Final Report 2024

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2024

FINAL REPORT

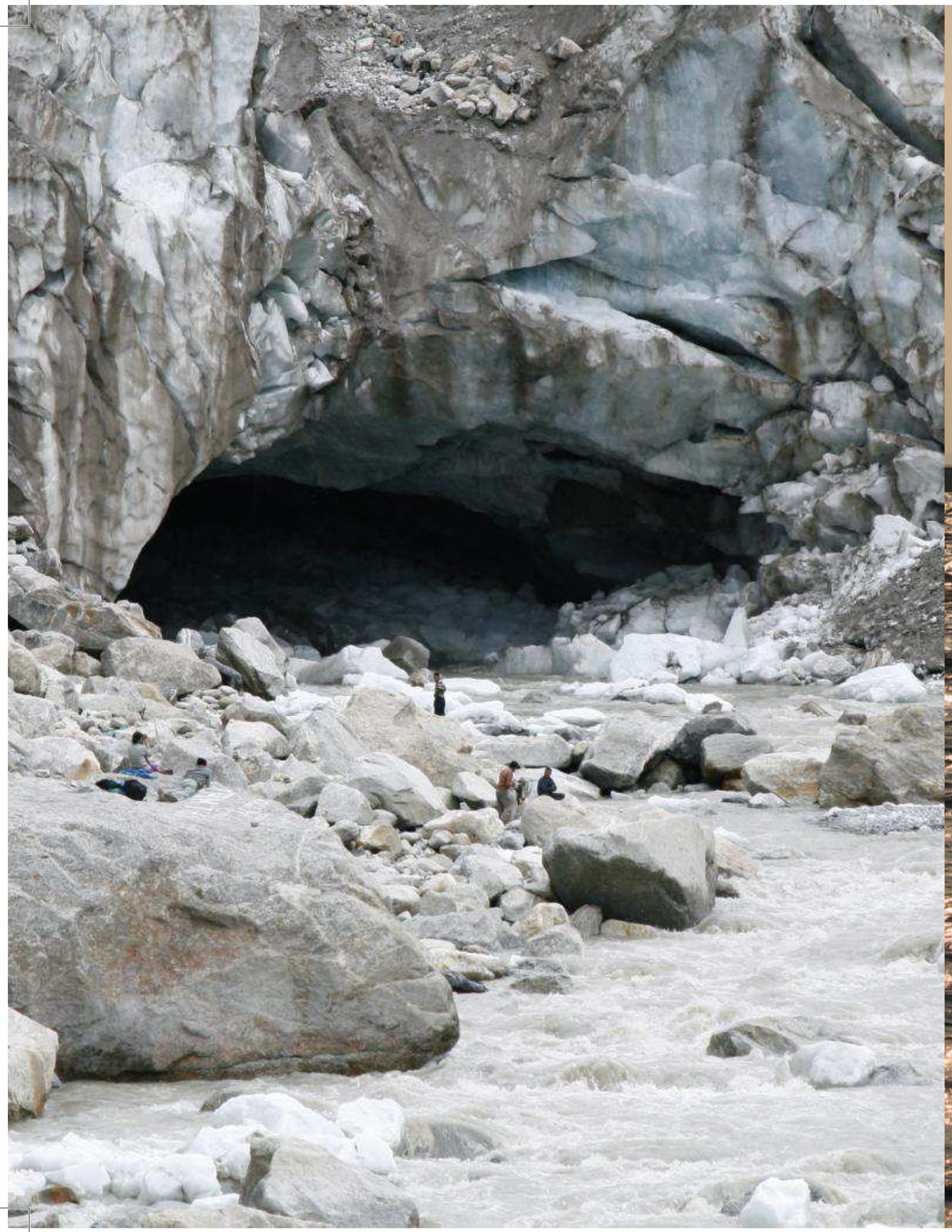








Scientific Exploration of Floral Diversity Near the Ganga Riverbanks for Ethnobotanical Purposes along with their Conservation and Economic Development of the Region via Skill Development Programs





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Code: Ad-35013/4/2022-KPMG-NMCG

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Meet our Inspiration & Mentors



SWAMI RAMDEV JI



ACHARYA BALKRISHNA JI

Meet our Team

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Context of the Project

The Ganga River, also known as the Ganga, holds immense importance in the Indian subcontinent due to its religious, cultural, ecological, and social significance. It is considered sacred by millions of Hindus, serving as a personification of the goddess Ganga. The river plays a central role in Hindu rituals and ceremonies; and it has historical and mythological significance. The Ganga is a life source for millions, providing water for drinking, agriculture, and industry. Its basin supports rich biodiversity and is economically vital for agriculture. The river has been historically important for transportation and trade; and it attracts tourists and pilgrims from around the world. However, the Ganga faces environmental challenges, including pollution, prompting conservation efforts to preserve its cultural, spiritual, and ecological value.

The Ganga River also holds significant geographical importance in the Indian subcontinent. Its vast basin, known as the Ganga River Basin, is one of the most extensive in the world, covering around 1,080,000 square kilometers. The river originates in the western Himalayas in the state of Uttarakhand and flows through several states, including Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal, before eventually emptying into the Bay of Bengal. The Ganga River and its numerous tributaries play a crucial role in shaping the geography of the regions they pass through. The river has formed fertile plains along its course, known as the Indo-Gangetic Plain, which is one of the most agriculturally productive regions in the world. The fertility of these plains has attracted human settlement and agricultural activities for thousands of years, making it one of the most densely populated areas on Earth. The Ganga River's flow and its interaction with the land have created dynamic and diverse ecosystems, ranging from mountainous regions in the north to the vast deltas in the south. These ecosystems support

a wide variety of flora and fauna, making it an essential biodiversity hotspot in the region. Additionally, the Ganga River's geography has played a crucial role in shaping the cultural and historical development of the areas it flows through. The river and its banks have been centers of civilization, witnessing the rise and fall of ancient empires and hosting various cultures and traditions over millennia. Furthermore, the river's flow has been harnessed for hydroelectric power generation, contributing to the region's energy needs and development. The Ganga River also provides transportation routes for the movement of goods and people, facilitating trade and economic activities.

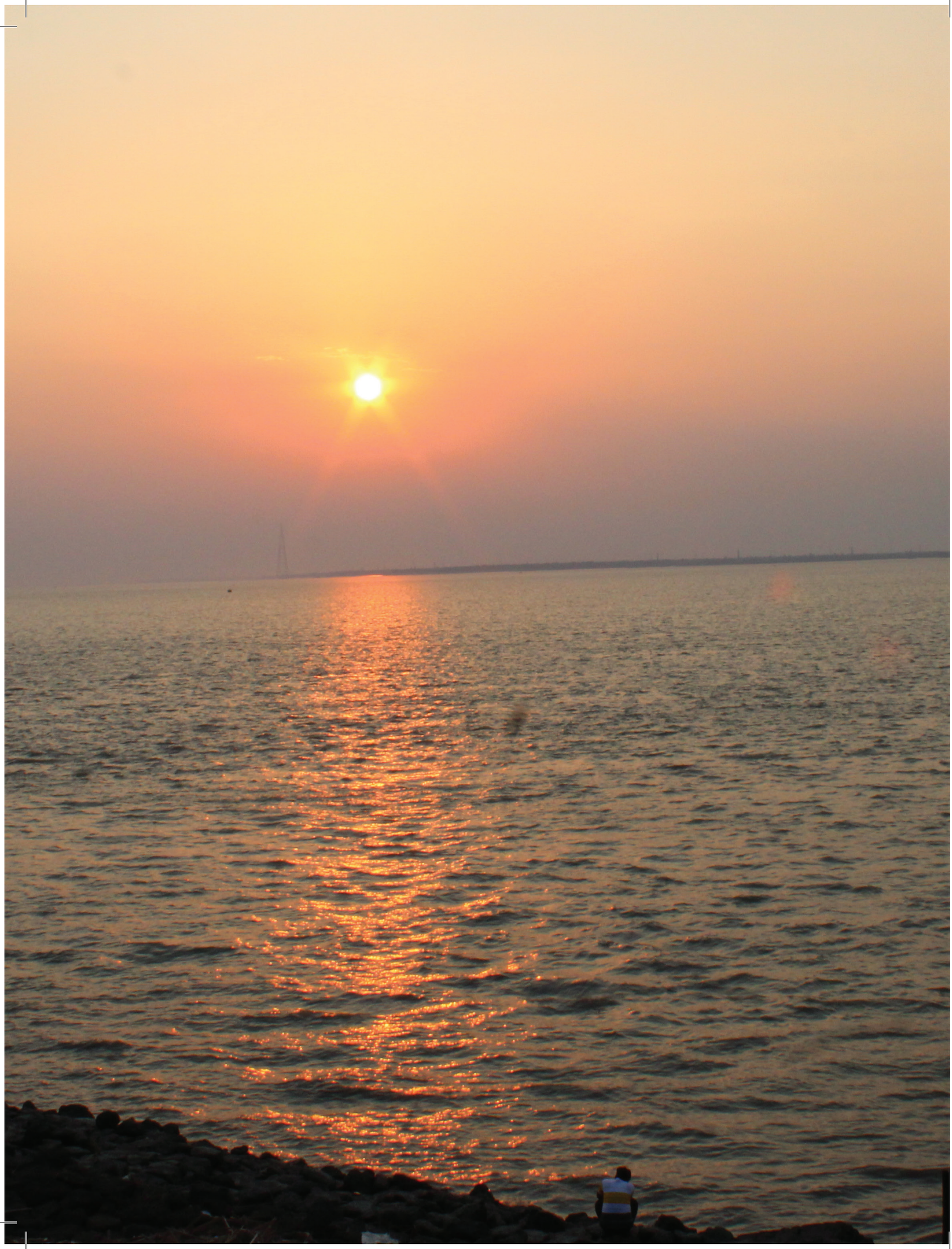
The Ganga River Basin faces significant challenges in water and soil quality due to pollution from human activities, such as industrial discharge, untreated sewage, and agricultural runoff. The river is heavily contaminated with chemicals, heavy metals, and pathogens, affecting aquatic life and human health. Similarly, intensive agriculture and urbanization impact soil quality through erosion and degradation. Conservation and restoration efforts like the Ganga Action Plan and Namami Gange project have been implemented to clean and rejuvenate the river and promote sustainable practices. However, ongoing efforts and community involvement are essential to achieve lasting improvements in water and soil quality in the Ganga Basin. The Ganga River is one of the most polluted rivers globally, with industrial effluents, untreated sewage, and agricultural runoff being the primary sources of pollution. Industrial pollution leads to the contamination of the river with toxic chemicals, heavy metals, and other harmful substances, adversely affecting aquatic life and posing risks to human health. The discharge of untreated sewage from urban centers introduces pathogens and organic matter into the river, leading to oxygen depletion and the formation of dead zones where aquatic life cannot survive. Intensive agricultural practices in the Ganga Basin involve the use of chemical fertilizers and pesticides, which are washed into the river through runoff, leading to water pollution and eutrophication. Soil quality in the Ganga Basin is also affected by agricultural practices, soil erosion, and urbanization and construction activities. To address these challenges, the Indian government and various organizations have launched conservation and restoration initiatives like the Ganga Action Plan and the Namami Gange project, which aim to improve water and soil quality. Encouraging sustainable agricultural practices, afforestation, and soil conservation measures are vital for reducing soil degradation and minimizing agricultural runoff. By adopting sustainable practices and mitigating pollution sources, there is hope for revitalizing the Ganga Basin's ecosystems and securing the well-being of the millions of people who depend on its resources.



Objectives of the Project



- Exploration of floral diversity along the Ganga River basin and herbarium preparation for medicinal plants
- Evaluation and documentation of the ethnobotanical and medicinal/commercial significance of the vegetation found in the Ganga Basin
- Phytochemical profiling of medicinally/ commercially significant medicinal plant species
- Explore the uncharted medicinal properties of selected medicinal plants using in silico analysis.
- Analysis of soil and water quality of the Ganga River basin and their impact on floral phytochemical diversity.
- Study the soil microbe interaction and its effect on the phytochemical diversity of the selected medicinal plant varieties.
- Training programs for selected stakeholders (farmers and traditional healing practitioners or Vaidya) along the Ganga River.



Executive Summary

The executive summary encapsulates the ambitious vision of a ground-breaking project dedicated to the meticulous study and preservation of the esteemed Ganga River ecosystem. With unwavering determination, this project embarks on an exhaustive exploration of the river's myriad facets, delving into its floral diversity, soil geochemistry, intricate plant-microbe relationships, and water quality. Spanning the entire length of the Ganga River, from its revered source at Gaumukh, Uttarakhand, to its revered terminus at Ganga Sagar, West Bengal, this endeavour leaves no stone unturned in its quest to safeguard and understand this vital natural resource. The project aims to comprehensively understand the biodiversity of the Ganga River basin, particularly focusing on the variety of plant species along its riverbanks. Through the collection and analysis of plant samples, the project endeavours to unravel the ecological richness of the region, shedding light on its diverse flora. Moreover, the study delves into the geochemistry of the soil, aiming to uncover its composition and properties throughout the Ganga River basin. This analysis holds significance as it provides valuable insights into soil fertility and suitability for agriculture, thus contributing to the promotion of sustainable farming practices in the region. In addition to plant and soil investigations, the project explores the intricate interactions between plants and microorganisms within the river basin. By studying these interactions, the research seeks to unveil the complex symbiotic relationships that play a pivotal role in maintaining ecosystem health along the Ganga River. Furthermore, the project is committed to monitoring the water quality of the Ganga River. Through the collection and analysis of water samples, researchers aim to evaluate the overall health of the river and identify potential environmental concerns or pollution issues requiring attention. Beyond its scientific endeavours, the project places a strong emphasis on community engagement and sustainability. It endeavours to foster the adoption of natural farming practices among local farmers in the Ganga basin, advocating for eco-friendly agricultural methods that not only preserve the region's biodiversity but also safeguard the health of the river ecosystem.

To illustrate the effectiveness of the study's objectives and vision, this report has been meticulously documented. The report has been divided into eight parts strategically arranged to enhance comprehension and provide a clear path for understanding and justifying

the study's trajectory. There were 5 teams were deployed consisting of 10 members each including expert taxonomist, botanist, microbiologist, environmental scientist. The survey and sampling section of the report outlines the meticulous strategies employed at the beginning of the study. Among the 26 specific sites along the riverbanks, there were 5 from Uttarakhand (UK), 10 from Uttar Pradesh (UP), 5 from Bihar (BH), 1 from Jharkhand (JH), and 5 from West Bengal (WB). These sites were strategically spaced at most 100 km apart to capture ecological variations effectively. The sampling process for plants, soil, and water followed established protocols set by government-authorized agencies, ensuring rigorous scientific standards. The project was divided into five expert teams, each tasked with surveying specific states in the region, including Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal. Covering 100% of the sampling sites from March 2023 to May 2024, the teams meticulously documented plant diversity. Additionally, 26 water and soil samples were gathered for physicochemical and microbial analysis. The survey also included 10 medicinal plants for phytochemical analysis, alongside soil samples from the rhizosphere to explore plant-microbe interactions.

In the second section of the study, we underscore our proactive engagement with farmers and local healers, aiming to empower them with valuable knowledge and skills in organic farming, soil health management, yoga, and traditional healing practices. A series of 42 comprehensive training sessions were meticulously conducted across the identified locations in this project. These sessions, totalling 80.25 hours of immersive learning, not only equipped 549 farmers and 82 local healers with practical insights and techniques but also held profound implications for the communities involved. By enhancing agricultural practices, the training aimed to improve crop yields, promote soil fertility, and foster sustainable farming methods, thereby contributing to food security and economic stability in the region. Furthermore, the incorporation of yoga and traditional healing practices into the training curriculum had broader implications for personal well-being and community health. Participants gained tools to manage stress, promote mental and physical wellness, and cultivate a holistic approach to healthcare, ultimately leading to improved quality of life for individuals and communities alike. Through these collaborative efforts, our outreach endeavours seek to strengthen community resilience, foster environmental stewardship, and promote the adoption of practices that support both human and ecological well-being.

From third to eighth section, we encompass our data records and results of different sections like ethnobotanical plants, plant diversity, water quality, soil quality, plant-microbe interaction, and lastly insilico approach.

In the third section, we delve into a detailed

analysis of plant diversity along the Ganga River at the 26 selected sites covering five states were selected, namely Uttarakhand (5 sites), Uttar Pradesh (10 sites), Bihar (5 sites), Jharkhand (1 sites), and West Bengal (5 sites). The study recorded total of 1117 species under 660 genera and 152 families. Where, 1073 species under 633 genera and 138 families of Angiosperms, 12 species under 10 genera and 5 families of Gymnosperm and 32 species under 17 genera and 9 families of Pteridophytes. Poaceae has been the largest family with 132 plants. Out of 1117 species, 603 species of herbs, 190 species of trees, 219 species of shrubs, 94 species of climbers, 5 species of epiphyte, and 6 species of lianas. These findings not only contribute to our understanding of the rich botanical heritage of the region but also hold implications for biodiversity conservation and ecosystem management. By documenting the plant diversity, we lay the groundwork for informed decision-making and sustainable conservation efforts aimed at preserving the ecological integrity of the Ganga River basin.

In the fourth section, ethnobotanical plants studies are reported. Moving on to our fifth section, we provide a concise overview of exploration of the therapeutic potential of selected medicinal plants through insilico methods. The insilico processes showed the therapeutic potentials of these plants, particularly in areas such as Cancer, Neurodegenerative disorders, and Viral diseases. These advancements represent promising avenues for future research and hold the potential to unlock novel medicinal properties of the selected plants.Further, these insilico studies are unveiling the newfound medicinal potential of these plants, paving the way for innovative approaches to healthcare and pharmaceutical development.

In the sixth segment of our study, we conducted an exhaustive examination of water quality across the entire expanse of the Ganga River, stretching from Gaumukh to Ganga Sagar. This investigation took place during the sampling and survey phase spanning April to May 2023. Employing meticulous scrutiny, we evaluated a range of physicochemical and microbiological parameters across the 26 water samples obtained from various points along the river. Our findings unveiled a diverse spectrum of water quality profiles, with notable disparities observed among different segments of the river. The analysis of these samples offered crucial insights into water quality and contamination levels throughout the Ganga River basin. In Uttarakhand, out of the 5 samples collected and all 5 are proved to be suitable for drinking and irrigation purpose, with none utilized for industrial purposes. Similarly, in Uttar Pradesh, out of 10 water samples collected all the samples are in range of totally suitable to medium suitable range yet none deemed suitable for industrial use. Transitioning to Bihar, all 5 out of 5 collected samples proved suitable for drinking and irrigation. In Jharkhand the only one water sample is Lower-Medium to medium Suitable for drinking and irrigation. Lastly,

in West Bengal, 5 samples met standards for both drinking water and irrigation. Overall, according to Drinking Water Quality (NSFWQI Index) 84% of all collected samples (26) are suitable for Drinking water quality. In case of irrigation water quality (SAR index), 54% of all collected water samples are totally suitable for irrigation. According to CPCB grading, Class A water cross ponds to only 3% whereas Class B is 8%, Class C is 15%, Class D is 33% and Class E corresponds to 41%.

These findings underscore the pressing need for targeted interventions to address water quality concerns along the Ganga River. They emphasize the critical importance of collaborative endeavours aimed at comprehensive watershed management and pollution control initiatives. Proactive measures must be initiated to mitigate pollution sources and safeguard the health and sustainability of this vital water resource. Notably, the analysis commenced in July 2023 and concluded in November 2023, enabling a thorough and detailed examination of water quality parameters over the specified period.

The seventh section delves into the assessment of soil quality parameters, focusing on the feasibility of organic farming within a 10 km radius of the Ganga River. Commencing in July 2023 and concluding in November 2023, this comprehensive study analyzed a total of 26 samples which includes various physicochemical parameters and heavy metal contents among the soil samples collected. The analysis of the total bulk soil collection provides crucial insights into the nutrient composition necessary for supporting plant growth. Notably, nitrogen emerges as a significant component, with an average content of 714.222 kg/ha, constituting approximately 69.27% of the total nutrient content. This underscores its pivotal role in facilitating essential processes for plant development. Phosphorus, with an average concentration of 238.027 kg/ha. Remarkably, potassium stands out as the predominant nutrient in the soil samples, with an average concentration of 1098.068 kg/ha. This observation raises questions regarding the potential presence of an exceptionally rich potassium reservoir in the soil or concerns related to excessive fertilization practices. Further investigation into potassium levels and corresponding agricultural practices is imperative to ensure optimal nutrient balance and sustainable crop productivity.

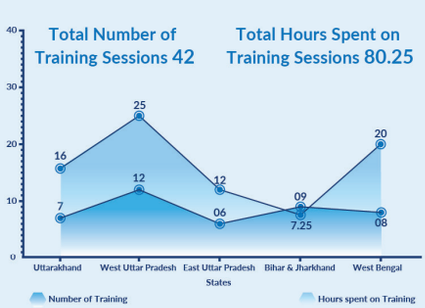
The analysis of the total rhizosphere soil collection provides valuable insights into microbial composition, underscoring the eighth and last chapter's focus on studying plant-microbe interactions. Commencing in July 2023 and concluding in December 2023, this comprehensive study analyzed a total of 155 samples, offering a robust exploration of microbial dynamics within the rhizosphere. The average rhizosphere bacterial concentration, determined to be 33.88 [Log (CFU/ml)], highlights the abundance of microbial life in this environment. Further investigation

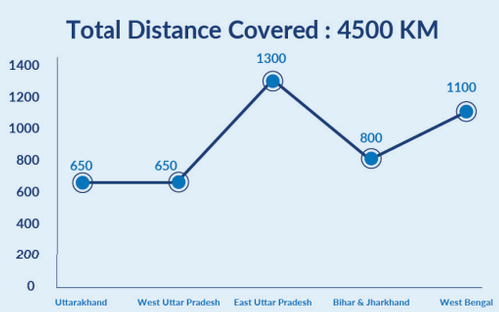
revealed average beneficial bacteria found about 25.18 [Log(CFU/ml)] crossponds to 74.32%. These findings carry significant implications for agriculture and ecosystem management. Understanding the intricate dynamics of plant-microbe interactions is crucial for optimizing agricultural practices and enhancing crop productivity. Leveraging beneficial microbes to promote soil health and nutrient cycling can contribute to sustainable agricultural systems, reducing the need for chemical inputs. The observation that *Achyranthes aspera* L. harbors the highest bacterial concentrations suggest a potential role of this plant species in shaping the microbial community within its rhizosphere. This insight opens avenues for further research into plant-microbe interactions and their implications for ecosystem functioning and plant health. Additionally, the relatively balanced microbial ecosystem within the rhizosphere of *Achyranthes aspera* L., as indicated by the ratio of beneficial bacteria to total bacteria at 1.34, suggests a favorable environment for plant growth and health. Harnessing the knowledge gained from this study can inform strategies for sustainable agriculture, ecosystem restoration, and biodiversity conservation.

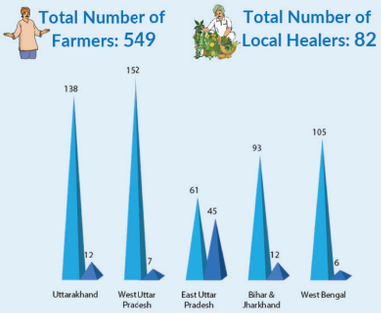
Our study comprehensively explored various aspects of the Ganga River ecosystem, from plant diversity to water and soil quality. By empowering local communities with knowledge and skills in organic farming and traditional healing practices, we aimed to enhance agricultural sustainability and community well-being. Our findings underscored the urgent need for targeted interventions to address water and soil contamination, emphasizing the importance of collaborative efforts in preserving this vital ecosystem. Overall, our study highlights the significance of interdisciplinary research in promoting environmental conservation and sustainable development in the Ganga River basin.

Survey, Sampling & Training









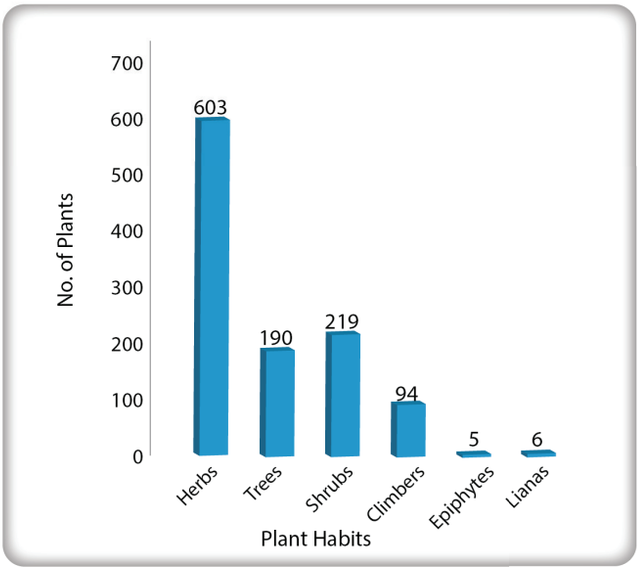
1117 Total Plant Species Reported

152 Total Plant Families Reported

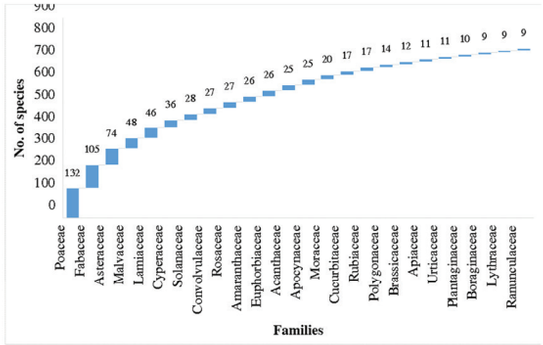
660 Genera

Plant Diversity Analysis

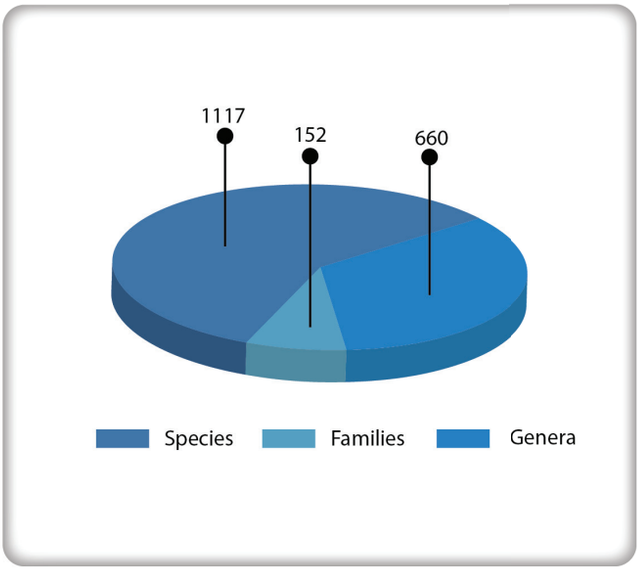
Plant Habit Distribution



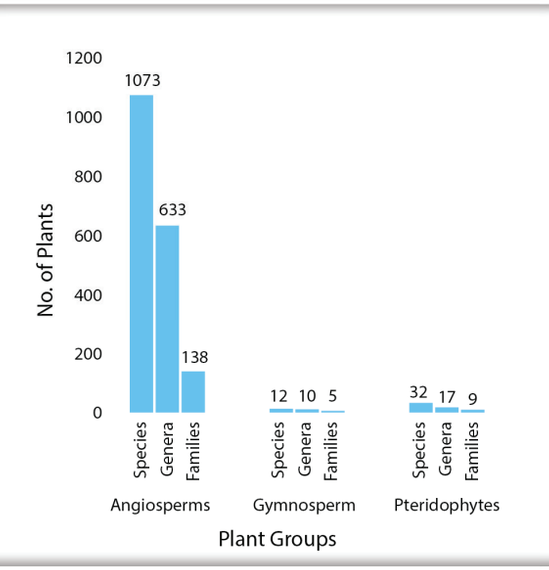
Plant Family Distribution



Species Diversity



Distribution of species under plant groups



26 Bulk Soil Collection

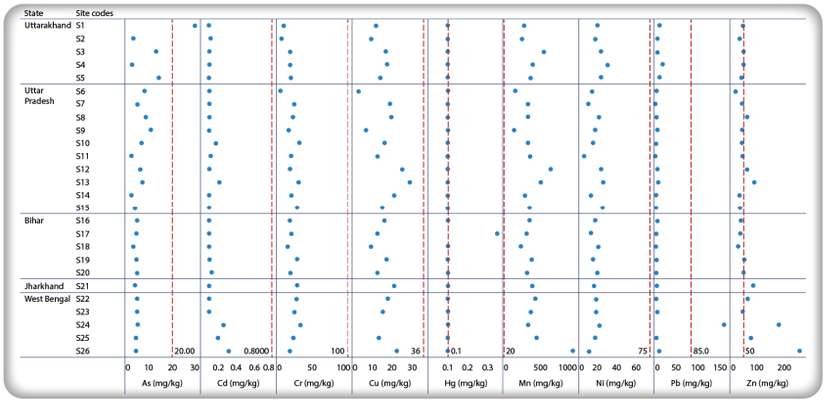
3.9 Average Heavy Metal Pollution Index

3.34 Avgerage Coliform (MPN)/ml in Water Samples

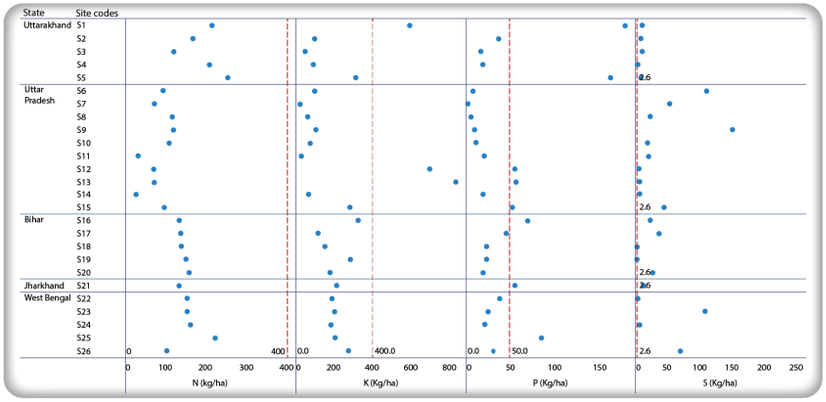
26 Water Collection

Soil Sample Analysis

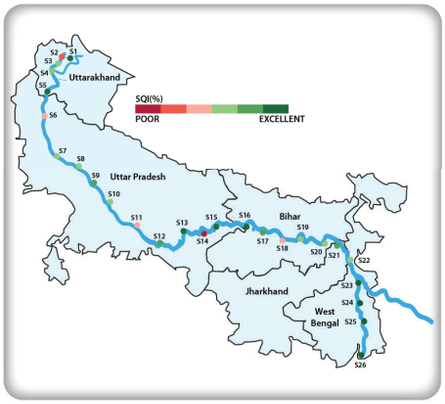
Heavy Metal Distribution in Soil Samples of Different States



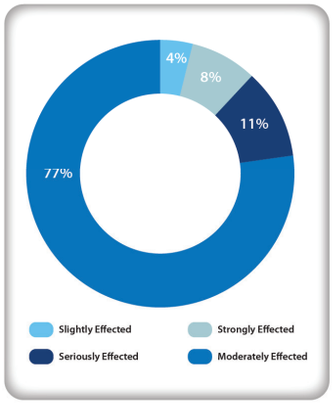
Nutritents Distribution in Soil Samples of Different States



Soil Quality in Different States

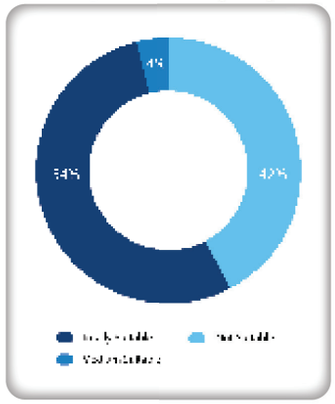


Heavy Metal Pollution in Soil Samples

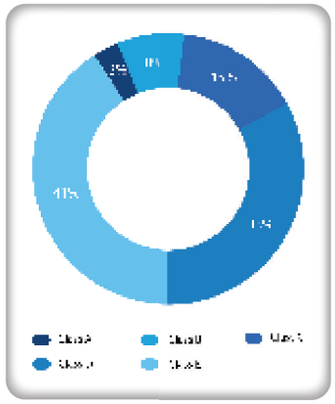


Water Sample Analysis

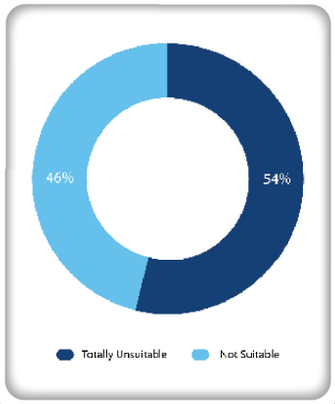
Irrigation Water Quality



Drinking Water Quality



Industrial Water Quality



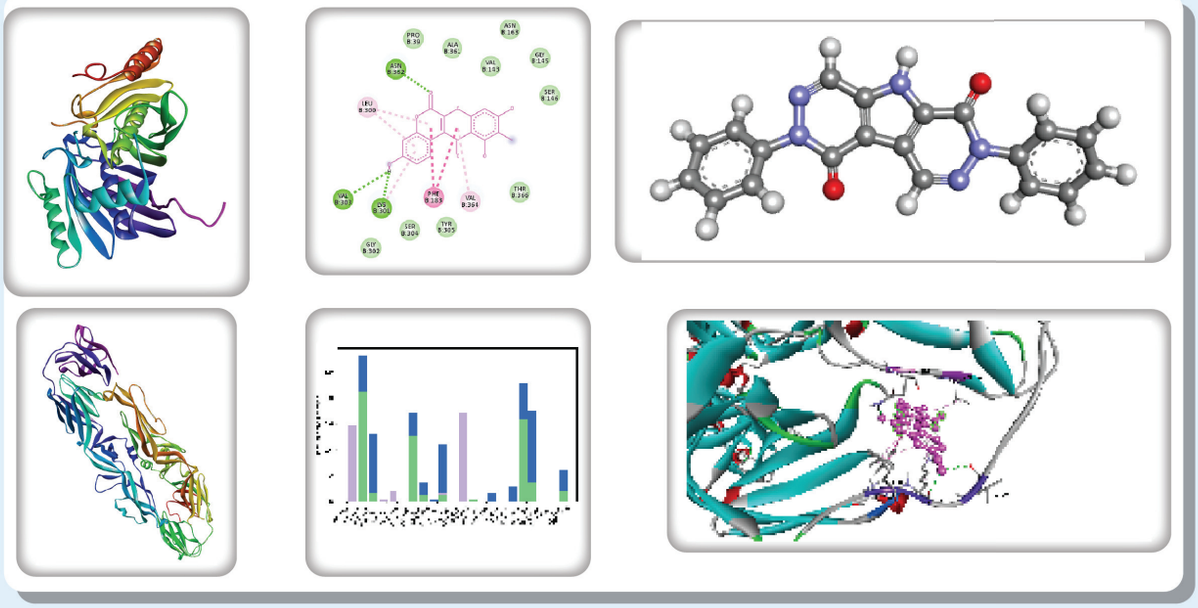
10 Medical Plants for In-silico Analysis

10 Target Diseases for In-silico Analysis

155 Rhizosphere Soil Samples

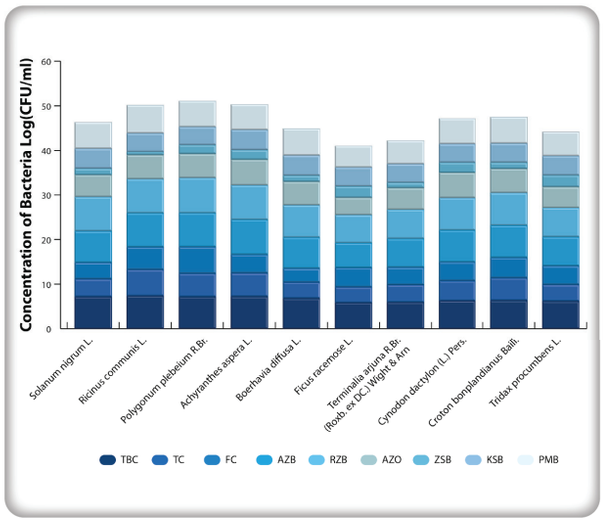
1.34 Beneficial Bacteria Ratio Total

Representation of In-silico Studies

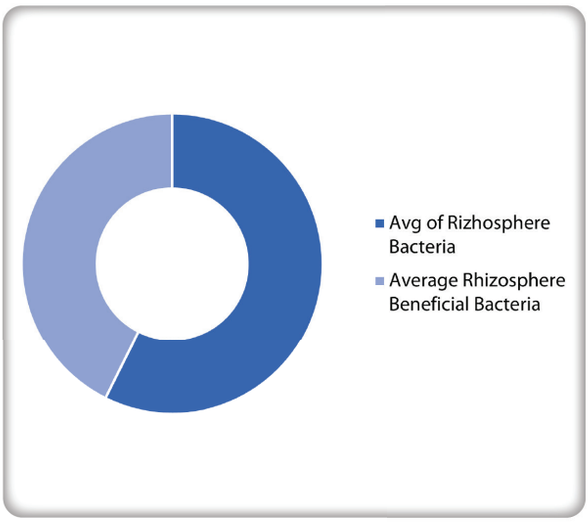


Plant-microbe Interaction

Plant & its comparison of Rhizosphere bacteria



Rhizosphere bacteria & its Beneficial Counter Part



Mapping Progress



COMPLETED

0 Overdue Task

August 2024 — **08** — Final Report Submission

Plant Identification, Herbarium Preparation — **07** — **Nov-Jul 2023-24**

Dec-Jul 2023-24 — **06** — Monograph of 10 Plants & Insilico study

Analysis of Plant, Water & Soil Yearly Report Submission — **05** — **Jun-Dec 2023**

Mar-May 2023 — **04** — Semester Report Survey, Sampling & Training

- UK
- W-UP
- E-UP
- BR & JH
- WB

Obtain Approvals from PCCF, Biodiversity Board, DM — **03** — **Feb-Mar 2023**

Feb-Mar 2023 — **02** — Preparation of SOPs

- Soil
- Plant
- Water

Site Selection & Planning — **01** — **Feb-Mar 2023**

FEB 2023

START



Section-I

Survey and Sampling





In an ambitious effort to understand and assess the ecological, hydro-chemical health of the Ganges River bed, a comprehensive survey and sampling initiative has been conducted, spanning from the pristine region of Gangotri (Uttarakhand) to the coastal expanse of Gangasagar (West Bengal). The study encompasses a multi-faceted approach, focusing on the collection and analysis of water, plant, and soil samples to derive critical insights into the overall environmental well-being of this vital river ecosystem.

The importance of survey and sampling in environmental studies, particularly in the context of the comprehensive initiative spanning from Gangotri to Gangasagar along the Ganges River basin, cannot be overstated. The collection and analysis of diverse samples from water, plants, and soil offers invaluable insights into the overall health and functioning of the ecosystem.

Importance of Survey and Sampling

Here are several key reasons highlighting the importance of survey and sampling according to the objective of the study.

Characterization of Plant Biodiversity

The plant biodiversity along the Ganges River basin is of immense ecological significance. Researchers have meticulously gathered plant specimens from diverse habitats, ranging from the frigid landscapes near Gangotri to the tropical conditions near Gangasagar. These plant samples serve a dual purpose – contributing to the creation of herbarium specimens for plant diversity analysis and providing material for detailed phytochemical studies. The herbarium will serve as a valuable resource for taxonomic studies, while the phytochemical analysis aims to identify and understand the chemical compounds present in these plants, shedding light on their potential ecological roles and medicinal properties. Plant samples contribute to the creation of herbarium specimens, which serve as a valuable resource for taxonomic studies. The survey helps in characterizing the plant biodiversity in different regions, identifying rare or endangered species, and understanding the distribution patterns of flora along the river.

