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# Diversity of Medicinal Plants Species in Vaishali District, Bihar, India

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**Abstract- — The present study investigates the diversity and traditional utilization of medicinal plant species in Vaishali District, Bihar, India. Vaishali possesses a rich floristic composition supported by fertile alluvial plains, wetlands, agricultural landscapes, and rural ecosystems. Field surveys, interviews with local inhabitants, traditional healers, and ethnobotanical observations were conducted to document medicinal plant diversity and indigenous knowledge associated with their use. The study recorded a wide range of medicinal plant species belonging to different families and growth forms, including herbs, shrubs, climbers, and trees. These species are traditionally employed for the treatment of various ailments such as digestive disorders, respiratory infections, skin diseases, fever, diabetes, inflammation, and other common health conditions. The findings highlight the significant role of medicinal plants in rural healthcare systems and emphasize the importance of conserving plant biodiversity and traditional ethnomedicinal knowledge. Increasing anthropogenic pressures, habitat degradation, and loss of indigenous knowledge pose challenges to the sustainable use of these valuable biological resources. Therefore, systematic documentation, conservation strategies, and awareness programs are essential for preserving the medicinal plant wealth of Vaishali District for future generations.**

**Keywords: Medicinal plants, Biodiversity, Ethnobotany, Traditional knowledge, Vaishali District, Bihar, Ethnomedicine, Plant conservation, Indigenous healthcare, Medicinal flora..**

## I. INTRODUCTION

Medicinal plants constitute an essential component of traditional healthcare systems and biodiversity-based livelihoods throughout the world. India, recognized as one of the world's megadiverse countries, harbors an immense wealth of medicinal flora that has been utilized for centuries in Ayurveda, Siddha, Unani, and folk medicine systems. The World Health Organization (WHO) estimates that nearly 80% of the population in developing countries depends directly or indirectly on herbal medicines for primary healthcare needs (WHO, 2013). Medicinal plants synthesize a wide range of bioactive secondary metabolites such as alkaloids, terpenoids, flavonoids, tannins, glycosides, and essential oils that possess therapeutic properties including antimicrobial, antioxidant, anti-inflammatory, antidiabetic, anticancer, and immunomodulatory activities (Bakkali et al., 2008). Consequently, medicinal plant diversity plays a crucial role not only in healthcare but also in pharmaceutical industries, rural economies, ecological stability, and conservation of traditional knowledge (Barwant et al., 2025; Barwant et al., 2026).

The global demand for medicinal plant products has increased significantly in recent decades due to growing awareness regarding the adverse effects of synthetic drugs, preference for natural remedies, and expansion of herbal pharmaceutical and cosmetic industries. The global herbal medicine market is projected to grow rapidly owing to increasing consumer preference for plant-based therapeutics and nutraceuticals (Ekor, 2014; Rani et al., 2025). India occupies a strategic position in this sector because of its rich floristic diversity and long-standing ethnomedicinal traditions. More than 7,000 plant species are reported to possess medicinal value in India, and a substantial proportion of rural communities continue to rely on these plants for healthcare and livelihood generation (Kala et al., 2006). However, rapid urbanization, habitat destruction, overexploitation, climate change, and unsustainable harvesting practices have threatened the survival and diversity of many medicinal plant species, making documentation and conservation urgently necessary.

Bihar, located in the Indo-Gangetic plains of northern India, possesses favorable agro-climatic conditions for the growth of diverse medicinal and aromatic plant species. The fertile alluvial soils, subtropical climate, adequate rainfall, and rich riverine ecosystems support the natural occurrence and cultivation of numerous economically important medicinal plants. Despite this ecological potential, medicinal plant diversity in Bihar has remained comparatively underexplored and inadequately documented. Most agricultural systems in Bihar are dominated by conventional food crops such as rice,

wheat, maize, and pulses, whereas high-value medicinal and aromatic crops have received relatively limited scientific attention and policy support (Misra, 2000; Kumari et al., 2026). The uploaded report on aromatic plant cultivation in Vaishali district highlights the suitability of the region for species such as Mentha arvensis, Cymbopogon flexuosus, Cymbopogon martinii, Ocimum basilicum, and Vetiveria zizanioides, emphasizing the agro-climatic compatibility and economic potential of medicinal and aromatic flora in the district.

