffron cultivation, one of the most valuable agricultural products of the region.

The Kashmir Valley possesses a temperate environment that supports dense forests, alpine meadows, wetlands, and rich floral diversity. Its unique ecological setting has historically supported a strong tradition of medicinal plant use and indigenous healthcare practices among rural and tribal communities.

Ladakh Region

Ladakh, administratively separated in 2019, represents a high-altitude cold desert ecosystem. Located between the Karakoram Range to the north and the Greater Himalayas to the south, Ladakh is one of the highest inhabited regions in the world. The terrain is rugged, barren, and marked by steep slopes, rocky surfaces, and minimal vegetation.

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Despite harsh environmental conditions, Ladakh holds immense ecological and strategic importance. Sparse vegetation consisting of shrubs, herbs, and alpine plants supports unique medicinal flora adapted to extreme climatic stress. The region also contains extensive glacial systems that feed the Indus River, making it a critical water source for downstream populations.

Climatic Divisions

Although Jammu and Kashmir lies within the subtropical latitudinal belt, its climate is largely influenced by altitude, relief, mountain barriers, and permanent snow cover. As a result, the region exhibits predominantly temperate and continental climatic characteristics. Based on temperature patterns, precipitation, and seasonal variations, Jammu and Kashmir is divided into three major climatic zones: Subtropical Jammu, Temperate Kashmir, and Sub-Arctic Ladakh.

i) Jammu Region – Subtropical Zone

The Jammu region experiences a humid subtropical monsoon climate. Summers are hot, with temperatures often exceeding 40°C during May and June, while winters remain mild to cool. The majority of rainfall occurs during the southwest monsoon period between July and September, supplemented by occasional winter rainfall caused by western disturbances.

Elevation in this zone ranges from below 300 meters to around 1,350 meters above mean sea level. Fertile alluvial soils and adequate rainfall support extensive agricultural practices. However, seasonal variability and occasional droughts or floods significantly influence agricultural productivity.

ii) Kashmir Region – Temperate Zone

The Kashmir Valley exhibits a temperate climate with well-defined seasons. Winters are cold and severe, characterized by snowfall, frost, and frequent precipitation, while summers remain mild and pleasant. Snowfall plays a crucial ecological role by regulating soil moisture and feeding rivers during the dry summer months.

The region receives an average annual rainfall of approximately 680 mm, with nearly 70 percent occurring during winter and spring months (December to May) due to western disturbances. Mean monthly temperatures range from about 1.2°C in winter to around 24.5°C during summer.

The climatic stability of the valley supports rich vegetation growth and creates favorable conditions for temperate medicinal plant species, many of which require cool temperatures and adequate moisture.

iii) Ladakh Region – Sub-Arctic / Cold Desert Zone

Ladakh represents a cold arid climatic zone characterized by extremely low precipitation (often less than 100 mm annually), intense solar radiation, and long, harsh winters. Temperatures may fall below –30°C during winter months, while summers remain short and dry.

Vegetation is sparse due to low moisture availability, yet several specialized medicinal plant species have adapted to survive under extreme climatic stress. These species often possess high therapeutic value due to the accumulation of bioactive compounds, making Ladakh ecologically significant despite its apparent barrenness.

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Biodiversity and Ecological Significance

Jammu and Kashmir forms an integral part of the Himalayan biodiversity hotspot, one of the most biologically rich and ecologically sensitive regions of the world. The wide altitudinal variation, complex geological structure, and diverse climatic conditions together create an exceptional range of habitats.

The region supports three major ecological systems: subtropical and temperate forests, alpine meadows, and wetland ecosystems. Forest vegetation includes coniferous species such as *Pinus wallichiana*, *Cedrus deodara*, *Abies pindrow*, and *Picea smithiana*, which play a critical role in soil stabilization, carbon sequestration, and climate regulation.

The alpine zones support valuable medicinal herbs such as *Podophyllum hexandrum*, *Aconitum heterophyllum*, *Saussurea costus*, and *Artemisia absinthium*. These species are highly sought after in traditional medicine and pharmaceutical industries, making them vulnerable to overexploitation.