Phytochemical Analysis for Medicinal Insights

The phytochemical analysis of plant samples offers insights into the chemical compounds present in the vegetation. This not only contributes to our understanding of plant ecology but also provides valuable information about potential medicinal properties, fostering advancements in pharmacology and healthcare.

Assessment of Water Quality

Water sampling is instrumental in assessing the quality of water along the river basin. Understanding parameters such as pH, dissolved oxygen, and pollutant concentrations helps in evaluating the suitability of water for human consumption, agriculture, and sustaining aquatic life.

Insights into Soil Health

Soil sampling and analysis provide insights into the health and fertility of the soil. This information is critical for assessing agricultural potential, understanding nutrient cycles, and identifying the impact of human activities on soil quality.

This holistic survey and sampling initiative aim to provide a comprehensive overview of the environmental conditions along the Ganges River basin. The findings will not only contribute to scientific knowledge but also play a pivotal role in formulating sustainable conservation and management strategies to safeguard this iconic and ecologically vital river system.

Strategies applied in Survey and Sampling

The following strategies have been employed to execute the study.

Selection of Sites

The selection of 26 sites for sampling and survey along the Ganges River, spanning from Gangotri to Ganganagar, is meticulously justified based on several critical factors. The total length of the Ganga River, covering a vast expanse of 2525 km, presents a diverse ecological landscape. Recognizing the significant variation in plant diversity with altitude, an estimated difference of up to 100 km in range is acknowledged. This variation necessitates strategic site selection to capture the full spectrum of flora along the river basin.

Furthermore, the biochemical characteristics of water and soil samples are anticipated to exhibit variability within a similar 100 km range. To ensure a comprehensive understanding of the environmental parameters, a maximum distance of 100 km was established between two sampling points. This approach accounts for the dynamic nature of the Ganges ecosystem and facilitates the collection of representative samples across diverse geographical and ecological conditions. The justification for the chosen number of sites aligns with the need to balance precision and comprehensiveness in the study. By strategically selecting 26 sites, the research endeavors to capture the nuances of the Ganges River's ecological dynamics, ensuring that the sampled data provides a robust foundation for a thorough environmental assessment from Gangotri to Ganganagar. The details of the sites have been given below (Table 1.1).

Table 1.1 Details of the Sampling and Survey sites

Codes	State	Nearby sites	Latitude (°N)	Longitude (°E)	Altitude (m)
S1	Uttarakhand	Gaumukh	30.7983	79.1542	4023
S2		Gangotri	30.9800	78.9300	3415
S3		Uttarkashi	30.7292	78.4428	1158
S4		Devprayag	30.1500	78.6000	830
S5		Haridwar	29.9667	78.1667	314
S6	Uttar Pradesh	Bijnor	29.3700	78.1300	225
S7		Narora	28.1967	78.3814	174
S8		Budaun	28.0500	79.1200	164
S9		Farrukhabad	27.3700	79.6300	151
S10		Bithoor	26.6127	80.2719	126
S11		Dalmau	26.0700	81.0300	115
S12		Prayagraj	25.4500	81.8500	98
S13		Mirzapur	25.1500	82.5800	80
S14		Varanasi	25.3189	83.0128	81
S15		Ballia	25.7625	84.1519	67
S16	Bihar	Revelganj	25.7800	84.6700	52
S17		Patna	25.6100	85.1414	53
S18		Barh	25.4800	85.7200	47
S19		Bahachouki	25.2975	86.3561	55
S20		Farka	25.2287	87.0949	42
S21	Jharkhand	Sahebganj	25.2500	87.6500	16
S22	West Bengal	Farakka Barrage Township	24.8200	87.9000	30
S23		Murshidabad	24.1800	88.2700	18
S24		Mayapur	23.4250	88.3908	11
S25		Hooghly	22.9089	88.3967	9
S26		Gangasagar	22.1910	88.1905	4

Involvement of Manpower

A collaborative effort comprising 49 scientists has been organized into five groups for the extensive study. Specifically, teams of scientists were deployed in Uttarakhand, West Uttar Pradesh, East Uttar Pradesh, and West Bengal, with ten teams operating in these regions. Additionally, a team of nine scientists conducted research in Bihar and Jharkhand.

Resources used in Survey and Sampling

- **Permission Letters from Approving authorities**

In this instance, consent has been obtained from the Principal Chief Conservator of Forests (PCCF) and the Biodiversity Boards of each state for the purpose of plant sampling. Permissions of this kind are not necessary for the soil or water. The Annexures contain the approval letters that are attached.

- **Standard operating procedures from Sampling**

For efficient and methodical sampling, standard operating procedures for collecting samples from plants, soil, and water have been developed. The specifics about the same are in the annexure.

Outcomes of the Survey and Sampling

The results of the survey and sampling are provided below according to the survey states.

01

14 Days

DURATION

02

4

District Covered

03

9

Villages Covered

04

650 KM

TOTAL DISTANCE

05

10

Manpower

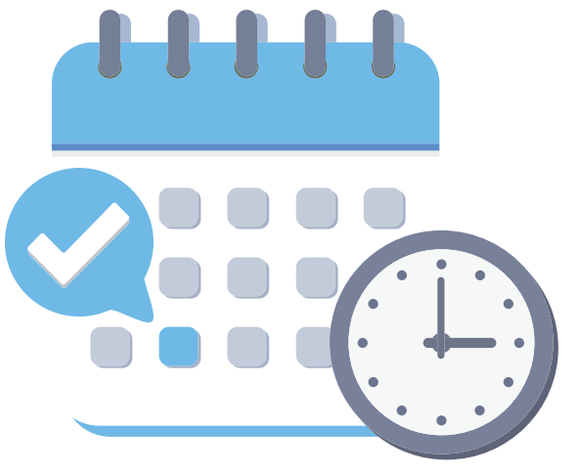


UTTARAKHAND

Uttarakhand is a state located in the northern part of India. It is bordered by Tibet to the north, Nepal to the east, and the Indian states of Himachal Pradesh and Uttar Pradesh to the west and south, respectively. The rivers of Uttarakhand are a significant natural resource in the Indian state. Uttarakhand is blessed with a vast network of rivers, which play a crucial role in the socio-economic development of the region. These rivers originate from the majestic Himalayan ranges and flow through the state, providing water for irrigation, hydropower generation, and supporting diverse ecosystems. The Ganga River holds immense significance in Uttarakhand. The length of this river in Uttarakhand is about 96 km. It serves as a lifeline for the state, providing water for irrigation, drinking, and hydropower generation. Additionally, the river plays a crucial role in the ecological balance of the region, supporting a diverse range of flora and fauna. Its waters are considered sacred, attracting millions of pilgrims each year. Moreover, the Ganga River acts as a source of inspiration for artists, writers, and poets, who draw upon its beauty and cultural significance. Overall, the Ganga River is an integral part of Uttarakhand's identity and plays a vital role in its socio-economic and cultural fabric.

Duration of Sampling

The sampling of the state of Uttarakhand was performed by a team of 10 scientists in the duration of 8th May to 22nd May 2023. The total number of days of sampling was 14 days.



Location of the Sampling Sites

There were five sites covering 4 districts and 9 villages. The details of the sites are given below.

Site 1: Gaumukh

Gaumukh, located in the Indian state of Uttarakhand, holds significant importance in the field of glaciology. As the source of the Bhagirathi River, which eventually merges with the Alaknanda River to form the mighty Ganga, Gaumukh is a crucial site for studying glacier dynamics and hydrology. The geographical coordinates were 30.92^{0}N, 79.07^{0}E. Additionally, Gaumukh serves as a pilgrimage site for devotees who believe that taking a dip in the sacred water of the Bhagirathi River can cleanse their sins. This spiritual significance further adds to the overall importance of Gaumukh.

Site 2: Gangotri

Gangotri holds great significance in the realm of Hinduism. Situated in the Indian state of Uttarakhand, it is the origin point of the holy river Ganga, known as the Bhagrathi in India. As a result, Gangotri is considered one of the Char Dhams, the four sacred pilgrimage sites in Hinduism. The coordinate of the sampling was 30.99° N, 78.94° E.The Gangotri glacier, which is the source of the Bhagrathi River, is in the Garhwal Himalayas at an altitude of about 4,000 meters above sea level. The glacier is fed by snow and ice melt from the surrounding peaks, and it is one of the largest glaciers in the Himalayas. The Bhagrathi River is known for its religious significance, as it is considered sacred by Hindus. It is believed that taking a dip in the holy river can cleanse one's sins and bring spiritual purification. The river is also home to a diverse range of flora and fauna, including several endangered species. Efforts are being made to clean and rejuvenate the river, but more needs to be done to ensure its long-term sustainability. Overall, the Bhagrathi River in Gangotri is a significant natural resource that requires careful management and conservation.

Site 3: Uttarkashi

Uttarkashi is a town located in the Uttarakhand state of India. It is situated on the banks of the Bhagirathi River. The town is known for its religious significance, as it is a gateway to several Hindu pilgrimage sites in the region. The coordinate of the place is 30.72° N, 78.43° E. The region of Uttarkashi, through which the Bhagirathi flows, is

known for its stunning natural beauty, with snow-capped peaks, lush green valleys, and picturesque landscapes. The river not only provides water for irrigation and drinking purposes but also supports a rich biodiversity, making it an important ecological resource. In Uttarkashi, the Bhagirathi is revered and worshipped by locals and visitors alike, who often undertake pilgrimages to its banks to seek spiritual solace and participate in religious rituals. The district is home to numerous temples and ashrams, further highlighting the religious significance of the river in this region. Overall, the presence of the Bhagirathi in Uttarkashi plays a vital role in the cultural, religious, and ecological fabric of the area, making it a cherished and revered natural resource.

Site 4: Devprayag

Devprayag is a small town located in the Tehri Garhwal district as well as Pauri-Garhwal District of the Indian state of Uttarakhand. The coordinate of the place is 30.14° N, 78.59° E. It is situated at the confluence of the Alaknanda and Bhagirathi rivers which ultimately forms river Ganga or Ganga. The Ganga River holds significant importance in Devprayag. It is a vital water resource for the region, providing irrigation for agriculture and serving as a source of drinking water. The Ganga River is considered sacred in Hinduism, and Devprayag is one of the five confluences of the river. This confluence, known as the Sangam, is believed to be a holy site where devotees can attain spiritual purification.

Site 5: Haridwar

Haridwar, located in the state of Uttarakhand, is one of the holiest cities for Hindus and is situated on the banks of the Ganga. The coordinate of the place is 29.94° N, 78.16° E. The Ganga River in Haridwar is believed to have the power to cleanse one's sins and grant salvation. The place is famous for hosting Maha Kumbh Mela in every 12 years. This belief is deeply rooted in Hindu mythology and is a driving force behind the large number of devotees who visit Haridwar. Apart from its religious significance, the Ganga River in Haridwar also plays a crucial role in the city's economy. The city is known for its vibrant and bustling ghats, which are the steps leading down to the river. These ghats serve as gathering places for devotees, where they perform various rituals and ceremonies. The presence of the Ganga River and the associated religious activities attract tourists from all over the world, contributing to the local economy through tourism and related industries. Furthermore, the Ganga River in Haridwar serves as a source of livelihood for many local communities. Fishing is a common occupation along the river, providing sustenance for numerous families. The river also supports agriculture in the

region, with farmers relying on its waters for irrigation. However, it is important to note that the Ganga River in Haridwar faces several challenges. Pollution is a major concern, with industrial and domestic waste being discharged into the river.

Survey and Sampling

As per the objective of the project plants, water and soil were collected as sampling materials. In the below section, the details of the sampling have been furnished.

Sampling of Flora

Our research aims to document and categorize the diverse plant species found in the Uttarakhand region, providing valuable insights into the botanical richness and ecological significance of Uttarakhand. Through extensive field surveys and taxonomic investigations, from the above-selected sites, a total of 1057 plant field numbers were documented and approximately 4228 plant specimens were collected for identification and herbarium preparation. Among them, 20 selected medicinal plant samples were also collected in bulk quantity for phytochemical analysis.

These findings could contribute to our understanding of the biodiversity hotspot that Uttarakhand represents, highlighting the need for conservation efforts to protect and preserve its unique plant life.

Sampling of Water

Our objective is to provide a comprehensive analysis of the water quality in this region. To achieve this, we collected water samples from above mentioned locations along the Ganga River in Uttarakhand. Various parameters such as pH, dissolved oxygen, and turbidity, were measured using portable DO meter, portable pH meter, and Turbidity meter. During the duration of the survey, a total of 5 water samples from the Ganga River were collected, each from one site mentioned above for the physicochemical and microbial analysis. According to the field data, the water samples were mostly greenish to brownish. Odor and foam are not detectable. The pH of the water samples was mostly neutral (6.7-8.6) in nature. During sampling, the temperature varies from 1°C to 24°C. The details of the water sampling of the 5 sites of Uttarakhand have been furnished below in Table 1.2.

Table 1.2 Details of Water samples and associated sampling parameters

Name of the Site	Coordinates of the sampling sites	The volume of water sample collected (ml)	Odor	Color	Foam	Temperature (°C)	pH
Gaumukh	30.92°N, 79.07°E	500	ND	Clear	ND	1.0	6.7
Gangotri Ghat, Gangotri	30.99°N, 78.94°E	500	ND	Clear	ND	6.8	7.2
Manikarnika Ghat, Uttarkashi	30.72°N, 78.43°E	500	ND	Clear	ND	15.8	7.7
Devprayag	30.14°N, 78.59°E	500	ND	Green	ND	24.0	8.3
Chandi Ghat Haridwar	29.94°N, 78.17°E	500	ND	Green	ND	24.6	8.6

ND: Not Detectable

Sampling of Soil

During the survey, a total of 5 soil samples were collected in bulk quantity, one each from the above five sites for physicochemical analysis. Additionally, a total of 20 soil samples from the rhizosphere of selected medicinal plants were collected for the study of plant-microbe interactions. During the collection of soil samples, infield data of the physical and environmental parameters has also been noted. A specialized soil meter is applied to capture the moisture, sunlight, temperature, and pH of the collected soil samples during the time of sampling. According to field data, the moisture of the soil samples was normal to dry. The pH of the samples was mostly in the acidic to neutral range (6.5 to 7). During sampling, the sunlight was recorded as low to normal, and the temperature varies from 27°C to 31°C. The details parameters of the soil samples from each site have cited below in Table 1.3.

Table 1.3 Details of sampling of soil

Name of the Site	Coordinates	Altitude (Meter)	The volume of soil sample collected (Kg)	Moisture	Sunlight	Temperature (°C)	pH
Bhojwasa, Gaumukh	30.567902, 79.030813	3794	1	DRY+	High+	9	7
Taknaur range Gangotri	31.039203, 78.746554	2506	1	DRY+	Low	17	7
Netala Uttarkashi	30.476199, 78.483766	1232	1	DRY	Low	18	6.5
Devprayag	30.135811, 78.304777	1014	1	NOR DRY+	NOR	23	7
Haridwar	29.916943, 78.088639	265	1	NOR	High	34	6.5


GPS Map Camera
Pathari Forest Range, Uttarakhand, India
Cheela Dam - Rishikesh Road, W5VG+W3V, Pathari Forest Range, Uttarakhand 249408, India
Lat 29.945291°
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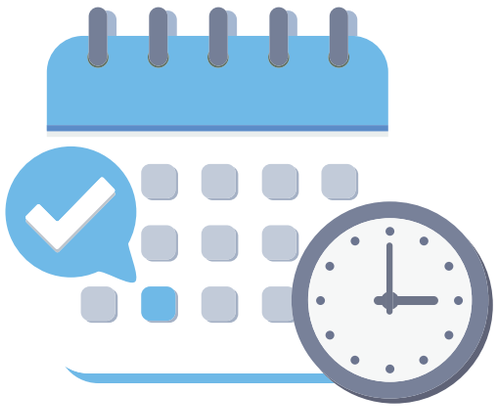
WEST UTTAR PRADESH

With over 200 million inhabitants, Uttar Pradesh plays a crucial role in shaping the social, political, and economic landscape of the country. Furthermore, the state's geographical location is noteworthy. Situated in the northern part of India, Uttar Pradesh shares its borders with several states, including Uttarakhand, Bihar, Madhya Pradesh, Rajasthan, Haryana, and Delhi. This strategic positioning makes it a key transit hub and a gateway to the northern region of India. The state is situated between 23°52'N and 31°28'N latitudes and 77°3'E and 84°39'E longitudes. In terms of economy, Uttar Pradesh is home to numerous industries, including textiles, leather goods, chemicals, and electronics. The Ganga River holds significant importance in the state of Uttar Pradesh. It runs around 1450 km through the state. It serves as a lifeline for the people residing in the region, providing them with various socio-economic benefits. The river plays a crucial role in supporting agriculture, as it provides water for irrigation purposes. This enables farmers to cultivate crops and contribute to the state's food production. Additionally, the Ganga River is a source of livelihood for many fishermen, who rely on its resources for their sustenance. Furthermore, the river is considered sacred by millions of Hindus, who believe that thaking a dip in its waters can cleanse them of their sins. As a result, the Ganga River attracts many pilgrims and tourists, contributing to the state's tourism industry. The famous Kumbh mela is celebrated at the confluence of Ganga and Yamuna river. Moreover, the river is also an important transportation route, facilitating the movement of goods and people across different parts of Uttar Pradesh.

> ***Due to vast area of Uttar Pradesh, the total sampling points have been divided into two groups (West UP & East UP)***

Duration of Sampling

The sampling of the state of Uttar Pradesh was performed by two teams consisting of 10 scientists each (UP-1 and UP-2). For the UP-1 team, the duration of the survey and sampling was from 20th March to 6th April 2023 (18 days).



Location of the Sampling Sites

The UP-1 team has covered around 6 districts and 13 villages. While the UP-2 team has covered 5 districts and 24 villages. The details are given below.

Site 1: Bijnor

Bijnor, Uttar Pradesh holds significant importance in various aspects. Firstly, geographically, it is in the northern part of India, specifically in the state of Uttar Pradesh. Bijnor is situated at a latitude of 29.4°N and a longitude of 78.1°E. This strategic location is near several major cities such as Delhi, Meerut, and Moradabad. Furthermore, the river Ganga in Bijnor, Uttar Pradesh is a significant geographical feature that warrants our attention. Its presence in this region has shaped the landscape and influenced the lives of the local population. We aim to provide a comprehensive understanding of the river's characteristics and its impact on the surrounding environment. By analyzing various data sources and conducting field studies, we have gathered valuable insights into the hydrological aspects of the Ganga in Bijnor. The Ganga in Bijnor serves as a crucial source of water for irrigation, drinking, and industrial purposes. However, it is also prone to pollution due to human activities and requires effective management strategies to ensure its long-term sustainability.

Site 2: Narora

Narora is a town located in the state of Uttar Pradesh, India. It is situated in the Bulandshahr district, approximately 150 kilometers east of the capital city, New Delhi. Narora is situated at a latitude of 28.19° N, and a longitude of 78.38° E. The town is known for its proximity to the Narora Atomic Power Station, which is one of the largest nuclear power plants in the country. The power station plays a vital role in meeting the electricity demands of the northern region and operates with a strong emphasis on safety and environmental protection.

Site 3: Budaun

Budaun is a city located in the state of Uttar Pradesh, India. It is situated in the Budaun district and serves as its administrative headquarters. The city is positioned at a latitude of 28.03°N and a longitude of 79.12°E. Budaun is surrounded by several other districts, including Bareilly to the north, Shahjahanpur to the west, and Farrukhabad to the south. The city covers an area of approximately 516 square kilometers and has a population of around 1.5 million people, according to the latest available data. Budaun has a rich historical background, with evidence of human habitation dating back to ancient times.

Site 4: Farrukhabad

Farrukhabad is a district located in the state of Uttar Pradesh, India. With a population of approximately 1.9 million people, it is an important administrative and commercial center in the region. Farrukhabad is situated at a latitude of 27.38° N, and a longitude of 79.58° E. The district is situated on the banks of the Ganga River, which provides a vital source of water for agriculture and other activities. The economy of Farrukhabad is primarily based on agriculture, with the cultivation of crops such as wheat, rice, sugarcane, and potatoes being the mainstay of the local economy. The region is also known for its handloom industry, particularly the production of muslin and silk fabrics.

Site 5: Bithoor

Bithoor, located in the state of Uttar Pradesh, India, is a historically significant town that holds great cultural and religious importance. Bithoor is situated at a latitude of 26.60° N, and a longitude of 80.26° E. Situated on the banks of the Ganga River, Bithoor has been a site of pilgrimage for devout Hindus for centuries. The town is renowned for its association with the legendary sage Valmiki, who is believed to have written the epic Ramayana in this very place. Today, Bithoor continues to attract visitors from all over the country who come to explore its rich historical and cultural heritage. The town is home to numerous temples and ashrams, which serve as centers of religious and spiritual activities. The Brahmavart Ghat, a sacred bathing ghat on the banks of the Ganga, is particularly revered by pilgrims.

Survey and Sampling

As per the objective of the project plants, water and soil were collected as sampling materials. In the below section, the details of the sampling have been furnished.

Sampling of Flora

Our research aims to document and categorize the diverse plant species found in the Uttar Pradesh region, providing valuable insights into the botanical richness and ecological significance of Uttar Pradesh. Through extensive field surveys and taxonomic investigations, from the above-selected sites, a total of 880 plant field numbers were documented and approximately 3520 plant specimens were collected for identification and herbarium preparation. Among them, 58 selected medicinal plant samples were also collected in bulk quantity for phytochemical analysis.

These findings could contribute to our understanding of the biodiversity hotspot that Uttar Pradesh represents, highlighting the need for conservation efforts to protect and preserve its unique plant life.

Sampling of Water

Our objective is to provide a comprehensive analysis of the water quality in this region. To achieve this, we collected water samples from above mentioned locations along the Ganga River in Uttar Pradesh. Various parameters such as pH, dissolved oxygen, and turbidity, were measured using portable DO meter, portable pH meter, and Turbidity meter. During the duration of the survey, a total of 5 water samples from the Ganga River were collected, each from one site mentioned above for the physicochemical and microbial analysis. According to the field data, the water samples were mostly greenish to brownish. Odor and foam are not detectable. The pH of the water samples was alkaline (8.6 to 9.4). During sampling, the temperature varies from 27°C to 30°C. The details of the water sampling of the 5 sites of Uttar Pradesh have been furnished below in Table 1.4.

Table 1.4 Details of Water samples and associated sampling parameters

Name of the Site	Coordinates of the sampling sites	The volume of water sample collected (ml)	Odor	Color	Foam	Temperature (°C)	pH
Daranagar Ganj, Bijnor	29.28°N 78.12°E	5000	ND	Green	ND	27.9	9.1
Ramghat, Narora	28.14°N 78.43°E	5000	ND	Green	ND	29.8	9.4
Kachla ghat, Budaun	27.93°N 78.85°E	5000	ND	Pale brown	ND	28.4	9.3
Durbasha muni ashram ghat, Farrukhabad	27.41°N 79.62°E	5000	ND	Pale brown	ND	30	9.2
Bithoor	26.61°N 80.27°E	5000	ND	Light green, brown	ND	27.6	8.6

ND: Not Detectable

Sampling of Soil

During the survey, a total of 5 soil samples were collected in bulk quantity, one each from the above five sites for physicochemical analysis. Additionally, a total of 58 soil samples from the rhizosphere of selected medicinal plants were collected for the study of plant-microbe interactions. During the collection of soil samples, infield data of the physical and environmental parameters has also been noted. A specialized soil meter is applied to capture the moisture, sunlight, temperature, and pH of the collected soil samples during the time of sampling. According to field data, the moisture of the soil samples was normal to dry. The pH of the samples was mostly in the acidic range (5.5 to 6). During sampling, the sunlight was recorded as low to normal, and the temperature varies from 27°C to 31°C. The details parameters of the soil samples from each site have cited below Table 1.5.

Table 1.5 Details of sampling of soil

Name of the Site	Coordinates	Altitude (Meter)	Quantity of soil sample collected (Kg)	Moisture	Sunlight	Temperature (°C)	pH
Daranagar Ganj, Bijnor	29.28°N 78.10°E	217	5	Nor	Low	29	5.5
Ramghat, Narora	28.14°N 78.43°E	179	5	Nor	Low+	31	6
Kachla ghat, Budaun	27.93°N 78.85°E	162	5	Dry	Low+	25	6
Durbasha muni ashram ghat, Farrukhabad	27.41°N 79.62°E	136	5	Dry	Nor	25	6
Bharmahanghat, Bithoor	26.61°N 80.27°E	113	5	Wet+	Nor	28	5.5


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Lat 28.362047° Long 78.255621°
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Bithoor, Uttar Pradesh, India
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Lat 22.849128°
Long 88.389503°
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GPS Map Camera
Google

01

13 Days

DURATION

02

5

District Covered

03

24

Villages Covered

04

1300 KM

TOTAL DISTANCE

05

10

Manpower

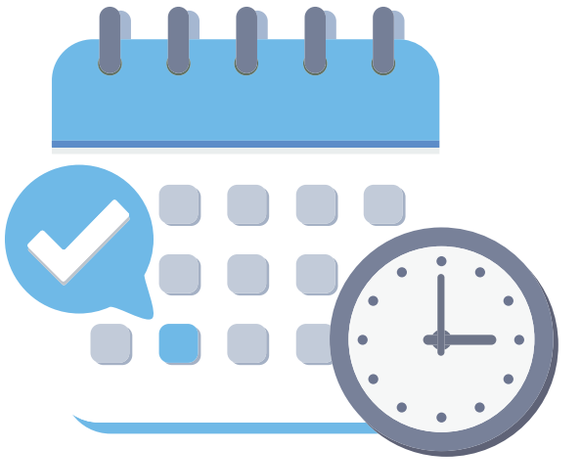


EAST UTTAR PRADESH

The Ganga River is vital to the economy of east Uttar Pradesh. It supports agriculture in the region through an extensive system of irrigation canals, including the Upper Ganga Canal and the Lower Ganga Canal. These canals have boosted the production of cash crops like sugarcane, cotton, and oilseeds. Additionally, the river serves as a crucial transportation route, connecting cities like Kanpur, Prayagraj, and Varanasi. Goods such as jute, tea, grain, and agricultural products are transported along the river. Moreover, the Ganga River attracts tourists who are captivated by its natural beauty and cultural significance. Varanasi, in particular, is a popular tourist destination, drawing thousands of visitors each year.

Duration of Sampling

For UP-2 team, the duration was 13 days, from 14th March to 27th March 2023.



Location of the Sampling Sites

UP-2 team has covered 5 districts and 24 villages of west Uttar Pradesh. The details are given below.

Site 1: Dalmau

Dalmau is a town located in the state of Uttar Pradesh, India. It falls under the Raebareli district and is situated on the banks of the Ganga River. The city is positioned at a latitude of 26.06°N and a longitude of 81.06°E. The town has a rich historical and cultural significance, with evidence of human habitation dating back to ancient times. The town is known for its architectural marvels, such as the Dalmau Fort, which was built during the reign of the Awadh dynasty. The fort showcases a blend of Mughal and Rajput architectural styles. The town also boasts of natural beauty, with lush green fields and the serene Ganga River flowing through its vicinity. Overall, Dalmau is a place of historical, cultural, and natural significance, offering a glimpse into the rich heritage of Uttar Pradesh.

Site 2: Prayagraj

Prayagraj, formerly known as Allahabad, is situated in the northern part of India. The Ganga River, one of the most sacred rivers in Hinduism, flows through the city. The city is positioned at a latitude of 25.43°N and a longitude of 81.84°E. Prayagraj is particularly renowned for the Kumbh Mela, a major religious festival held every twelve years, where millions of devotees gather to take a dip in the Ganga. The presence of the Ganga River in Prayagraj has not only religious significance but also plays a crucial role in the city's ecosystem and economy. The river provides water for irrigation, supports diverse aquatic life, and serves as a transportation route for goods and people. Additionally, the Ganga River is a source of inspiration for artists, poets, and writers, who often depict its beauty and spiritual essence in their works. In conclusion, the Ganga River in Prayagraj holds immense cultural, religious, and ecological importance, making it a significant landmark in the region.

Site 3: Mirzapur

Specifically, in the district of Mirzapur, Uttar Pradesh, the Ganga holds significant cultural, religious, and ecological importance. The city is positioned at a latitude of 25.13°N and a longitude of 82.56°E. The Ganga in Mirzapur extensively aims to understand its hydrological characteristics, water quality, and the impact of human activities on its ecosystem. Our findings reveal that the Ganga in Mirzapur serves as a vital source of water for irrigation, domestic use, and industrial purposes. However, we have also observed that the river faces challenges such as pollution from agricultural runoff, industrial waste, and domestic sewage, which have adverse effects on the water quality and biodiversity. Through our research, we aim to contribute to the understanding of the Ganga in Mirzapur and propose measures for its conservation and sustainable management.

Site 4: Varanasi

Varanasi, also known as Kashi, is one of the oldest inhabited cities in the world and is considered a sacred place by Hindus. The city is positioned at a latitude of 25.31°N and a longitude of 82.97°E. The Ganga River, flowing through Varanasi, is believed to be a personification of the Hindu goddess Ganga. It is considered holy and is worshipped by millions of devotees. The river is also associated with Moksha, the ultimate liberation from the cycle of birth and death. From an ecological perspective, the Ganga River supports a diverse ecosystem and is home to numerous species of fish, birds, and other aquatic life. However, the river faces significant challenges, including pollution and over-extraction of water. Efforts are being made to restore and conserve the Ganga River, including the implementation of the Ganga Action Plan and the construction of sewage treatment plants. In conclusion, the Ganga River in Varanasi holds immense cultural, religious, and ecological significance. It is a symbol of spirituality and devotion for millions of people, while also serving as a vital ecosystem that requires conservation and restoration efforts.

Site 5: Balia

Balia, Uttar Pradesh is a city located in the eastern part of the Indian state of Uttar Pradesh. It is situated on the banks of the river Ganga. The town is positioned at a latitude of 25.41 °N and a longitude of 86.31°E. Balia has a rich historical and cultural heritage, with evidence of human habitation in the region dating back to ancient times. Balia is also known for its religious significance, with numerous temples and shrines dedicated to various deities. The city has a diverse population, with people from different religious and ethnic backgrounds living together harmoniously. Balia is also an important center for trade and commerce, with a thriving agricultural sector and a bustling market. The city is well-connected to other parts of the state and the country through a network of roads and railways. In conclusion, Balia, Uttar Pradesh is a historically and culturally significant city with a rich heritage and a vibrant community.

Survey and Sampling

As per the objective of the project plants, water and soil were collected as sampling materials. In the below section, the details of the sampling have been furnished.

Sampling of Flora

Our research aims to document and categorize the diverse plant species found in the Uttar Pradesh region, providing valuable insights into the botanical richness and ecological significance of Uttar Pradesh. From the selected sites, a total of 969 plant field numbers were documented and 3876 plant specimens were collected for identification and herbarium preparation. Among them, 70 selected medicinal plant samples were also collected in bulk for phytochemical analysis. These findings could contribute to our understanding of the biodiversity hotspot that Uttar Pradesh represents, highlighting the need for conservation efforts to protect and preserve its unique plant life.

Sampling of Water

Our objective is to provide a comprehensive analysis of the water quality in this region. To achieve this, we collected water samples from above mentioned locations along the Ganga River in Uttar Pradesh. Various parameters such as pH, dissolved oxygen, and turbidity, were measured using portable DO meter, portable pH meter, and Turbidity meter. During the duration of the survey, a total of 5 water samples from the Ganga River were collected, each from one site mentioned above for the physicochemical and microbial analysis. According to the field data, the water samples were mostly greenish. Odor and foam were not detectable during sampling. The pH of the water samples was mostly alkaline (8.4 to 8.6) in nature. During sampling, the temperature varies from 28.4°C to 32.2°C. The details were furnished in Table 1.6.

Table 1.6 Details of Water samples and associated sampling parameters

Name of the Site	Coordinates of the sampling sites	The volume of water sample collected (ml)	Odor	Color	Foam	Temperature (°C)	pH
Agastha Ganga Bridge Dalmau	26.05°N, 81.03°E	5000	ND	Blue	ND	31.5	8.5
Nagvasuki Mandir Prayagraj	25.46°N, 81.88°E	5000	ND	Greenish	ND	31.4	8.5
Pakka Ghat, Mirzapur	25.15°N, 82.56°E	5000	ND	Greenish	ND	28.4	8.4
Malahiya, Gadwa Ghat, Varanasi	25.29°N, 83.00°E	5000	ND	Greenish	ND	32.2	8.6
Ganga Ghat, Balia	25.73°N, 84.14°E	5000	ND	Greenish	ND	29.6	8.5

ND: Not Detectable

Sampling of Soil

During the survey, a total of 5 soil samples were collected in bulk quantity, one each from the above sites for physicochemical analysis. Additionally, a total of 72 soil samples from the rhizosphere of the selected medicinal plant were collected for the study of the interaction of plant microbes. According to field data, the moisture of the soil samples was dry to wet. The pH of the samples range from acidic to basic range (6.5 to 8.5). During sampling, the sunlight was recorded as low, and the temperature varies from 31°C to 38°C. The details parameters of the soil samples from each site have cited below in Table 1.7.

Table 1.7 Details of sampling of soil

Name of the Site	Coordinates	Altitude (Meter)	The volume of soil sample collected (Kg)	Moisture	Sunlight	Temperature (°C)	pH
Dalmau	26.34°N 81.12°E	91	5	Dry+	Low+	31	7
Praygraj	25.25°N 81.53°E	90	5	Wet-	Low+	33	8.1
Mirzapur	25.85°N 81°53°E	91	5	Wet-	Low-	32	8.3
Varanasi	25.15°N 83.13°E	80	5	Dry+	Low+	38	7.8
Ballia	35.45°N 83.56°E	67	5	Wet	Low+	34	6.5


GPS Map Camera
Sarai Dilawar, Uttar Pradesh, India
27.33° C
222° SW
12.85 31% 116 m 39.0 µT
Senpur, Uttar Pradesh, India
33.42° C
233° SW
11.09 10% 95 m 34.0 µT
Raebareli, Uttar Pradesh, India
35.85° C
317° NW
19.22 16% 107 m 44.0 µT
Prayagraj, Uttar Pradesh, India
20.62° C
53° NE
9.68 80% 100 m 22.0 µT
Prayagraj, Uttar Pradesh, India
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Prayagraj, Uttar Pradesh, India
Arail Rd, Barna, Arail, Prayagraj, Uttar Pradesh 211008, India
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296° NW
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18/03/2023 09:48 AM GMT +05:30
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Mirzapur, Uttar Pradesh, India
5G3J+V56, Ojhala Pul, Mirzapur, Uttar Pradesh 231307, India
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Note : Captured by GPS Map Camera
20.06° C
137° SE
8.71 53% 67 m 26.0 µT

01

20 Days

DURATION

02

5

District Covered

03

18

Villages Covered

04

800 KM

TOTAL DISTANCE

05

09

Manpower



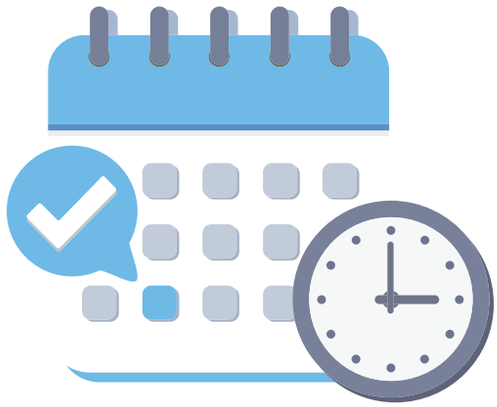
BIHAR-JHARKHAND

Bihar, a state located in the eastern part of India, is a region of great historical and cultural significance. With a population of over 100 million people, Bihar is the third most populous state in India. Bihar is in the eastern region of India, between latitudes 24°20'10"N and 27°31'15"N and longitudes 83°19'50"E and 88°17'40"E. It is bordered by Nepal to the north, West Bengal to the east, Uttar Pradesh to the west, and Jharkhand to the south. The state capital of Bihar is Patna, which is also the largest city in the state. In terms of geography, Bihar is primarily a fertile plain, with the Ganga River flowing through the state. The Ganga River holds significant importance in the state of Bihar. It serves as a lifeline for the people residing in this region. The length of the river Ganga in Bihar is only about 445 km. The river is not only a lifeline for the people of Bihar, but also a source of irrigation for agriculture, which is the main occupation of much of the population. The river not only provides water for irrigation and drinking purposes but also supports various economic activities such as fishing and transportation. Additionally, the Ganga River is considered sacred by millions of Hindus, who believe that taking a dip in its holy waters can cleanse their sins. Moreover, the river is home to a diverse range of flora and fauna, making it an ecologically significant ecosystem. Overall, the Ganga River plays a vital role in the socio-economic and cultural fabric of Bihar.

The Ganga River also holds significant importance in the state of Jharkhand. The length of the river Ganga in Jharkhand is only about 40km. It serves as a vital water resource, providing irrigation for agricultural activities and supporting the livelihoods of the local communities. Additionally, the river plays a crucial role in the transportation of goods and people, facilitating trade and commerce in the region. Furthermore, the Ganga River is of great cultural and religious significance, with numerous temples and ghats located along its banks. These sites attract pilgrims and tourists, contributing to the local economy. Overall, the Ganga River in Jharkhand is a multifaceted resource that impacts various aspects of the state's socio-economic and cultural fabric.

Duration of Sampling

The sampling of the state of Bihar and Jharkhand was performed team consisting of 9 scientists. The duration of the survey and sampling was from 15th March to 3rd April 2023 (20 days).



Location of the Sampling Sites

The team covered around 5 districts and 18 villages. Among them, 4 districts and 17 villages were from the state of Bihar, and 1 district and 1 village from Jharkhand. The details of the places have been described below.

Site 1: Revelganj

Revelganj, Bihar, located in the eastern part of India, is a town that holds significant importance in the region. The coordinate of the place is 25.76° N, 84.67°E. With a population of approximately 50,000 people, Revelganj serves as a vital economic and cultural center for its residents. The town is situated on the banks of the Ganga River, which not only provides a picturesque backdrop but also plays a crucial role in the daily lives of the locals. The economy of Revelganj primarily relies on agriculture, with most of the population engaged in farming activities. The fertile soil and favorable climate in the region make it suitable for the cultivation of crops such as rice, wheat, and sugarcane. In addition to agriculture, small-scale industries, such as textiles and handicrafts, also contribute to the town's economy. The educational infrastructure in Revelganj is steadily improving, with several schools and colleges providing quality education to the residents. The town is also well-connected to other parts of Bihar through a network of roads and railways, facilitating transportation and trade. Overall, Revelganj, Bihar, with its rich cultural heritage, thriving economy, and scenic beauty, continues to be a significant hub in the region.