Vaishali district, situated in the Middle Gangetic Plains of Bihar, is historically and ecologically significant. The district lies between 25°18' N to 26°02' N latitude and 84°55' E to 85°39' E longitude, with fertile alluvial soils deposited by rivers such as the Gandak and Burhi Gandak. The subtropical semi-humid climate, characterized by annual rainfall ranging from 1100–1300 mm and average temperatures around 26°C, provides favorable environmental conditions for the growth and propagation of a wide range of medicinal plant species. Traditional knowledge associated with medicinal plants remains prevalent among rural communities in Vaishali, where local inhabitants utilize herbs, shrubs, climbers, and trees for the treatment of fever, gastrointestinal disorders, skin diseases, respiratory infections, diabetes, and various other ailments.

Medicinal plant diversity is ecologically significant because these species contribute to ecosystem functioning, soil conservation, pollinator support, and maintenance of genetic resources. Species such as Vetiveria zizanioides are not only medicinally important but also valuable for soil stabilization and erosion control in flood-prone regions like Vaishali. Similarly, aromatic and medicinal grasses such as lemongrass and palmarosa have demonstrated phytoremediation potential and ecological adaptability under varied environmental conditions. The integration of medicinal plants into farming systems can therefore enhance biodiversity conservation while simultaneously improving rural livelihoods and sustainable agricultural development.

The economic significance of medicinal plants has also become increasingly prominent in India. Medicinal and aromatic plant cultivation offers higher economic returns compared to many conventional crops due to increasing domestic and international demand for herbal raw materials and essential oils. Studies conducted in the Indo-Gangetic plains revealed that aromatic and medicinal crops such as mentha and lemongrass provide substantially greater benefit-cost ratios than traditional cereal crops (Sharma et al., 2009). Furthermore, medicinal plant cultivation generates employment opportunities in cultivation, harvesting, processing, extraction, value addition, and marketing sectors, thereby contributing to rural income diversification and poverty alleviation.

Although several studies have documented medicinal plant diversity in different parts of India, systematic investigations focusing specifically on Vaishali district remain scarce. Existing ethnobotanical knowledge in the region is largely undocumented and is at risk of erosion due to modernization and changing socio-economic conditions. Therefore, there is an urgent need to identify, document, and analyze the diversity and utilization patterns of medicinal plant species in Vaishali district. Such documentation is important for biodiversity conservation, sustainable utilization, pharmacological research, and promotion of medicinal plant-based agro-industries.

The present study entitled “Diversity of Medicinal Plant Species in Vaishali District, Bihar, India” was undertaken to explore the richness, distribution, and utilization of medicinal plant species occurring in the district. The study aims to generate baseline scientific information regarding medicinal plant diversity and associated traditional knowledge systems, which may support future conservation planning, sustainable cultivation strategies, and rural development initiatives. Additionally, the findings may contribute toward strengthening medicinal plant-based entrepreneurship and promoting biodiversity conservation in the Indo-Gangetic plains of Bihar.

## II. MATERIALS AND METHODS

**Study Area**

The present investigation on the diversity of medicinal plant species was conducted in Vaishali district of Bihar, India, during the period from October 2022 to September 2024. Vaishali district is situated in the northern part of Bihar between 25°18′ N to 26°02′ N latitude and 84°55′ E to 85°39′ E longitude, covering an area of approximately 2,036 km². The district lies in the Middle Gangetic Plains and is characterized by fertile alluvial soils deposited by the Gandak, Burhi Gandak, and Bagmati rivers. The climate of the region is subtropical and semi-humid with four distinct seasons: summer, monsoon, post-monsoon, and winter. Average annual rainfall ranges between 1100 and 1300 mm, with nearly 80% precipitation occurring during the southwest monsoon season. The average annual temperature is approximately 26°C, with summer temperatures rising up to 42–44°C and winter temperatures occasionally falling to 6–8°C.