Faunal diversity includes several rare and endangered species such as the Kashmir stag (*Cervus hangul*), Himalayan black bear (*Ursus thibetanus*), snow leopard (*Panthera uncia*), musk deer, and Himalayan monal. Wetlands such as Wular Lake, Dal Lake, and Hokersar Wetland serve as important habitats for migratory birds and function as ecological buffers regulating hydrological balance.

Figure 1: Map of India

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Figure 2: Map of Jammu & Kashmir

Study Area /Site: Pahalgam

Physical Parameters

Pahalgam is a well-known town located in the Anantnag district of Jammu and Kashmir, celebrated for its dense forests, tranquil environment, and scenic landscapes. Situated at an altitude of about 2,130 meters (6,990 feet) above mean sea level, the town lies along the banks of the Lidder River. The geomorphology of Pahalgam is characterized by gently sloping alpine pastures, thick coniferous woodlands, and rugged Rocky Mountains, making it a distinctive geomorphological unit within the Kashmir Valley.

The region experiences a moderate mountain climate with marked seasonal variations. Summers are mild and pleasant, with temperatures ranging from 11°C to 25°C, whereas winters are harsh, marked by intense cold and heavy snowfall. The area receives an average annual precipitation of nearly 1,200 mm, much of which falls as snow during winter months. This precipitation plays a crucial role in sustaining the hydrology of the Lidder River and maintaining ecological balance. The presence of fertile alluvial soils rich in organic matter supports diverse plant life, while rocky and glacial terrains host specialized vegetation adapted to extreme conditions.

Biological Parameters

Pahalgam exhibits rich biological diversity shaped by its altitudinal gradient and mountain ecology. The vegetation of the area is predominantly alpine, grading into subalpine zones above extensive temperate coniferous forests. The dominant forest vegetation comprises conifer species such as *Pinus wallichiana* (Blue Pine), *Cedrus deodara* (Deodar), *Abies pindrow* (Himalayan Fir), and *Picea smithiana* (Spruce). At higher elevations, deciduous species including *Betula utilis* (Himalayan Birch) and several *Acer* species are commonly found.

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The understory vegetation is characterized by shrubs such as *Rosa*, *Berberis*, and *Viburnum* species, along with a wide variety of herbs and grasses. The region is particularly significant for medicinal plant diversity, hosting important species such as *Podophyllum hexandrum*, *Aconitum heterophyllum*, and *Saussurea costus*. These plants are traditionally used by local communities to treat digestive disorders, respiratory ailments, fever, and inflammatory conditions. Notably, *Podophyllum hexandrum* is recognized for its anticancer properties, while *Aconitum heterophyllum* is valued for gastrointestinal and febrile treatments, highlighting their ethnobotanical and pharmacological importance.

Faunal diversity in Pahalgam includes several native mammals, birds, insects, and aquatic species. Threatened mammals such as the Himalayan brown bear (*Ursus arctos isabellinus*), ibex (*Capra ibex*), and Himalayan musk deer (*Moschus chrysogaster*) inhabit the region. The avifauna includes notable species like the Himalayan monal (*Lophophorus impejanus*) and the koklass pheasant (*Pucrasia macrolopha*), along with migratory waterfowl. Aquatic biodiversity is supported by endemic fish species (*Schizothorax* spp.) found in the Lidder River, which plays a crucial role in sustaining local ecosystems.

Geographical Parameters

Pahalgam is strategically located at the confluence of the Lidder Valley and Sheshnag Valley, in close proximity to the Pir Panjal Range. This geographical positioning gives the town significant geomorphological and ecological importance within the Kashmir Himalayas. The Lidder River, originating from the Kolahoi Glacier, serves as the primary lifeline of Pahalgam, shaping the valley's landscape and sustaining its surrounding ecosystems.