Site 2: Patna

Patna, the capital city of Bihar, is a significant urban center in India. Situated on the southern bank of the Ganga River, Patna holds immense historical and cultural importance. With a rich heritage dating back to ancient times, the city has witnessed the rise and fall of several dynasties and empires. In terms of geographical location, Patna is positioned at 25.6°N latitude and 85.1°E longitude. It spans an area of around 136 square kilometers, making it one of the largest cities in the state. Patna is surrounded by the districts of Vaishali to the north, Nalanda to the south, and Samastipur to the east. Today, Patna is a bustling metropolis with a population of over 2 million people. It serves as an important economic and commercial hub, contributing significantly to the state's GDP. The city is known for its thriving industries, including textiles, sugar milling, and handicrafts. Additionally, Patna is a major center for education and administration, hosting numerous universities, colleges, and government offices. The Ganga River holds significant importance in Patna, Bihar. It serves as a vital lifeline for the city, providing various benefits to the local population. The river plays a crucial role in the economy, transportation, and religious practices of the region. Additionally, it serves as a source of water for agricultural activities, contributing to the agricultural productivity of the area. The Ganga River also holds immense religious significance, with numerous ghats and temples situated along its banks, attracting pilgrims and tourists from all over the country. Furthermore, the river serves as a venue for various cultural and social events, fostering a sense of community and cultural heritage among the residents of Patna. Overall, the Ganga River is an integral part of the city's identity and plays a vital role in the lives of the people of Patna and Bihar. In conclusion, Patna, Bihar's capital city, is a vibrant urban center with a rich historical and cultural heritage. Its strategic location, favorable climate, and economic significance make it a prominent city in the region.

Site 3: Barh

Barh District is a town and the 39th District of Bihar in India. The coordinate of the place 25.47°N, 85.70° E. It is located on the southern bank of the Ganga. According to the 2011 Census of India, Barh had a total population of 316,348 residents, with 162,354 males and 153,994 females. Barh, situated in the Indian state of Bihar, is a town that owes its existence to the mighty Ganga River. The town is strategically located on the banks of the sacred river, which has been a source of sustenance and spiritual significance for the local population for centuries. The Ganga River in Barh not only provides

a lifeline for agriculture and irrigation, supporting the region's agricultural economy but also serves as a major transportation route, facilitating trade and commerce. The riverfront bustles with activity as boats sail along its waters, carrying goods and connecting the town to other parts of the state. Moreover, the Ganga River holds immense religious importance in Barh, attracting pilgrims and devotees who come to take holy dips and offer prayers at its banks. The town's culture and traditions are deeply intertwined with the river's presence, and various festivals and rituals are celebrated in honor of the Ganga.

Site 4: Bahachoki

Bahachoki is a Village in Dharhara Block in Munger District of Bihar State, India. It belongs to Munger Division. It is located 17 KM South of the District headquarters Munger. The coordinate of the place is 25.29° N, 86.35° E. Bahachoki is 157 KM from the State capital Patna. This Ganga River plays a crucial role in the lives of the local population, serving as a source of water for irrigation, transportation, and religious activities.

Site 5: Farka

Farka is a picturesque village nestled in the state of Bihar, India. Surrounded by lush green fields and serene landscapes, this quaint hamlet offers a refreshing escape from the hustle and bustle of city life. The coordinate of the village is 25.22°N, 87.09° E. The Ganga River's presence in Farka has a profound impact on the lives of its residents, shaping their daily routines and cultural practices. The Ganga's waters are not only a source of sustenance for agriculture and livelihoods but also hold immense religious significance for the local community. The riverbanks become a hub of spiritual activities, where devotees gather to perform rituals, offer prayers, and immerse themselves in the holy waters to seek blessings and cleanse their souls. The Ganga's sacred essence permeates every aspect of life in Farka, and its serene beauty enhances the village's overall charm. Residents revere the river, and its conservation is of utmost importance to them, as they understand its role in sustaining the ecological balance and nourishing the land. The Ganga River's presence in Farka creates a harmonious and profound connection between nature and spirituality, making it a cherished and cherished aspect of village life.

Site 6: Sahibganj (Jharkhand)

Sahibganj, located in the eastern Indian state of Jharkhand, is a city blessed by the majestic presence of the Ganga River. The coordinate of the place is 25.23°N, 87.64°E. This historic city holds great significance due to its strategic location on the banks of the holy river. The Ganga River, with its perennial flow, not only provides a source of water for agriculture and daily needs but also plays a crucial role in the livelihood of the local community. Fishing is a prominent occupation here, and the bountiful river supports the livelihoods of numerous fishermen and their families. Moreover, the Ganga River is an integral part of the religious and cultural fabric of Sahibganj. Pilgrims and devotees from all over the region visit the city to bathe in its sacred waters and offer prayers. The riverfront also serves as a venue for various cultural and religious events, which further strengthen the sense of community and foster a spirit of togetherness among the residents. However, despite its significance, the Ganga River also faces environmental challenges in the form of pollution and encroachment. The impact of human activities on the river's water quality and the surrounding ecosystem remains a concern, and efforts are being made to preserve the sanctity of this lifeline. Nevertheless, the Ganga River continues to be an intrinsic part of Sahibganj's identity, contributing to its economic, cultural, and spiritual growth, and reminding its inhabitants of the need to safeguard this precious natural resource for future generations.

Survey and Sampling

As per the objective of the project plants, water and soil were collected as sampling materials. In the below section, the details of the sampling have been furnished

Sampling of Flora

Our research aims to document and categorize the diverse plant species found in Bihar and Jharkhand regions, providing valuable insights into the botanical richness and ecological significance of Bihar and Jharkhand. Through extensive field surveys and taxonomic investigations, from the selected sites, a total of 738 plant field numbers were documented and 2952 plant specimens were collected for identification and herbarium preparation. Among them, 71 selected medicinal plant samples were also collected in bulk amounts for phytochemical analysis. These findings could contribute to our understanding of the biodiversity hotspot that Bihar and Jharkhand represent, highlighting the need for conservation efforts to protect and preserve its unique plant life.

Sampling of Water

Our objective is to provide a comprehensive analysis of the water quality in this region. To achieve this, we collected water samples from above mentioned locations along the Ganga River in Bihar and Jharkhand. Various parameters such as pH, dissolved oxygen, and turbidity, were measured using portable DO meter, portable pH meter, and Turbidity meter. During the duration of the survey, a total of 6 water samples from the Ganga River were collected, each from a site mentioned above for the physicochemical and microbial analysis. According to the field data, the water samples were mostly colorless. Odor and foam were not detectable during sampling. The pH of the water samples was mostly alkaline (8.4 to 8.7) in nature. During sampling the temperature varies from 24.2°C to 28.3°C. The details of the water sampling of the 5 sites of Bihar and 1 site from Jharkhand have been furnished below in Table 1.8.

Table 1.8 Details of Water samples and associated sampling parameters

Name of the Site	Coordinates of the sampling sites	The volume of water sample collected (ml)	Odor	Color	Foam	Temperature (°C)	pH
Revelganj Ghat	25.79°N, 84.62°E	5000	ND	ND	ND	24.2	8.7
Mahatma Gandhi Setu, Patna	25.63°N, 85.21°E	5000	Fishy	ND	ND	25.8	8.4
Kashi Umanath Mandir, Barh	25.49°N, 85.71°E	5000	ND	ND	ND	27.1	8.7
Kutulpur, Bahachouki	25.18°N 86.21°E	5000	ND	ND	ND	28.3	8.4
Maharshi Mehi Ashram, Farka	25.24°N, 87.06°E	5000	ND	ND	Small Foam	27.9	8.7
Garam Ghat, Sahibganj	25.29°N, 87.62°E	5000	ND	ND	ND	26	8.7

ND: Not Detectable

Sampling of Soil

During the survey, a total of 6 soil samples were collected in bulk, one from each of the above sites for physicochemical analysis. Furthermore, a total of 71 soil samples from the rhizosphere of the selected medicinal plant samples were collected for the study of the interaction of plant microbes. According to field data, the moisture of the soil samples was dry to wet. The pH of the samples was mostly in the acidic to normal range (6 to 7). During sampling, the sunlight was recorded as low to high, and the temperature varies from 24°C to 30°C. The details parameters of the soil samples from each site have cited below Table 1.9.

Table 1.9 Details of Sampling of Soil

Name of the Site	Coordinates	Altitude (Meter)	The volume of soil sample collected (Kg)	Moisture	Sunlight	Temperature (°C)	pH
Revelganj	25.43°N 84.49°E	69	5	Dry+	Low+	24	6.7
Patna	25.38°N 85.12°E	36	5	Dry+	Low	26	6.7
Barh	25.38°N 85.12°E	30	5	Dry	High	26	6.7
Bahachouki	25.17°N 86.20°E	18	5	Dry+	Low	30	7
Farka	29.03°N 87.05°E	22	5	Dry+	Low	25	7
Sahibganj	25.14°N 87.39°E	17	5	Wet	Low	25	6


GPS Map Camera
जेतिया, बिहार, भारत
P44J+56X, जेतिया, बिहार 841101, भारत
Lat 25.705137°
Long 85.130536°
18/03/23 10:26 AM GMT +05:30
Google



01

22 Days
DURATION

02

4
District Covered

03

22
Villages Covered

04

1100 KM
TOTAL DISTANCE

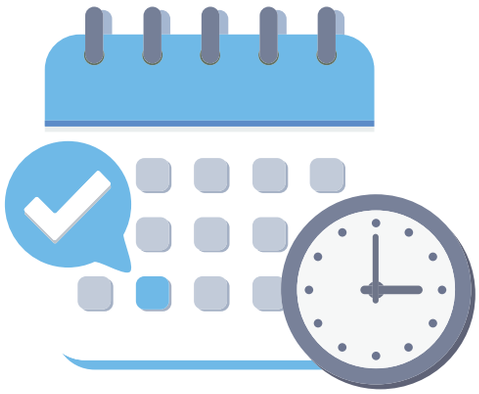
05

10
Manpower

WEST BENGAL

West Bengal, situated in the eastern part of India, is a state brimming with cultural richness and natural beauty. One of its most significant geographical blessings is the river Ganga, which plays a vital role in shaping the state's identity and socio-economic landscape. The Ganga, often referred to as the lifeline of India, flows through the western border of West Bengal, touching several districts along its course. The river's impact on the state is profound, shaping not only its physical geography but also its cultural, religious, and economic aspects. From a cultural perspective, the Ganga holds immense significance for the people of West Bengal. It is deeply revered and considered sacred by most of the population. Downstream of the farraka barrage, River Ganga splits,into two, Bhagirathi (Hooghly) on the right and Padma on the left. Bhagirathi (Hooghly) meets the Bay of Bengal about 150 km downstream of Kolkata. Padma enters Bangladesh and meets river Brahmputra and Meghna before finally joining the Bay of Bengal. Many significant religious festivals and rituals are centered around the river, attracting thousands of devotees from all over the state and beyond. The Ganga also plays a crucial role in the state's economy. The fertile plains along the riverbanks provide excellent conditions for agriculture, making it an essential agricultural hub. The fertile alluvial soil allows for the cultivation of a wide range of crops, including rice, jute, and various fruits and vegetables. The river's water is used for irrigation, ensuring a steady supply of water to the fields. Furthermore, the Ganga supports a thriving fishing industry in West Bengal. The river's waters are abundant in fish, providing livelihoods to numerous fishermen and their families in the state. However, despite its vital contributions, the Ganga in West Bengal also faces significant challenges. Pollution and overexploitation have led to environmental degradation threatening the river's ecological balance and the health of those dependent on it. The state government, along with various NGOs and environmental activists, is striving to address these issues through conservation efforts and awareness campaigns. Sustainable development and pollution control measures are being implemented to ensure the Ganga's continued contribution to West Bengal's socio-economic well-being. In conclusion, the Ganga River's impact on West Bengal is multi-dimensional. Beyond its physical presence, the river's significance is deeply ingrained in the state's cultural fabric, religious practices, and economic activities. By preserving and protecting this lifeline, West Bengal can continue to benefit from its numerous contributions while maintaining a sustainable and harmonious relationship with one of nature's greatest gifts.

Duration of Sampling



The sampling of the state of West Bengal was performed by the team consisting of 10 scientists. The duration of survey and sampling was from 20th March to 7th April 2023 (19 days).

Location of the Sampling Sites

The team covered around 4 districts and 22 villages. The details of the places have been described below.

Site 1: Farrakka

Farrakka, a town located in the state of West Bengal, India, holds significant importance due to its proximity to the mighty Ganga River. The coordinate of the place is 24.77° N, 87.91° E. Nestled along the eastern bank of the Ganga, Farrakka serves as a vital link between West Bengal and the neighboring state of Bihar. The town is best known for the Farrakka Barrage, an engineering marvel constructed across the Ganga that plays a crucial role in diverting water to the Hooghly River and maintaining navigability for river traffic. Moreover, Farrakka acts as a gateway to the diverse landscapes and cultural heritage of West Bengal, attracting tourists and travelers keen to explore the enchanting Ganga River and the surrounding regions.

Site 2: Hazarduari

Hazarduari Palace, located in Murshidabad district of West Bengal, India, stands as a magnificent testament to the grandeur of the bygone era. The coordinate of the place is 24.19° N, 88.27° E. The name "Hazarduari" translates to "a thousand doors," owing to the remarkable architecture of the palace that boasts an astonishing one thousand doors, of which only 900 are actual doors, while the rest are false ones. This historic edifice served as the residence of the Nawabs of Bengal during the 19th century and is now a museum that exhibits an exquisite collection of artifacts and relics from that era. The impact of the Ganga River on Hazarduari is noteworthy as the palace is located close to the riverbanks, and the river's ebb and flow have influenced the region's history and culture over the centuries. The Ganga has not only provided a lifeline for agricultural activities and livelihoods but has also facilitated trade and transportation in this region. Moreover, the Ganga's spiritual significance has deeply influenced the lives and beliefs of the people, adding a spiritual and cultural dimension to Hazarduari and its surroundings. The confluence of history, architecture, and the Ganga' influence makes Hazarduari a captivating destination for history enthusiasts, architecture aficionados, and those seeking to connect with the spiritual essence of the Ganga River.

Site 3: Mayapur

Mayapur, situated on the banks of the sacred Ganga River in the Nadia district of West Bengal, India, holds immense religious significance for millions of devotees around the world. The town is situated at 23.42° N, 88.38°E. It is renowned as the birthplace of Sri Chaitanya Mahaprabhu, a revered saint and the 15th-century proponent of the Gaudiya Vaishnavism tradition. The town serves as the global headquarters of the International Society for Krishna Consciousness (ISKCON), attracting devotees and pilgrims from various corners of the globe. The impact of the Ganga on Mayapur is deeply ingrained in its spiritual fabric. The river is considered the lifeblood of the town, not only nourishing its fertile lands for agricultural purposes but also serving as a prominent site for sacred rituals and religious ceremonies. Pilgrims flock to the riverbanks to perform ablutions and seek spiritual purification. The Ganga are believed to purify the souls of the devout and bless them with spiritual enlightenment. The serene flow of the river and its sacred waters create an atmosphere of tranquility and devotion, making Mayapur an oasis of spirituality and a beacon of devotion along the course of the holy Ganga River.

Site 4: Hooghly

Hooghly district, located in the state of West Bengal, India, is an area of rich historical and cultural significance. The coordinate of the place is 22.90° N, 88.38° E. The district takes its name from the Hooghly River, which flows through its heart. The Hooghly River, a distributary of the Ganga in West Bengal, India, has a profound impact on the region's economic, environmental, cultural, and social aspects. It serves as a vital waterway for trade and transportation, supporting the Kolkata Port and fishing industry. However, pollution from rapid urbanization and industrialization threatens its ecological importance and the livelihoods of those dependent on it. The river holds religious significance, attracting pilgrims and tourists to its banks for festivals and cultural experiences. Managing Hooghly's resources and conserving its ecosystem are essential to sustain its positive contributions and mitigate the challenges it faces.

Site 5: Gangasagar

Gangasagar, also known as Sagar Island, is a revered and picturesque destination situated in the southern part of West Bengal, India. Gangasagar is located at 21.39^0 N 88.04^0 E, at an elevation of only 4 meters. Located at the confluence of the Ganga River and the Bay of Bengal, this sacred island holds immense religious significance for Hindus. Every year, during the auspicious Makar Sankranti festival, millions of devotees from all over the country gather here to take a holy dip in the waters to cleanse their sins. The island is home to the iconic Gangasagar Mela, one of the largest religious gatherings in India. Apart from its religious importance, Gangasagar captivates visitors with its serene beaches and natural beauty. The tranquil environment, coupled with the spiritual aura, makes Gangasagar a unique and soul-stirring destination, attracting both pilgrims and tourists seeking a moment of peace and divine connection.

Survey and Sampling

As per the objective of the project, plants, water, and soil were collected as sampling materials. In below section the details of the sampling have been furnished

Sampling of Flora

Our research aims to document and categorize the diverse plant species found in the West Bengal region, providing valuable insights into the botanical richness and ecological significance of West Bengal. Through extensive field surveys and taxonomic investigations, from the selected sites, a total of 692 plant field numbers were documented and 2768 plant specimens were collected for identification and herbarium preparation. Among them, 15 selected medicinal plant samples were also collected in bulk quantity for phytochemical analysis. These findings could contribute to our understanding of the biodiversity hotspot that West Bengal represents, highlighting the need for conservation efforts to protect and preserve its unique plant life.

Sampling of Water

Our objective is to provide a comprehensive analysis of the water quality in this region. To achieve this, we collected water samples from above mentioned locations along the Ganga River in West Bengal. Various parameters such as pH, dissolved oxygen, turbidity, were measured using portable DO meter, portable pH meter and Turbidity meter. In the duration of survey, a total of 5 water samples from the Ganga River were collected, each from one site mentioned above for the physico chemical and microbial analysis. According to the field data, the water samples were mostly greenish to dirty gray in color. Mostly fishy odor but no foams were detectable during sampling. The pH of the water samples was mostly in alkaline range (8.5 to 8.9). During sampling, the sunlight was recorded as low to normal, and the temperature varies from 28.8°C to 32.9°C.The details of the water sampling of the 5 sites of West Bengal have been furnished below in Table 1.10.

Table 1.10 Details of Water Samples and Associated Sampling Parameters

Name of the Site	Coordinates of the sampling sites	Volume of water sample collected (ml)	Odor	Color	Foam	Temperature (°C)	pH
Barrage Township, Farraka	24.81°N, 87.91°E	5000	Fishy	Bluish Green	ND	29.7	8.8
Mahula, Hazarduri	23.99°N, 88.22°E	5000	Fishy	Blue	ND	32.9	8.9
Mayapur	23.41°N, 88.38°E	5000	Fishy	Sea green	ND	28.8	8.9
Chinsurah, Hoogly	22.91°N, 88.40°E	5000	Fishy	Greenish	ND	29.5	8.5
Sultanpur, Diamond Harbour	22.17°N, 88.19°E	5000	Fishy	Dirty Grey	ND	30	8.5

ND: Not Detectable

Sampling of Soil

During the survey, a total of 5 soil samples were collected in bulk quantity, one each from the above sites for physico chemical analysis. Furthermore, a total of 15 soil samples from the rhizosphere of selected medicinal plant were collected for the study of the interaction of plant microbes. The field data has been collected by portable Soil meter. According to field data, the moisture of the soil samples was dry to wet. The pH of the samples was mostly in the acidic to normal range (5 to 7). During sampling, the sunlight was recorded as low to normal, and the temperature varies from 27°C to 31°C. The details parameters of the soil samples from each site have cited below in Table 1.11.

Table 1.11 **Details of Sampling of Soil**

Name of the Site	Coordinates	Altitude (Meter)	Volume of soil sample collected (Kg)	Moisture	Sunlight	Temperature (°C)	pH
Govinda Rampore (Farraka)	24.82°N; 87.91°E	35	5	Dry+	Low	28	7
Mahula (Hazarduari)	23.99°N 88.22°E	14	5	Dry	NOR	30	6.5
Rudrapara (Mayapur)	23.41°N 88.38°E	8	5	Wet	Low	27	7
Bhatpara (Hoogly)	22. 84°N 88.38°E	9	5	Dry+	Low	30	7
Dimond Harbour	22.17°N 88.18°E	3	5	Wet+	Low	31	5


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Comparative Study

The comparative study of survey and sampling across various regions in India reveals distinctive trends in coverage. Bihar-Jharkhand emerges as a standout region, with the maximum sites covered (6), showcasing a robust and extensive sampling effort. Conversely, all other regions, including Uttarakhand, West Uttar Pradesh, East Uttar Pradesh, and West Bengal, covered five sites each, contributing to a total of 26 sites across all regions.

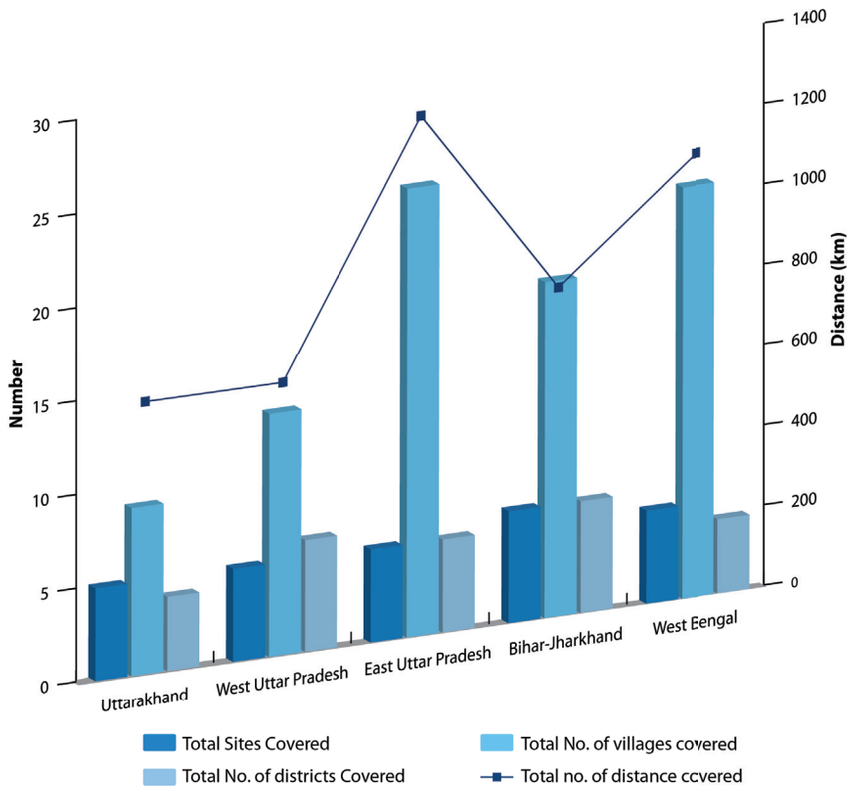


Fig. 1.1 Details of geographic parameters for sampling and survey

In terms of villages covered, East Uttar Pradesh leads with 24 villages, reflecting a comprehensive and diverse survey approach. Uttarakhand, on the other hand, covers the minimum number of villages (9), indicating a more targeted survey strategy. The total number of villages covered across all regions comes to 86. District-wise, West Uttar Pradesh and Bihar-Jharkhand cover the maximum number of districts (6 each), showcasing an extensive survey reach. In contrast, Uttarakhand and West Bengal cover the minimum number of districts (4 each). The total number of districts covered across all regions is 25. Examining the total distance covered, East Uttar Pradesh's significant effort becomes apparent with a maximum distance of 1300 units, suggesting a thorough exploration of a larger

geographical area. In contrast, Uttarakhand and West Uttar Pradesh cover the minimum distance (650 km each). The overall total distance covered across all regions is 4500 km, offering a comprehensive perspective on the scale of the survey efforts. These findings underscore the diverse and nuanced survey strategies adopted across different regions, emphasizing the necessity for context-specific considerations to interpret the results accurately and recognize the unique characteristics influencing survey design and implementation (Fig 1.1).

The survey conducted across Northern India encompassed a wide geographical range, yielding substantial data on plant biodiversity and medicinal resources (Fig 1.2).

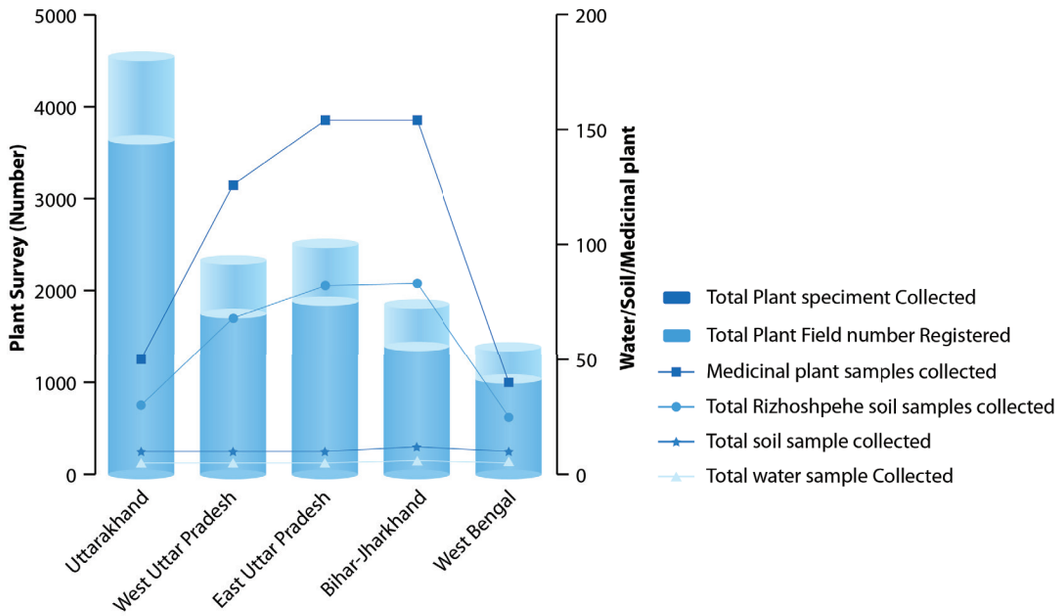


Fig. 1.2 Details of the survey and sampling materials

With a total of 9700 plant specimens collected, Uttarakhand emerged as the leader, followed by West Uttar Pradesh, East Uttar Pradesh, Bihar-Jharkhand, and West Bengal. However, only 30% of these specimens were formally documented, indicating a potential gap in the comprehensive understanding of the region's plant life. The distribution of registered specimens showcased Uttarakhand with the highest number (910), emphasizing the necessity for improved documentation processes in other states. In terms of environmental assessments, 26 water and 26 soil samples were collected evenly across all surveyed states, contributing to a holistic understanding of the region's ecological health. Noteworthy is the specific focus on rhizosphere soil, with 236 samples collected, showcasing variations across states, and highlighting its importance in studying the ecological interactions and health of plant species. Simultaneously, 236 medicinal plant samples were collected, mirroring the distribution of rhizosphere soil samples, to correlate between soil health and the presence of medicinal plants.





Section-II

Training of Traditional Healers and Farmers



In the dynamic landscape of contemporary agriculture and healthcare, the imperative to bridge the gap between tradition and innovation is more pronounced than ever. This chapter delves into the critical realms of empowering farmers for organic agriculture and facilitating an exchange of traditional healing knowledge with local practitioners. Both endeavors align with the broader goals of sustainable practices and holistic well-being in India (Williams et al., 2020).

In a world increasingly recognizing the significance of sustainable farming practices, the training of farmers for optimal soil quality is paramount. The health and fertility of the soil form the bedrock of a thriving agricultural ecosystem. Specialized training programs serve as the catalyst for farmers to delve into organic and regenerative farming techniques. From cover cropping and crop rotation to composting and biochar application, these programs equip farmers with the knowledge and skills needed to enhance soil structure, nutrient content, and water-holding capacity. The shift to organic farming is not merely a change in methodology; it represents a paradigm shift in agricultural practices. Comprehensive training becomes the linchpin for this transition, arming farmers with the expertise to implement practices such as composting, intercropping, and chemical-free pest management. Practical insights gained through hands-on demonstrations and interactive sessions bridge the gap between theory and application, enabling farmers to optimize yields while reducing dependence on synthetic inputs. Understanding certification processes and marketing opportunities associated with organic produce further underscores the economic benefits linked to sustainable agriculture (Zschaeffer, 2018).

In the realm of healthcare, the collaboration between modern medicine and the profound knowledge held by local healers emerges as a compelling narrative. Acknowledging the invaluable insights of local healers, deeply rooted in traditional medicines and remedies, is central to a comprehensive healthcare approach.

An exchange of knowledge with these practitioners unveils a treasure trove of indigenous wisdom, offering alternative or complementary treatments to conventional medical interventions (Allen et al., 2020).

This collaborative approach is not merely about coexistence but about mutual respect and recognition. Training programs emphasize cultural sensitivity, highlighting the expertise of local healers as indispensable contributors to healthcare systems. Joint research initiatives involving farmers, healers, and scientists explore the efficacy and safety of traditional remedies, potentially integrating them into mainstream healthcare. As we navigate this intersection of tradition and modernity, ethical considerations guide the process. Training programs address crucial ethical aspects such as informed consent, responsible sourcing of ingredients, and potential interactions with conventional medications. This ensures the safety of patients and upholds ethical standards in the practice of traditional healing. (Lampiao et al., 2019)

By promoting collaboration and knowledge exchange, this chapter envisions a symbiotic relationship where farmers gain skills contributing to sustainable practices and local healers' wisdom is acknowledged and preserved. This collaborative approach leads to a more inclusive and effective healthcare system, particularly beneficial for communities with limited access to conventional options.

Strategies applied in Training Sessions

The implementation of effective strategies is paramount in realizing the goals of training farmers for organic agriculture and fostering collaboration with local healers.

Training of Farmers

In the agricultural domain, the emphasis on sustainable practices necessitates a strategic approach to equip farmers with the knowledge and skills essential for optimal soil quality and organic farming. Key strategies include soil quality testing, tailored training programs covering diverse organic and regenerative farming techniques, practical demonstrations, usage of biofertilizers, and interactive sessions.

Training and Knowledge Exchange with Traditional Healers

In the realm of healthcare, strategies are essential for facilitating an exchange of knowledge between modern medicine and traditional healing practices. Recognizing the profound insights of local healers, strategies involve building mutual respect and know-how of medicinal plant cultivation through cultural sensitivity in training programs.

Outcomes of the Training Sessions

The detailed outcomes of the training program according to the states are given below.

01



10
Manpower Involved

02



130
Farmers

03



12
Local Hearler

04



7
Training Sessions

05



16
Hours of Training Program



UTTARAKHAND

A series of studies in Uttarakhand, India have explored the awareness, beliefs, and practices of farmers about organic farming. (Pandey & Singh 2012) found that while farmers were generally aware of organic farming, they lacked knowledge about certification and standards. (Bodapti & Chander 2013) highlighted the importance of integrating indigenous knowledge and practices with organic farming, particularly in the management of livestock and the use of renewable resources. (Panneerselvam et al., 2011) identified barriers to conversion to organic farming, including lack of knowledge and institutional support, but also noted the potential benefits, such as reduced input costs and increased income. Galvin (2014) further emphasized the role of human agencies in organic agriculture, particularly in the context of state initiatives and smallholder farmers. These studies collectively underscore the need for targeted education and support to enhance the adoption and success of organic farming in Uttarakhand.

Uttarakhand, also known as the "Herbal State", has a rich history of traditional medicine and medicinal plants. The traditional healthcare system in the region consists of two systems: the folk stream and the classical stream. The folk stream is based on oral tradition and is practiced by local villagers and tribal communities.

Uttarakhand has a limited number of medical facilities. Due to a lack of modern health facilities, poverty, and other factors, people in rural and hilly areas still rely on traditional medicines for their health care. A study in the Urgam Valley of Uttarakhand found that 51 species from 31 families are used for local health care. According to the State Medicinal Board, Uttarakhand, and the National Medicinal Plant Board, India, 1,642 medicinal plants from 177 families and 869 genera have been reported from the state. (Singh et al., 2019)

Details about training sessions

As per the objective of the project, the training of farmers regarding organic farming practices and medicinal plant cultivation practices is under mandate. Along with this, the interaction and exchange of knowledge of traditional herbs with traditional healers were associated with this. Apart from that, associated Yoga training was also performed. The details of the training sessions are shown in Table 2.1.

Table 2.1 Details of Training conducted in Uttarakhand.

Area	Number of Training	Training location Name	Date of the training	Duration in Hours	Number of Farmers obtained training	Number of Healers who interacted/ obtained training
Haridwar-Rishikesh	2	Alawalpur (Laxsar),	09/05/2023	2.5	23	1
		Mala, Yamkeshwar Block	10/05/2023	2.5	29	0
Devprayag	1	-Tunagi	14/05/2023	2.0	25	0
Uttarkashi	3	Sangrali	16/05/2023	2.0	17	4
		Gyansu,	16/05/2023	2.0	11	0
		Raithal, Bhatwari	17/05/2023	2.0	14	0
Gangotri-Gomukh	1	Purali	18/05/2023	3.0	19	7
Total	**7**			**16**	**138**	**12**

Spanning the regions of Haridwar-Rishikesh, Devprayag, Uttarkashi, and Gangotri-Gomukh in Uttarakhand, the training survey comprised 16 sessions, totaling 16 hours, dedicated to imparting knowledge and skills to farmers and healers. In the Haridwar-Rishikesh region, the Alawalpur session on 09/05/2023, lasting 2.5 hours, facilitated the training of 23 farmers (representing 71.88% of participants) and 1 healer (8.33% of participants). Subsequently, the Mala session on 10/05/2023, with a duration of approximately 2.5 hours, saw the complete participation of 29 farmers (100% of participants). Transitioning to Devprayag, the Tunagi session on 14/05/2023, lasting 2.0 hours, achieved full participation with 25 farmers (100% of participants) and no healers. In Uttarkashi, three sessions were conducted: Sangrali on 16/05/2023, involving 17 farmers (100% of participants) and 4 healers (36.36% of participants), Gyansu on 16/05/2023, with 11 farmers (100% of participants) and no healers, and Raithal on 17/05/2023, training 14 farmers (100% of participants) with no healer participation. The Gangotri-Gomukh session in Purali on 18/05/2023, lasting 3.0 hours, successfully trained 19 farmers (100% of participants) and 7 healers (100% of participants). Overall, across all sessions, a total of 138 farmers (92% of the total participants) and 12 healers (28.57% of participants) received valuable training. The diverse array of sessions and their durations underscore the adaptability of the training program to cater to the specific needs of each region, contributing significantly to

the agricultural and healing practices' overall development in the surveyed areas.

Noteworthy is the significant healer participation in the Gangotri-Gomukh session, indicating a keen interest from the healer community. The varied locations and durations of the training sessions highlight the adaptability of the program to the specific needs of each region, contributing to the overall agricultural and healing development in the surveyed areas.


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01
10
Manpower Involved

02
152
Farmers

03
07
Local Hearler

04
12
Training Sessions

05
25
Hours of Training Program

WEST UTTAR PRADESH

Due to the extensive geographical area of the state of Uttar Pradesh, the training sessions have been conducted by two different groups of scientists. First, the West Uttar Pradesh region has been detailed.

The knowledge and popularity of organic farming among farmers in Uttar Pradesh seem to be mixed. While the state is known for conventional farming of economic crops like sugarcane, rice, wheat, pulses, and potatoes, there are also examples of progressive farmers transitioning to organic farming, such as Colonel K.C. Mishra in Basti district (Chaudhary, 2023). India has been making significant strides in organic farming, with the highest number of organic farmers in the world and a substantial increase in organic agriculture land under cultivation (Invest India, 2019). Additionally, there are initiatives at the government level, such as the Galvanizing Organic Bio-Agro Resources Dhan (GOBARdhan) scheme, to encourage farmers to use organic fertilizers (Domains, 2018). However, a composite analysis based on an organic index ranks Uttar Pradesh 19th in terms of the progress of organic farming in Indian states (Koner & Laha, 2023). This suggests that while there is some presence of organic farming in the state, it may not be as widespread as in some other parts of the country.

The state of Uttar Pradesh in India has a rich tradition of ethnomedicinal healers who practice traditional medicine and use folk remedies for various ailments (Singh & Singh, 2009). While the specific details about ethnomedicinal healers in Uttar Pradesh are not directly available in the provided search results, it is evident that India has a long history of traditional medicine, with Ayurveda being the most representative system (Shi et al., 2021). The World Health Organization has also established the Global Centre for Traditional Medicine in India, reflecting the country's commitment to harnessing the potential of traditional medicine through modern science (World 2022). Therefore, it can be inferred that ethnomedicinal healers and traditional healing practices are an integral part of India's cultural and healthcare heritage, including in the state of Uttar Pradesh.

West Uttar Pradesh

The Details of Training conducted in West Uttar Pradesh are shown in Table 2.2.

Table 2.2 Details of Training conducted in West Uttar Pradesh.

Area	Number of Training organized in each site of the survey	Training location Name	Date	Duration in Hours	Farmers	Healers
Bijnor	2	Jahanabad	04-04-2023	2	8	0
Bulandshahr / Narora	1	Anupshahr	04-02-2023	2	8	1
Farrukhabad	2	Balipatti Rani Gaon, Amritpur, Farrukhabad	26-03-2023	2	18	0
		Nagriya Jawahar, Rajepur, Farrukhabad	27-03-2023	2.5	21	0
Budaun	2	Bhagirath Ghat, Kachhla, Budaun	29-03-2023	2	1	0
		Nagar Panchayat Bhavan, Kachhla, Budaun	29-03-2023	3	29	0
Kanpur / Bithoor	5	Arogyadham, Bithoor, Kanpur	23-03-2023	2	1	0
		Ramel Nagar, Bithoor, Kanpur	23-03-2023	3	26	6
		Tulsi Arogya Kendra, Jajmau, Kanpur	24-03-2023	2	3	0
		Dhanvantari Sewa Samiti, Kanpur East, Kanpur	24-03-2023	1	6	0
		Sanjati Badshahpur, Village Kanpur Nagar, Kanpur	25-03-2023	3.5	31	0
Total	**12**			**25**	**152**	**7**

In Bijnor, two training sessions were organized in Jahanabad on 04-04-2023, each lasting 2 hours, resulting in the training of 8 farmers with no healer participation. In Bulandshahr/ Narora, a session in Anupshahr on 04-02-2023, lasting 2 hours, trained 8 farmers and 1 healer. In Farrukhabad, two sessions were conducted at Balipatti Rani Gaon, Amritpur, Farrukhabad, on 26-03-2023 (2 hours, training 18 farmers with no healers), and Nagriya Jawahar, Rajepur, Farrukhabad, on 27-03-2023 (2.5 hours, training 21 farmers with no healers). Budaun saw two sessions at Bhagirath Ghat, Kachhla, Budaun, on 29-03-2023 (2 hours, training 1 farmer with no healers), and Nagar Panchayat Bhavan, Kachhla, Budaun, on 29-03-2023 (3 hours, training 29 farmers with no healers). In Kanpur/ Bithoor, five sessions were organized at Arogyadham, Bithoor, Kanpur, on 23-03-2023 (2 hours, training 1 farmer with no healers), Ramel Nagar, Bithoor, Kanpur, on 23-03-2023 (3 hours, training 26 farmers and 6 healers), Tulsi Arogya Kendra, Jajmau, Kanpur, on 24-03-2023 (2 hours, training 3 farmers with no healers), Dhanvantari Sewa Samiti, Kanpur East, Kanpur, on 24-03-2023 (1 hour, training 6 farmers with no healers), and Sanjati Badshahpur, Village Kanpur Nagar, Kanpur, on 25-03-2023 (3.5 hours, training 31 farmers with no healers). In total, across all sessions, 25 farmers were trained, along with 7 healers, constituting 100% and 46.67% of the total participants, respectively.