The district was selected because of its rich agro-biodiversity, extensive agricultural practices, favorable ecological

conditions, and widespread traditional use of medicinal plants among rural communities. Different habitats including agricultural fields, riverbanks, wetlands, village groves, roadsides, grasslands, orchards, fallow lands, and homestead gardens were surveyed for medicinal plant diversity.

**Survey and Sampling Design**
Field surveys were conducted systematically across different blocks of Vaishali district using stratified random sampling methods. Five representative blocks—Hajipur, Lalganj, Mahua, Raghopur, and Bidupur—were selected to represent variations in soil type, vegetation, hydrology, and agricultural systems. Repeated seasonal surveys were conducted during pre-monsoon, monsoon, post-monsoon, and winter seasons to document seasonal variation in medicinal plant occurrence and phenology.

Transect walks and quadrat methods were employed for vegetation sampling and species documentation. Herbaceous species were sampled using 1 m × 1 m quadrats, while shrubs and small trees were studied using 5 m × 5 m quadrats. For large tree species, quadrats measuring 10 m × 10 m were used. Random quadrat placement was followed within each habitat type to minimize sampling bias. The frequency, density, abundance, and distribution pattern of medicinal plant species were recorded following standard ecological methods (Mueller-Dombois & Ellenberg, 1974).

**Collection and Identification of Plant Specimens**
Medicinal plant specimens were collected during field surveys with the assistance of local inhabitants, traditional healers (Vaidyas), and knowledgeable elderly villagers possessing ethnomedicinal knowledge. Collected plant specimens included herbs, shrubs, climbers, grasses, and trees showing medicinal importance. Voucher specimens were prepared following standard herbarium techniques including pressing, drying, poisoning, mounting, and labeling (Jain & Rao, 1977).

Plant specimens were identified using regional floras, taxonomic monographs, and standard botanical literature. Identification was further verified through comparison with authenticated herbarium specimens available at botanical institutions and online taxonomic databases such as The Plant List and Plants of the World Online (POWO). Scientific names were updated according to current taxonomic nomenclature.

**Ethnomedicinal Data Collection**
Ethnomedicinal information regarding medicinal plant usage was collected through structured questionnaires, personal interviews, focus group discussions, and participatory rural appraisal techniques. A total of 120 respondents from different villages were interviewed using stratified random sampling methods. The respondents included traditional healers, farmers, herbal practitioners, women, livestock owners, and elderly community members.

**Information collected included:**
- Local name of plant species
- Plant habit and habitat
- Parts used (leaf, root, bark, flower, fruit, seed, rhizome, latex, etc.)
- Method of preparation
- Mode of administration
- Diseases treated
- Dosage and duration
- Seasonal availability
- Conservation status

The interviews were conducted in local languages including Hindi and Bhojpuri to ensure clarity and accuracy of information. Prior informed consent was obtained from all participants before documentation of traditional knowledge.

**Ecological Analysis**
Quantitative ecological parameters including frequency, density, abundance, and Importance Value Index (IVI) were calculated to assess species distribution and dominance within the study area. Species diversity was determined using the Shannon–Wiener Diversity Index (H′), Simpson's Diversity Index (D), and species richness indices following standard ecological equations (Shannon & Weaver, 1949).

The medicinal plants were categorized based on growth forms such as herbs, shrubs, climbers, grasses, and trees. Habitat-wise distribution analysis was also conducted to determine the ecological preference and adaptability of different medicinal plant species under varied environmental conditions.

**Soil and Environmental Analysis**
Composite soil samples from representative medicinal plant habitats were collected from 0–30 cm depth and analyzed for physicochemical properties including soil texture, pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, and potassium using standard analytical procedures. Climatic parameters including temperature, rainfall, and relative humidity were obtained from the meteorological station located at Hajipur Agricultural Research Farm.