Geographically, Pahalgam is situated at approximately 34.01° N latitude and 75.19° E longitude and functions as a major gateway for pilgrimage and trekking routes leading to the Amarnath Cave and the Kolahoi Glacier. The region exhibits pronounced glaciological features, including moraines, cirques, hanging valleys, and other landforms shaped by past and present glacial activity. Owing to its rugged terrain and high-altitude setting, Pahalgam remains vulnerable to natural hazards such as landslides and avalanches, particularly during periods of snowmelt and heavy precipitation. These risks pose challenges to sustainable development, emphasizing the need for careful land-use planning and effective disaster mitigation strategies.

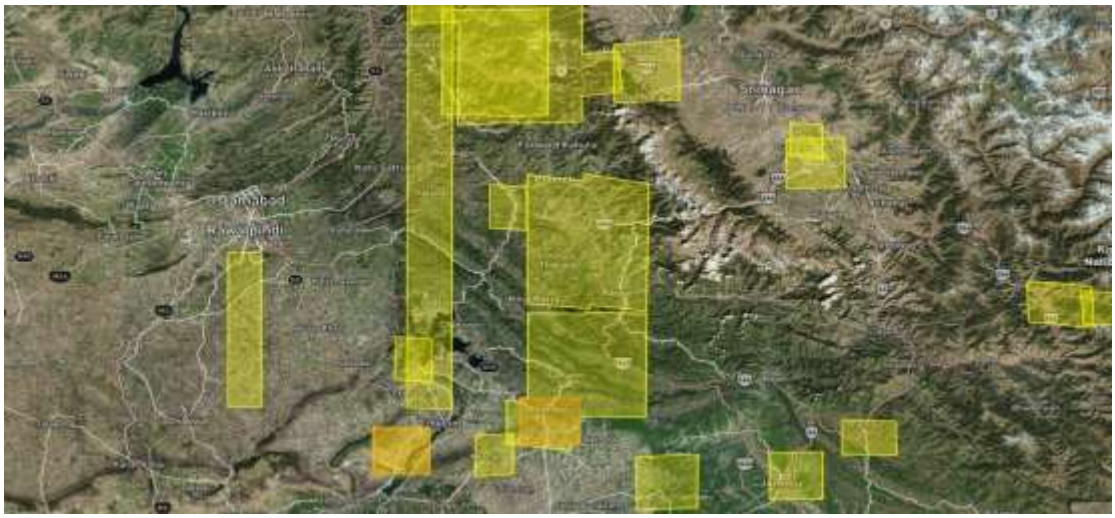

Figure 3: Satellite Imagery of Pahalgam Valley

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Primary Study Sites: Kothpatri, Aru Valley, Lidderwat

Kashmir Valley, located within the Himalayan region, represents an ecologically rich landscape characterized by diverse altitudes, climatic gradients, and high biodiversity. Within this valley, Aru Valley, Kothpatri, and Lidderwat have been identified as primary study sites for the present research. These locations are distinguished by their unique ecosystems, ranging from temperate forest zones to subalpine and alpine meadows, which support a wide variety of medicinal plant species. The variation in elevation and microclimatic conditions across these sites creates ideal natural settings for examining plant diversity, distribution patterns, and ecological adaptations. Moreover, these areas are closely associated with indigenous communities who possess rich traditional knowledge related to medicinal plant use. The coexistence of ecological diversity and ethnomedicinal practices makes these sites particularly suitable for ethnobotanical research and conservation-oriented studies.

a) Kothpatri

Location and Geography

Kothpatri is situated approximately 12 km beyond Pahalgam, at an elevation of about 2,400 meters above sea level. The area serves as an important gateway to trekking routes leading toward the Kolahoi Glacier. Its landscape is marked by snow-capped mountain peaks, dense coniferous forests, and expansive alpine meadows, creating a cool temperate environment with high ecological value.

Flora and Medicinal Significance

Kothpatri supports several important medicinal plant species, including *Rheum emodi* (Indian rhubarb), *Aconitum heterophyllum* (Atis), and *Podophyllum hexandrum* (Himalayan Mayapple). These plants are valued for their anti-inflammatory, analgesic, and anticancer properties and are widely used in traditional as well as contemporary medicine. The ecological setting, positioned between forested tracts and grazing lands, offers significant opportunities to study interactions between wild flora, pastoral activities, and forest ecosystems.