Amirabad Bamiari, Uttar Pradesh, India
Unnamed Road, Amirabad Bamiari, Uttar Pradesh 209621, India
Lat 27.466426° Long 79.63811°
27/03/23 12:07:14 PM
GPS Map Camera
Kanpur, Uttar Pradesh, India
H7V8+5RW, Mandhana-Bithoor Rd, Ramel Nagar, Bithoor, Kanpur, Uttar Pradesh 209201, India
Lat 26.593079°
Long 80.267169°
23/03/23 03:56 PM GMT +05:30
GPS Map Camera
Kanpur, Uttar Pradesh, India
H7V8+5RW, Mandhana-Bithoor Rd, Ramel Nagar, Bithoor, Kanpur, Uttar Pradesh 209201, India
Lat 26.593108°
Long 80.267119°
23/03/23 04:39 PM GMT +05:30
नमामि गंगे योजना के अंतर्गत
GPS Map Camera
Kanpur, Uttar Pradesh, India
H7V8+5RW, Mandhana-Bithoor Rd, Ramel Nagar, Bithoor, Kanpur, Uttar Pradesh 209201, India
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Long 80.267178°
23/03/23 04:19 PM GMT +05:30
महात्मा गांधी
GPS Map Camera
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GHGW+4V4, Farrukhabad, Uttar Pradesh 209622, India
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Long 79.596763°
26/03/23 02:06 PM GMT +05:30
Amirabad Bamiari, Uttar Pradesh, India
Unnamed Road, Amirabad Bamiari, Uttar Pradesh 209621, India
Lat 27.466641° Long 79.638111°
27/03/23 12:52:22 PM
GPS Map Camera
Farrukhabad, Uttar Pradesh, India
GHGW+4V4, Farrukhabad, Uttar Pradesh 209622, India
Lat 27.525092°
Long 79.596773°
26/03/23 02:22 PM GMT +05:30
Amirabad Bamiari, Uttar Pradesh, India
Unnamed Road, Amirabad Bamiari, Uttar Pradesh 209621, India
Lat 27.466481° Long 79.638285°
27/03/23 02:54:02 PM
GPS Map Cam
Farrukhabad, Uttar Pradesh, India
GHGW+4V4, Farrukhabad, Uttar Pradesh 209622, India
Lat 27.525167°
Long 79.596743°
26/03/23 02:45 PM GMT +05:30
GPS Map Camer
Farrukhabad, Uttar Pradesh, India
GHGW+4V4, Farrukhabad, Uttar Pradesh 209622, India
Lat 27.525154°
Long 79.596755°
26/03/23 02:50 PM GMT +05:30
Pipraul Kham, Uttar Pradesh, India
WVJ5+PJ5, NH 530B, Pipraul Kham, Uttar Pradesh 243636, India
Lat 27.932738° Long 78.860028°
29/03/23 12:45:42 PM
Amirabad Bamiari, Uttar Pradesh, India
Unnamed Road, Amirabad Bamiari, Uttar Pradesh 209621, India
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27/03/23 11:48:41 AM
Kachhla, Uttar Pradesh, India
WVM6+X7, Kachhla, Uttar Pradesh 243636, India
Lat 27.934913° Long 78.860462°
29/03/23 12:28:09 PM
Pipraul Kham, Uttar Pradesh, India
WVG4+C78, SH 33, Pipraul Kham, Uttar Pradesh 243636, India
Lat 27.926914° Long 78.855074°
29/03/23 12:38:44 PM

01

10
Manpower Involved

02

61
Farmers

03

45
Local Hearler

04

06
Training Sessions

05

12
Hours of Training Program



EAST UTTAR PRADESH

The Details of Training conducted in East Uttar Pradesh are shown in Table 2.3.

Table 2.3 Details of Training conducted in East Uttar Pradesh.

Area	Number of Training organized in each site of the survey	Training location Name	Date	Duration in Hours	Farmers	Healers
Raebareli	1	Chhajjoopur	13.3.23	2	10	11
Prayagraj	1	Prayagraj	19.3.23	2	02	07
Mirzapur	2	Vindhyachal, Gopalpur	20.3.23, 21.3.23	2	01	13
Varanasi	1	Narottampur	23.3.23	3	22	07
Ballia	1	Narainpur	24.3.23	3	26	07
Total	**6**			**12**	**61**	**45**

In the comprehensive training survey across various regions, multiple sessions were organized to impart knowledge and skills to farmers and healers. In Raebareli, a singular training session was organized in Chhajjoopur on 13.3.23, encompassing a 2-hour duration. This session facilitated the training of 2 farmers, and notably, 10 healers participated, representing 90.91% of the total participants. Similarly, in Prayagraj, a training session on 19.3.23, spanning 2 hours, resulted in the training of 2 farmers and 7 healers. Moving to Mirzapur, two sessions were conducted in Vindhyachal, Gopalpur, on 20.3.23 and 21.3.23, each lasting 2 hours. The first session trained 1 farmer and 13 healers, while the second session trained an additional 1 farmer. In Varanasi, a training session in Narottampur on 23.3.23, with a duration of 3 hours, registered the training of 22 farmers and 7 healers. Finally, in Ballia, the Narainpur session on 24.3.23, lasting 3 hours, trained 26 farmers and 7 healers. Summing up the results across all sessions, a total of 61 farmers were trained, and 45 healers received valuable training, constituting 73.77% and 77.78% of the total participants, respectively.

These comprehensive findings highlight the varied nature of the sessions, both in terms of duration and participant engagement, emphasizing the adaptability of the training program to cater to the specific needs of each region. Overall, these initiatives contribute significantly to the holistic development of agricultural and healing practices in the surveyed areas.


GPS Map Camera
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33V6+94H, Chhajjoopur, Uttar Pradesh 229207, India
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17/03/2023 12:03 PM GMT +05:30
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313° NW
19.15 21% 115 m 29.0 µT
GPS Map Camera
Prayagraj, Uttar Pradesh, India
CVM6+5M3, Allahabad fort, Prayagraj, Uttar Pradesh 211003, India
Lat N 25° 25' 58.5048" Long E 81° 51' 43.4556"
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20.63° C
91° E
10.26 69% 91 m 20.0 µT
GPS Map Camera
Narainpur, Uttar Pradesh, India
HW7P+CG6, Narainpur, Uttar Pradesh 277501, India
Lat N 25° 33' 45.1476" Long E 83° 56' 12.0588"
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236° SW
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GPS Map Camera
Narainpur, Uttar Pradesh, India
HW7P+CG6, Narainpur, Uttar Pradesh 277501, India
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294° NW
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GPS Map Camera
Chhajjoopur, Uttar Pradesh, India
33V6+94H, Chhajjoopur, Uttar Pradesh 229207, India
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125° SE
19.15 21% 116 m 24.0 µT
GPS Map Camera
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CVM6+5M3, Allahabad fort, Prayagraj, Uttar Pradesh 211003, India
Lat N 25° 25' 58.3284" Long E 81° 51' 43.5096"
19/03/2023 07:28 AM GMT +05:30
Note : Captured by GPS Map Camera
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55° NE
10.26 69% 91 m 37.0 µT
GPS Map Camera
Prayagraj, Uttar Pradesh, India
CVM6+5M3, Allahabad fort, Prayagraj, Uttar Pradesh 211003, India
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Note : Captured by GPS Map Camera
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169° S
10.26 69% 91 m 34.0 µT
GPS Map Camera
Prayagraj, Uttar Pradesh, India
CVM6+5M3, Allahabad fort, Prayagraj, Uttar Pradesh 211003, India
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19/03/2023 07:18 AM GMT +05:30
Note : Captured by GPS Map Camera
20.63° C
101° E
10.26 69% 91 m 21.0 µT
GPS Map Camera
Vindhyachal, Uttar Pradesh, India
5F5G+7Q5, Vindhyachal, Uttar Pradesh 231307, India
Lat N 25° 9' 25.0848" Long E 82° 28' 40.4472"
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Note : Captured by GPS Map Camera
22.69° C
239° SW
17.35 41% 152 m 27.0 µT
GPS Map Camera
Mirzapur, Uttar Pradesh, India
5G3H+FW7, Gopalpur, Mirzapur, Uttar Pradesh 231307, India
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21/03/2023 09:31 AM GMT +05:30
Note : Captured by GPS Map Camera
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GPS Map Camera
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5RVX+35V, Narottmpur, Uttar Pradesh 221305, India
Lat N 25° 11' 33.7992" Long E 82° 50' 51.9468"
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Note : Captured by GPS Map Camera
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GPS Map Camera
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GPS Map Camera
Narainpur, Uttar Pradesh, India
HW7P+CG6, Narainpur, Uttar Pradesh 277501, India
Lat N 25° 33' 45.7452" Long E 83° 56' 11.0184"
24/03/2023 02:12 PM GMT +05:30
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GPS Map Camera
Narottmpur, Uttar Pradesh, India
5RVX+35V, Narottmpur, Uttar Pradesh 221305, India
Lat N 25° 11' 33.9792" Long E 82° 50' 52.2276"
23/03/2023 07:11 AM GMT +05:30
Note : Captured by GPS Map Camera
17.99° C
225° SW
8.75 48% 82 m 31.0 µT



01

09
Manpower Involved

02

93
Farmers

03

12
Local Hearler

04

09
Training Sessions

05

7.25
Hours of Training Program

BIHAR-JHARKHAND

A single team of qualified individuals conducted the training sessions that were arranged across Jharkhand and Bihar. Consequently, it was reported as a group.

Several studies have been conducted to assess the knowledge, attitude, and practices of farmers towards organic farming in the Bihar and Jharkhand regions. A study in Jharkhand found that tribal farmers have a positive perception of organic farming (Pandey et al., 2022). However, it is also noted that farmers' knowledge of organic farming needs to be enhanced, suggesting that there is room for improvement in this area (Awareness of Farmers towards Organic Farming 2021). Furthermore, indigenous communities in Jharkhand have shown resistance to the introduction of genetically modified seeds, indicating a preference for traditional and organic farming practices (CEED, 2023). These findings suggest that while there is a positive trend towards organic farming in the region, there is also a need for further education and awareness among farmers.

The distribution of local healers of ethnomedicinal knowledge in Bihar and Jharkhand is primarily found among the tribal communities in these regions. Traditional medicinal practitioners, often referred to as healers, play a significant role in preserving and passing on ethnomedicinal knowledge. In Jharkhand, for example, about 32 tribal communities are known to commonly use medicinal plants based on their traditional knowledge (Anand 2019). The practice of ethnomedicine in these areas is often a group-based activity, involving the entire village in the process of gathering materials and preparing remedies, with the main healer leading the healing process (Chaudhuri et al., 2020). The ethnomedicinal formulations used by the tribes in Jharkhand comprise a wide variety of plant species, reflecting the rich traditional knowledge of the local healers (Tomar et al., 2012). The preservation of this knowledge is considered crucial, and there are efforts to document the ethnomedical practices for future generations (Chaudhuri et al., 2020). Local traditional herbal practitioners and Vaidhyas are among the key sources of ethnomedicinal knowledge in these regions (Sahu et al., 2024).

Details about training sessions

The Details of Training conducted in Bihar & Jharkhand are shown in Table 2.4.

Table 2.4 Details of Training Conducted in Bihar & Jharkhand

Area	Number of Training organized in each site of the survey	Training location Name	Date	Duration in Hours	Farmers	Healers
Revelganj	01	Chapra	20-03-2023	01	07	02
Patna	01	Patna	18-03-2023	0.5	06	01
Barh	02	Barh and Krishi Vigyan Kendra (Barh)	23-03-2023 24-03-2023	1.3	37	02
Bahachauki	01	Munger	28-03-2023	1	03	02
Farka	03	Farka, Kurpat and Mahadatpur	29-03-2023 30-03-2023 31-03-2023	0.5 1.15 1.30	29	03
Sahibganj (Jharkhand)	01	Sahibganj	26-03-2023	0.5	11	02
Total	**09**			**7.25**	**93**	**12**

In the comprehensive training survey across various regions, multiple sessions were organized to impart knowledge and skills to farmers and healers. In Revelganj, Bihar a single training session was organized in Chapra on 20-03-2023, lasting 1 hour, resulting in the training of 7 farmers and 2 healers. Moving to Patna, a session on 18-03-2023, with a brief duration of 0.5 hours, trained 6 farmers and 1 healer. In Barh, two sessions were conducted at Barh and Krishi Vigyan Kendra (Barh) on 23-03-2023 and 24-03-2023, with durations of 1.3 hours each. These sessions collectively trained 37 farmers and 2 healers. Bahachauki, in Munger, hosted a training session on 28-03-2023, lasting 1 hour, training 3 farmers and 2 healers. In Farka, three sessions were organized on 29-03-2023, 30-03-2023, and 31-03-2023, with durations of 0.5, 1.15, and 1.30 hours, respectively. These sessions collectively trained 29 farmers and 3 healers. On March 26, 2023, Sahibganj in Jharkhand logged a training session that lasted roughly 0.5 hours and trained 2 healers and 11 farmers. In total, across all sessions, 93 farmers were trained, along with 12 healers, respectively. The cumulative duration of all sessions was 7.25 hours.

The diverse range of sessions and durations, coupled with the high percentage of participant engagement, illustrates the adaptability and effectiveness of the training program in addressing the specific needs of each region. Overall, these initiatives significantly contribute to the comprehensive development of agricultural and healing practices in the surveyed areas.


GPS Map Camera
Sahibganj, Jharkhand, India
6JVM+VJH, Talkies Field Rd, Sahibganj,
Jharkhand 816109, India
Lat 25.245119°
Long 87.633757°
26/03/23 07:30 AM GMT +05:30
Google

01



10
Manpower Involved

02



105
Farmers

03



06
Local Hearler

04



08
Training Sessions

05



20
Hours of Training Program



WEST BENGAL

Training in organic farming is of great importance to farmers in India due to the potential benefits it offers in terms of sustainable agriculture, environmental friendliness, and soil health.

Organic farming is gaining popularity in West Bengal, India. Many people have become health-conscious and are aware of the negative effects of hybrid farming and other such methods, which affect the food that we consume. Due to this, many organic food startups have grown up in Bengal (GetBengal, 2023). With the help of organic farming, some entrepreneurs are getting involved in the field of new-age natural agriculture. Bengal has witnessed considerable growth in the organic food business to become the second largest in India. However, despite widespread awareness of the potential environmental degradation and climatic change, most farmers in the Gangetic Delta region still produce their crops inorganically. A study on North 24 Parganas, West Bengal, showed that conventional farmers have a mixed attitude toward organic farming. Lack of infrastructure and logistical supply chain support hampers the scaling-up process of organic farming in far-off villages, while in near-city organic farming, lack of land, pressure of commercialization, and industrialization prove a constant threat to its scaling up. The West Bengal government has taken initiatives to promote organic farming in the state (Ghosh & Ghosh, 2023).

The state of West Bengal in India is rich in traditional medicinal knowledge and practices. Several studies have documented the use of ethnomedicinal plants by tribal communities and traditional healers in the region. For example, an ethnobotanical survey in Paschim Medinipur district documented 20 ethnomedicinal plant species used by tribal communities and medicinal healers, with a high degree of informant consensus for each species (Sarkhel, 2014). Another study emphasized the indigenous knowledge of native tribes in the Malda district on the utilization of wild plant species for local healthcare, with a focus on the expertise of aged knowledgeable healers (Saha et al., 2014). Additionally, West Bengal is known for its rich floral biodiversity and the high occurrence of medicinal plants used in traditional medicine (Vineeta et al., 2022). These studies highlight the significant role of traditional healers and indigenous knowledge in the healthcare practices of West Bengal.

Details about training sessions

The Details of Training conducted in West Bengal are shown in Table 2.5.

Table 2.5 Details of Training Conducted in West Bengal

Area	Number of Training organized in each site of the survey	Training location Name	Date	Duration in Hours	Farmers	Healers
Farakka	01	Zafar Ganj	25.03.2023	03	20	1
Hazarduwari/Malda	03	Hazardwari	26.03.2023	05	45	1
Hoogley/ Nadia	01	Bhatpara	23.03.2023	02	6	2
Diamond Harbour/ Ganganagar	03	Suza Pur	27.03.2023	02	10	1
		Rajapur Mahula	29.03.2023	02	15	0
		Rabindranagar	03.04.2023	02	03	0
		Gangasagar	**03.04.2023**	**02**	03	0
		Kakdweep	04.04.2023	2	3	1
		Total		**20**	**105**	**6**

Farmers and healers were the target audience for several training sessions that were held as part of the extensive training survey conducted in different regions. Twenty farmers and one healer in Farakka were trained during a three-hour session that took place in Zafar Ganj on March 25, 2023. Three sessions were held in Hazarduwari/Malda. The first session, held on March 26, 2023, in Hazardwari, lasted for five hours and trained forty-five farmers and one healer. In Hoogley/Nadia, a single, two-hour session on March 23, 2023, in Bhatpara instructed six farmers and two healers. Three sessions were held in the Diamond Harbour/ Gangasagar region: two hours each on March 27, 2023, in Suza Pur (training 10 farmers and 1 healer); two hours each on March 29, 2023, in Rajapur Mahula (training 15 farmers); and two hours each on April 3, 2023, in Rabindranagar (training 3 farmers). There was also a session at Gangasagar on April 3, 2023. (2 hours, training 3 farmers). On April 4, 2023, Kakdweep held a two-hour training session for three farmers and one healer. In all, 105 farmers and 6 healers received valuable training throughout the sessions, signifying 100% participation from both groups. The overall training time of 20 hours is reflected in the cumulative results. The training program's adaptability and efficacy are demonstrated by the wide range of sessions and participant numbers, which have greatly aided in the comprehensive development of agricultural and therapeutic practices in the assessed areas.


GPS Map Camera
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QW5C+9X9, Jafar Ganj, West Bengal 742236, India
Lat 24.758815° Long 87.922514°
25/03/23 05:51 PM GMT +05:30
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45° NE
7.92 m
28 m
Google
GPS Map Camera
Jafar Ganj, West Bengal, India
QW5C+9X9, Jafar Ganj, West Bengal 742236, India
Lat 24.758789° Long 87.922402°
25/03/23 06:02 PM GMT +05:30
33.34° C
328° NW
5.03 m
28 m
Google
GPS Map Camera
Rajapur, West Bengal, India
X6VH+GC5, Rajapur, West Bengal 742134, India
Lat 23.992951° Long 88.228444°
29/03/23 11:04 AM GMT +05:30
34.06° C
325° NW
8.55 m
18 m
Google
MG TRAVELS
GPS Map Camera
Mahula, West Bengal, India
X6WC+FM5, Rajapur, Mahula, West Bengal 742134, India
Lat 23.996939° Long 88.221621°
29/03/23 12:30 PM GMT +05:30
34.06° C
190° S
3.05 m
14 m
Google
GPS Map Camera
Gangasagar, West Bengal, India
J3PG+V4, Gangasagar, West Bengal 743373, India
Lat 21.637223° Long 88.07532°
03/04/23 06:46 PM GMT +05:30
31.45° C
268° W
26.14 m
5 m
Google
GPS Map Camera
Diamond Harbour, West Bengal, India
55HV+9WR, Rabindra Nagar, Diamond Harbour, West Bengal 743331, India
Lat 22.178247° Long 88.194747°
03/04/23 09:15 AM GMT +05:30
31.67° C
349° N
6.19 m
0 m
Google
MG TRAVELS

Comparative Study

The comparative study of the training sessions organized in the 5 said states has been summarized in Fig.2.1

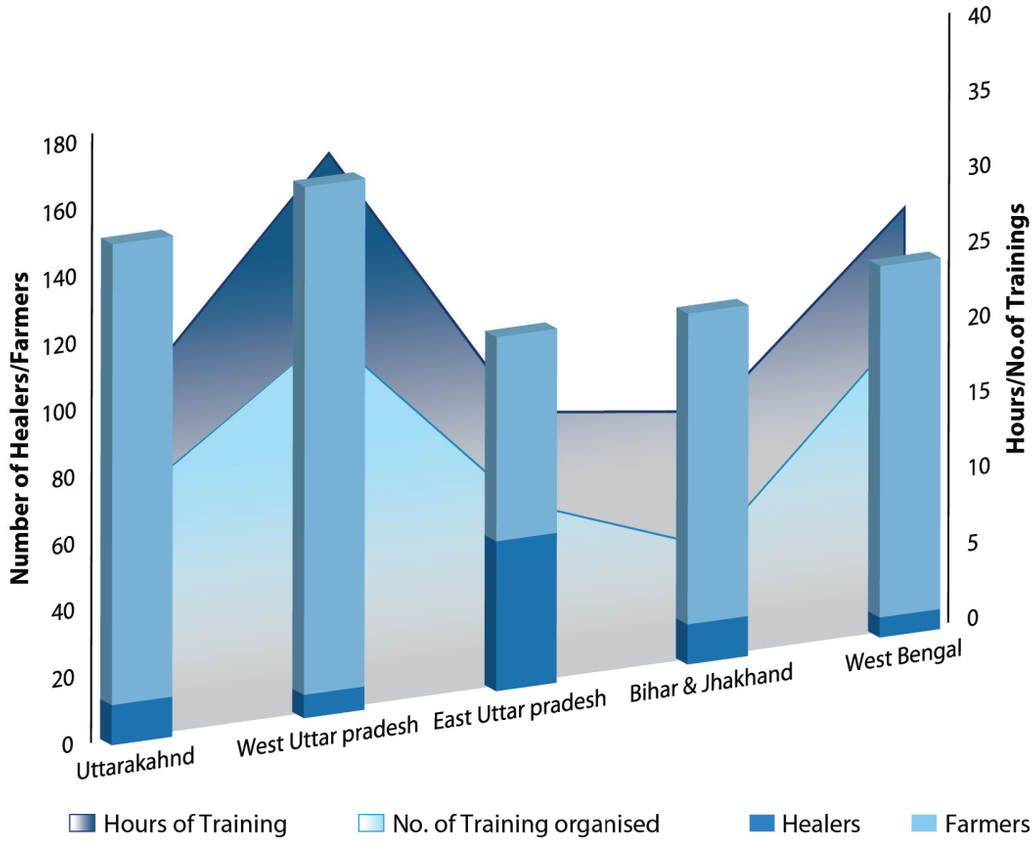


Fig. 2.1 Comparative analysis of the training session organized.

In Uttarakhand, the training initiative achieved a balanced ratio, with 12 healers and 138 farmers trained during 7 sessions over 16 hours. This reflects a ratio of approximately 1:11, emphasizing an inclusive approach to ensure both healers and farmers benefit from the training program. The high farmer-to-healer ratio indicates a primary focus on agricultural practices while acknowledging the importance of integrating traditional healing methods.

West Uttar Pradesh, with 12 training sessions, achieved a ratio of 1:21 between the 7 trained healers and 152 farmers. This emphasizes a farmer-centric approach, suggesting a concerted effort to enhance agricultural practices in the region. The relatively low healer-to-farmer ratio may indicate a prioritization of modern farming techniques over traditional healing practices. In East Uttar Pradesh, the training program resulted in a healer-to-farmer ratio of approximately 1:1.4, reflecting a substantial focus on engaging healers. This suggests a recognition

of the significance of traditional healing practices, potentially contributing to the preservation of cultural heritage alongside agricultural development.

Bihar & Jharkhand, with a ratio of 1:7.75 between the 12 trained healers and 93 farmers, signifies a balanced approach to training. This indicates an effort to integrate traditional healing practices with modern agricultural techniques, fostering a more holistic and inclusive development strategy.

West Bengal, with 6 trained healers and 105 farmers during 8 training sessions, achieved a ratio of approximately 1:17.5. This suggests a concerted effort to balance the engagement of healers and farmers, acknowledging the importance of both perspectives in the context of sustainable agriculture and well-being.

These ratio values provide additional insights into the distribution of training efforts, emphasizing the strategic approach each region takes in balancing the training between healers and farmers. Achieving an optimal balance ensures a holistic and inclusive development strategy, acknowledging the symbiotic relationship between modern agricultural practices and traditional healing methods. Overall, the results across these regions underscore the importance of targeted and adaptable training programs tailored to regional contexts. The implications include potential improvements in agricultural practices, preservation of traditional healing methods, and overall community development, contributing to the broader goals of sustainable agriculture and holistic well-being.

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Section-III

Phyto Diversity Analysis



Plant diversity, an intricate tapestry woven by countless species across various ecosystems, is a critical determinant of ecological health and resilience. Defined as the variety of plant species within a specific geographical area, plant diversity encompasses genetic, species, and ecosystem diversity, each layer contributing to the intricate web of life. Understanding the intricacies of plant diversity requires the application of diverse methodologies, ranging from traditional taxonomic surveys to cutting-edge molecular techniques and ecological assessments.

Taxonomic surveys represent the bedrock of plant diversity studies, relying on the fundamental principles of botany. Field biologists embark on expeditions armed with keen observational skills and collection tools, documenting the rich tapestry of plant life. The morphological characteristics of plants, including leaf shapes, flower structures, and growth habits, serve as the basis for identification and classification. This meticulous process, often involving skilled taxonomists, contributes to the creation of comprehensive species lists and guides our understanding of the distribution of plant life within a given region (Chandra 2021).

In India, the Ganga basin is great reservoir of biodiversity, species richness, and distinctiveness that interest people from different parts of the earth. From ancient times, plant communities have been a key source of interest for investigators. The biodiversity depends on altitude, climate, and the Ganga water for sustenance, controlling soil erosion along the Ganga banks (Sati, 2021). The Ganga Basin comprises a total of 8,51,675 km^2 forest area, out of which, dense forest covers 5.6%, open forest covers 0.25%, mangrove covers 13.25%, scrub covers 4.61%, and non-forest covers 85.6% (FSI, 1995). In the Upper Ganga basin, the floral diversity is high in alpine meadows from the source of the Ganga up to Rishikesh. Below the alpine meadows dense coniferous forests deodar, spruce, cedar, and fir grow with rich diversity. In the Lower Ganga Basin, white siris, cotton trees, duabanga, and sterculia grow. Sundarbans, in the Ganges Delta, is the largest estuarine forest in the world. Moist deciduous forests are found in the Lower Gangetic Plains, which covers tropical and subtropical moist broadleaf forests eco-region (Sati, 2020).

Economically, the plant diversity of the Ganga Basin holds immense potential. Many plant species in the region have economic value, either through traditional uses

by local communities or through the development of new products. Non-timber forest products, medicinal plants, and traditional handicraft materials are just a few examples of the economic opportunities tied to the basin's plant diversity. Sustainable harvesting practices, informed by a thorough understanding of plant ecology, can ensure the long-term viability of these resources. Culturally, the Ganga River is deeply intertwined with the religious and cultural fabric of India. The flora along its banks holds profound significance in religious rituals and practices. Studying plant diversity in this context provides not only a scientific understanding of the species present but also a cultural appreciation of the intricate relationships between people and plants. Preserving this diversity becomes not just an ecological imperative but a cultural responsibility, ensuring the continuity of age-old traditions and practices. The methods employed to study plant diversity in the Ganga Basin echo the broader approaches used in plant biology (Dey & Adhikari, 2019).

Seasonal variations, flood levels, and species composition due to differing soil types and water supply functions all have a significant impact on the distribution of plant species along the Ganga. There are many different species of medicinal plants in the river basin. The indigenous people have relied on the river for water and therapeutic purposes since ancient times to meet their basic needs.

Material and Methods

A floristic survey along the Ganga River from Gomukh (Uttarakhand) to Gangasagar (West Bengal) was done during the period of March 2023 to May 2024 from 26 sites (Table 3.1).

In the field while collecting the plant, some important information's have been noted carefully in field note book such as morphological characters (plant habit & hight, leaf morphology, inflorescence & arrangement of floral parts, flowers fragrance & colour, fruits morphology, Seed characters, etc.), ecology (habitat & locality), phenology (flowering & fruiting) and GPS coordinates.

The standard procedures were followed for collection and preparation of voucher specimens (Lawrence, 1951; Jain & Rao, 1977). All herbarium specimens prepared in the present study have been deposited at Patanjali Research Foundation Herbarium (PRFH) for future records after their proper identification. Each species was furnished with up-to-date nomenclature with recently accepted name and important synonyms after consulting protologues and different authentic works like revisions and floras. In addition, different websites like Plant of the World Online (POWO), Global Biodiversity Information Facility (GBIF), The International Plant Names Index (IPNI), Germplasm Resources Information Network (GRIN), International Legume Database and Information Service (ILDIS), and Tropicos have also been consulted to update the nomenclature. Each species has been provided correct name and arranged alphabetically under 26 sites.

Table 3.1 The sites selected for the sampling.

Codes	State	Nearby sites	Latitude (°N)	Longitude (°E)	Altitude (m)
S1	Uttarakhand	Gaumukh	30.7983	79.1542	4023
S2		Gangotri	30.9800	78.9300	3415
S3		Uttarkashi	30.7292	78.4428	1158
S4		Devprayag	30.1500	78.6000	830
S5		Haridwar	29.9667	78.1667	314
S6	Uttar Pradesh	Bijnor	29.3700	78.1300	225
S7		Narora	28.1967	78.3814	174
S8		Budaun	28.0500	79.1200	164
S9		Farrukhabad	27.3700	79.6300	151
S10		Bithoor	26.6127	80.2719	126
S11		Dalmau	26.0700	81.0300	115

Codes	State	Nearby sites	Latitude (°N)	Longitude (°E)	Altitude (m)
S12		Prayagraj	25.4500	81.8500	98
S13		Mirzapur	25.1500	82.5800	80
S14		Varanasi	25.3189	83.0128	81
S15		Ballia	25.7625	84.1519	67
S16	Bihar	Revelganj	25.7800	84.6700	52
S17		Patna	25.6100	85.1414	53
S18		Barh	25.4800	85.7200	47
S19		Bahachouki	25.2975	86.3561	55
S20		Farka	25.2287	87.0949	42
S21	Jharkhand	Sahebganj	25.2500	87.6500	16
S22	West Bengal	Farakka Barrage Township	24.8200	87.9000	30
S23		Murshidabad	24.1800	88.2700	18
S24		Mayapur	23.4250	88.3908	11
S25		Hooghly	22.9089	88.3967	9
S26		Gangasagar	22.1910	88.1905	4

Outcome of the study

The present scientific exploration of floral diversity along the Ganga River starts from Gomukh, Uttarakhand to Gangasagar, West Bengal, was done during 2023-2024 in two different seasons as pre-monsoon and post-monsoon. For this study, 26 sites covering five states were selected, namely Uttarakhand (5 sites), Uttar Pradesh (10 sites), Bihar (5 sites), Jharkhand (1 sites), and West Bengal (5 sites). The study recorded total of 1117 species under 660 genera and 152 families (Fig. 3.1).

Where, 1073 species under 633 genera and 138 families of Angiosperms, 12 species under 10 genera and 5 families of Gymnosperm and 32 species under 17 genera and 9 families of Pteridophytes (Fig. 3.2). Poaceae has been the largest family with 132 plants species followed by Fabaceae (105 species), Asteraceae (74 species), Malvaceae (48 species), Lamiaceae (46 species), Cyperaceae (36 species), Solanaceae (28 species), Convolvulaceae (27 species), Rosaceae (27 species), Amaranthaceae (26 species), Euphorbiaceae (26 species), Acanthaceae (25 species), Apocynaceae (25 species), Moraceae (20 species), Cucurbitaceae (17 species), Rubiaceae (17 species), Polygonaceae (14

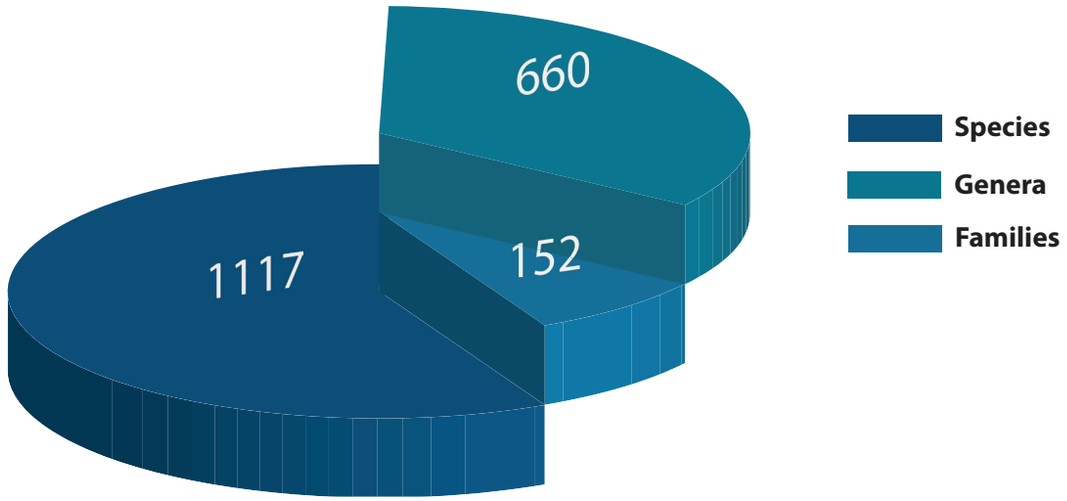


Fig. 3.1 Distribution of species, genera and families

species), Brassicaceae (12 species), Apiaceae (11 species), Urticaceae (11 species), Plantaginaceae (10 species).

Among all these families, some dominated families are represented in Fig 3.3. Out of 1117 species, 603 species of herbs, 190 species of trees, 219 species of shrubs, 94 species of climbers, 5 species of epiphyte, and 6 species of lianas (Fig. 3.4).

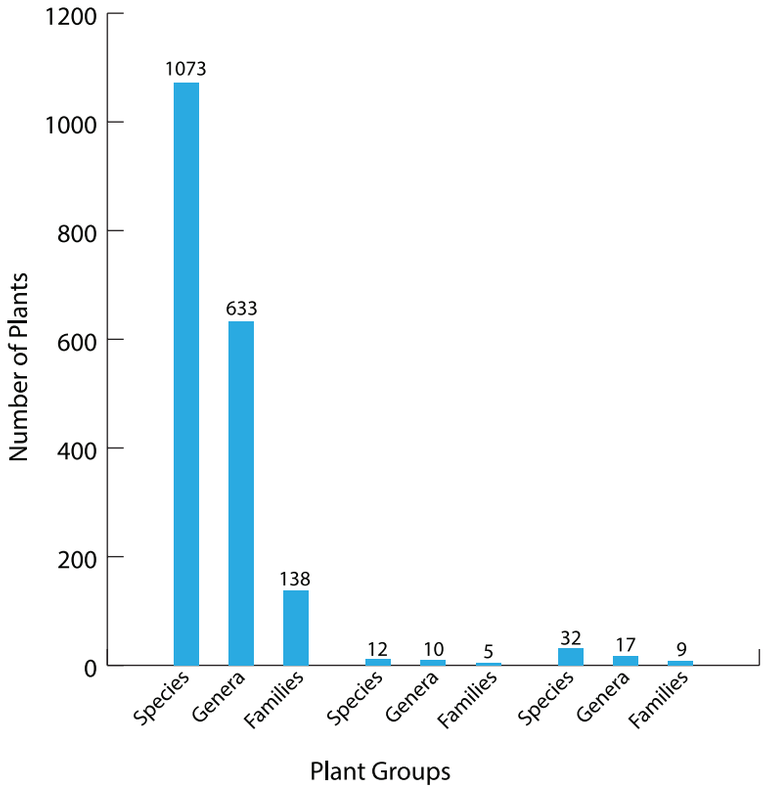


Fig. 3.2 Distribution of species under plant groups.

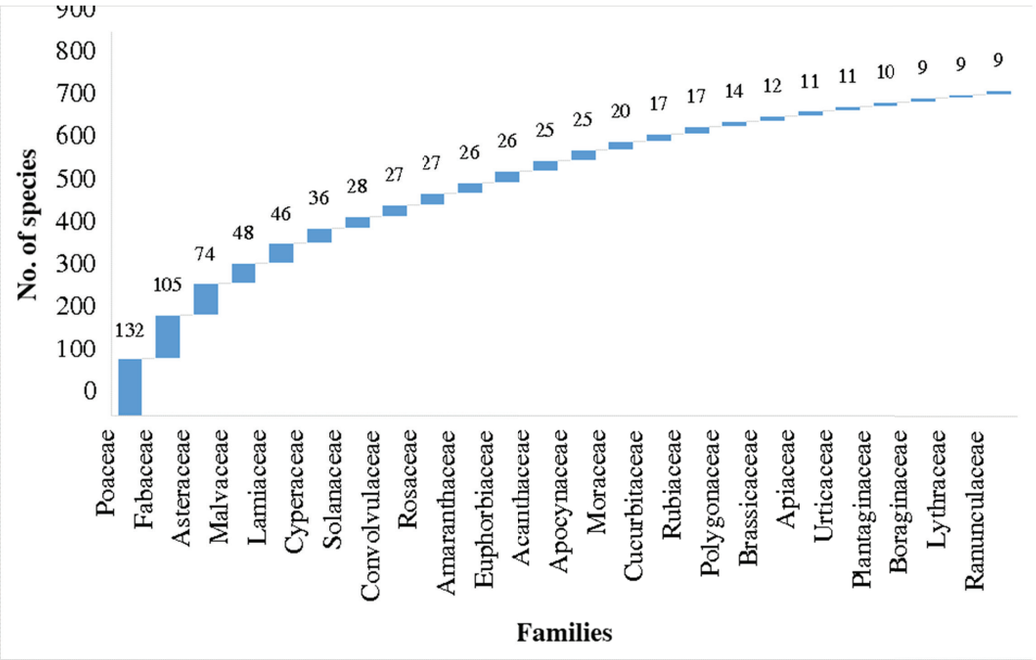


Fig. 3.3 Distribution of species under families.

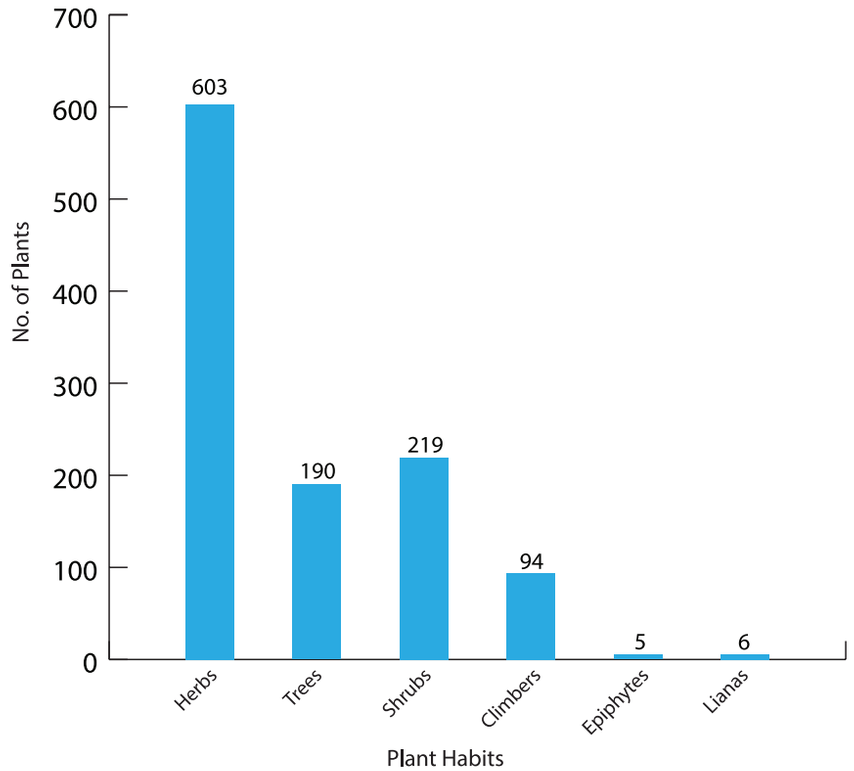


Fig. 3.4 Distribution of species under different habits.

The distribution of plant diversity according to the surveyed states has been given below.