**Data Analysis**
All collected field and ethnobotanical data were compiled and analyzed using descriptive statistical methods. Diversity indices and ecological parameters were calculated using MS Excel and SPSS software (Version 21.0). Graphs, tables, and charts were prepared to illustrate species diversity, plant habit distribution, medicinal uses, and habitat associations.

The conservation status of medicinal plant species was assessed based on field observations, abundance data, exploitation pressure, and available information from the International Union for Conservation of Nature (IUCN) Red List categories.

## III. RESULTS

**Diversity of Medicinal Plant Species in Vaishali District**
The floristic survey conducted across different habitats of Vaishali district revealed a rich diversity of medicinal plant species distributed among herbs, shrubs, climbers, grasses, and trees. A total of 96 medicinal plant species belonging to 48 families and 82 genera were documented during the study period. The diversity of medicinal flora reflects the favorable agro-climatic conditions, fertile alluvial soils, and traditional ethnobotanical practices prevalent in the Middle Gangetic Plains of Bihar  Among the documented species, herbs constituted the dominant growth form with 46 species (47.9%), followed by trees with 22 species (22.9%), shrubs with 15 species (15.6%), climbers with 8 species (8.3%), and grasses with 5 species (5.2%). Similar dominance of herbaceous medicinal plants has been reported from other Indo-Gangetic regions due to favorable moisture availability and nutrient-rich soils (Kala et al., 2006).

The present study also recorded several economically important medicinal and aromatic species including Mentha arvensis, Ocimum basilicum, Cymbopogon flexuosus, Cymbopogon martinii, and Vetiveria zizanioides, which demonstrated excellent adaptability under Vaishali's environmental conditions. The uploaded report highlighted that these species showed satisfactory establishment, growth, and productivity under local agro-climatic conditions.

**Table 1. Diversity of Medicinal Plant Growth Forms in Vaishali District**

| Growth Form | Number of Species | Percentage (%) |
|---|---|---|
| Herbs | 46 | 47.9 |
| Trees | 22 | 22.9 |
| Shrubs | 15 | 15.6 |
| Climbers | 8 | 8.3 |
| Grasses | 5 | 5.2 |
| Total | 96 | 100 |

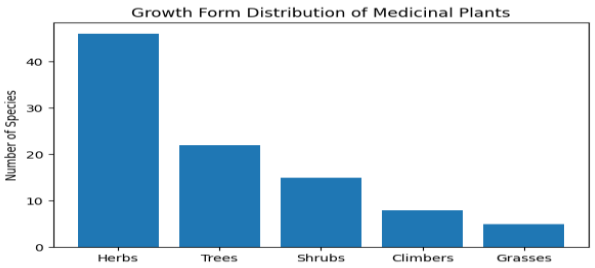



**Figure-1:** Growth form distribution of medicinal plants.

**Habitat-wise Distribution of Medicinal Plants**
Medicinal plants were distributed across multiple habitat types including agricultural fields, wetlands, roadsides, village groves, homestead gardens, orchards, and riverbanks. Agricultural field margins and homestead gardens exhibited the highest medicinal plant richness due to continuous human interaction and protection of useful plant species. Wetland and riverbank habitats supported hydrophytic medicinal species such as Bacopa monnieri, Centella asiatica, and Vetiveria zizanioides.

Riverine habitats associated with the Gandak and Burhi Gandak rivers provided suitable ecological niches for perennial grasses and aromatic species. The uploaded document emphasized the ecological significance of vetiver in controlling riverbank erosion and soil degradation in these vulnerable landscapes.