Ethnobotanical Context

The Gujjar and Bakarwal communities inhabiting and seasonally migrating through the Kothpatri region possess extensive traditional knowledge related to medicinal plant use. These communities employ local plant resources to treat ailments such as digestive disorders, skin diseases, and inflammatory conditions. Systematic documentation of their ethnobotanical practices is essential for strengthening conservation initiatives, promoting sustainable resource use, and preserving indigenous knowledge systems.

b) Lidderwat

Location and Geography

Lidderwat is a remote high-altitude destination located approximately 11 km from Aru Valley, at an elevation of about 3,400 meters above sea level. Situated within the Kolahoi Basin, Lidderwat is characterized by expansive alpine meadows bordered by dense forest patches and intersected by snow-fed streams originating from surrounding glaciers. Its isolation and altitude create a relatively undisturbed ecological setting with pronounced alpine characteristics.

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Flora and Medicinal Significance

The area supports pristine alpine vegetation, including several rare and high-value medicinal plant species such as *Saussurea costus* (Kuth), *Angelica glauca* (Choru), and *Arnebia benthamii* (Ratanjot). These species are highly sought after in traditional medicine and Ayurvedic systems due to their antimicrobial, anti-inflammatory, and tonic properties. Lidderwat therefore offers exceptional opportunities for high-altitude medicinal plant research within a largely intact natural habitat.

Challenges and Conservation

Despite its remoteness, Lidderwat faces ecological pressure from overharvesting of medicinal plants and excessive grazing. These activities threaten habitat stability and species regeneration. Scientific investigations and community-based conservation initiatives in the area can provide valuable insights into sustainable resource management, habitat restoration, and participatory ecological conservation strategies.

c) Aru Valley

Location and Geography

Aru Valley is an ecologically pristine mountain valley situated about 12 km from Pahalgam, at an elevation of approximately 2,408 meters above sea level. Surrounded by the Himalayan ranges, the valley is characterized by rolling alpine grasslands, clustered coniferous forests, and clear river channels. Aru serves as an important access point to high-altitude destinations such as the Kolahoi Glacier and the Tarsar-Marsar Lakes, making it a valuable natural laboratory for ecological and environmental research.

Flora and Fauna

The alpine and subalpine ecosystems of Aru Valley support a rich diversity of medicinal plants, including *Aconitum heterophyllum* (Ativisha), *Saussurea costus* (Kuth), and *Podophyllum hexandrum* (Indian Mayapple), all widely used in traditional medicine for their therapeutic properties. The valley also provides important habitats for high-altitude wildlife and a variety of bird species, reflecting its high conservation value.

Tourism and Environmental Impact

Aru Valley attracts nature-based tourism due to its tranquil landscape and outdoor recreation opportunities. However, increasing tourist pressure has led to habitat disturbance, waste accumulation, and heightened stress on local natural resources, posing potential threats to sensitive medicinal plant populations and ecosystem stability.

4. RESEARCH METHODOLOGY

Pahalgam, located in the Anantnag district of Jammu and Kashmir, was selected as the study area due to its rich biodiversity, varied ecological settings, and long-standing tradition of medicinal plant use. According to the Census of India (2011), Pahalgam has a total population of 9,264, comprising 5,541 males and 3,723 females. The overall literacy rate of the village is 64.87%, slightly lower than the state average of 67.16%. Male literacy stands at 80.57%, whereas female literacy is comparatively lower at

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40.01%. The child population (0–6 years) accounts for 13.44% of the total population, and the child sex ratio of 989 females per 1,000 males is higher than the state average, reflecting relatively better demographic balance.