01
5
Sites

02
637
Species

03
112
Families

04
607
Angiosperms

05
73
Poaceae

UTTARAKHAND

The plant diversity of 5 sites of Uttarakhand reveals a total of 112 families, contributing to a total of 637 species. Among the families, Poaceae is the dominant, constituting 73 species followed by Fabaceae (60 species), Asteraceae (37 species) and distribution of species under 20 leading families are shown in Fig. 3.5. Angiosperms comprising 607 species, and Pteridophytes exhibit a comparatively lower count, with 22 species. Among the identified habitats, herbaceous plants dominate with a total of 338 species. Trees (107 species), shrubs (86 species), climbers (50 species), undershrubs (46 species), aquatic and woody herbs (7 species) showcase varied representation.

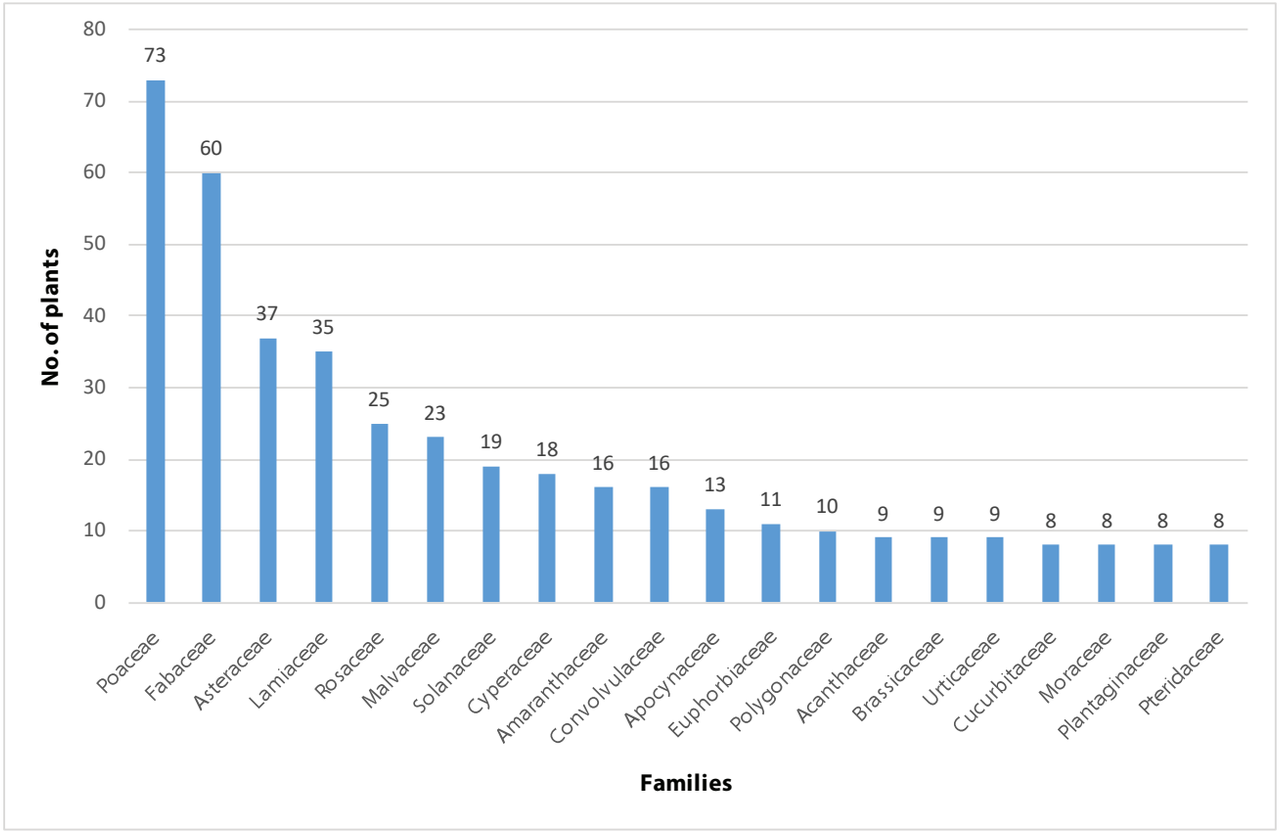
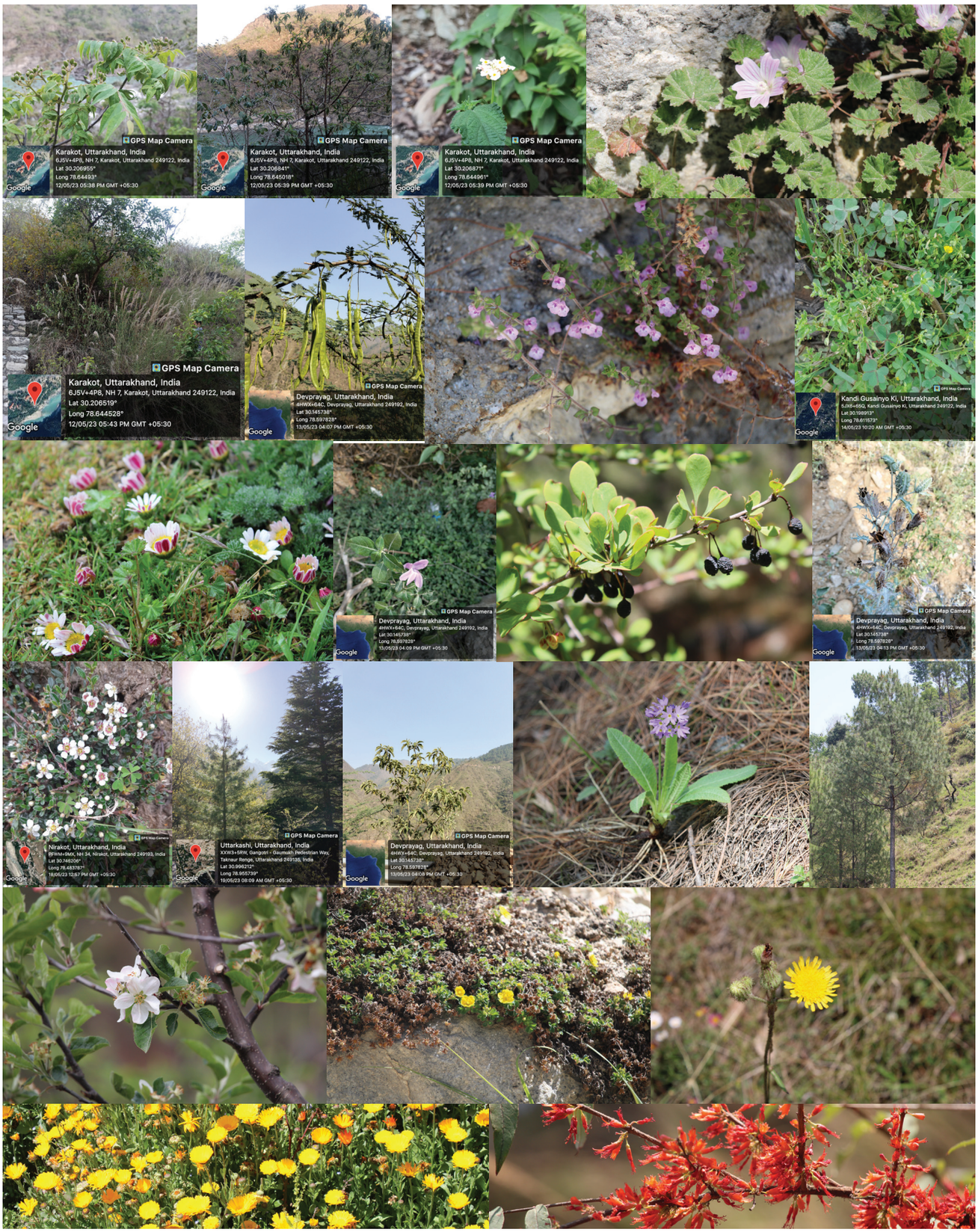


Fig. 3.5 Distribution of species under families.


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Long 78.645018°
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01

5
Sites

02

536
Spedes

03

94
Families

04

525
Angiosperms

05

66
Fabaceae



UTTAR PRADESH

The study recorded total 536 species under 94 families. Among the families, Fabaceae emerges as the most prevalent with 49 species. Fabaceae accounts for 66 species, Poaceae stands as the second dominant family with 55 species. Asteraceae and Malvaceae constituting 40 and 30 species. Distribution of species under 20 leading families are shown in Fig. 3.6. Angiosperms dominate the distribution with a significant count of 525 species. In contrast, Gymnosperms and Pteridophytes exhibit 4 and 7 species respectively. Herb is the dominant habitat group, with a substantial count of 277 species. Shrubs represents 58 species, Trees also demonstrate a significant presence, with 102 species. Climbers, undershrubs, and aquatic herbs with 50, 37, and 8 species respectively.

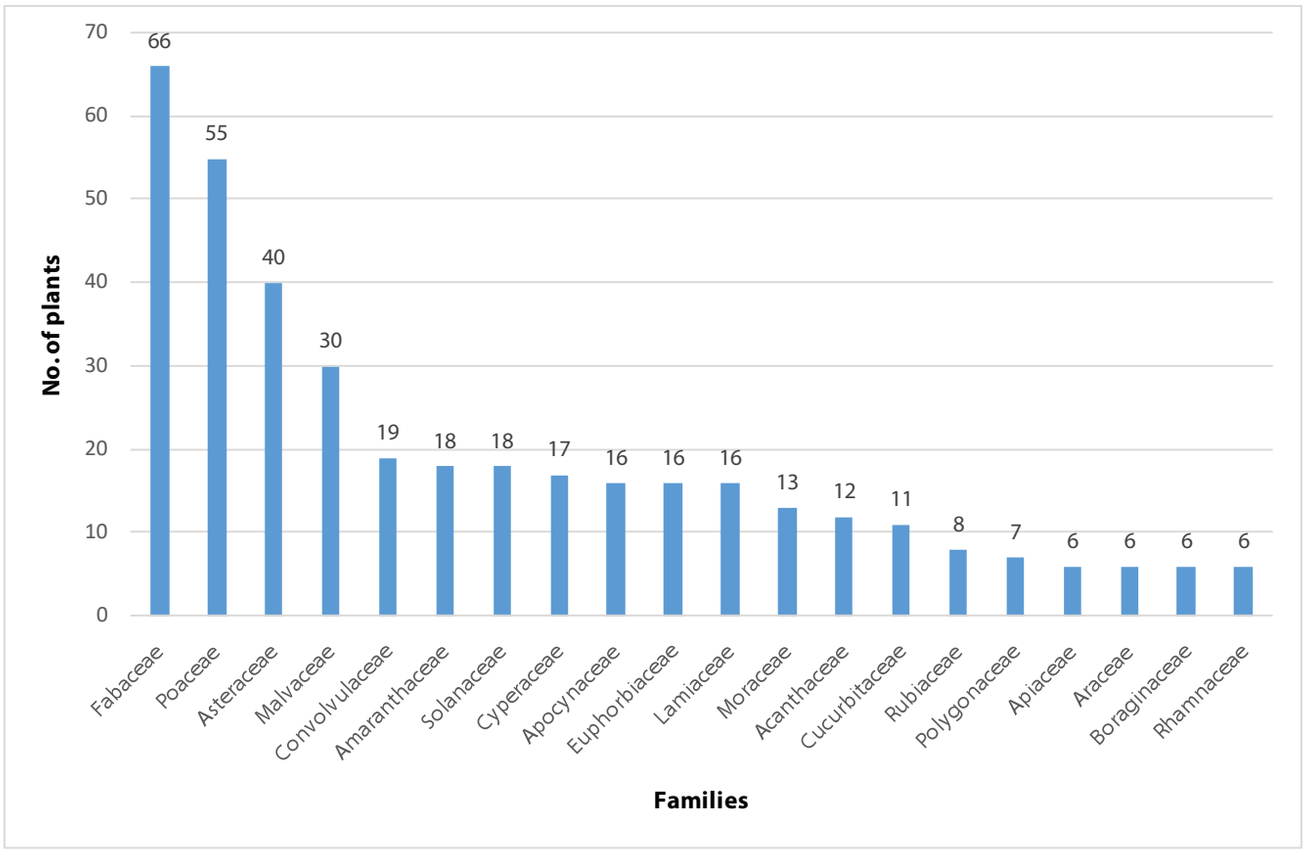
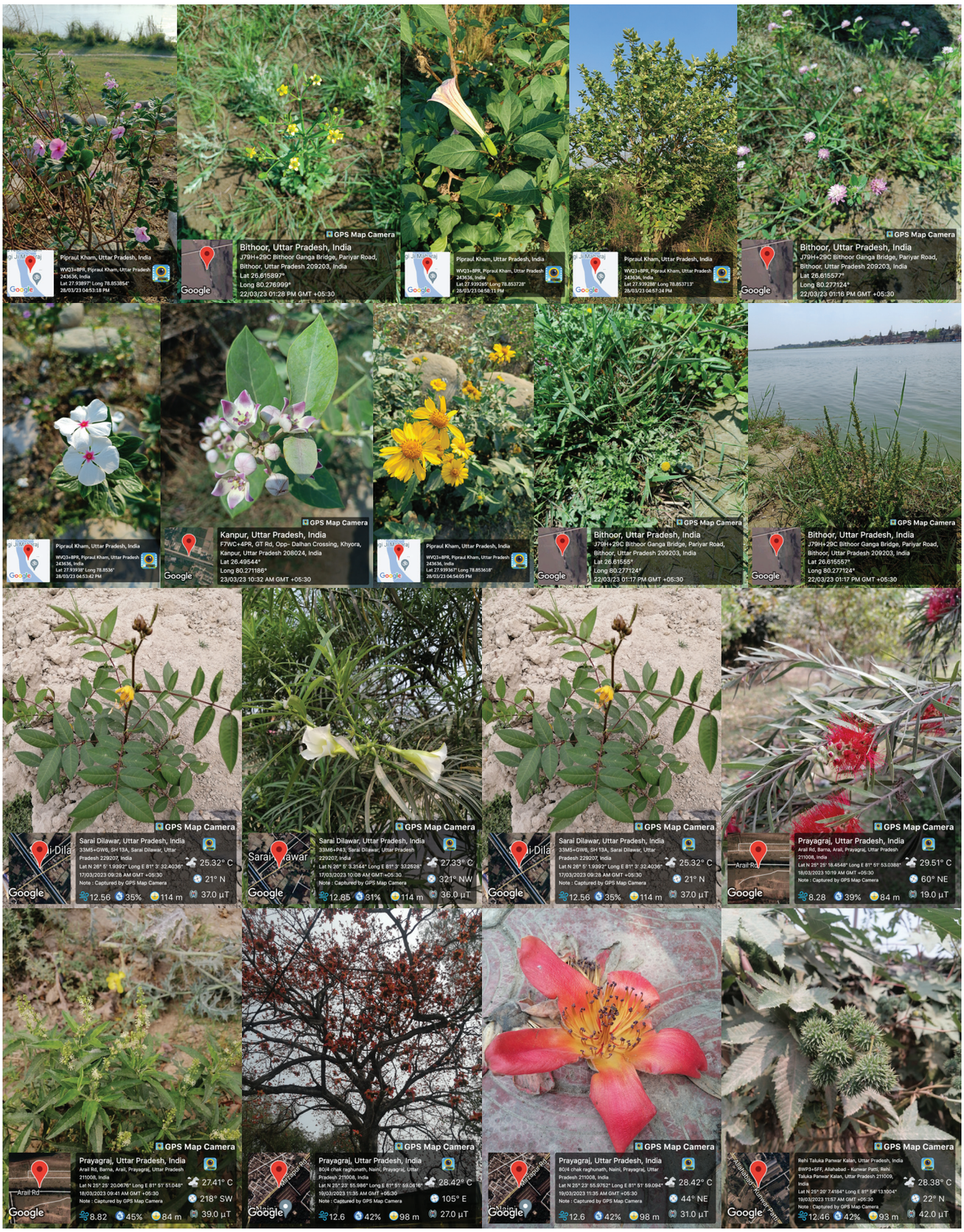


Fig. 3.6 Distribution of species under families.


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17/03/2023 09:28 AM GMT +05:30
Note : Captured by GPS Map Camera
25.32° C
21° N
12.56 35% 114 m 37.0 µT
GPS Map Camera
Sarai Dilawar, Uttar Pradesh, India
33M6+P43, Sarai Dilawar, Uttar Pradesh 229207, India
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Note : Captured by GPS Map Camera
27.33° C
321° NW
12.85 31% 114 m 36.0 µT
GPS Map Camera
Sarai Dilawar, Uttar Pradesh, India
33M6+GW6, SH 13A, Sarai Dilawar, Uttar Pradesh 229207, India
Lat N 26° 5' 1.9392" Long E 81° 3' 32.4036"
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Note : Captured by GPS Map Camera
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21° N
12.56 35% 114 m 37.0 µT
GPS Map Camera
Prayagraj, Uttar Pradesh, India
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60° NE
8.28 39% 84 m 19.0 µT
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28.42° C
105° E
12.6 42% 98 m 27.0 µT
GPS Map Camera
Prayagraj, Uttar Pradesh, India
80/4 chak raghunath, Naini, Prayagraj, Uttar Pradesh 211008, India
Lat N 25° 23' 55.9752" Long E 81° 51' 59.094"
19/03/2023 11:35 AM GMT +05:30
Note : Captured by GPS Map Camera
28.42° C
44° NE
12.6 42% 98 m 31.0 µT
GPS Map Camera
Rehi Taluka Panwar Kalan, Uttar Pradesh, India
8WP3+5FF, Allahabad - Kunwar Patti, Rehi Taluka Panwar Kalan, Uttar Pradesh 211009, India
Lat N 25° 20' 7.4184" Long E 81° 54' 13.1004"
19/03/2023 11:57 AM GMT +05:30
Note : Captured by GPS Map Camera
28.38° C
22° N
12.46 42% 93 m 42.0 µT



01
5
Sites

02
314
Species

03
74
Families

04
310
Angiosperms

05
46
Poaceae

BIHAR

In the 5 sites of Bihar, study revealed a total of 314 species under 74 families. The most dominant families are Poaceae (46 species), Fabaceae (33 species), Asteraceae (24 species) Malvaceae (19 species), Amaranthaceae & Lamiaceae (13 species). Distribution of species under 20 leading families are shown in Fig. 3.7. Angiosperms with 310 species, Pteridophytes consisting of only 4 species. Herbs constituting a significant portion of the total diversity with 170 occurrences species. Additionally, climbers representing 36 species. Trees and shrubs also contribute substantially, with 42 and 27 species respectively. Undershrubs and aquatic herbs exhibit 26 and 11 species respectively.

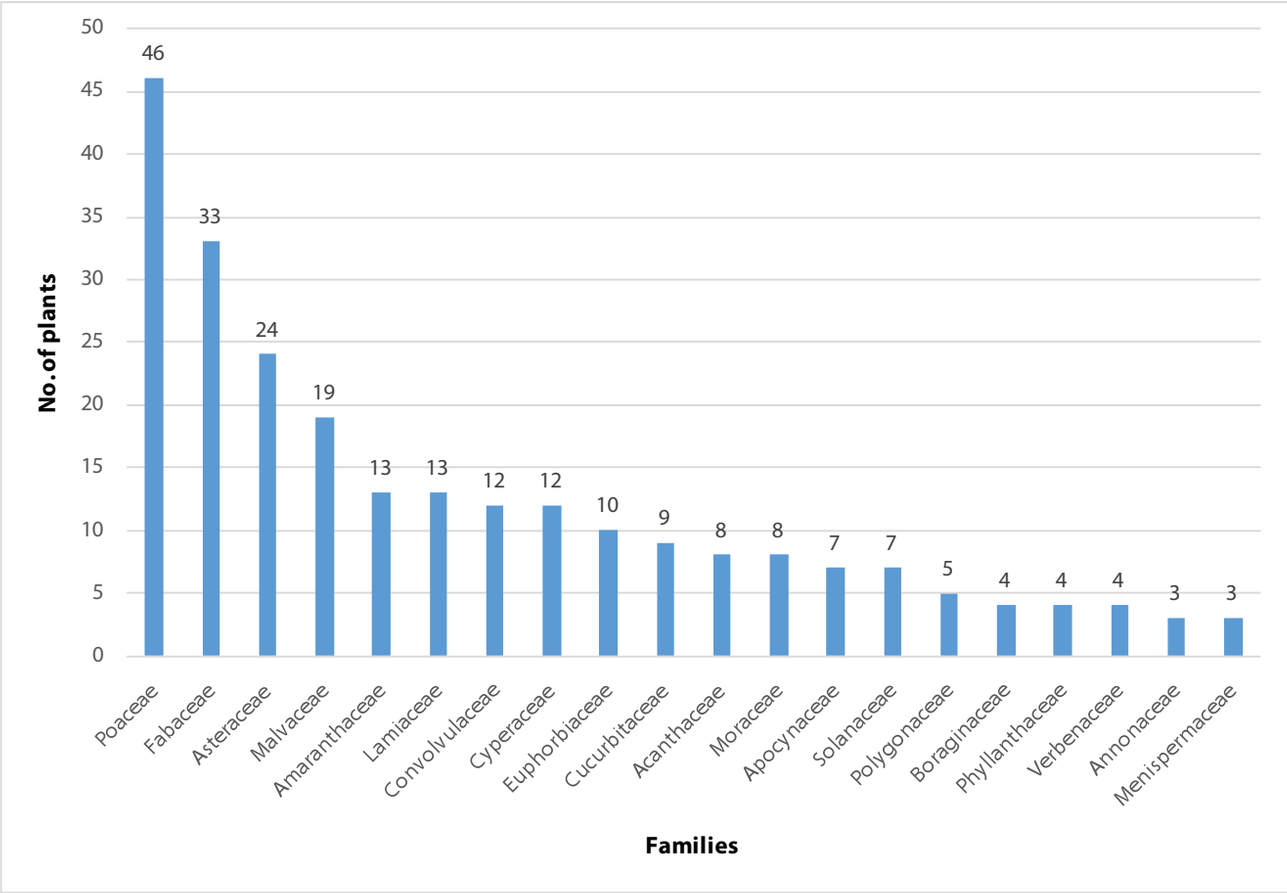


Fig. 3.7 Distribution of species under families.


GPS Map Camera
Salarpur, Bihar, India
78WW+FWM Jangli adda stadium salarpur medni chowki lakhisarai, Salarpur, Bihar 811106, India
Lat 25.296061°
Long 86.34796°
28/03/23 01:36 PM GMT +05:30
GPS Map Camera
Salarpur, Bihar, India
78WW+FWM Jangli adda stadium salarpur medni chowki lakhisarai, Salarpur, Bihar 811106, India
Lat 25.29601°
Long 86.34797°
28/03/23 01:49 PM GMT +05:30
GPS Map Camera
पुन्दरख, बिहार, भारत
FQVW+GHG, पुन्दरख, बिहार 803221, भारत
Lat 25.493626°
Long 85.795958°
23/03/23 09:32 AM GMT +05:30
GPS Map Camera
Patna, Bihar, India
Barh, Bihar, India
Lat 25.490153°
Long 85.705926°
22/03/23 01:22 PM GMT +05:30
Patna, Bihar, India
Barh, Bihar, India
Lat 25.490153°
Long 85.705926°
22/03/23 01:21 PM GMT +05:30
GPS Map Camera
Patna, Bihar, India
Barh, Bihar, India
Lat 25.490153°
Long 85.705926°
22/03/23 01:44 PM GMT +05:30
GPS Map Camera
Saran, Bihar, India
M4C6+G65, Digha - Sonpur Bridge, Bihar 800011, India
Lat 25.670443°
Long 85.108545°
23/03/23 09:03 AM GMT +05:30
GPS Map Camera
Saran, Bihar, India
M4C6+G65, Digha - Sonpur Bridge, Bihar 800011, India
Lat 25.670443°
Long 85.108545°
23/03/23 09:08 AM GMT +05:30
GPS Map Camera
Bahachoki, Bihar, India
79X3+JCG, Bahachoki, Bihar 811212, India
Lat 25.300488°
Long 86.353571°
28/03/23 03:05 PM GMT +05:30
GPS Map Camera
Mekra, Bihar, India
FR6W+3Q2, Bhagalpur - Patna Rd, Mekra, Bihar 803221, India
Lat 25.460276°
Long 85.846989°
23/03/23 10:37 AM GMT +05:30
GPS Map Camera
Naruada, Bihar, India
FPWW+CF2, Naruada, Bihar 803215, India
Lat 25.495562°
Long 85.745973°
23/03/23 08:58 AM GMT +05:30

01

1
Sites

02

159
Species

03

58
Families

04

154
Angiosperms

05

21
Poaceae



JHARKHAND

An analysis of the species of 1 site of Jharkhand revealed that 159 species belong to 58 families. Poaceae is the dominant family, representing with 21 species. Fabaceae contributing with 18 species, Acanthaceae & Euphorbiaceae (8 species), Lamiaceae (7 species), and Asteraceae (6 species). Distribution of species under 20 leading families are shown in Fig. 3.8. Angiosperms, constituting the majority with 154 species. Herbs comprising 78 species recorded. Trees also representing 23 species. Shrubs contributing 16 species. Climbers and undershrubs represent, with 20 and 14 species respectively.

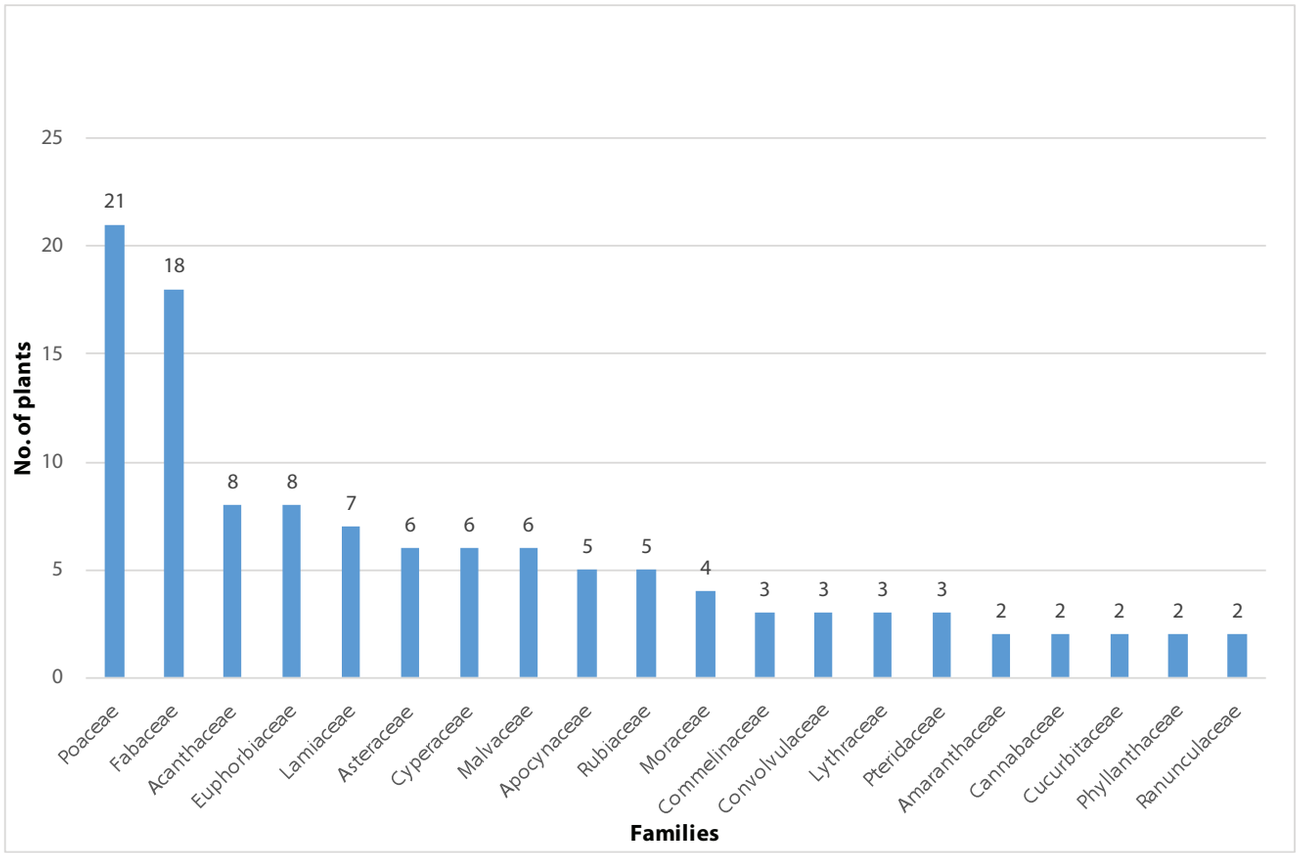


Fig. 3.8 Distribution of species under families.


GPS Map Camera
Barabitauvna, Jharkhand, India
6JHC+WCC, Barabitauvna, Jharkhand 816109, India
Lat 25.229877°
Long 87.62208°
26/03/23 09:28 AM GMT +05:30
Google



01
5
Sites

02
357
Species

03
82
Families

04
345
Angiosperms

05
23
Asteraceae

WEST BENGAL

The plant diversity in West Bengal is represented by 357 species belonging to 82 Families. Among the prominent families, Poaceae leads with 36 species, Fabaceae with 34 species. The Asteraceae family, comprising 23 species, Amaranthaceae with 15 species. Distribution of species under 20 leading families are shown in Fig. 3.9. Angiosperms, with a count of 345 species and Pteridophyte represents 12 species. Aquatic herbs, numbering 13, Climbers with 41 species. Epiphytes with 2 species, Herbs dominate with 184 species, while trees (45 species) and shrub (44 species). Undershrub with 26 species.

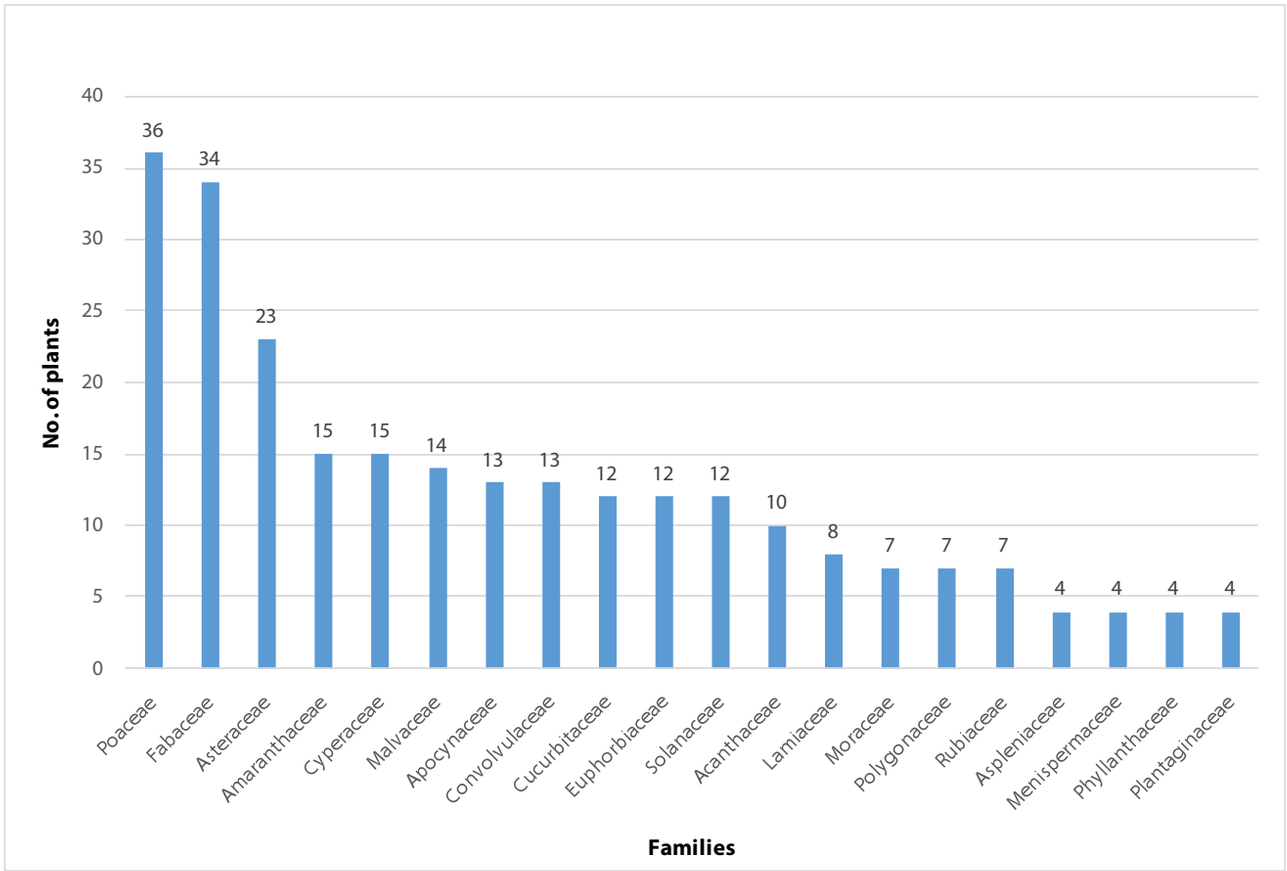
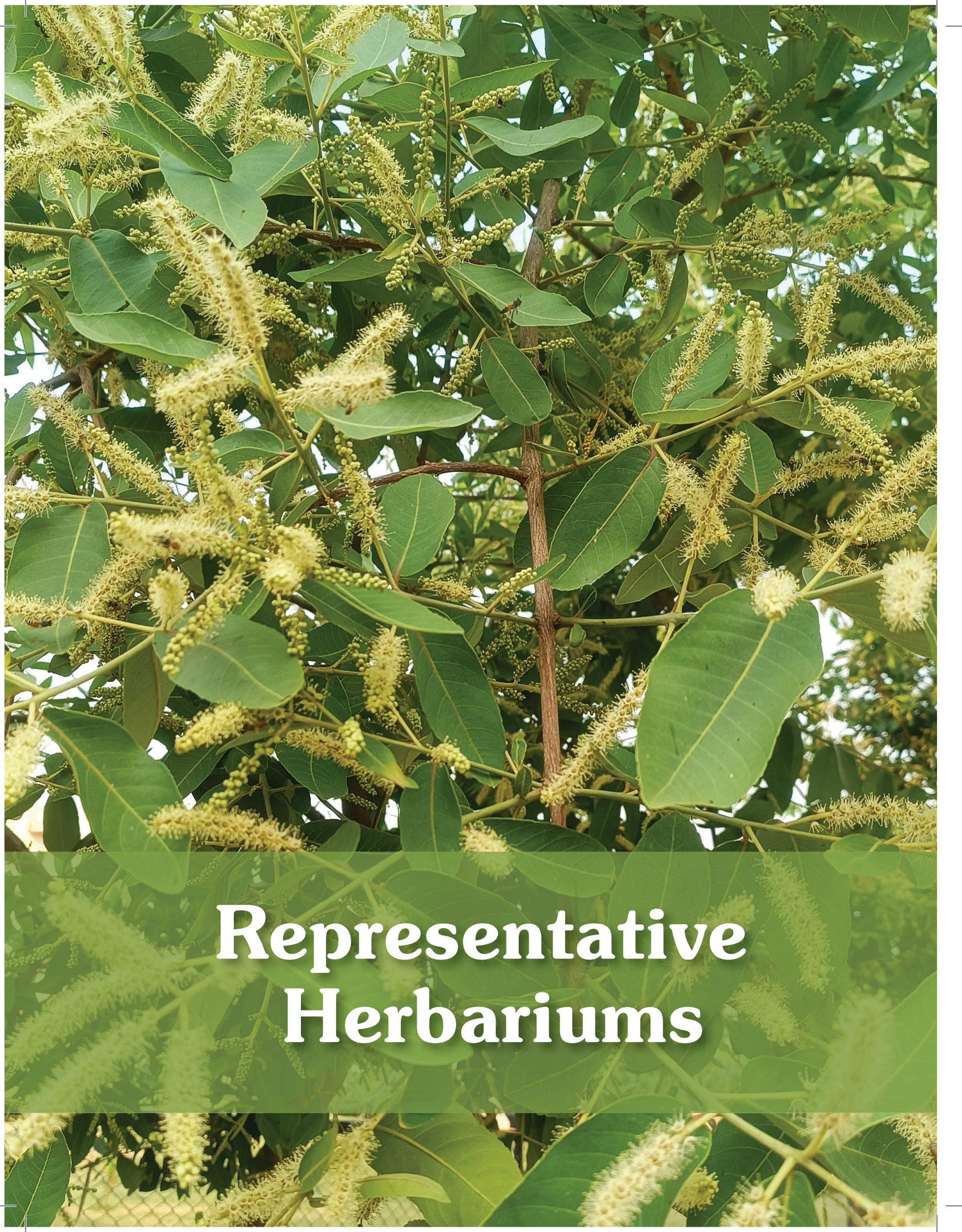


Fig. 3.9 Distribution of species under families.