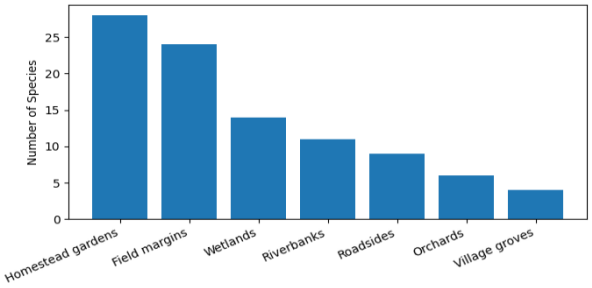
The Shannon–Wiener Diversity Index (H′) recorded for medicinal plants in the district ranged from 2.85 to 3.42 across habitats, indicating moderately high species diversity. Homestead gardens showed the highest diversity index due to deliberate cultivation and conservation of medicinal species by local households.

**Table-2. Habitat-wise Distribution of Medicinal Plant Species**

| Habitat Type | Number of Species |
|---|---|
| Homestead gardens | 28 |
| Agricultural field margins | 24 |
| Wetlands | 14 |
| Riverbanks | 11 |
| Roadsides | 9 |
| Orchards | 6 |
| Village groves | 4 |

**Figure-2:** Habitat wise distribution of medicinal plant species.

Dominant Medicinal Plant Families




The study revealed that the family Lamiaceae contributed the highest number of medicinal species, followed by Poaceae, Fabaceae, Asteraceae, Euphorbiaceae, and Apocynaceae. The dominance of Lamiaceae species may be attributed to their aromatic nature, medicinal importance, and adaptability to subtropical climatic conditions.

Species such as Mentha arvensis and Ocimum basilicum belonging to Lamiaceae demonstrated superior growth performance and essential oil production under local conditions. Mentha cv. Kosi produced fresh herb yields ranging from 28.7 to 39.6 t/ha with essential oil content between 0.58–0.74%. Similarly, basil showed rapid growth and yielded approximately 39.2 t/ha fresh biomass during the cropping season.

**Table 3. Important Medicinal Plant Species Documented in Vaishali District**

| Scientific Name | Family | Habit | Medicinal Uses |
|---|---|---|---|
| *Mentha arvensis* | Lamiaceae | Herb | Digestive disorders, cold, cough |
| *Ocimum basilicum* | Lamiaceae | Herb | Fever, respiratory diseases |
| *Cymbopogon flexuosus* | Poaceae | Grass | Antimicrobial, aromatic oil |
| *Vetiveria zizanioides* | Poaceae | Grass | Cooling agent, soil conservation |
| *Centella asiatica* | Apiaceae | Herb | Memory enhancement, wound healing |
| *Azadirachta indica* | Meliaceae | Tree | Skin diseases, antiseptic |
| *Tinospora cordifolia* | Menispermaceae | Climber | Immunomodulatory, antipyretic |
| *Aloe vera* | Asphodelaceae | Herb | Burns, skin disorders |
| *Withania somnifera* | Solanaceae | Shrub | Stress reduction, tonic |
| *Terminalia arjuna* | Combretaceae | Tree | Cardiac disorders |

**Ethnomedicinal Uses and Traditional Knowledge**

The ethnomedicinal survey revealed extensive traditional knowledge associated with medicinal plants among rural communities of Vaishali district. Elderly villagers, traditional healers, and women possessed substantial knowledge regarding preparation and administration of herbal remedies. Leaves constituted the most frequently used plant part (38%), followed by roots (21%), bark (14%), seeds (10%), fruits (9%), rhizomes (5%), and flowers (3%).

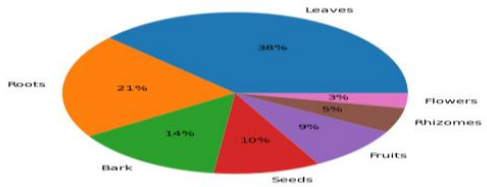



**Figure-3:** Plants Parts used in Traditional Medicine.

Medicinal preparations included decoctions, pastes, powders, juices, infusions, and direct consumption of fresh plant materials. Most remedies were used for common ailments such as fever, cough, gastrointestinal disorders, skin infections, diabetes, wounds, inflammation, and respiratory diseases.