Pahalgam is inhabited by several tribal communities that significantly contribute to the cultural fabric and traditional knowledge systems of the region. The Gujjars form one of the major indigenous communities, traditionally engaged in pastoralism, dairy production, and seasonal migration to alpine pastures. Although historically nomadic, many Gujjars have gradually diversified into agriculture, small-scale trade, and government employment. They primarily follow Islam and possess a distinct dialect, along with rich traditions of folk music and handicrafts. The Bakarwals represent another prominent tribal group in the area, sharing a similar transhumant lifestyle centered on sheep and goat herding. During summer months, they migrate to high-altitude grazing grounds. The Bakarwals also practice Islam and primarily speak the Gojri language. Their cultural identity is deeply rooted in traditional music, crafts, and pastoral practices. Smaller tribal groups such as Gaddi and Sippi are also present, reflecting similar pastoral traditions and close ties to the region.

The study area was selected based on its ecological significance and extensive historical use of medicinal plants (Dar et al., 2021). The region's diverse topography, forest cover, and favourable climatic conditions provide ideal settings for investigating medicinal plant diversity and indigenous ecological knowledge. To capture ecological variation, three primary study sites—Kothpatri, Aru Valley, and Lidderwat—were selected, each representing distinct vegetation types, altitudinal zones, and habitat conditions suitable for medicinal plant growth.

In addition to the primary field sites, secondary data were collected from the State Forest Research Institute (SFRI), Seer, which served as a supporting study location. The institute provided valuable information on medicinal plant distribution ranges, conservation status, and management practices within the region (Sharma & Kour, 2019).

The fieldwork for the present study was conducted over a three-year period (2021–2023) to account for seasonal variations in plant availability, phenological changes, and differences in medicinal plant use across seasons. This extended duration enabled a comprehensive understanding of medicinal plant diversity, ecological dynamics, and traditional usage patterns in the Pahalgam region.

5. COLLECTION OF PLANT SPECIMEN

Field investigations were carried out through systematic and repeated visits to the selected study sites for the collection of medicinal plant specimens. Standard botanical collection and identification methods, as prescribed by Jain and Rao (1977), were strictly followed to ensure scientific accuracy and reliability. During field surveys, each plant specimen was carefully documented using its updated scientific name along with vernacular names, diagnostic morphological characteristics, medicinal uses, plant parts utilized, and details of its natural habitat.

Collected specimens were preserved following standard herbarium techniques. Fresh plant materials were pressed, dried properly, and mounted on herbarium sheets. Each herbarium sheet was labeled with complete field information, including the date of collection, precise locality, altitude, habitat

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description, and ecological notes. This systematic documentation ensured authenticity and future reference value of the collected specimens.

To assess the conservation status of the recorded medicinal plants, the IUCN Red List of Threatened Species (2023) was consulted. Additional verification and regional conservation details were obtained from the Department of Forestry, Jammu and Kashmir. This approach helped in identifying threatened, vulnerable, and endangered species and provided a scientific basis for conservation-oriented analysis within the study area.

6. FIELD INTERVIEW

The ethnobotanical survey was initiated through structured and semi-structured field interviews conducted with 78 informants selected from the study area. The age of the respondents ranged from 18 to 78 years, enabling the documentation of both inherited traditional knowledge and contemporary practices related to medicinal plant use. The informants were chosen using purposive and snowball sampling techniques, focusing on individuals known for their familiarity with traditional healthcare practices.

Among the respondents, male informants demonstrated relatively higher levels of ethnobotanical knowledge and greater willingness to share information compared to female participants. This pattern may be attributed to sociocultural norms and the pastoral lifestyle of the region, where men are more frequently involved in livestock herding, forest activities, and seasonal migration, allowing greater exposure to medicinal plant resources. Most of the informants were illiterate, while those with formal education had attained schooling up to the secondary level.

All interviewees belonged to the Muslim religious community, which constitutes the dominant population in the study area. Interviews were primarily conducted in Urdu, the commonly used language for communication, to ensure clarity and comfort for the participants. Detailed demographic characteristics of the informants, including age, gender, education level, and occupation, are presented in figure 1.