GPS Map Camera
Bhatpara, West Bengal, India
V98Q+M5G, ESD Machinery, Jagatdal, Bhatpara, West Bengal 743132, India
Lat 22.866746°
Long 88.387771°
23/03/23 01:28 PM GMT +05:30
13.33 m
2 m
Google
GPS Map Camera
Bhatpara, West Bengal, India
V98Q+M5G, ESD Machinery, Jagatdal, Bhatpara, West Bengal 743132, India
Lat 22.866786°
Long 88.387837°
23/03/23 01:31 PM GMT +05:30
11 m
2 m
Google



Representative Herbariums



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Shakti, GOI

Sampling Site (With Code): Budaun, Uttar Pradesh (S-8)	
Collection Number: 2843	
Botanical Name: Achyranthes aspera L.	
Vedic Name: Apāmārgakaḥ caturasraḥ	
Family: Amaranthaceae	Habit: Herb
Common/Vernacular Name: Putkanda, Apamarga	
Locality: Kachhla	District/State: Budaun, Uttar Pradesh
Date of Collection: 28.03.2023	Flowering and Fruiting: March-December
Ecological Notes: Common; found along roadsides and open places.	
Collector: Amita Singh	Identified By: Anupam Srivastava 13/01/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Shakti, GOI

Sampling Site (With Code): Gangasagar, West Bengal (S-26)	
Collection Number: 4389	
Botanical Name: Boerhavia diffusa L.	
Vedic Name: Punarnavakaḥ raktakāṇḍaḥ	
Family: Nyctaginaceae	Habit: Herb
Common/Vernacular Name: Punarnava	
Locality: Diamond Harbour	District/State: South 24 Parganas, West Bengal, India
Date of Collection: 04-04-2023	Flowering and Fruiting: Throughout the year
Ecological Notes: Common; found near roadsides, forests and river canals.	
Collector: Seema Bisht	Identified By: Anupam Srivastava 10/01/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Shakti, GOI

Sampling Site (With Code): Kachhla, Budaun, Uttar Pradesh (S-8)	
Collection Number: 2805	
Botanical Name: Cynodon dactylon (L.) Pers.	
Vedic Name: Dūrvikā śataparvā	
Family: Poaceae	Habit: Herb
Common/Vernacular Name: Doorwa, Doob Ghas	
Locality: Kachhla	District/State: Budaun, Uttar Pradesh
Date of Collection: 28.03.2023	Flowering and Fruiting: Throughout the year
Ecological Notes: Common; found along roadside and open places.	
Collector: Amita Singh	Identified By: Anupam Srivastava 20/01/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Shakti, GOI

Sampling Site (With Code): Narora, Uttar Pradesh (S-7)	
Collection Number: 2985	
Botanical Name: Ficus racemosa L.	
Vedic Name: Payovṛkṣakaḥ udumbaraḥ	
Family: Moraceae	Habit: Tree
Common/Vernacular Name: Gular	
Locality: Anupshahr	District/State: Bulandshahr, Uttar Pradesh
Date of Collection: 01.04.2023	Flowering and Fruiting: March-August
Ecological Notes: Common; found in open shady places, roadsides and edges of crop fields.	
Collector: Dr. Amit Kumar	Identified By: Anupam Srivastava 17/01/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Bithoor, Kanpur, Uttar Pradesh(S-10)	
Collection Number: 2687	
Botanical Name: Ricinus communis L.	
Vedic Name: Eraṇḍakaḥ paṅcāṅgulaḥ	
Family: Euphorbiaceae	Habit: Tree
Common/Vernacular Name: Caster bean, Arandi	
Locality: Bithoor	District/State: Kanpur, Uttar Pradesh
Date of Collection: 22.03.2023	Flowering and Fruiting: March-December
Ecological Notes: Common; found along roadsides and open places.	
Collector: Ankur Kumar	Identified By: Dr. Ramesh Kumar



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Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Narora, Uttar Pradesh (S-7)	
Collection Number: 2965	
Botanical Name: Croton bonplandianus Baill.	
Vedic Name: Muktatantukaḥ aromavṛntaḥ	
Family: Euphorbiaceae	Habit: Herb
Common/Vernacular Name:	
Locality: Anupshahr	District/State: Bulandshahr, Uttar Pradesh
Date of Collection: 01.04.2023	Flowering and Fruiting: March-October
Ecological Notes: Common; found along roadsides and open places.	
Collector: Dr. Bhasker Joshi	Identified By: Anupam Srivastava 17/01/2024



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Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Dalmau, Uttar Pradesh (S-11)	
Collection Number: 44	
Botanical Name: Polygonum plebeium R.Br.	
Vedic Name: Purusandhikaḥ aśiraḥ	
Family: Polygonaceae	Habit: Herb
Common/Vernacular Name: Machhechi	
Locality: Sarai Dilawar, Raebareli	District/State: Raebareli, Uttar Pradesh
Date of Collection: 17.03.2023	Flowering and Fruiting: January-December
Ecological Notes: Common; grow as weed in wasteland, fields crop and along roadsides.	
Collector: Dr. Ishwar Prakash Sharma	Identified By: Anupam Srivastava 23/03/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Bijnor, Uttar Pradesh (S-6)	
Collection Number: 3165	
Botanical Name: Solanum nigrum L.	
Vedic Name: Vṛkpañcakam kṛṣṇaphalam	
Family: Solanaceae	Habit: Herb
Common/Vernacular Name: Makoy, American Black Nightshade	
Locality: Bijnor	District/State: Bijnor, Uttar Pradesh
Date of Collection: 05.04.2023	Flowering and Fruiting: Throughout the year
Ecological Notes: Common; found in fields, along roadsides and in waste places.	
Collector: Ankur Kumar	Identified By: Anupam Srivastava 19/01/2024



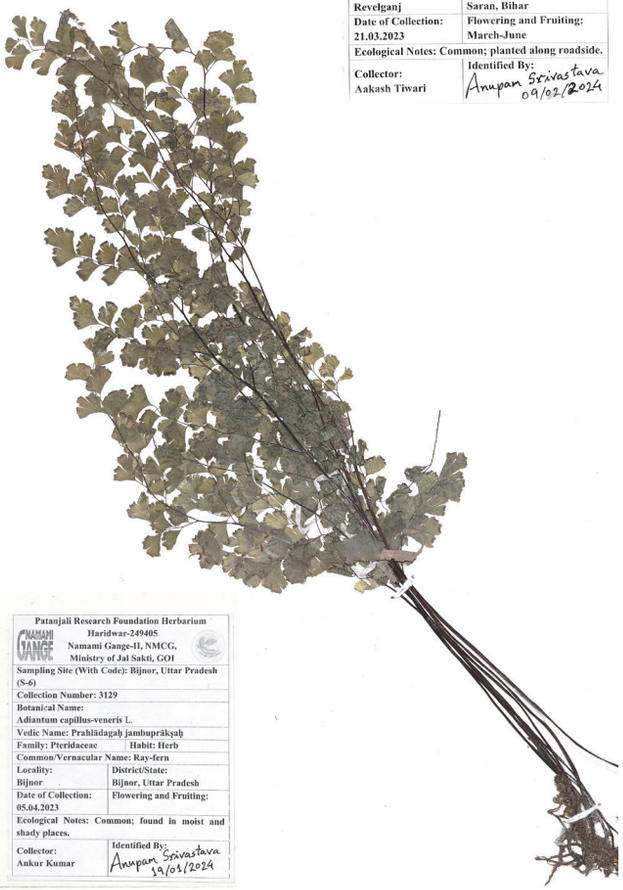
Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Revelganj, Bihar (S-16)	
Collection Number: 1200	
Botanical Name: Acacia auriculiformis A.Cunn. ex Benth.	
Vedic Name: Bālapatrakam karṇakam	
Family: Fabaceae	Habit: Tree
Common/Vernacular Name: Earleaf Acacia	
Locality: Revelganj	District/State: Saran, Bihar
Date of Collection: 21.03.2023	Flowering and Fruiting: March-June
Ecological Notes: Common; planted along roadside.	
Collector: Aakash Tiwari	Identified By: Anupam Srivastava 09/02/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Devprayag, Uttarakhand (S-4)	
Collection Number: 5705	
Botanical Name: Acacia dealbata Link	
Vedic Name: Bālapatrakam raupyaroma	
Family: Fabaceae	Habit: Tree
Common/Vernacular Name:	
Locality: Devprayag-Chandrabadni road	District/State: Tehri Garhwal, Uttarakhand
Date of Collection: 13.05.2023	Flowering and Fruiting: April-June
Ecological Notes: Common; found in open places of Oak-Pine forest.	
Collector: Prashant Vats	Identified By: Anupam Srivastava 25/01/2024



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Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Bijnor, Uttar Pradesh (S-6)	
Collection Number: 3129	
Botanical Name: Adiantum capillus-veneris L.	
Vedic Name: Prahlādagaḷ jambuprākṣaḷ	
Family: Pteridaceae	Habit: Herb
Common/Vernacular Name: Ray-fern	
Locality: Bijnor	District/State: Bijnor, Uttar Pradesh
Date of Collection: 05.04.2023	Flowering and Fruiting:
Ecological Notes: Common; found in moist and shady places.	
Collector: Ankur Kumar	Identified By: Anupam Srivastava 19/01/2024



Patanjali Research Foundation Herbarium
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Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Farrukhabad, Uttar Pradesh (S-9)	
Collection Number: 2707	
Botanical Name: Butea monosperma (Lam.) Kuntze	
Vedic Name: Palāśakaḷ raktapuṣpaḷ	
Family: Fabaceae	Habit: Tree
Common/Vernacular Name: Dhak, Tesu	
Locality: Farrukhabad	District/State: Farrukhabad, Uttar Pradesh
Date of Collection: 26.03.2023	Flowering and Fruiting: March-May
Ecological Notes: Common; found in the mixed forest and along roadsides.	
Collector: Ankur Kumar	Identified By: Anupam Srivastava 16/01/2024



Patanjali Research Foundation Herbarium
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Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Devprayag, Uttarakhand (S-4)	
Collection Number: 5781	
Botanical Name:	
Cedrus deodara (Roxb. ex D.Don) G.Don	
Vedic Name: Devadrujah dṛdhakāṣṭhaḥ	
Family: Pinaceae	Habit: Tree
Common/Vernacular Name: Deodar	
Locality: Devprayag-Chandrabadni Road	District/State: Tehri Garhwal, Uttarakhand
Date of Collection: 13.05.2023	Flowering and Fruiting: August-December
Ecological Notes: Common; found in moist montane forests along with Oak.	
Collector:	Identified By: Anupam Srivastava



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Ministry of Jal Sakti, GOI

Sampling Site (With Code): Narora, Uttar Pradesh (S-7)	
Collection Number: 2978	
Botanical Name:	
Parkinsonia aculeata L.	
Vedic Name: Srakphullakam śilāṇupatram	
Family: Fabaceae	Habit: Tree
Common/Vernacular Name: Vilayati-cheonkar	
Locality: Anupshahr	District/State: Bulandshahr, Uttar Pradesh
Date of Collection: 01.04.2023	Flowering and Fruiting: March-June
Ecological Notes: Common; found along the roadsides and open places.	
Collector: Dr. Bhasker Joshi	Identified By: Anupam Srivastava 17/01/2024



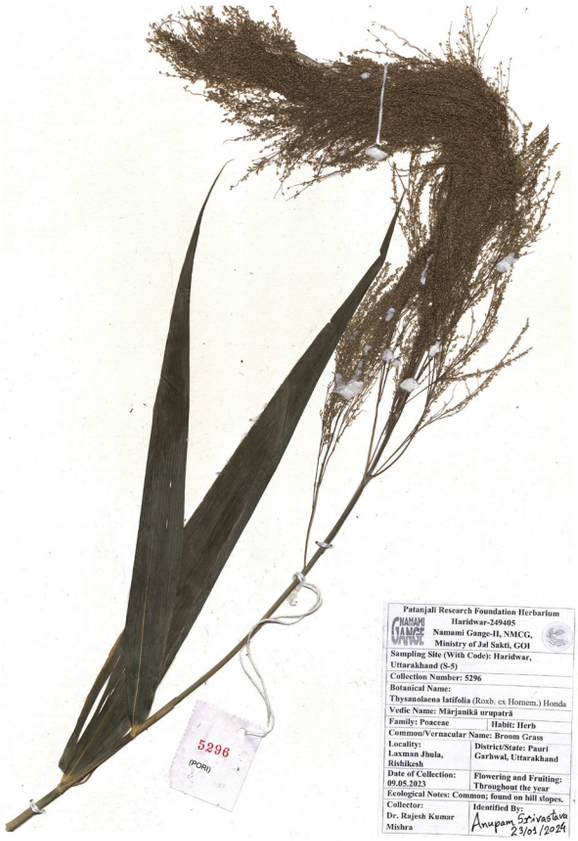
Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Bijnor, Uttar Pradesh (S-6)	
Collection Number: 3126	
Botanical Name: Fernandoa adenophylla (Wall. ex G.Don) Steenis	
Vedic Name: Jatudalukam sarpiphalam	
Family: Bignoniaceae	Habit: Tree
Common/Vernacular Name: Katsagon	
Locality: Bijnor	District/State: Bijnor, Uttar Pradesh
Date of Collection: 05.04.2023	Flowering and Fruiting: July-February
Ecological Notes: Common; found along roadsides.	
Collector: Prashant Vats	Identified By: Anupam Srivastava 19/01/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Sakti, GOI

Sampling Site (With Code): Farakka, West Bengal (S-22)	
Collection Number: 4227	
Botanical Name: Crateva magna (Lour.) DC.	
Vedic Name: Varuṇakaḥ vṛtākapuṃskaḥ	
Family: Capparaceae	Habit: Tree
Common/Vernacular Name: Large Garlic Pear	
Locality: Farakka	District/State: Murshidabad, West Bengal
Date of Collection: 26.03.2023	Flowering and Fruiting: February-July
Ecological Notes: Common; found in dry waste-lands and roadsides.	
Collector: Vikram Singh	Identified By: Anupam Srivastava 15/02/2024



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Sampling Site (With Code): Haridwar, Uttarakhand (S-5)	
Collection Number: 5296	
Botanical Name: Thysanolaena latifolia (Roxb. ex Hornem.) Honda	
Vedic Name: Marjanikā urupatrā	
Family: Poaceae	Habit: Herb
Common/Vernacular Name: Broom Grass	
Locality: Laxman Jhula, Rishikesh	District/State: Pauri Garhwal, Uttarakhand
Date of Collection: 09.05.2023	Flowering and Fruiting: Throughout the year
Ecological Notes: Common; found on hill slopes.	
Collector: Dr. Rajesh Kumar Mishra	Identified By: Anupam Srivastava 23/01/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Shakti, GOI

Sampling Site (With Code): Haridwar, Uttarakhand (S-5)	
Collection Number: 5152	
Botanical Name: Wigandia urens (Ruiz & Pav.) Kunth	
Vedic Name: Syānaromapatrakam cirapradalam	
Family: Boraginaceae	Habit: Tree
Common/Vernacular Name: Stinging Wigandia, Fiberglass Plant	
Locality: Garud Chatti, Rishikesh	District/State: Pauri Garhwal, Uttarakhand
Date of Collection: 10.05.2023	Flowering and Fruiting: March-September
Ecological Notes: Occasionally; found along roadsides, open and waste places.	
Collector: Aashish Kumar	Identified By: Dr. Ramesh Kumar



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Shakti, GOI

Sampling Site (With Code): Mirzapur, Uttar Pradesh (S-13)	
Collection Number: 456	
Botanical Name: Wrightia tinctoria subsp. rothii (G.Don) Ngan	
Vedic Name: Cirbhiṭakaḥ golaphalaḥ	
Family: Apocynaceae	Habit: Tree
Common/Vernacular Name: Indrajau	
Locality: Saket puri, Mirzapur	District/State: Mirzapur, Uttar Pradesh
Date of Collection: 21.03.2023	Flowering and Fruiting: December-February
Ecological Notes: Common; found in deciduous forest.	
Collector: Dheeraj Lal	Identified By: Anupam Srivastava 17/02/2024



Patanjali Research Foundation Herbarium
Haridwar-249405
Namami Gange-II, NMCG,
Ministry of Jal Shakti, GOI

Sampling Site (With Code): Narora, Uttar Pradesh (S-7)	
Collection Number: 2912	
Botanical Name: Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	
Vedic Name: Virakaḥ arjunaḥ	
Family: Combretaceae	Habit: Tree
Common/Vernacular Name: Arjun	
Locality: Anupshahr	District/State: Bulandshahr, Uttar Pradesh
Date of Collection: 01.04.2023	Flowering and Fruiting: March-December
Ecological Notes: Common; found along roadsides.	
Collector: Dr. Rajesh Kumar Mishra	Identified By: Anupam Srivastava 17/03/2024

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Section-IV

Ethnobotanical Plants



The Ganga River watershed is known as "a treasure house of drugs" since it is home to several economically valuable medicinal plants that grow there naturally. It is said that the Vedic era marked the beginning of the traditional medical system that grew up around the Ganga Valley (Sati, 2021). The Ganga's source region is a vital storehouse for medicinal plants. As early as 1000 BC, ancient Indian writings mention the existence of a variety of therapeutic plants in the Himalaya (Bargali et al., 2022). The common medicinal plants reported in this area are *Abies pindrow*, *Aconitum ferox*, *A. heterophyllum*, *Angelica glauca*, *Berberis asiatica*, *Bergenia ciliata*, *B. stracheyi*, *Betula utilis*, *Cannabis sativa*, *Geranium wallachianum, Saussurea simpsonina*, *Skimmia laureola*, *Taxus baccata*, etc. (Bhatt and Vashishtha, 2008; Rawat et al., 2010; Kumar and Singhal, 2019). The middle Ganga basin which passes through Uttar Pradesh, Bihar, Jharkhand, and West Bengal has a rich diversity of medicinal plants. This basin is mainly a reservoir of the *Vachellia nilotica* subsp. *indica, Achyranthes aspera, Adhatoda vasica, Aegle marmelos, Alternanthera sessilis, Asparagus racemosus, Chenopodium album, Datura stramonium, Euphorbia hirta, Ficus racemosa, Gymnema sylvestre, Bergera koenigii, Polygonum plebium, Rauwolfia serpentina, Ricinus communis, Solanum nigrum, Tridax procumbens, Withania somnifera,* etc. (Singh et al., 2013; Chowdhury, 2014; Subhash and Rahul, 2018; Verma et al., 2020).

The deltaic tract that approaches the mangrove reserves and leads to the Bay of Bengal is traversed by the lower Ganga basin. Compared to the hydrophytic and amphibious plants, most terrestrial plants are found in ecosystems. Xerophytes, are at one extreme and can survive dry spells and thrive in low water conditions, while hydrophytes are at the other. While a limited number of aquatic plants live in marine environments, the majority of aquatic plants are found in freshwater and wetland environments, where the water may be moving or stagnant. The common medicinal plants in this region are *Avicennia marina, Avicennia officinalis, Excoecaria agallocha, Hydrolea zeylanica, Hygroryza aristate, Ipomoea aquatica, Limnophila indica, Monochoria hastata, Nelumbo nucifera, Polygonum glabrum, Scirpus grosus, Sonneratia apetala, Vallisneria spiralis,* etc. (Mondal et al., 2012; Gupta and Roy, 2012; Chakraborty et al., 2016; Sarkar et al., 2019).

Field Survey

The field survey was conducted in selected sites with a total of five teams. Different teams surveyed different states with the help of a valid questionnaire (Annexure I). The questionnaire contained information on the gender and age of informants, along with the local name, part used, mode of administration method, and ailment treated by the medicinal plant. This study is based on the information from the respondents who are directly or indirectly dependent on the Ganga River and live around it. For the study purpose, the respondents were selected from the villages and given the respondent number. The respondent number with four digits for example 1.1.1.1; in which the first digit represents the state, the second digit represents the district, the third digit represents the village, and the last digit represents the respondent from the village. Data were collected according to the objectives of the study using procedures such as an interview schedule, field observation, and individual and group interaction. All the medicinal information was recorded.

AILMENT CATEGORIES

During the study, a total of sixty-two different disease conditions were recognized which were grouped into fifteen use categories (Table 4.1). Different respondent refers to the same or similar symptomatic diseases by different names, and their treatment procedures vary as well.

Table 4.1 Ailment use categories along with their disease conditions

Ailment Categories	Use Categories	Disease Conditions
Category 1	Dermatological disorders	Acne, Boil, Cut, Eczema, Inflammation, Leprosy, Pimples, Psoriasis, Swelling, Wound
Category 2	Cardiovascular disorders	Anemia, Blood Clotting, Blood disorder, Blood pressure
Category 3	Gastro-intestinal ailments	Appetite loss, Gastric problems, Hepatic disorder, Indigestion, stomachache
Category 4	Liver problems	Jaundice, Liver problems
Category 5	Metabolic disorders	Diabetes, Sugar
Category 6	Stone problem	Kidney stone, Stone

Ailment Categories	Use Categories	Disease Conditions
Category 7	Renal disorders	Cholera, Chronic Renal Pain, Diarrhea, Dysentery, Hemorrhoids (Piles)
Category 8	Skeleto-muscular system disorders	Arthritis or Joint pain, Bone disease, Physical disorder, Toothache, Uric acid (Hyperuricemia)
Category 9	Fever, Cough, and Cold	Asthma, Cold, Cough, Dengue, Fever, Malaria
Category 10	Nervous system disorders	Brain tonic, Epilepsy, Mental disorder, Nervous disease
Category 11	Cancer and ulcer	Cancer, Ulcer
Category 12	Ear, nasal, and eye disease	Ear, Eye, Nasal, and Throat diseases
Category 13	Genito-urinary ailments	Impotency, Lactation, Menstrual problems, Sexual disorder, Spermatorrhea, Urinary disease
Category 14	Poisonous bites	Scorpion sting, Snakebite
Category 15	Others	Hair problems, Headache, Internal injury

QUANTITATIVE ANALYSIS OF ETHNOBOTANICAL DATA

The data were entered into an Excel sheet and quantitatively it was analyzed. The frequencies and percentages were used to summarize ethnobotanical data. The informant consensus factor (ICF), use value (UV), relative frequency of citation (RFC), and fidelity level (FL) were calculated by these parameters.

COMPREHENSIVE ACHIEVEMENTS OF THE STUDY

Informant's Socio-demographic Characteristics

A total of 147 respondents from 39 localities of 18 districts from all around the Ganga River have interacted throughout the study. A maximum of 63 (42.86%) respondents were from 5 localities of Bihar who expressed a willingness to share their knowledge. In order of shared responses, after Bihar, Uttar Pradesh shared the most with 49 (33.33%) from 23 localities, followed by Uttarakhand with 19 (12.93%) from 5 localities, Jharkhand with 10 (6.80%) from 1 locality, and West Bengal with 6 (4.08%) from 5 localities (Fig 4.1).

In this study, Bihar is in the leading position among the respondents, which means that most of the Bihari people conserve their ancestor's knowledge about medicinal plants. Uttar Pradesh shares the most area of the river, hence it contributed the maximum respondents after Bihar. Uttarakhand is a hilly state that contributes the maximum area of the river but the villages are very scattered and far from the river, hence the respondents were less than Uttar Pradesh and Bihar. In Jharkhand, the river flows through a single district and covers about 80 km, here we selected a single site, hence here the respondents were less. West Bengal contributes about 520 km of the river but here we found very less respondents, it was mainly due to language problems, most of the natives from this state were facing language issues during the interactions.

Among all the 147 respondents, 103 were male, accounting for around 70.07% of the sample, and 44 were women, making up approximately 29.93%. Four age categories were used to categorize the respondents: 18-35, 36-50, 51-65, and >65 years. Of the total, a maximum of 50 (34.01%) respondents were between the ages of 51 and 65 years; 48 (32.65%) were between the ages of 36 and 50; 38 (25.85%) were between the ages of 18 and 35; and 11 (7.48%) were older than 65. In this study, the upper age group informers were higher than youngers which indicates the more experienced persons belong to the upper age groups and conserve their ancestor's traditional knowledge. 25.85% of young age respondents also indicate that they carry on with their ancestor's traditional knowledge which could be important for further therapeutic practices.

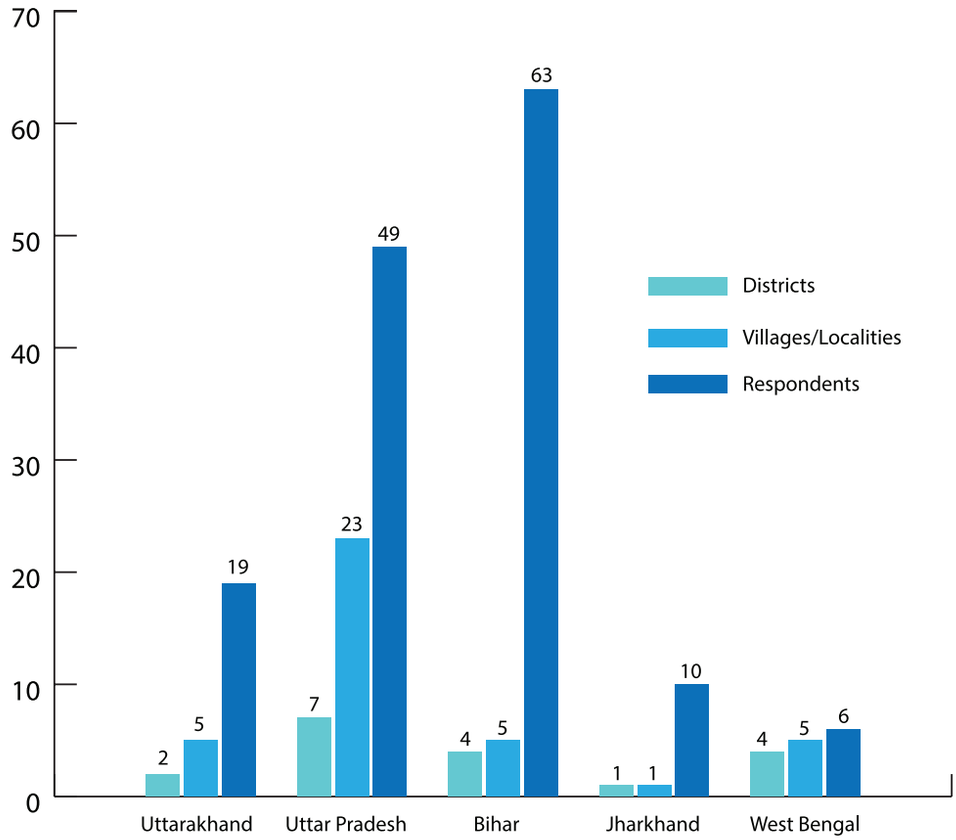


Fig. 4.1 Number of respondents, their villages or localities along with respective districts in various states

Plant Exploration

The respondents were aware of the uses of a variety of plants to treat common ailments. A total of 114 plants belonging to different plant families have been identified and documented.

Ethnomedicinal Plants and their Respective Families

All 114 medicinal plants identified in the study are classified into 58 plant families. Across all the families, Asteraceae had a leading position with a maximum of 8 plant species. Asteraceae was followed by Fabaceae, Lamiaceae, Apocynaceae, and Euphorbiaceae, with 7, 7, 6, and 5 plants, respectively (Fig. 4.2). Apart from these five families, the 10 families namely Acanthaceae, Amaryllidaceae, Apiaceae, Moraceae, Myrtaceae, Piperaceae, Poaceae, Ranunculaceae, Solanaceae, and Zingiberaceae each had 3 plant species; 8 families namely Araceae, Combretaceae, Convolvulaceae, Malvaceae, Menispermaceae, Phyllanthaceae, Rosaceae, and Rutaceae each had 2 plant species; while the remaining 35 families

namely Amaranthaceae, Anacardiaceae, Annonaceae, Asparagaceae, Asphodelaceae, Aspleniaceae, Berberidaceae, Boraginaceae, Cannabaceae, Caprifoliaceae, Caricaceae, Costaceae, Cucurbitaceae, Fagaceae, Gentianaceae, Juglandaceae, Lauraceae, Liliaceae, Melanthiaceae, Meliaceae, Moringaceae, Musaceae, Nyctaginaceae, Oleaceae, Orchidaceae, Papaveraceae, Plantaginaceae, Polygonaceae, Pontederiaceae, Saxifragaceae, Taxaceae, Theaceae, Ulmaceae, Verbenaceae, and Vitaceae each had single plant species (Fig. 4.3).

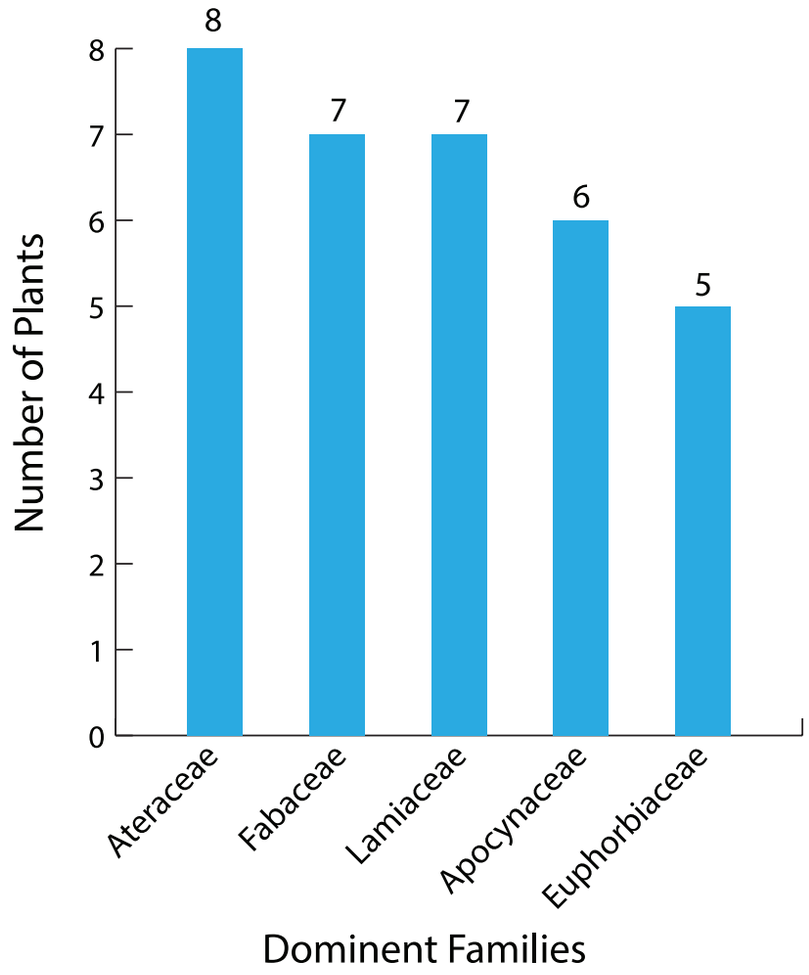


Fig. 4.2 Dominant five Plant families with respect to their numbers of medicinal plants

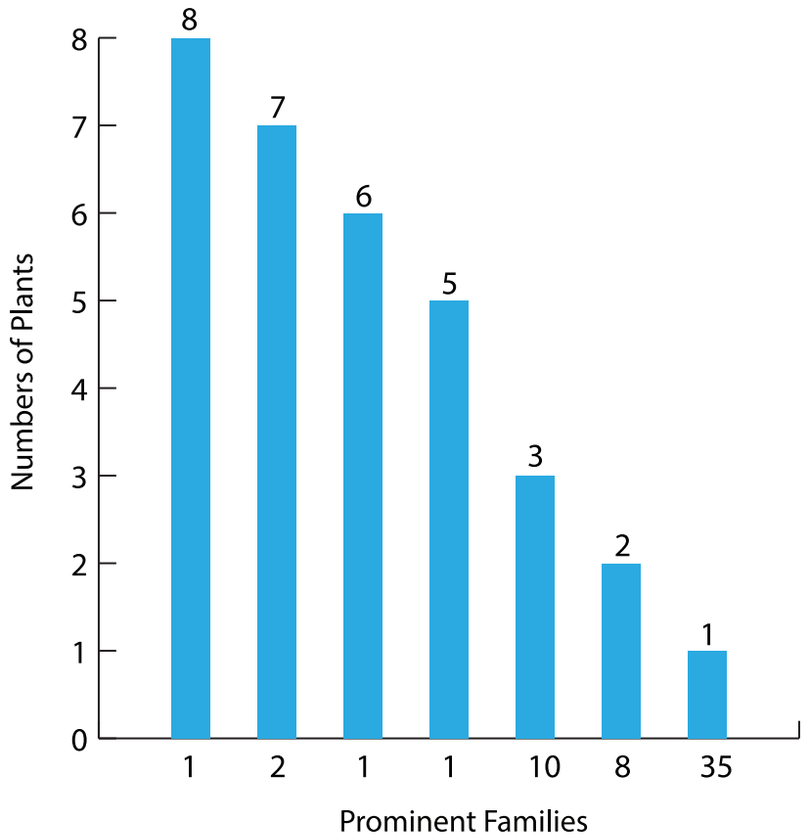


Fig. 4.3 Number of plants and their prominent families

Ethnomedicinal Plants and Their Habits

The habits of all 114 plants were analyzed. Seven different habits have been identified, including herb, shrub, tree, and climber. The maximum 55 (48.25%) medicinal plants were found to be herbaceous, followed by trees (34; 29.82%), shrubs (16; 14.04%), and climbers (9; 7.89%) (Fig. 4.4). Among all the plants one herb, *i.e. Thelypteris subpubescens* was recognized from the pteridophyte group. The majority of plants were herbaceous due to their widespread availability, typical method of preparing herbal remedies, and active participation in digestion and metabolism (Uniyal et al., 2006; Lulekal et al., 2013; Balkrishna et al., 2023).

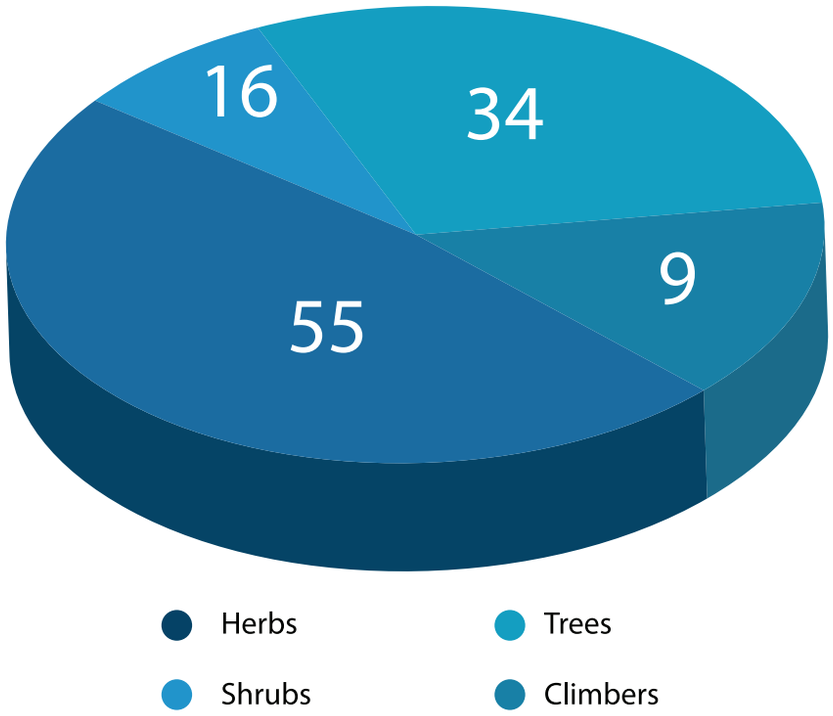


Fig. 4.4 Total number of medicinal plants with their habits

Ethnomedicinal Plant Parts Used in Different Ailments

The whole plant, a plant part or parts, or an ooze of any recognized medicinal plant has ethnomedicinal significance. 45 species of plants were evaluated for their leaves, accounting for most of their value for plant part utilization. The whole plant utilization of 22 plants was the second highest value. It was followed by roots (19 plants), fruits (16 plants), and seeds (9 plants). 6 plants were recorded for each stem value and flower value. 5 plants were recognized for their bark values, 3 plants for their rhizome values, 2 plants each for bulb and latex values, and a single plant was recognized for their tuber value (Fig. 4.5). The leaves have the highest value because the shoot parts, which contain a significant quantity of phenolic compounds, terpenoids, and alkaloids, are frequently employed in the manufacture of herbal medicines.

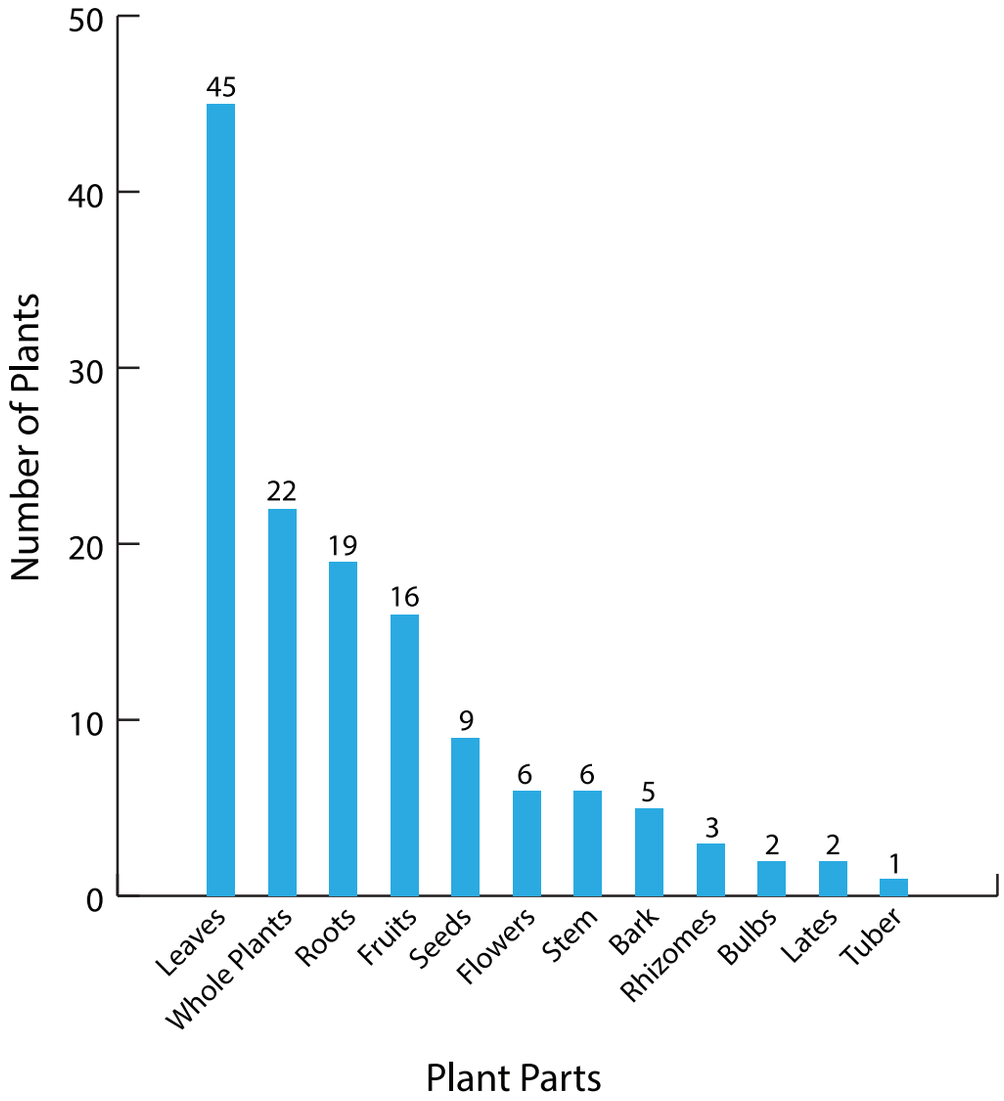


Fig. 4.5 Different used medicinal plant parts with respect to the number of plants

Administration Modes of Ethnomedicinal Plants

All the identified plants have a different administration mode. A maximum of 45 plants are administrated as a decoction, followed by 26 plants in paste form, 19 as juice, 26 with water extract, 15 in powder form, 14 plants used raw or direct form, 8 used in cooking, 5 with oil extract, 4 plants used with their heated leaves, 3 each are used for chewing and toothbrushing, 2 each for garland and smelling or fumes, and 1 each for tonic and vinegar (Fig. 4.6).

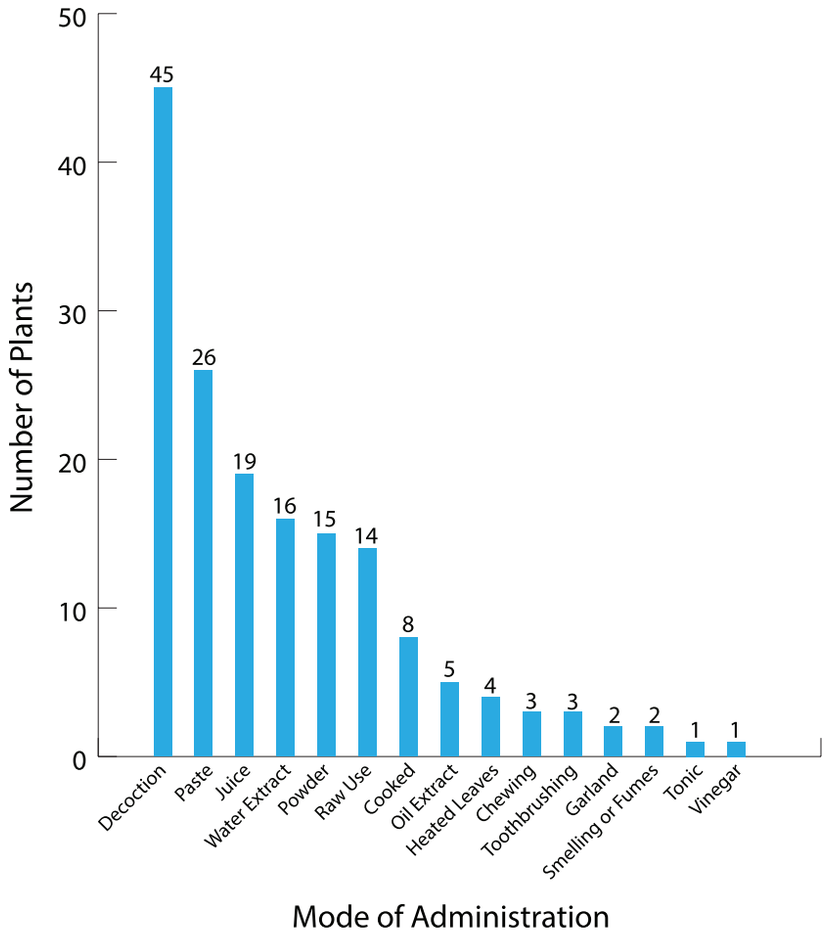


Fig. 4.6 Number of medicinal plants and their mode of administration

Ailment Categories

A variety of plants were used in various sites throughout the study areas to treat the various disease conditions that were divided into fifteen categories. Among the different ailments categories, 128 respondents discussed a maximum of 31 plants in Category 9, followed by Category 1, which was treated by a total of 27 plants that were discussed by 59 respondents. 11 respondents discussed 7 plants in Category 2; 48 respondents discussed 23 plants in Category 3; 47 respondents discussed 12 plants in Category 4; 55 respondents discussed 16 plants in Category 5; 12 respondents discussed 2 plants in Category 6; 40 respondents discussed 17 plants in Category 7; 61 respondents discussed 21 plants in Category 8; 10 respondents discussed 6 plants in Category 10; 34 respondents discussed 7 plants in Category 11; 20 respondents discussed 6 plants in Category 12; 10 respondents discussed 8 plants in Category 13; 4 respondents discussed 3 plants in Category 14; and 14 respondents discussed 6 plants in Category 15 (Fig. 4.7).