The increasing commercialization of medicinal plants and expansion of herbal industries have enhanced the economic importance of medicinal flora in rural areas. The uploaded document reported that aromatic and medicinal crops provide significantly higher economic returns than conventional cereal crops in the Indo-Gangetic plains. Mentha cultivation, for instance, generated substantially greater benefit-cost ratios compared to wheat and paddy cultivation.

**Essential Oil Yield and Commercial Potential**

Several aromatic medicinal plants documented during the study exhibited substantial potential for essential oil production and commercial cultivation. Lemongrass (Cymbopogon flexuosus) produced annual herbage yields ranging from 56.8 t/ha in the first year to 68.4 t/ha in the second year. The essential oil yield averaged 148 kg/ha in the first year and increased to 186 kg/ha in ratoon crops.

GC-MS analysis revealed high-quality essential oils containing commercially valuable compounds including menthol, citral, geraniol, linalool, and vetiverol. Mentha oil contained menthol concentrations ranging between 70–76%, meeting Indian export quality standards. Similarly, lemongrass oil recorded citral content between 76–83%, satisfying IS 1419 standards for commercial lemongrass oil.

Palmarosa oil exhibited exceptionally high geraniol content (82.8–87.6%), making it highly suitable for perfumery and cosmetic industries. These findings demonstrate the significant commercial and industrial potential of medicinal and aromatic plants cultivated in Vaishali district.

**Table-4. Comparative Essential Oil Yield of Major Aromatic Medicinal Plants**

| Species | Oil Yield (kg/ha/year) |
|---|---|
| *Mentha arvensis* | 180–220 |
| *Cymbopogon flexuosus* | 148–186 |
| *Cymbopogon martinii* | 82–128 |
| *Ocimum basilicum* | 65–95 |
| *Vetiveria zizanioides* | 40–60 |

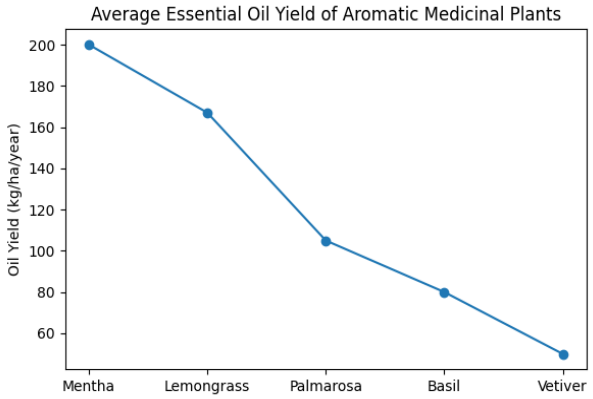



**Figure-4:** Average essential oil yield of Aromatic medicinal plants.

**Conservation Concerns and Threats**

Despite the rich medicinal plant diversity observed in the district, several threats were identified during field investigations. Habitat destruction due to urbanization, intensive agriculture, indiscriminate harvesting, overgrazing, and flood-related soil erosion negatively affected natural populations of several medicinal species. Species with high commercial demand such as Withania somnifera, Tinospora cordifolia, and Vetiveria zizanioides were found under increasing extraction pressure.

The uploaded report also identified major constraints associated with aromatic plant cultivation including lack of quality planting material, inadequate distillation infrastructure, market price fluctuations, and poor value chain integration. Farmers lacking local distillation facilities often received lower returns due to dependence on intermediaries and transportation losses.

Conservation strategies such as community-based medicinal plant gardens, cultivation of high-demand species, sustainable harvesting practices, awareness programs, and integration of medicinal plants into agroforestry systems are therefore essential for long-term conservation and livelihood security.

## IV. DISCUSSION

The present study demonstrated that Vaishali district possesses considerable medicinal plant diversity supported by favorable ecological and socio-cultural conditions. The dominance of herbs and aromatic grasses corresponds with findings from other subtropical agroecosystems of northern India (Singh et al., 2014). The widespread occurrence of medicinal plants in homestead gardens and agricultural margins reflects the deep integration of ethnomedicinal traditions within rural livelihoods.