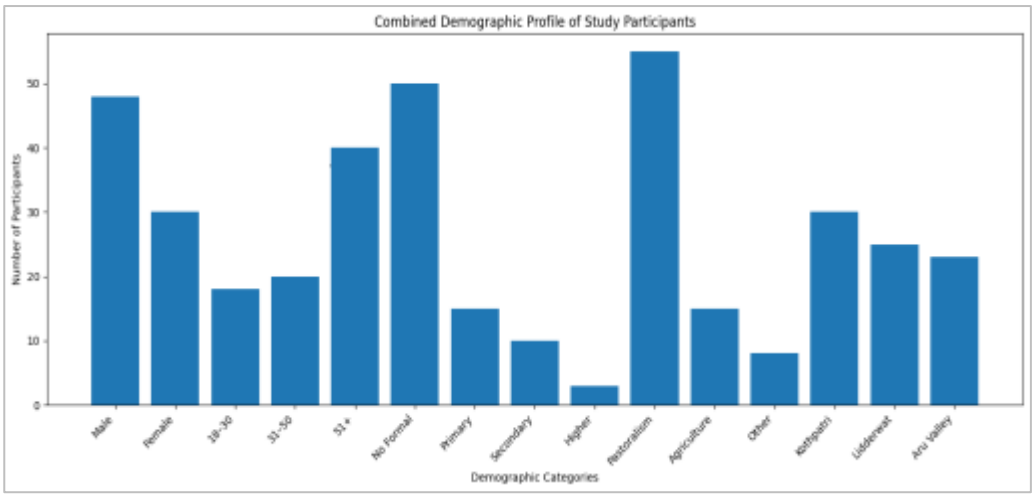

Fig 1: Demographic Details of The Participants

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Participants were selected based on their in-depth traditional knowledge of medicinal plants used to treat various diseases. Elderly individuals, pastoralists, and traditional healers were given priority during selection. Before conducting interviews or discussions, verbal informed consent was obtained from all participants in accordance with the ethical guidelines of the International Society of Ethnobiology. Ethical standards were strictly followed to respect local customs, cultural values, and traditional beliefs. Confidentiality of personal information was ensured, and participants were informed that the documented knowledge would be used solely for academic and conservation purposes. Data were collected using a semi-structured questionnaire covering personal details, plant identification, medicinal uses, preparation methods, and conservation awareness.

7. RESULTS

The ethnobotanical survey conducted between 2021 and 2023 in Pahalgam, covering the study sites of Kothpatri, Lidderwat, and Aru Valley, included participants from diverse socio-demographic backgrounds. Overall, male respondents constituted 61.5% of the sample, while females accounted for 38.5%. The higher male participation may be attributed to prevailing socio-cultural norms and the greater involvement of men in pastoral and forest-related activities in the region. Age-wise distribution revealed that a majority of participants (51.3%) were aged 51 years and above, followed by those in the 31–50 years age group (25.6%) and 18–30 years (23.1%). This pattern indicates that traditional ethnobotanical knowledge is predominantly retained among older generations, who possess extensive experiential understanding of medicinal plant use.

Educational analysis showed significant limitations, with 64.1% of respondents having no formal education. Participants with primary education constituted 19.2%, secondary education 12.8%, and higher education only 3.9%. These findings reflect limited educational access in the mountainous region and explain continued dependence on traditional knowledge systems for healthcare and livelihoods. Occupationally, pastoralism emerged as the dominant livelihood, engaging 70.5% of participants, followed by agriculture (19.2%), while 10.3% were involved in other occupations. Region-wise representation was relatively balanced, with Kothpatri (38.5%), Lidderwat (32.1%), and Aru Valley (29.4%), ensuring comprehensive coverage of the study area and strengthening the reliability of ethnobotanical insights gathered.