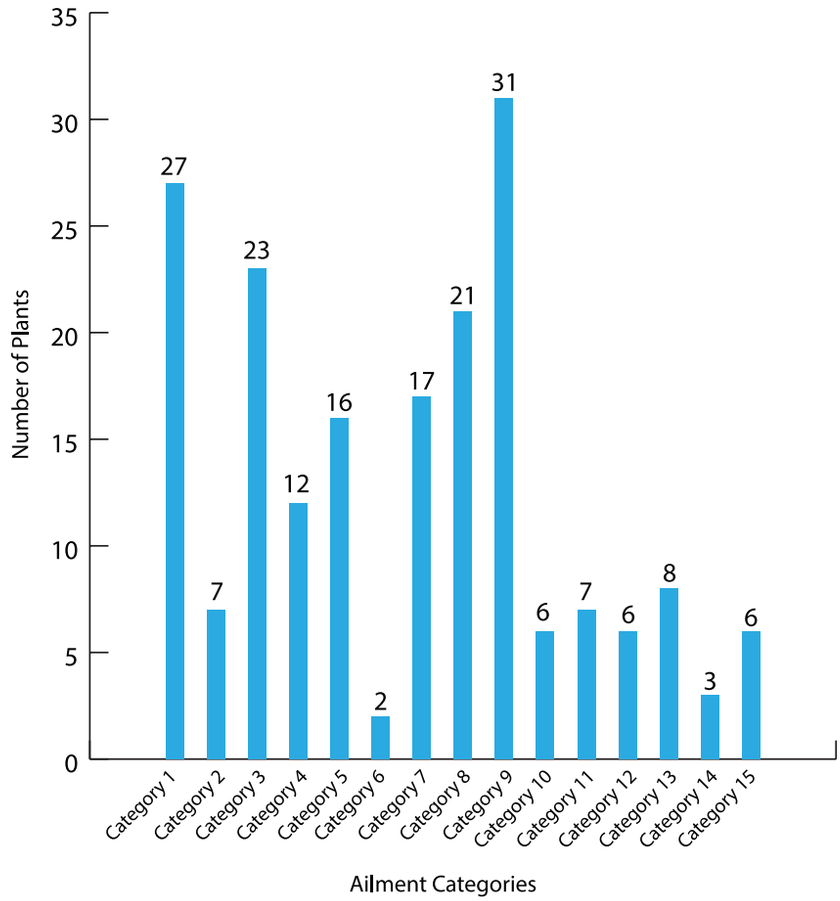


Fig. 4.7 Number of plant species with respect to the treatment of various ailment categories

PLANT'S QUANTITATIVE ANALYSIS

Informant Consensus Factor (ICF)

ICF is a potential method for determining the frequency of therapeutic plants for different ailment categories. The current study examined a total of 15 ailment categories, with ICF values ranging from 0 to 1. The highest ICF value of 0.91 was reported for category 6 (stone problem) followed by 0.85 for category 9 (fever, cough, and cold), 0.84 for category 12 (ear, nasal and eye disease), 0.82 for category 11 (cancer and ulcer). Remaining categories had the ICF values as 0.66 (category 1), 0.40 (category 2), 0.57 (category 3), 0.76 (category 4), 0.71 (category 5), 0.61 (category 7), 0.71 (category 8), 0.50 (category 10), 0.36 (category 13), 0.33 (category 14), and 0.62 (category 15) (Table 4.2).

The highest ICF value indicates that a considerable percentage of informants' report using taxa to treat a broad variety of diseases, whereas the lowest ICF value indicates that taxa are only used to cure a small number of diseases (Gazzaneo et al., 2005; Rehman et al., 2017). Category 6 (stone problem) has the highest ICF value because

this is very common in the study area due to people's unawareness. Over the past 30 years, there has been a notable global growth in the stone problem. The main reason is the overuse of medications, although it is also a result of changing environments and lifestyles (Matlaga et al., 2003). Fever, cough, and cold are categorized under category 9 which has the second largest ICF value because they are very common symptoms due to changes in climate and unusual lifestyles.

Table 4.2 ICF values for various ailment categories

Ailment Categories	No. of Plants	No. of Informants	Used Reports	ICF
Category 1	27	59	77	0.66
Category 2	7	11	11	0.40
Category 3	23	48	52	0.57
Category 4	12	47	47	0.76
Category 5	15	55	53	0.71
Category 6	2	12	12	0.91
Category 7	17	40	42	0.61
Category 8	21	61	70	0.71
Category 9	31	128	196	0.85
Category 10	6	10	11	0.50
Category 11	7	34	35	0.82
Category 12	6	20	32	0.84
Category 13	8	10	12	0.36
Category 14	3	4	4	0.33
Category 15	6	14	14	0.62

Use Value (UV)

UV is used for quantitative data analysis that confirms the relative importance of ethnomedicinal plants to the population. The higher UV indicates more use reports for a plant species which is significant among informants whereas, the lower UV indicates fewer use reports. In the current study the UV value range from 1 to 5. The plant with the highest UV is *Ocimum americanum* (5.00) followed by *Pontederia crassipes* (3.00), *Malus domestica* (2.50), and each *Bacopa monnieri*, *Euphorbia hirta*, *Euphorbia thymifolia*, and *Paris polyphylla* with 2.00 UV (Table 4.3). The high use of these plant species indicates the common occurrence and importance among respondents as they frequently use these plants in herbal therapies for various ailments. The UV

simply indicates the local importance of plant species against different ailments. The plants with the least UV as indicated in Table 4.3 were more effective against various ailments and could be used in other therapeutic uses, hence these plants can be used in the development of human pharmaceuticals (Macuja et al., 2015; Rehman et al., 2017; Balkrishna et al., 2023).

Relative Frequency of Citation (RFC)

RFC describes the most frequent ethnomedicinal plants and their local significance concerning informants. A higher RFC score implies that plant species are more prevalent among the informants. The score varies from 0 to 1; a greater value implies that the informants provided more knowledge about a plant species (Medeiros et al., 2011). In this study, the RFC ranges from 0.01 to 0.30. The plant with the highest RFC is *Tinospora cordifolia* (0.30) followed by *Ocimum tenuiflorum* (0.28), *Curcuma longa* (0.25), *Piper nigrum* (0.24), and *Zingiber officinale* (0.23) (Table 4.3). As these plants are more common and frequently used by the inhabitants hence their RFC is high. The plant *Tinospora cordifolia* had the highest RFC value (0.30) because it is an important herb that is used to cure common ailments such as fever, asthma, cough, cold, fever, blood pressure, malaria, dengue, diabetes, etc.; which was discussed by a total of 43 respondents in a total of 44 disease conditions. The other topmost RFC-valued plants were *Ocimum tenuiflorum, Curcuma longa, Piper nigrum,* and *Zingiber officinale* which have been widely used in home remedies and commonly utilized by the local inhabitants for curing their general disease conditions. The other plants were also recorded with their important herbal uses and their quantitative data is presented in Table 4.3.

Fidelity Level (FL)

The FL was measured for every identified plant in the study area. The FL has ranged between 0.06 and 29.25 (Table 4.3). The maximum FL value was recorded in *Tinospora cordifolia* (29.25). *Curcuma longa* and *Ocimum tenuiflorum* each had a 25.17 FL value and were the second most frequently used plants in the Ganga River watershed. *Zingiber officinale* and *Piper nigrum* possessed third and fourth positions in terms of their utilization and had the FL values 23.13 and 21.77 respectively. Out of the documented 114 plants, twelve have more than ten FL values (Fig. 4.8). These are the medicinal plants that are utilized the most commonly in the studied area. The maximum FL indicates the frequency and high use of the plant by the informants in the study area. These dominated plants are frequently utilized throughout the Ganga River watershed hence having high FL values. The remaining plants have limited and area-specific utilization hence, had lower FL values.

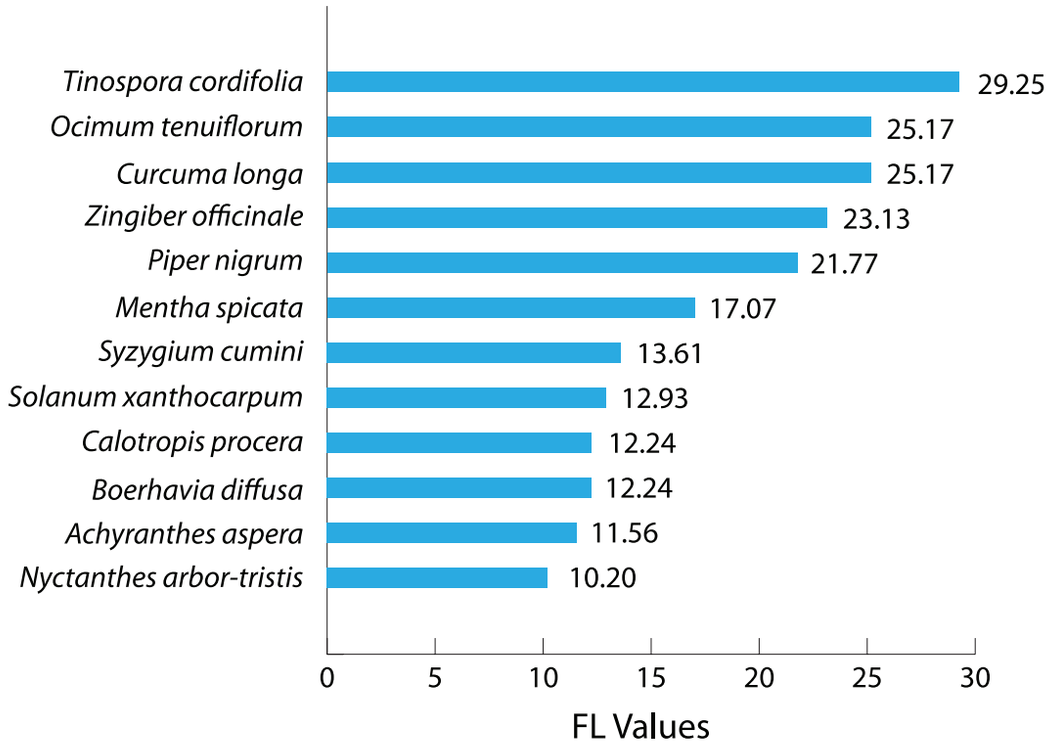


Fig. 4.8 Dominated medicinal plants having greater than ten FL values

The FL value was calculated for each ailment category that represents the uses of medicinal plants within the category; a higher FL indicates the higher utilization of plants (Table 4.4). In category 1, a total of 27 plants were used that ranged between 1.69 and 8.47 FL values; the maximum Fl was recorded for *Argemone mexicana* (8.74), followed by *Calotropis procera*, *Holoptelea integrifolia*, and *Solanum nigrum* each with 5.08 FL values. Under category 2, a total of 7 plants (*Citrus* × *limon*, *Dactylorhiza hatagirea*, *Malus domestica*, *Phyllanthus emblica*, *Pontederia crassipes*, *Solanum nigrum*, *Tinospora cordifolia*) were used and each had 9.09 FL values because each plant was discussed by the single respondent under this category. Under category 3, a total of 23 plants were discussed by the respondents among them *Phyllanthus emblica*, *Solanum nigrum*, *Terminalia bellirica*, and *Terminalia chebula* had a maximum of 4.17 FL values; while the remaining 19 plants had 2.08 FL values (Table 4.4).

In category 4, a total of 12 plants were used among them *Boerhavia diffusa* had a maximum of 4.26 FL value while the remaining plants had 2.13 FL values. Under category 5, a total of 16 plants were used and each plant had 1.85 FL values. In category 6, 2 plants namely *Bergenia ciliata* and *Solanum nigrum* were used and each had 8.33 FL values. In category 7, a total of 17 plants were discussed among them the 5 plants (*Achyranthes aspera*, *Aconitum heterophyllum*, *Aegle marmelos*, *Calotropis*

procera, *Camellia sinensis*, *Cassia fistula*) were dominated with their maximum FL values of 5.00 each while the remaining 12 plants each had 2.50 FL values. In category 8, a total of 21 plants were used among them 11 plants (*Berberis asiatica*, *Calotropis procera*, *Cissus quadrangularis*, *Colocasia esculenta*, *Curcuma longa*, *Malus domestica*, *Nyctanthes arbor-tristis*, *Ocimum tenuiflorum*, *Trigonella foenum-graecum*, *Vitex negundo*, *Wrightia tinctoria*) with their maximum FL value of 3.39 and remaining 10 plants (*Achyranthes aspera*, *Cascabela thevetia*, *Euphorbia tithymaloides*, *Juglans regia*, *Ocimum americanum*, *Phyllanthus emblica*, *Piper betle*, *Prunus cerasoides, Solanum virginianum*, *Thelypteris subpubescens*) with 1.69 FL values (Table 4.4).

In category 9, a total of 31 plants were discussed, among them *Tinospora cordifolia* was a highly utilized plant with a maximum of 4.69 FL values followed by *Nyctanthes arbor-tristis* and *Ocimum tenuiflorum*, both of which had 3.13 FL values. In category 10, a total of 6 plants were used among them *Convolvulus prostrates* was highly utilized plant with FL value of 20, while the remaining 5 plants (*Amomum subulatum*, *Artabotrys hexapetalus*, *Bacopa monnieri*, *Nardostachys jatamansi*, *Piper betle*) each with FL value of 10. In category 11, a total of 7 plants were discussed among them the *Taxus wallichiana* had a maximum of 5.88 FL value while the remaining plants (*Acmella oleracea*, *Mentha spicata*, *Piper betle*, *Piper nigrum*, *Solanum nigrum*, *Syzygium aromaticum*) each with a FL value of 2.94. In category 12, a total of 6 plants were used along them *Achyranthes aspera* and *Ocimum tenuiflorum* were frequently used with 15 FL values followed by 10 FL (*Crinum asiaticum*) and 5 FL (*Argemone mexicana*, *Ficus benghalensis*, *Psidium guajava*).

In category 13, a total of 8 plants were discussed among them 5 plants (*Asparagus racemosus*, *Boerhavia diffusa*, *Cynodon dactylon*, *Hibiscus rosa-sinensis*, *Thalictrum foliolosum*) with 20 FL and 3 plants (*Acanthus ilicifolius*, *Bombax ceiba*, *Piper betle*) with 10 FL value. In category 14, a total of 3 plants have been discussed among them *Launaea procumbens* was with a maximum of 50 FL value and remaining plants namely *Calotropis procera* and *Cascabela thevetia* each had 25 FL values. Six plants (*Aloe vera*, *Ocimum tenuiflorum*, *Rheum austral*, *Solanum virginianum*, *Trigonella foenum-graecum*, *Wrightia tinctoria*) have been discussed under category 15 where each plant had 7.14 FL values (Table 4.4).

A lot of plants fall into the same use category. It's interesting to find the species that are most frequently used to cure a given ailment; this may be done using the FL (Muhakr et al., 2024). The highest FL denotes the species' high frequency and usage in the study area as well as the categories of ailments. FL is intended to measure a species' significance for a certain objective. It is believed that medicinal plants with high FL values are more likely to be biologically active if they are used frequently for the same disease category (Trotter et al., 2019). Higher FL values show that the informants had more preference for that specific plant and that it has significant potential as a medicine (Ayyanar et al., 2011).

Table 4.3 Use value (UV), relative frequency of citation (RFC), and fidelity level (FL) value of the identified medicinal plants

S No.	Botanical Names	Use Reports	Plant Informants	UV	RFC	FL
1	*Acanthus ilicifolius* L.	1	1	1.00	0.01	0.68
2	*Achyranthes aspera* L.	21	17	1.24	0.14	11.56
3	*Acmella oleracea* (L.) R.K.Jansen	12	12	1.00	0.08	8.16
4	*Aconitum heterophyllum* Wall. ex Royle	20	13	1.54	0.14	8.84
5	*Aegle marmelos* (L.) Corrêa	4	4	1.00	0.03	2.72
6	*Ajuga integrifolia* Buch.-Ham. ex D.Don	4	4	1.00	0.03	2.72
7	*Albizia lebbeck* (L.) Benth.	1	1	1.00	0.01	0.68
8	*Allium humile* Kunth	2	2	1.00	0.01	1.36
9	*Allium sativum* L.	2	2	1.00	0.01	1.36
10	*Aloe vera* (L.) Burm.f.	6	5	1.20	0.04	3.40
11	*Amomum subulatum* Roxb.	2	2	1.00	0.01	1.36
12	*Angelica glauca* Edgew.	4	4	1.00	0.03	2.72
13	*Argemone mexicana* L.	9	7	1.29	0.06	4.76
14	*Arisaema propinquum* Schott	2	2	1.00	0.01	1.36
15	*Artabotrys hexapetalus* (L.f.) Bhandari	2	2	1.00	0.01	1.36
16	*Asparagus racemosus* Willd.	13	9	1.44	0.09	6.12
17	*Azadirachta indica* A.Juss.	3	3	1.00	0.02	2.04
18	*Bacopa monnieri* (L.) Wettst.	2	1	2.00	0.01	0.68
19	*Barleria prionitis* L.	1	1	1.00	0.01	0.68
20	*Berberis lycium* Royle	9	9	1.00	0.06	6.12
21	*Bergenia ciliata* (Haw.) Sternb.	11	11	1.00	0.07	7.48
22	*Boerhavia diffusa* L.	10	9	1.11	0.14	12.24
23	*Bombax ceiba* L.	1	1	1.00	0.01	0.68
24	*Cajanus cajan* (L.) Huth	7	7	1.00	0.05	4.76

S No.	Botanical Names	Use Reports	Plant Informants	UV	RFC	FL
25	*Calotropis procera* (Aiton) W.T.Aiton	20	18	1.11	0.14	12.24
26	*Camellia sinensis* (L.) Kuntze	2	2	1.00	0.01	1.36
27	*Cannabis sativa* L.	7	4	1.75	0.05	2.72
28	*Carica papaya* L.	8	8	1.00	0.05	5.44
29	*Carum carvi* L.	2	2	1.00	0.01	1.36
30	*Cascabela thevetia* (L.) Lippold	9	7	1.29	0.06	4.76
31	*Cassia fistula L.*	3	2	1.50	0.02	1.36
32	*Catharanthus roseus* (L.) G.Don	5	5	1.00	0.03	3.40
33	*Cenchrus purpureus* (Schumach.) Morrone	2	2	1.00	0.01	1.36
34	*Cinnamomum verum* J.Presl	1	1	1.00	0.01	0.68
35	*Cissus quadrangularis* L.	1	1	1.00	0.01	0.68
36	*Citrus × limon* (L.) Osbeck	5	5	1.00	0.03	3.40
37	*Clerodendrum infortunatum* L.	8	8	1.00	0.05	5.44
38	*Colocasia esculenta* (L.) Schott	1	1	1.00	0.01	0.68
39	*Convolvulus prostratus* Forssk.	3	3	1.00	0.02	2.04
40	*Cordia myxa* L.	8	8	1.00	0.05	5.44
41	*Crinum asiaticum* L.	5	5	1.00	0.03	3.40
42	*Cucumis sativus* L.	3	3	1.00	0.02	2.04
43	*Curcuma longa* L.	37	37	1.00	0.25	25.17
44	*Cyanthillium cinereum* (L.) H.Rob.	2	2	1.00	0.01	1.36
45	*Cynodon dactylon* (L.) Pers.	8	8	1.00	0.05	5.44
46	*Dactylorhiza hatagirea* (D.Don) Soó	9	9	1.00	0.06	6.12
47	*Datura stramonium* L.	4	4	1.00	0.03	2.72
48	*Eclipta prostrata* (L.) L.	2	2	1.00	0.01	1.36
49	*Euphorbia hirta* L.	2	1	2.00	0.01	0.68
50	*Euphorbia neriifolia* L.	1	1	1.00	0.01	0.68

S No.	Botanical Names	Use Reports	Plant Informants	UV	RFC	FL
51	*Euphorbia thymifolia* L.	2	1	2.00	0.01	0.68
52	*Euphorbia tithymaloides* L.	3	3	1.00	0.02	2.04
53	*Ficus benghalensis* L.	1	1	1.00	0.01	0.68
54	*Fritillaria cirrhosa* D.Don	2	2	1.00	0.01	1.36
55	*Glycyrrhiza glabra* L.	2	2	1.00	0.01	1.36
56	*Gymnema sylvestre* (Retz.) R.Br. ex Sm.	1	1	1.00	0.01	0.68
57	*Hellenia speciosa* (J.Koenig) S.R.Dutta	1	1	1.00	0.01	0.68
58	*Hibiscus rosa-sinensis* L.	1	1	1.00	0.01	0.68
59	*Holoptelea integrifolia (*Roxb.) Planch.	4	4	1.00	0.03	2.72
60	*Ipomoea carnea* subsp. *fistulosa* (Mart. ex Choisy) D.F.Austin	2	2	1.00	0.01	1.36
61	*Juglans regia* L.	2	2	1.00	0.01	1.36
62	*Justicia adhatoda* L.	7	5	1.40	0.05	3.40
63	*Lablab purpureus* (L.) Sweet	1	1	1.00	0.01	0.68
64	*Lantana camara* L.	1	1	1.00	0.01	0.68
65	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	2	2	1.00	0.01	1.36
66	*Malus domestica* (Suckow) Borkh.	10	4	2.50	0.07	2.72
67	*Mangifera indica* L.	1	1	1.00	0.01	0.68
68	*Mentha spicata* L.	26	25	1.04	0.18	17.01
69	*Mikania micrantha* Kunth	5	3	1.67	0.03	2.04
70	*Moringa oleifera* Lam.	2	2	1.00	0.01	1.36
71	*Morus alba* L.	12	12	1.00	0.08	8.16
72	*Musa* × *paradisiaca* L.	5	5	1.00	0.03	3.40
73	*Nardostachys jatamansi* (D.Don) DC.	4	4	1.00	0.03	2.72

S No.	Botanical Names	Use Reports	Plant Informants	UV	RFC	FL
74	*Nerium oleander* L.	4	3	1.33	0.03	2.04
75	*Nyctanthes arbor-tristis* L.	15	15	1.00	0.10	10.20
76	*Ocimum americanum* L.	5	1	5.00	0.03	0.68
77	*Ocimum tenuiflorum* L.	41	37	1.11	0.28	25.17
78	*Origanum majorana* L.	1	1	1.00	0.01	0.68
79	*Paris polyphylla* Sm.	4	2	2.00	0.03	1.36
80	*Phyllanthus amarus* Schumach. & Thonn.	1	1	1.00	0.01	0.68
81	*Phyllanthus emblica* L.	14	13	1.08	0.10	8.84
82	*Piper betle* L.	6	6	1.00	0.04	4.08
83	*Piper longum* L.	3	3	1.00	0.02	2.04
84	*Piper nigrum* L.	35	32	1.09	0.24	21.77
85	*Pontederia crassipes* Mart.	6	2	3.00	0.04	1.36
86	*Prunus cerasoides* Buch.-Ham. ex D.Don	2	2	1.00	0.01	1.36
87	*Psidium guajava* L.	5	5	1.00	0.03	3.40
88	*Quercus leucotrichophora* A. Camus	7	5	1.40	0.05	3.40
89	*Ranunculus sceleratus* L.	1	1	1.00	0.01	0.68
90	*Rheum australe* D.Don	8	8	1.00	0.05	5.44
91	*Ricinus communis* L.	6	6	1.00	0.04	4.08
92	*Saccharum officinarum* L.	2	2	1.00	0.01	1.36
93	*Solanum nigrum* L.	19	11	1.73	0.13	7.48
94	*Solanum virginianum* L.	22	19	1.16	0.15	12.93
95	*Stevia rebaudiana* (Bertoni) Bertoni	1	1	1.00	0.01	0.68
96	*Streblus asper* Lour.	4	3	1.33	0.03	2.04
97	*Swertia chirayita* (Roxb.) H.Karst.	5	5	1.00	0.03	3.40
98	*Syzygium aromaticum* (L.) Merr. & L.M.Perry	1	1	1.00	0.01	0.68

S No.	Botanical Names	Use Reports	Plant Informants	UV	RFC	FL
99	*Syzygium cumini* (L.) Skeels	20	20	1.00	0.14	13.61
100	*Tagetes erecta* L.	1	1	1.00	0.01	0.68
101	*Taxus wallichiana* Zucc.	7	4	1.75	0.05	2.72
102	*Terminalia bellirica* (Gaertn.) Roxb.	3	3	1.00	0.02	2.04
103	*Terminalia chebula* Retz.	2	2	1.00	0.01	1.36
104	*Thalictrum foliolosum* DC.	4	4	1.00	0.03	2.72
105	*Thelypteris subpubescens* (Blume) K.Iwats.	2	2	1.00	0.01	1.36
106	*Tinospora cordifolia* (Willd.) Hook.f. & Thomson	44	43	1.02	0.30	29.25
107	*Tinospora crispa* (L.) Hook.f. & Thomson	7	7	1.00	0.05	4.76
108	*Trachyspermum ammi* (L.) Sprague	1	1	1.00	0.01	0.68
109	*Tridax procumbens* L.	4	4	1.00	0.03	2.72
110	*Trigonella foenum-graecum* L.	11	11	1.00	0.07	7.48
111	*Vachellia nilotica* subsp. *indica* (Benth.) Kyal. & Boatwr.	1	1	1.00	0.01	0.68
112	*Vitex negundo* L.	1	1	1.00	0.01	0.68
113	*Wrightia tinctoria* (Roxb.) R.Br.	7	5	1.40	0.05	3.40
114	*Zingiber officinale* Roscoe	34	34	1.00	0.23	23.13

Table 4.4 Fidelity level (FL) value of identified medicinal plants for the various disease categories

Ailment Category	S No.	Medicinal Plants	Plant Informants	FL
Category 1	1	*Achyranthes aspera* L.	2	3.39
	2	*Argemone mexicana* L.	5	8.47
	3	*Arisaema propinquum* Schott	1	1.69
	4	*Azadirachta indica* A.Juss.	1	1.69
	5	*Berberis lycium* Royle	1	1.69

Ailment Category	S No.	Medicinal Plants	Plant Informants	FL
	6	*Calotropis procera* (Aiton) W.T.Aiton	3	5.08
	7	*Cannabis sativa* L.	2	3.39
	8	*Cascabela thevetia* (L.) Lippold	1	1.69
	9	*Dactylorhiza hatagirea* (D.Don) Soó	2	3.39
	10	*Datura stramonium* L.	2	3.39
	11	*Eclipta prostrata* (L.) L.	2	3.39
	12	*Euphorbia neriifolia* L.	2	3.39
	13	*Holoptelea integrifolia (*Roxb.) Planch.	3	5.08
	14	*Ipomoea carnea* subsp. *fistulosa* (Mart. ex Choisy) D.F.Austin	1	1.69
	15	*Lablab purpureus* (L.) Sweet	1	1.69
	16	*Malus domestica* (Suckow) Borkh.	1	1.69
	17	*Mikania micrantha* Kunth	1	1.69
	18	*Moringa oleifera* Lam.	1	1.69
	19	*Morus alba* L.	1	1.69
	20	*Ocimum americanum* L.	2	3.39
	21	*Ocimum tenuiflorum* L.	1	1.69
	22	*Paris polyphylla* Sm.	1	1.69
	23	*Ranunculus sceleratus* L.	2	3.39
	24	*Rheum australe* D.Don	2	3.39
	25	*Solanum nigrum* L.	3	5.08
	26	*Tagetes erecta* L.	1	1.69
	27	*Tridax procumbens* L.	2	3.39
Category 2	1	*Citrus* × *limon* (L.) Osbeck	1	9.09
	2	*Dactylorhiza hatagirea* (D.Don) Soó	1	9.09
	3	*Malus domestica* (Suckow) Borkh.	1	9.09
	4	*Phyllanthus emblica* L.	1	9.09
	5	*Pontederia crassipes* Mart.	1	9.09
	6	*Solanum nigrum* L.	1	9.09
	7	*Tinospora cordifolia* (Willd.) Hook.f. & Thomson	1	9.09

Ailment Category	S No.	Medicinal Plants	Plant Informants	FL
Category 3	1	*Aconitum heterophyllum* Wall. ex Royle	1	2.08
	2	*Allium humile* Kunth	1	2.08
	3	*Aloe vera* (L.) Burm.f.	1	2.08
	4	*Angelica glauca* Edgew.	1	2.08
	5	*Asparagus racemosus* Willd.	1	2.08
	6	*Carum carvi* L.	1	2.08
	7	*Cassia fistula L.*	1	2.08
	8	*Citrus* × *limon* (L.) Osbeck	1	2.08
	9	*Euhorbia hirta* L.	1	2.08
	10	*Euphorbia thymifolia* L.	1	2.08
	11	*Mentha spicata* L.	1	2.08
	12	*Ocimum americanum* L.	1	2.08
	13	*Paris polyphylla* Sm.	1	2.08
	14	*Phyllanthus amarus* Schumach. & Thonn.	1	2.08
	15	*Phyllanthus emblica* L.	2	4.17
	16	*Pontederia crassipes* Mart.	1	2.08
	17	*Solanum nigrum* L.	2	4.17
	18	*Syzygium cumini* (L.) Skeels	1	2.08
	19	*Terminalia bellirica* (Gaertn.) Roxb.	2	4.17
	20	*Terminalia chebula* Retz.	2	4.17
	21	*Trachyspermum ammi* (L.) Sprague	1	2.08
	22	*Trigonella foenum-graecum* L.	1	2.08
	23	*Vachellia nilotica* subsp. *indica* (Benth.) Kyal. & Boatwr.	1	2.08
Category 4	1	*Boerhavia diffusa* L.	1	2.13
	2	*Cajanus cajan* (L.) Huth	1	2.13
	3	*Calotropis procera* (Aiton) W.T.Aiton	1	2.13
	4	*Cannabis sativa* L.	1	2.13
	5	*Carica papaya* L.	1	2.13
	6	*Cucumis sativus* L.	1	2.13

Ailment Category	S No.	Medicinal Plants	Plant Informants	FL
	7	*Musa* × *paradisiaca* L.	1	2.13
	8	*Pontederia crassipes* Mart.	1	2.13
	9	*Psidium guajava* L.	1	2.13
	10	*Saccharum officinarum* L.	1	2.13
	11	*Solanum nigrum* L.	1	2.13
	12	*Wrightia tinctoria* (Roxb.) R.Br.	2	4.26
Category 5	1	*Ajuga integrifolia* Buch.-Ham. ex D.Don	1	1.85
	2	*Azadirachta indica* A.Juss.	1	1.85
	3	*Berberis lycium* Royle	1	1.85
	4	*Catharanthus roseus* (L.) G.Don	1	1.85
	5	*Hellenia speciosa* (J.Koenig) S.R.Dutta	1	1.85
	6	*Clerodendrum infortunatum* L.	1	1.85
	7	*Glycyrrhiza glabra* L.	1	1.85
	8	*Gymnema sylvestre* (Retz.) R.Br. ex Sm.	1	1.85
	9	*Malus domestica* (Suckow) Borkh.	1	1.85
	10	*Mangifera indica* L.	1	1.85
	11	*Mikania micrantha* Kunth	1	1.85
	12	*Origanum majorana* L.	1	1.85
	13	*Phyllanthus emblica* L.	1	1.85
	14	*Stevia rebaudiana* (Bertoni) Bertoni	1	1.85
	15	*Syzygium cumini* (L.) Skeels	1	1.85
	16	*Tinospora cordifolia* (Willd.) Hook.f. & Thomson	1	1.85
Category 6	1	*Bergenia ciliata* (Haw.) Sternb.	1	8.33
	2	*Solanum nigrum* L.	1	8.33
Category 7	1	*Achyranthes aspera* L.	2	5.00
	2	*Aconitum heterophyllum* Wall. ex Royle	1	2.50
	3	*Aegle marmelos* (L.) Corrêa	1	2.50
	4	*Calotropis procera* (Aiton) W.T.Aiton	1	2.50
	5	*Camellia sinensis* (L.) Kuntze	1	2.50
	6	*Cassia fistula L.*	2	5.00

Ailment Category	S No.	Medicinal Plants	Plant Informants	FL
	7	*Cynodon dactylon* (L.) Pers.	1	2.50
	8	*Euhorbia hirta* L.	2	5.00
	9	*Euphorbia thymifolia* L.	2	5.00
	10	*Euphorbia tithymaloides* L.	1	2.50
	11	*Lantana camara* L.	1	2.50
	12	*Morus alba* L.	1	2.50
	13	*Ocimum americanum* L.	1	2.50
	14	*Quercus leucotrichophora* A. Camus	2	5.00
	15	*Ricinus communis* L.	1	2.50
	16	*Tridax procumbens* L.	2	5.00
	17	*Wrightia tinctoria* (Roxb.) R.Br.	1	2.50
Category 8	1	*Achyranthes aspera* L.	1	1.69
	2	*Berberis lycium* Royle	2	3.39
	3	*Calotropis procera* (Aiton) W.T.Aiton	2	3.39
	4	*Cascabela thevetia* (L.) Lippold	1	1.69
	5	*Cissus quadrangularis* L.	2	3.39
	6	*Colocasia esculenta* (L.) Schott	2	3.39
	7	*Curcuma longa* L.	2	3.39
	8	*Euphorbia tithymaloides* L.	1	1.69
	9	*Juglans regia* L.	1	1.69
	10	*Malus domestica* (Suckow) Borkh.	2	3.39
	11	*Nyctanthes arbor-tristis* L.	2	3.39
	12	*Ocimum americanum* L.	1	1.69
	13	*Ocimum tenuiflorum* L.	2	3.39
	14	*Phyllanthus emblica* L.	1	1.69
	15	*Piper betle* L.	1	1.69
	16	*Prunus cerasoides* Buch.-Ham. ex D.Don	1	1.69
	17	*Solanum virginianum* L.	1	1.69
	18	*Thelypteris subpubescens* (Blume) K.Iwats.	1	1.69
	19	*Trigonella foenum-graecum* L.	2	3.39

Ailment Category	S No.	Medicinal Plants	Plant Informants	FL
	20	*Vitex negundo* L.	2	3.39
	21	*Wrightia tinctoria* (Roxb.) R.Br.	2	3.39
Category 9	1	*Aconitum heterophyllum* Wall. ex Royle	1	0.78
	2	*Albizia lebbeck* (L.) Benth.	1	0.78
	3	*Allium sativum* L.	1	0.78
	4	*Barleria prionitis* L.	2	1.56
	5	*Calotropis procera* (Aiton) W.T.Aiton	1	0.78
	6	*Cannabis sativa* L.	1	0.78
	7	*Cenchrus purpureus* (Schumach.) Morrone	1	0.78
	8	*Cinnamomum verum* J.Presl	1	0.78
	9	*Clerodendrum infortunatum* L.	2	1.56
	10	*Cordia myxa* L.	1	0.78
	11	*Curcuma longa* L.	2	1.56
	12	*Cyanthillium cinereum* (L.) H.Rob.	1	0.78
	13	*Fritillaria cirrhosa* D.Don	1	0.78
	14	*Glycyrrhiza glabra* L.	1	0.78
	15	*Justicia adhatoda* L.	3	2.34
	16	*Mentha spicata* L.	1	0.78
	17	*Nerium oleander* L.	2	1.56
	18	*Nyctanthes arbor-tristis* L.	4	3.13
	19	*Ocimum americanum* L.	1	0.78
	20	*Ocimum tenuiflorum* L.	4	3.13
	21	*Piper longum* L.	1	0.78
	22	*Piper nigrum* L.	1	0.78
	23	*Quercus leucotrichophora* A. Camus	1	0.78
	24	*Solanum virginianum* L.	2	1.56
	25	*Streblus asper* Lour.	2	1.56
	26	*Swertia chirayita* (Roxb.) H.Karst.	1	0.78
	27	*Taxus wallichiana* Zucc.	2	1.56
	28	*Terminalia bellirica* (Gaertn.) Roxb.	2	1.56

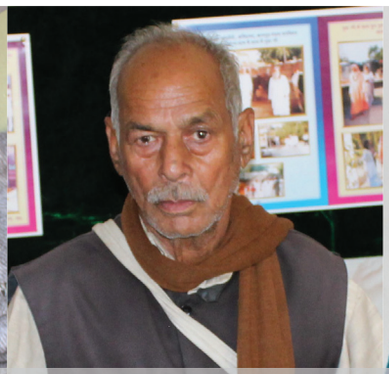
Ailment Category	S No.	Medicinal Plants	Plant Informants	FL
	29	*Tinospora cordifolia* (Willd.) Hook.f. & Thomson	6	4.69
	30	*Tinospora crispa* (L.) Hook.f. & Thomson	2	1.56
	31	*Zingiber officinale* Roscoe	1	0.78
Category 10	1	*Amomum subulatum* Roxb.	1	10.00
	2	*Artabotrys hexapetalus* (L.f.) Bhandari	1	10.00
	3	*Bacopa monnieri* (L.) Wettst.	1	10.00
	4	*Convolvulus prostratus* Forssk.	2	20.00
	5	*Nardostachys jatamansi* (D.Don) DC.	1	10.00
	6	*Piper betle* L.	1	10.00
Category 11	1	*Acmella oleracea* (L.) R.K.Jansen	1	2.94
	2	*Mentha spicata* L.	1	2.94
	3	*Piper betle* L.	1	2.94
	4	*Piper nigrum* L.	1	2.94
	5	*Solanum nigrum* L.	1	2.94
	6	*Syzygium aromaticum* (L.) Merr. & L.M.Perry	1	2.94
	7	*Taxus wallichiana* Zucc.	2	5.88
Category 12	1	*Achyranthes aspera* L.	3	15.00
	2	*Argemone mexicana* L.	1	5.00
	3	*Crinum asiaticum* L.	2	10.00
	4	*Ficus benghalensis* L.	1	5.00
	5	*Ocimum tenuiflorum* L.	3	15.00
	6	*Psidium guajava* L.	1	5.00
Category 13	1	*Acanthus ilicifolius* L.	1	10.00
	2	*Asparagus racemosus* Willd.	2	20.00
	3	*Boerhavia diffusa* L.	2	20.00
	4	*Bombax ceiba* L.	1	10.00
	5	*Cynodon dactylon* (L.) Pers.	2	20.00
	6	*Hibiscus rosa-sinensis* L.	2	20.00
	7	*Piper betle* L.	1	10.00
	8	*Thalictrum foliolosum* DC.	2	20.00

Ailment Category	S No.	Medicinal Plants	Plant Informants	FL
Category 14	1	*Calotropis procera* (Aiton) W.T.Aiton	1	25.00
	2	*Cascabela thevetia* (L.) Lippold	1	25.00
	3	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal	2	50.00
Category 15	1	*Aloe vera* (L.) Burm.f.	1	7.14
	2	*Ocimum tenuiflorum* L.	1	7.14
	3	*Rheum australe* D.Don	1	7.14
	4	*Solanum virginianum* L.	1	7.14
	5	*Trigonella foenum-graecum* L.	1	7.14
	6	*Wrightia tinctoria* (Roxb.) R.Br.	1	7.14


Acanthus ilicifolius L.
Achyranthes aspera L.
Argemone mexicana L.
Calotropis procera (Aiton) W.T.Aiton
Bergenia ciliata (Haw.) Sternb
Eclipta prostrata (L.) L.
Solanum virginianum L.
Curcuma longa L.
Hellenia speciosa (J.Koenig) S.R.Dutta
Morus alba L.
Taxus wallichiana Zucc.
Thelypteris subpubescens (Blume) K.Iwats.
Nerium oleander L.