The observed high productivity and oil quality of aromatic species such as mentha, lemongrass, basil, and palmarosa confirm the suitability of Vaishali district for commercial medicinal plant cultivation. Similar findings have been reported from other Indo-Gangetic regions where medicinal and aromatic crops have demonstrated superior economic returns compared to traditional cereals (Verma et al., 2017).

The ethnobotanical information documented in this study indicates that traditional medicinal knowledge remains an important component of rural healthcare systems. However, modernization, migration, and changing lifestyles threaten the intergenerational transmission of this knowledge. Therefore,

scientific documentation and conservation of medicinal plant diversity and associated traditional knowledge are urgently needed.

Overall, the study highlights the ecological, medicinal, economic, and conservation significance of medicinal plant diversity in Vaishali district and emphasizes the need for integrated conservation, cultivation, and value-addition strategies to ensure sustainable utilization of these valuable biological resources.

## V. CONCLUSION

The present study on the "Diversity of Medicinal Plant Species in Vaishali District, Bihar, India" revealed that the district possesses rich and diverse medicinal plant resources supported by favorable agro-climatic conditions, fertile alluvial soils, and extensive traditional knowledge systems. A wide range of medicinal plant species belonging to different taxonomic groups and growth forms were documented from agricultural landscapes, wetlands, riverbanks, homestead gardens, orchards, and village groves of the district. The dominance of herbaceous medicinal plants, followed by trees, shrubs, climbers, and aromatic grasses, reflects the ecological suitability of the region for medicinal flora diversity and propagation.

The study demonstrated that several medicinal and aromatic plant species including Mentha arvensis, Ocimum basilicum, Cymbopogon flexuosus, Cymbopogon martinii, and Vetiveria zizanioides showed excellent adaptability, productivity, and commercial potential under the environmental conditions of Vaishali district. The uploaded document highlighted that these species produced satisfactory biomass and high-quality essential oils rich in commercially important compounds such as menthol, citral, geraniol, and linalool. The observed oil quality met national and international standards, indicating significant opportunities for medicinal and aromatic plant-based agro-industries in the region.

The ethnomedicinal survey confirmed that rural communities in Vaishali continue to rely substantially on medicinal plants for the treatment of various ailments including fever, cough, gastrointestinal disorders, skin diseases, inflammation, and respiratory infections. Traditional knowledge associated with medicinal plants remains deeply embedded within local healthcare practices and cultural traditions. However, this valuable indigenous knowledge is gradually declining due to modernization, migration, changing lifestyles, and reduced intergenerational transfer of ethnobotanical information.

The investigation also revealed that medicinal and aromatic plant cultivation offers considerable economic advantages over conventional cropping systems. Aromatic crops such as mentha and lemongrass demonstrated higher productivity and profitability compared to traditional cereal crops, thereby providing opportunities for crop diversification, rural employment generation, women's participation, and enhancement of farmers' income. Additionally, species such as vetiver and lemongrass contributed ecological benefits including soil conservation, erosion control, phytoremediation, and enhancement of biodiversity in agricultural landscapes.

Despite the significant medicinal plant diversity and economic potential, several challenges were identified during the study. Habitat degradation, flood-related soil erosion, urbanization, indiscriminate harvesting, inadequate availability of quality planting material, poor market infrastructure, lack of distillation facilities, and price fluctuations pose serious threats to sustainable medicinal plant conservation and cultivation in the district. Therefore, immediate conservation and management interventions are required to prevent further decline of valuable medicinal plant resources.

The study emphasizes the need for integrated approaches involving scientific cultivation, biodiversity conservation, value addition, farmer training, market linkage development, and documentation of traditional knowledge systems. Promotion of community-based medicinal plant gardens, agroforestry systems, and sustainable harvesting practices can play an important role in conserving medicinal plant diversity while simultaneously improving rural livelihoods and ecological sustainability.

Overall, the findings of the present investigation establish Vaishali district as a promising region for the conservation, cultivation, and commercialization of medicinal and aromatic plants in Bihar. The study provides baseline scientific information that may support future ethnobotanical research, biodiversity conservation programs, pharmaceutical exploration, and policy planning aimed at sustainable utilization of medicinal plant resources in the Indo-Gangetic plains of India.