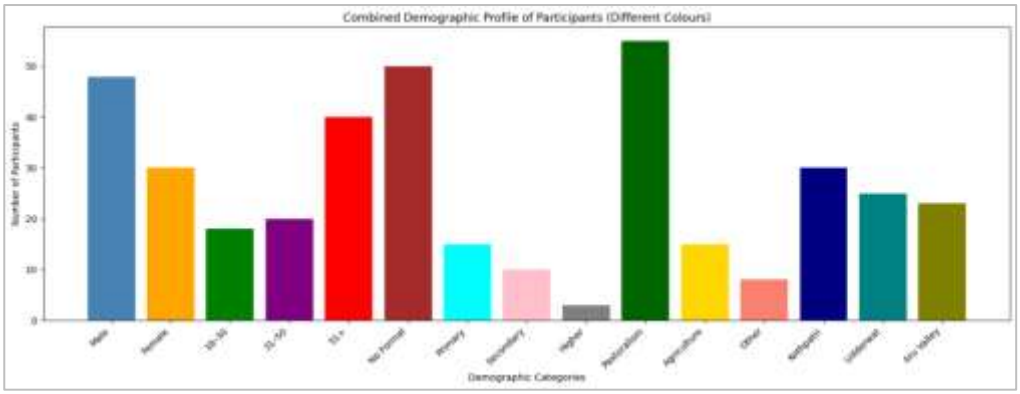

Fig 2: Demographic Details of The Participants

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Analysis of Current Threats and Their Impact on the Distribution of Medicinal Plants in Pahalgam valley.

Medicinal plants in the Pahalgam Valley are increasingly threatened by both environmental and anthropogenic pressures, which have significantly affected their distribution and survival. Climate change has altered temperature and precipitation patterns, disrupting the growth cycles and habitat suitability of high-altitude species such as *Picrorhiza kurroa*, *Rheum emodi*, and *Trillium govanianum*. Deforestation and habitat loss have further endangered shade-dependent plants including *Berberis aristata*, *Aconitum heterophyllum*, and *Podophyllum hexandrum*. Pollution resulting from tourism and vehicular activity has degraded soil and air quality, adversely affecting species like *Artemisia absinthium*, *Valeriana jatamansi*, and *Dioscorea deltoidea*. Unsustainable harvesting and illegal collection have severely reduced populations of commercially valuable plants such as *Saussurea costus* and *Nardostachys jatamansi*. Additionally, tourism-induced soil compaction and the spread of invasive species, including *Parthenium hysterophorus* and *Lantana camara*, further threaten native medicinal flora, underscoring the urgent need for conservation and sustainable management strategies.

8. CONCLUSION AND FUTURE WORK

The ethnobotanical survey conducted in Pahalgam, covering the Lidderwat, Aru Valley, and Kothpatri regions, documented 60 medicinal plant species traditionally used by the Gujjar and Bakarwal communities. This documentation significantly contributes to the preservation of indigenous knowledge systems and emphasizes the vital role of local biodiversity in sustaining traditional healthcare practices. A large proportion of the recorded species belonged to families such as Asteraceae, Solanaceae, and Lamiaceae, reflecting their high pharmacological importance due to the presence of bioactive compounds. Oral administration was identified as the most common mode of treatment, although topical and combined applications further demonstrate the adaptability and depth of indigenous medical practices.

The study revealed distinct gendered and generational patterns in knowledge transmission, with older males serving as the primary custodians of ethnobotanical knowledge. This highlights the urgent need to involve women and younger generations through community-based awareness and education programs. Despite low levels of formal education among respondents, their extensive botanical knowledge underscores the strength of oral traditions and experiential learning. The alarming finding that 57.1% of documented species fall under globally threatened categories necessitates immediate conservation actions, including habitat restoration, sustainable harvesting, and reinforcement of ex-situ conservation efforts such as those at SFRI Seer Hamdaan.

Future research should adopt a multi-disciplinary and integrative approach. Priority should be given to ethnopharmacological validation of frequently used species like *Aconitum heterophyllum*, *Rubia cordifolia*, and *Acorus calamus* for potential drug development. Strengthening intergenerational knowledge transfer through school herbal gardens and cultural storytelling initiatives is equally essential. Community-based conservation models, medicinal plant cooperatives, nurseries, and digital documentation with GIS mapping can enhance long-term monitoring and sustainable management.

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Given increasing pressures from tourism, climate change, and habitat degradation, policy-level interventions—including eco-tourism regulations, strict enforcement of conservation laws, and benefit-sharing mechanisms—are critical. Integrating scientific research with traditional knowledge and community participation can transform the region into a model for sustainable ethnobotanical conservation, ensuring that this invaluable heritage is preserved for future generations.

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