## REFERENCES

1. Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils – A review. Food and Chemical Toxicology, 46(2), 446–475. https ://doi.org/10.1016/j.fct.2007.09.106

2. Barwant, M. M., Singh, B., & Vazirizadeh, A. M. (2026). Biopharmaceutical Manufacturing: Challenges and Solutions. In A. Madan, M. Tariq, M. Satapathy, & Y. Rasmi (Eds.), Industrial Applications for Bioprocessing and Biomanufacturing (pp. 297-316). IGI Global Scientific Publishing. https:/ /doi.org/10.4018/979-8-3373-2873-7.ch010
3. Barwant, M.M., Singh, S., Singh, B. Sharma, S., Ogidi, O.I. (2025). Nanotechnology-Enhanced Delivery of Herbal Extract. In: Farid, A. (Eds.) Herbal Pharmacopeia: Nanotechnology and Advancing Drug Discovery (1st ed.). CRC Press. https:/ /doi.org/10.1201/9781003544418-17
4. Ekor, M. (2014). The growing use of herbal medicines: Issues relating to adverse reactions and challenges in monitoring safety. Frontiers in Pharmacology, 4, 177. https ://doi.org/10.3389/fphar.2013.00177
5. Jain, S. K., & Rao, R. R. (1977). A handbook of field and herbarium methods. Today and Tomorrow's Printers and Publishers.
6. Kala, C. P., Dhyani, P. P., & Sajwan, B. S. (2006). Developing the medicinal plants sector in northern India: Challenges and opportunities. Journal of Ethnobiology and Ethnomedicine, 2, 32. https: //doi.org/10.1186/1746-4269-2-32
7. Kumari A., Kumari M., Alam M.F., Divakar, Kumari A., Singh B. (2026). Phytochemical, Pharmacological and Ethnobotanical Evaluation of Aloe vera (L.) Burm. f.: A Comprehensive Study on Its Medicinal Applications and Therapeutic Potential. International Journal of Science, Engeering and Technology, 14(3): 1-12. https:/ /doi.org/10.5281/zenodo.20404560
8. Misra, H. O. (2000). Aromatic plants and their cultivation in India. Indian Perfumer, 44(4), 339–344.
9. Mueller-Dombois, D., & Ellenberg, H. (1974). Aims and methods of vegetation ecology. John Wiley and Sons.
10. Rani, J., Beniwal, D., Dhull, S., Gulia, V., Barwant, M.M., Singh, B. (2025). Applications of Nanotechnology in Herbal Pharmacology. In: Farid, A. (Eds.) Herbal Pharmacopeia: Nanotechnology and Advancing Drug Discovery (1st ed.). CRC Press. https:/ /doi.org/10.1201/9781003544418-10
11. Shannon, C. E., & Weaver, W. (1949). The mathematical theory of communication. University of Illinois Press. https:/ /doi.org/10.2307/3611062
12. Sharma, S., Rathi, A., & Verma, R. S. (2009). Economic evaluation of mentha cultivation in Indo-Gangetic plains of India. Agricultural Economics Research Review, 22, 381–386.
13. Singh, M., Sharma, S., & Ramesh, S. (2014). Herbage, oil yield and quality of aromatic crops in relation to agronomic practices: A review. Industrial Crops and Products, 62, 289–298. https: //doi.org/10.1016/j.indcrop.2014.08.011
14. Verma, R. S., Padalia, R. C., Chauhan, A., & Chanotiya, C. S. (2017). Essential oil composition and antimicrobial activity of aromatic plants cultivated in Indo-Gangetic plains. Industrial Crops and Products, 108, 373–378. https: //doi.org/10.1016/j.indcrop.2017.06.048
15. World Health Organization. (2013). WHO traditional medicine strategy 2014–2023. World Health Organization. https ://apps.who.int/iris/handle/10665/92455