Khushi Ram



Samar Singh Bhadauriya



Leela Devi



Daya Ram



Vijay Kishor Chourasia



Asha Devi Dalmau



Lal Baba Mirzapur



Sushila Devi Mirzapur



Ram Prakash Saran



Baleshwar Rai



Jai Krishna



Bapi Mistry

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Section-V

In Silico Analysis



The insilico study of medicinal plants holds profound significance in the quest to unearth unknown medicinal activities for treating lifestyle diseases, particularly when focusing on botanical specimens sourced from the Gangetic region. This region, endowed with a rich biodiversity owing to its fertile plains and unique climate, has been a cradle for diverse flora with potential therapeutic properties. By harnessing the power of insilico methodologies, scientists and researchers can delve into the molecular intricacies of these medicinal plants without resorting to traditional, time-consuming experimental approaches.

The current study sites involve the Gangetic region from Gaumukh (Uttarakhand) to Gangasagar (West Bengal). The Gangetic region's flora has been traditionally revered for its healing properties in ancient medicinal practices like Ayurveda. Through insilico studies, we can leverage cutting-edge computational tools and techniques to analyze the chemical composition of these medicinal plants at the molecular level. This approach enables the identification of bioactive compounds, their interactions, and potential pharmacological activities. Moreover, insilico studies facilitate the prediction of the plants' efficacy in addressing specific lifestyle diseases, offering a more streamlined and cost-effective approach to drug discovery. The exploration of unknown medicinal activities becomes particularly pertinent in the context of lifestyle diseases, which have become a global health challenge. Lifestyle diseases such as diabetes, cardiovascular disorders, and obesity often lack comprehensive and effective treatments. The insilico study of medicinal plants from the Gangetic region allows for a systematic investigation into the potential of these natural compounds to target the underlying molecular mechanisms associated with such diseases.

Thus, in conclusion, the insilico study of medicinal plants from the Gangetic region not only aligns with the rich cultural and botanical heritage of the area but also provides a promising avenue for discovering novel therapeutic agents. This approach not only accelerates drug discovery processes but also underscores the importance of preserving and harnessing the wealth of traditional knowledge embedded in the diverse ecosystems of regions like the Gangetic plains. As we navigate the challenges of modern lifestyle diseases, the integration of insilico studies with traditional wisdom opens exciting possibilities for advancements in medicinal research and healthcare.

Plant selection and Occurrence

When selecting plants for cultivation or conservation, one crucial factor to consider is their occurrence in a specific geographic region. This criterion plays a fundamental role in ensuring that the chosen species can adapt and thrive in the local environment. By focusing on plants that naturally exist in the region, we can take advantage of their inherent ability to flourish in the prevailing climate, soil conditions, and ecosystem. This approach also aligns with principles of ecological sustainability, as native plants are often well-integrated into the local biodiversity. Through a meticulous assessment of the occurrence of medicinal plants, stakeholders can make informed decisions that contribute to the preservation of regional flora, promote ecosystem health, and harness the inherent benefits of plants adapted to the unique ecological niches of a particular area. To support this study, we have referred to various authoritative sources such as the Flora of British India (1885), Flora of Upper Gangetic Plain (1960), Botany Bihar Orissa (1961), Flowering plants of Uttarakhand, a Checklist (2007), Flora of Uttar Pradesh (2020 & 2022), and conducted field observations.

Based on these references and observations, we have carefully selected ten multirange medicinal plants for further study, as outlined in (Section 3). These plants have been chosen for their potential to provide valuable insights into their medicinal properties and their adaptability to diverse ecological conditions. By delving deeper into their characteristics and benefits, we aim to contribute to the broader understanding of regional flora and the sustainable utilization of medicinal plants. In summary, the selection of plants for cultivation or conservation must consider their occurrence in a specific geographic region. This approach ensures the adaptation and resilience of chosen species to the local environment, leveraging their inherent ability to thrive in the prevailing climate, soil conditions, and ecosystem. By focusing on native plants, we not only promote ecological sustainability but also preserve regional flora and harness the unique benefits of plants adapted to specific ecological niches.

Methodology adopted

The current studies focused on largely unexplored therapeutic capabilities of ten medicinal plants: *Boerhavia diffusa*, *Cynodon dactylon*, *Croton bonplandianus*, *Ficus racemose*, *Achyranthes aspera*, *Ranunculus sceleratus*, *Ricinus communis*, *Solanum nigrum*, *Terminalia arjuna*, and *Tridax procumbens*, using an in-silico approach. The methodology employed molecular docking, ADMET (Absorption, Distribution, Metabolism, Excretion, and Toxicity) analysis, and

Molecular Dynamics (MD) simulations to predict interactions between bioactive compounds from these plants and selected target proteins associated with various diseases (Van Der Spoel et al., 2005; Bowers et al., 2006; Trott and Olson, 2010; Olasupo et al., 2020). The results of molecular docking analysis unveiled potential binding affinities between bioactive compounds of the selected medicinal plants and target proteins involved in diverse therapeutic areas such as inflammation, cancer, cardiovascular diseases, microbial infections, and neurogenerative diseases. Additionally, ADMET predictions were utilized to evaluate the pharmacokinetic properties, bioavailability, and potential toxicity of these compounds. Moreover, MD simulations were implemented to gain insights into the dynamic behavior and stability of ligand-protein complexes over time. These simulations provided valuable information on conformational changes, flexibility, and overall stability of the interactions, enhancing our understanding of the molecular mechanisms underlying the observed binding affinities.

Though all these in silico investigation, the identified bioactive compounds and their interactions with target proteins provide a foundation for further experimental validation, potentially paving the way for the development of novel therapeutic agents derived from these natural sources. The unexplored therapeutic possibilities of these specific medicinal plants in addressing various diseases are outlined as follows.

Results

The results from the Insilico analysis are documented in the monograph of the respective plants. Here, the summary of the insilico analysis of various plants has been given as below.

Achyranthes aspera L.



***Achyranthes aspera* L.**

Achyranthes aspera L., commonly known as Prickly Chaff Flower, belongs to the Amarathaceae family. This upright or prostrate, annual or perennial shrub is prevalent as a weed along roadsides, particularly in tropical and subtropical regions worldwide. (Singh at al., 2021; Mengie et al 2021). Traditional healers extensively use this plant for treating asthma, and various parts of the plant exhibit positive effects on conditions such as hydrophobia, snakebite, urinary calculi, influenza, rabies, piles, diarrhea, renal dropsy, gonorrhea, bronchitis, and abdominal pain (Emon et al., 2020). The plant is rich in phytochemicals, including saponin, flavonoid, terpenoid, steroid, phenolic compounds, and tannins (Lanjwani et al., 2021; Christi et al., 2022). Given the robust literature support for its therapeutic potential, *A. aspera* and its potential active compounds hold promise for the development of new drugs for treating cervical cancer (CC). Cervical cancer is the fourth most common malignancy and a significant

contributor to female mortality globally (Xia et al., 2023). General symptoms in affected patients include foul-smelling discharge, bleeding between periods, post-menopausal bleeding, urinary urgency, backache, and lower abdominal pain (Reichheld et al., 2020). Human papillomavirus (HPV) is identified as the causative agent in nearly all cases of CC (Chatterjee et al., 2019). Surgery is the most employed treatment, and chemo-radiotherapy is considered based on the disease stage, albeit with compromises to the patient's quality of life and financial burden (Du et al., 2021). Exploring anticancer drugs with minimal side effects is crucial due to the adverse effects induced by conventional chemotherapeutic agents. Addressing the challenges associated with CC, a comprehensive in silico study was conducted to target the human papillomavirus oncoprotein E6 (PDB: 4GIZ) using phytoconstituents from *A. aspera*. After preparing the phytochemical library, an initial screening process based on druglikeness, following Lipinski's Rule of five was performed. Potential phytocompounds underwent molecular docking to determine their binding affinities with the target proteins. Ethyl iso-allocholate exhibited notable binding affinity of -9 kcal/mol with human papillomavirus oncoprotein E6. ADMET profiling was conducted to validate the lead compound as a potential drug candidate. Molecular dynamic simulations of 100 ns were performed for the lead compound to ensure structural stability and analyze interaction energy. Ethyl iso-allocholate successfully passed all-important ADMET parameters, showed potent bioactivities and a good bioavailability score. These findings conclude ethyl iso-allocholate from *A. aspera* as a potential drug candidate against CC and establish a solid foundation for future investigations and the development of targeted therapies.

Boerhavia diffusa L.



***Boerhavia diffusa* L.**

Boerhavia diffusa L., an herbaceous plant belonging to the family Nyctaginaceae, is renowned for its rejuvenating properties and is commonly referred to as Punarnava, red spiderling, spreading hogweed, and tarvine (Gour, 2021; Pandey et al., 2019). Indigenous to India and Brazil, this herb exhibits a wide distribution across tropical, subtropical, and temperate regions (Gaur et al., 2022; Rutwick Surya and Praveen, 2021). In the traditional medicinal practices of India, Vaidyas, herbal experts, and tribal communities have extensively employed *B. diffusa* to address various ailments, establishing its integral role in Ayurveda, Unani, Siddha, Homeopathy, and the modern pharmaceutical industry (Ali et al., 2022; Gupta et al., 2022). Noteworthy attributes attributed to this plant in the literature encompass its immunomodulatory, antifibrinolytic, hepatoprotective, antidiabetic, antioxidant, anti-convulsant, and anticancer properties (Juneja et al., 2020). While

preliminary investigations have indicated potential health benefits, particularly in the context of anticancer properties, it is imperative to acknowledge the limited extent of scientific evidence, necessitating further research to validate its efficacy in cancer treatment and prevention. According to GLOBOCAN 2020, Lung cancer has emerged as a widespread health concern globally, ranking as the second most prevalent form of cancer. To explore novel avenues in drug design and development, a comprehensive in silico study targeted the epidermal growth factor receptor (EGFR) protein, a preferred therapeutic intervention target. The preparation of a phytochemical library of *B. diffusa* was followed by an initial screening based on druglikeness utilizing Lipinski's Rule of five. Further, the potential phytocompounds underwent molecular docking to assess binding affinities with target protein, with liridionine exhibiting notable affinity of -10.1 kcal/mol with EGFR proteins (PDB: 5HG8). ADMET profiling was subsequently employed to validate liridionine as a potential drug candidate. To ensure structural stability and analyze interaction energy, molecular dynamics simulations of 100 ns were conducted on Liridionine-EGFR complex. Liridionine demonstrated favorable pharmacokinetic properties, good bioavailability score, and potent bioactivities, signifying its safety and suitability as a drug candidate. Furthermore, molecular dynamics simulations confirmed the stability of the protein-ligand complex of liridionine with EGFR, offering structural insights into its potential as a therapeutic agent against lung cancer. In summary, this study identifies the promising potential of liridionine from *B. diffusa* as a natural therapeutic targeting EGFR, thereby providing a foundational basis for subsequent research and development of targeted therapies for lung cancer.

Croton bonplandianus Baill.



***Croton bonplandianus* Baill.**

Croton bonplandianus Baill., commonly known as three-leaved caper, Ban Tulasi, and Kala Bhangra, is a petite annual herb belonging to the Euphorbiaceae family (Joshi, 2014; Singh at al., 2011). Native to southern Bolivia, Paraguay, southwestern Brazil, and northern Argentina, it has become an invasive weed in the wastelands of India, Bangladesh, and other South Asian countries (Bhavana et al., 2020; Ghosh et al., 2013). Traditionally utilized for alleviating various health issues, including gastrointestinal disorders, hepatic problems, respiratory diseases, malaria, rheumatism, and chickenpox, the plant's leaves reportedly contain alkaloids, flavonoids, glycosides, steroids, phenols, tannins, and saponins (Singha et al., 2022; Jeeshna et al., 2011). Given the strong literary support, there is potential for *C. bonplandianus* and its active compounds to offer valuable insights into developing new drugs for treating viral diseases. The lack of literature on the plant's antiviral potential necessitates

scientific exploration to validate its efficacy in this regard. Japanese encephalitis, a prevalent vector-borne zoonotic encephalitic disease worldwide, has a mortality rate ranging from 5 to 30% (Folly et al., 2021). To address this, an in-depth in silico study was conducted to target Japanese encephalitis virus (JEV) structural and non-structural proteins using phytoconstituents from *C. bonplandianus*. After preparing the phytochemical library of *C. bonplandianus*, an initial screening based on druglikeness, employing Lipinski's Rule of five, was performed. Potential phytocompounds underwent molecular docking to determine their binding affinities with target proteins. Ursolic acid exhibited notable binding affinity of -10.4 kcal/mol with nsp5 (PDB: 4K6M), providing structural insights into its potential as a therapeutic agent against JEV. ADMET profiling was carried out to validate Ursolic acid as a potential drug candidate. To ensure structural stability and analyze interaction energy, molecular dynamic simulations of 100 ns were conducted on the Ursolic acid-nsp5 complex. Ursolic acid displayed acceptable pharmacokinetic parameters, bioactivities, and bioavailability score. In addition, the compound depicted stability throughout the duration of simulations. In summary, this study identifies the promising potential of ursolic acid from *C. bonplandianus* as a natural therapeutic targeting nsp5, laying the foundation for subsequent research and development of targeted therapies for JEV infection.

Cynodon dactylon (L.) Pers.



***Cynodon dactylon* (L.) Pers.**

Cynodon dactylon (L.) Pers., commonly known as Bermuda grass or Durva grass, is a perennial grass widely distributed in tropical and subtropical regions, with a history of use in folk medicine due to its pharmacological properties (Bouabdallah et al., 2023). *C. dactylon* encompasses a variety of bioactive compounds, including flavonoids, alkaloids, terpenoids, and phenolic acids. These constituents showcased diverse therapeutic activities, such as antioxidant, anti-inflammatory, anti-cancer, and immunomodulatory effects (Kalimuthu et al., 2022; Soares et al., 2023). While preliminary research suggested potential health benefits of *C. dactylon*, particularly in relation to its anti-cancer properties, it was crucial to acknowledge the limited extent of scientific evidence. Further research was imperative to solidify its efficacy in treating or preventing cancer. Globally, Epithelial Ovarian Cancer (EOC) poses a substantial health challenge, prompting the exploration of novel

therapeutic agents. This study aimed to utilize computational tools to investigate the therapeutic potential of *C. dactylon* in addressing Epithelial Ovarian Cancer. By identifying and scrutinizing the bioactive compounds from *C. dactylon* and key proteins associated with EOC, the research sought to unravel the molecular mechanisms underlying the potential anti-cancer effects of this traditional medicinal plant.

Following the preparation of the phytochemical library of *C. dactylon*, an initial screening process based on druglikeness, through Lipinski's Rule of five, was conducted. Potential phytocompounds were then subjected to molecular docking to ascertain the binding affinities with target proteins. Stigmasterol acetate and Arundoin emerged with notable binding affinity with Poly [ADP-ribose] polymerase-1 (PDB id: 1UK1). Additionally, Beta-sitosterol exhibited significant binding affinity with Mitogen-activated protein kinase 3 (MAPK3; PDB id: 4QTB). ADMET profiling was conducted to validate the lead compound as a potential drug candidate. To ensure structural stability and analyze interaction energy, molecular dynamic simulations were performed for all lead compounds.

Ficus racemosa L.



***Ficus racemose* L.**

Ficus racemose L., a member of the Moraceae family, held significant medicinal importance in India and had a historical presence in Ayurveda, the ancient Indian healing tradition, renowned for its efficacy against various ailments (Pahar et al., 2022). This included conditions such as diabetes, liver disorders, inflammation, diarrhea, respiratory and urinary problems, as well as hemorrhoids (Chaware et al., 2020). The extract from *F. racemosa* demonstrated promising benefits in the treatment of Parkinson's disease (PD), likely attributed to its neuroprotective properties derived from antioxidant and anti-inflammatory properties (Al-Musayeib et al., 2017; Kannan et al., 2024). To identify active constituents and potential targets for PD treatment, a combination of molecular docking, ADMET profiling, and molecular dynamic simulation was employed. In the molecular docking process, twenty target proteins, including TNF, AKT1, CASP3,

PPARG, STAT3, PTGS2, BCL2, EGFR, HIF1A, ESR1, MAPK3, HSP90AA1, MMP9, GSK3B, APP, MTOR, PPARA, MMP2, PARP1, and MAOA, were specifically selected. Among the several phytoconstituents of *F. racemosa*, only (24E)-24-N-Propylidenecholesterol, Campesterol, Cycloartenol, Kaempferol, and Phytol, with the PARP1 protein, exhibited significant binding affinity of -10.9, -10.9, -10.5, -10.8, and -10.0 kcal/mol, respectively. All the chosen phytochemicals exhibited strong binding affinity, indicating a robust interaction with the target. Additionally, they successfully passed the ADMET profiling parameters, implying that they fulfilled the criteria for absorption, distribution, metabolism, excretion, and toxicity. The lead compounds, namely (24E)-24-N-Propylidenecholesterol and Kaempferol derived from *F. racemosa*, showed enhanced structural resilience and stability in terms of Root Mean Square Deviation (RMSD), Root Mean Square fluctuations (RMSF), Radius of Gyration (Rg), and Solvent Accessible Surface Area (SASA), indicating their potential as neuroprotective agents in the context of PD. Although Kaempferol exhibited higher potency than (24E)-24-N-Propylidenecholesterol, attributed to its more stable structural conformation, higher hydrogen bonds formation, and comparatively higher free binding energy. In conclusion, Kaempferol extracted from *F. racemosa* could be considered as a potential drug candidate for the treatment of PD. However, it is essential to note that in-vivo and/or in-vitro studies should be conducted to ensure the efficacy of Kaempferol against PD, providing a more comprehensive understanding of its therapeutic potential.

Solanum nigrum L.



***Solanum nigrum* L.**

Solanum nigrum L., colloquially known as "Black Nightshade," is a member of the Solanaceae family with a widespread distribution across Europe, Asia, North America, South America, Australia, and Africa (Campisi et al., 2019). This plant has been traditionally employed in folk medicine for addressing various health concerns, including pain, inflammation, fever, malaria, and enteric diseases (Birru et al., 2022). The current body of evidence suggests the herb's potential as a robust anti-cancer agent, exhibiting efficacy against diverse cancer types such as cervical, breast, endometrial, and ovarian cancers (Patel et al., 2009; Khan et al., 2016; Tai et al., 2012; Wang et



al., 2015). The therapeutic attributes of the plant are ascribed to a spectrum of essential secondary metabolites, encompassing alkaloids, terpenoids, steroids, flavonoids, tannins, glycosides, and saponins (Sivaraj et al., 2020). Nipah virus infection represents a highly infectious and zoonotic malady, with fruit bats belonging to the genus *Pteropus* serving as its natural reservoir (Thomas et al., 2019). The etiological agent responsible for the disease is the Nipah virus (NiV), categorized within the family Paramyxoviridae and genus Henipavirus (Hassan et al., 2018). Notably, the virus manifests a substantial fatality rate in humans, and the absence of a standard vaccine, coupled with the potential for human-to-human transmission, has prompted the World Health Organization (WHO) to designate it as a global health priority, emphasizing the urgency for research and development initiatives (Skowron et al., 2022). The present study aims to identify potential Nipah virus inhibitors sourced from *S. nigrum*, employing a comprehensive in silico methodology. A compilation of phytoconstituents from *S. nigrum* was subjected to filtration based on Lipinski's rule of five. The selected compounds underwent molecular docking with the target protein, NiV glycoprotein (PDB ID: 2VSM). Among these, Diadzin emerged as a promising compound, exhibiting a favorable binding affinity of -8.8 kcal/mol against the targeted protein. Diadzin not only demonstrated satisfactory ADMET properties but also showcased significant bioactivities and good bioavailability scores. Furthermore, the stability of the compound-protein complex was sustained throughout 100 ns molecular dynamics simulations.
In essence, this research identifies the potential therapeutic efficacy of Diadzin from *S. nigrum* as a natural agent targeting NiV GP, a key protein in the pathogenesis of Nipah virus infection. These findings lay a foundation for future investigations and the formulation of targeted therapies with enhanced treatment options and improved outcomes for individuals afflicted with this concerning viral disease.

Ranunculus sceleratus L.



***Ranunculus sceleratus* L.**

Ranunculus sceleratus L., commonly known as celery-leaved buttercup or cursed buttercup, is a member of the Ranunculaceae family, typically found in damp habitats such as marshes, ditches, and the edges of ponds (Kim et al., 2023). *R. sceleratus* has been used in traditional medicine across various cultures, particularly for its vesicant properties, which cause blistering and were applied to treat warts and other skin conditions. The therapeutic potential of *R. sceleratus* lies in its rich phytochemical composition, including alkaloids, saponins, flavonoids, and glycosides. Melanoma, a highly aggressive form of skin cancer, presents a significant challenge in



oncology due to its resistance to conventional treatments and high potential for metastasis. In the quest for novel therapeutic strategies, researchers have turned their attention to natural compounds, uncovering the potential of *R. sceleratus*, a lesser-known medicinal plant, in combating this deadly disease. The study highlights unexplored therapeutic potential of *R.sceleratus* against melanoma, utilizing advanced techniques such as molecular docking, ADMET analysis, and molecular dynamics simulations.
Out of an initial pool of 75 phytochemicals, 17 were meticulously selected based on Lipinski's rule of five and ADMET parameters, which ensure drug-likeness and safety in potential therapeutic applications. Among these, Luteolin-7-O-glucuronide emerged as the most promising candidate, demonstrating the highest binding affinity and significant interaction stability with the Phosphatidylinositol-4,5-Bisphosphate 3-Kinase Catalytic Subunit Alpha (PIK3CA) target, a critical component in melanoma pathogenesis. Additionally, Luteolin 7-O-glucoside and Apigenin 7-glucuronide also exhibited notable interactions with the 3ZIM receptor, with Luteolin 7-O-glucoside showing a superior binding affinity, indicating its potential as a potent therapeutic agent. Further validation through molecular dynamics simulations and binding free energy analysis confirmed that Luteolin-7-O-glucuronide, Luteolin 7-O-glucoside, and Apigenin 7-glucuronide form stable and effective interactions with the 3ZIM receptor, a key player in melanoma progression.
Despite minor differences in stability and flexibility, all three compounds demonstrated comparable interaction strength and stability, suggesting their potential as effective inhibitors for the PIK3CA. These findings provide a crucial foundation for future research, highlighting the need for further exploration and optimization of these compounds in the development of targeted therapies against melanoma.

Ricinus communis L.



***Ricinus communis* L.**

Ricinus communis L., a member of the Euphorbiaceae family, is globally acknowledged for its extensive traditional and ethnomedicinal applications (Khalid et al., 2022). Recognized as the "Castor oil plant" and "castor bean," this botanical species, originating in Africa, has been disseminated to India and China and is presently amenable to cultivation worldwide (Kebede and Shibeshi, 2022; Agyenim-Boateng et al., 2019). Substantiated by a multitude of studies, the castor plant manifests a broad spectrum of medicinal attributes. Notably, castor oil serves diverse therapeutic purposes, functioning as a laxative, labor pain inducer, analgesic for soreness, foot pain, and backache, as well as an ophthalmic solution for dry eyes. It additionally functions as an edema-reducing agent and contributes to formulations addressing skin diseases (Agyenim-Boateng et al., 2019; Rani and Sood, 2021). Phytochemical investigations of the plant

have revealed presence of alkaloids, flavonoids, phenols, tannins, cardiac glycosides, quinones, saponins, terpenoids, phlobatannins and volatile oils (Bari et al., 2021). Gastric cancer, a malignant neoplasm of the digestive tract, represents a critical global health challenge due to its substantial morbidity and mortality rates (Tu et al., 2021). Surgical resection, considered the optimal treatment for patients in the early stages of the disease, faces obstacles due to delayed diagnoses and frequently leads to postoperative recurrence and mortality. Moreover, chemotherapeutic medications yield suboptimal outcomes and are constrained by their high toxicity (Vetrivel et al., 2020; Tu et al., 2021). Addressing these challenges emphasizes the urgent need for the development of innovative drugs that offer heightened efficacy while minimizing cellular toxicity. To alleviate this problem, a comprehensive in silico study targeting the ACOT-4 protein associated with gastric cancer was conducted. Phytoconstituents of R. communis, scrutinized through Lipinski's rule of five, underwent molecular docking with ACOT-4. Notably, 2,7-Diphenyl-1,6-dioxopyridazino[4,5:2′,3′] pyrrolo[4′,5′-d]pyridazine emerged as a promising compound, exhibiting a robust binding affinity of -9 kcal/mol against ACOT-4. Subsequent evaluations encompassed ADMET properties, bioactivities, and bioavailability scores for the lead compound. Lastly, the lead compound-ACOT-4 complex underwent 100 ns molecular dynamics simulations to assess structural stability. Encouragingly, the lead compound demonstrated satisfactory ADMET properties, significant bioactivities, and favorable bioavailability scores. Furthermore, the compound-protein complex-maintained stability throughout the simulation. These findings concludes 2,7-Diphenyl-1,6-dioxopyridazino[4,5:2′,3′] pyrrolo[4′,5′-d]pyridazine from R. communis as a potential drug candidate for gastric cancer, laying a substantive groundwork for future inquiries and the development of targeted therapeutic interventions.

Terminalia arjuna (Roxb. ex DC.) Wight & Arn.



***Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.**

Terminalia arjuna (Roxb. ex DC.) Wight & Arn, a member of the Combretaceae family and native to the Indian subcontinent, has emerged as a promising candidate for exploring novel therapeutic potentials against breast cancer (Amalraj and Gopi, 2017; Das et al., 2020). This interest was fueled by the plant's rich array of bioactive phytochemicals, including triterpenoids, flavonoids, and saponins, which had demonstrated various pharmacological activities, such as antioxidant, anti-inflammatory, and cardioprotective effects (Ramesh and Palaniappan,



2023). Breast cancer was the most prevalent cancer among Indian females, with a significant impact on public health (Shareef et al., 2016). Researchers had directed their focus towards *T. arjuna* as a potential source of innovative treatment options. The aim of the present study was to find out the unexplored therapeutic potential of *Terminalia arjuna* in breast cancer treatment. The initial phase of the study involved the creation of a phytochemical library for *Terminalia arjuna*, followed by a screening process based on druglikeness, utilizing Lipinski's Rule of five. To explore deeper into the potential mechanisms of action, molecular docking studies were conducted, targeting significant genes associated with breast cancer, including CENPM, SHCBP1, CKS2, RACGAP1, HMMR, and KIF4A. Crystal structures of these genes were obtained from the Protein Data Bank (PDB) and AlphaFold Protein Structure Database, facilitating the molecular docking studies. Ellagic Acid, Baicalein, and (+)-Leucocyanidin emerged as promising candidates, exhibiting the best binding scores with Cyclin-dependent kinases regulatory subunit 2 (CKS2). The docking poses of these compounds demonstrated strong binding affinities, with Ellagic Acid at -10.1 Kcal/mol, Baicalein at -10.0 Kcal/mol, and (+)-Leucocyanidin at -9.4 Kcal/mol. Furthermore, these lead compounds successfully passed the ADMET profiling parameters, indicating their potential for absorption, distribution, metabolism, excretion, and low toxicity. To further validate the structural stability and analyze interaction energy, MD simulations were conducted for all lead compounds. These simulations provided valuable insights into the compounds' behavior over time, contributing to a comprehensive understanding of their potential therapeutic impact. While research is ongoing, the findings from this study hold promise for the development of *Terminalia arjuna*-based therapies for breast cancer. The exploration of its bioactive compounds and their interactions with crucial breast cancer-related genes represents a step forward in uncovering novel treatment avenues.

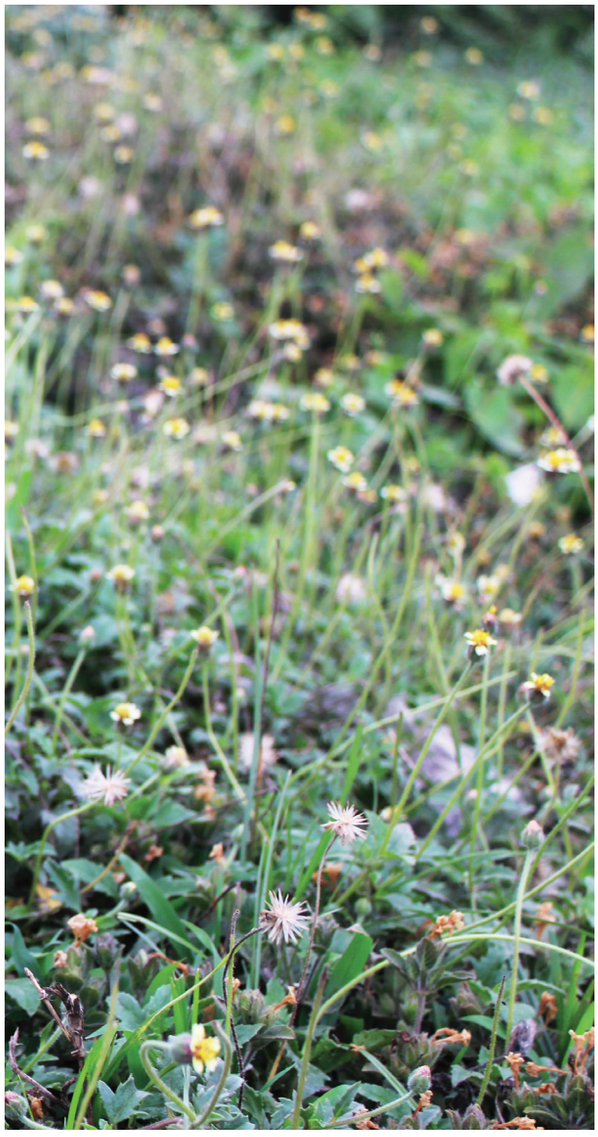
Tridax procumbens L.

Tridax procumbens L., a member of the Asteraceae family, is a prevalent tropical grass known by various names such as Jayanti Veda and Ghamra in Hindi, and Coat Buttons in English, owing to its distinctive blossoms (Pungle et al., 2022). With a historical presence in Ayurveda, *T. procumbens* has been utilized as a traditional remedy for ailments like cancer, jaundice, and liver diseases due to its rich composition of secondary metabolites, including alkaloids, steroids, phytosterols, tannins, carotenoids, flavonoids, fatty acids, and minerals (Ingole et al., 2022). These



***Tridax procumbens* L.**

compounds contribute to its diverse pharmacological activities, encompassing anticoagulant, antimicrobial, anti-arthritic, antioxidant, anti-hyperglycemic, antifungal, insect repellent, anti-inflammatory, analgesic, liver protective, and anti-cancer properties (Ingole et al., 2022; Lakhera et al., 2022). Despite the remarkable medicinal implications of *T. procumbens*, there is a noticeably lacking published studies exploring the therapeutic potential of its phytoconstituents against glioma. Glioma, a prevalent malignant brain tumor arising from glial cells, poses significant challenges in treatment despite advancements in molecular understanding (Yang et al., 2022). Subsequently, we conducted a comprehensive exploration of therapeutic targets and mechanisms against glioma. In this investigation, we employed in-silico methods to assess the pharmacological potential of *T. procumbens* phytocompounds. Molecular docking analysis, and ADMET identified promising leads, particularly luteolin, and quercetin represented potential inhibitory activities against HSP90 and SRC proteins. Specifically, luteolin-HSP90 and quercetin-SRC complexes exhibited strong binding affinities and stable structural interactions. Furthermore, the MD simulations unveiled stable interactions, highlighting luteolin's heightened inhibitory potential against HSP90. Additionally, quercetin demonstrated substantial binding affinity with the target protein proto-oncogene tyrosine-protein kinase (SRC), displaying both structural stability and remarkably least interaction energy. The study's integrated approach identifies potential phytocompounds from *T. procumbens*, emphasizing luteolin and quercetin as promising candidates for glioma treatment.



Status of the Study

The Insilco study has been completed for 100% of the selected plant species (Table 4.1). The details of the present section is documented in monographs of the respective plants.

Table 4.1 Status of the Insilco study of the medicinal plants

Sl. No.	Plant name	Status
1.	*Achyranthes aspera* L.	Completed
2.	*Boerhavia diffusa* L.	Completed
3.	*Croton bonplandianus* Baill.	Completed
4.	*Cynodon dactylon* (L.) Pers.	Completed
5.	*Ficus racemosa* L.	Completed
6.	*Solanum nigrum* L.	Completed
7.	*Ranunculus sceleratus* L.	Completed
8.	*Ricinus communis* L.	Completed
9.	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Completed
10.	*Tridax procumbens* L.	Completed

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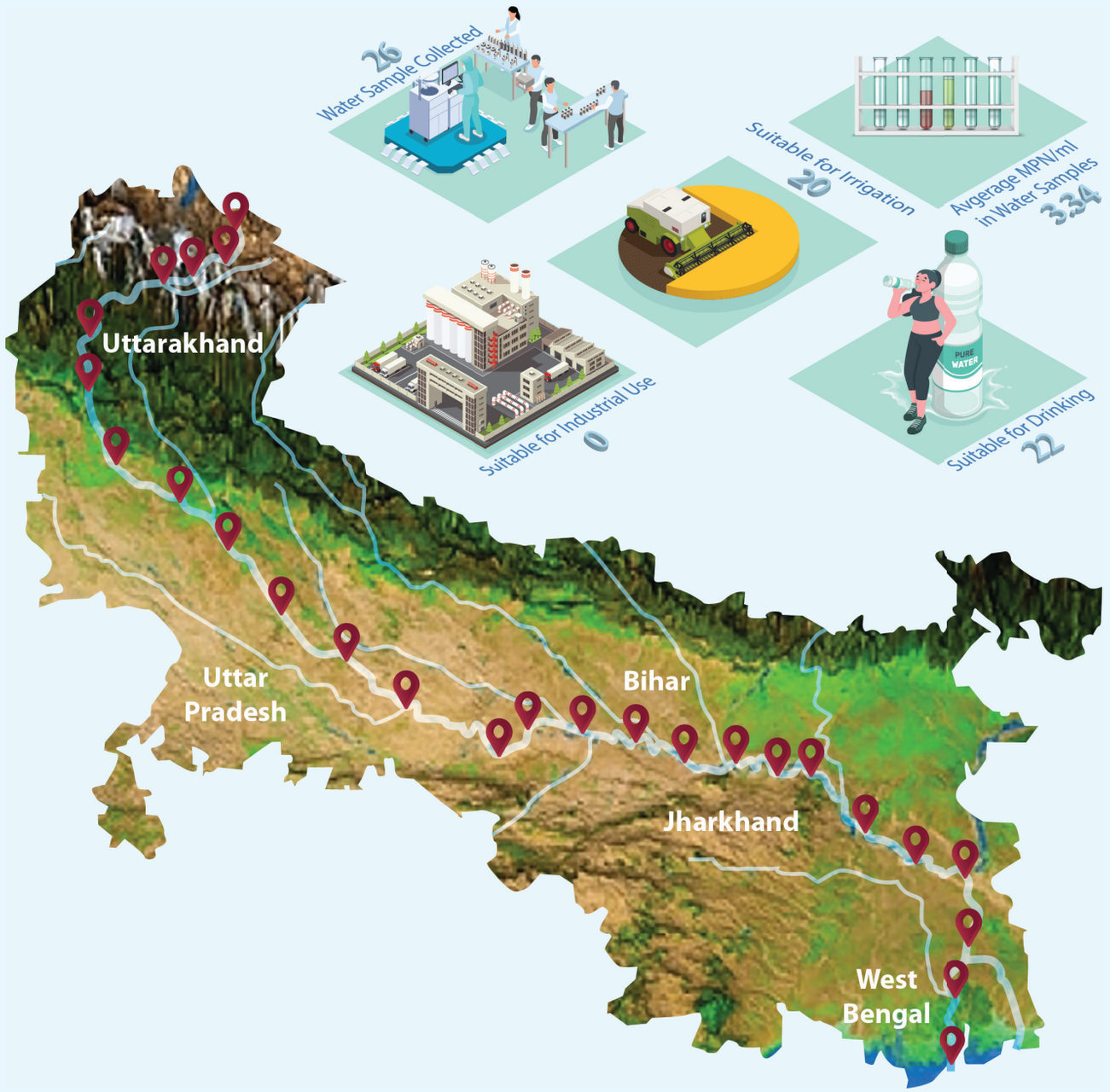
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Section-VI

Water Quality Analysis


Rudraprayag | 2024.06.20 07:59

The basin, which refers to the Ganges-Brahmaputra-Meghna basin, is a crucial resource for the people living in India, Nepal, and Bangladesh. It supports the livelihoods of over 300 million people in the region by providing water for irrigation, drinking, and other activities. The river Ganga passes along 29 Class I cities, 23 Class II cities, and approximately 50 towns. This has led to the release of various types of waste such as industrial, sewage, and other types of waste into this mighty river ecosystem. It has become a victim of pollution due to releasing these wastes, which can have long-lasting and devastating effects on the river's ecosystem and the people who depend on it. When treating wastewater, several problems occur in the first stage because of the accumulation of solid particles in the wastewater, which must be reduced by basic primary treatment. This review explores the innovative use of microbial biofilms in revolutionizing wastewater treatment in the Ganga River. The Ganga River's water quality in India poses a significant concern, primarily from pollution caused by human waste, industrial contaminants, and agricultural runoff. A comprehensive study conducted in West Bengal revealed that the Ganga River's water has been designated as polluted and unsuitable for consumption. The sources of pollution were identified as seawater influx, geogenic factors, and anthropogenic activities (Syed Yakub Ali *et al.,* 2021). Researchers have discovered that the Ganga River's water quality is deteriorating due to human activities. Elevated nitrate concentrations have been identified at multiple locations along the riverbanks in West Bengal. Ongoing endeavors are dedicated to enhancing the water quality of the river, exemplified by initiatives like Namami Gange. This program is designed not only to curb the influx of pollution into the river but also to rejuvenate landscapes along the waterway. State-of-the-art real-time water quality monitoring systems have been implemented to assess the Ganga River's water quality across multiple parameters (Singh et al., 2022).

The rationale behind water testing of the Ganga River is to assess its suitability for various uses, such as drinking, irrigation, and industrial applications. The river plays a crucial role in sustaining the lives of millions of people, and its water quality is of utmost importance. With this goal in mind, the objectives of the current section are the following.

- Analysis of physico-chemical parameters of water samples
- Analysis of microbial quality of water samples
- Analysis of the suitability of using the water samples

Material and Methods

The following section comprises the site selection for sample collection and details of analytical methods and microbial methods.

SITE SELECTION

Selecting an appropriate site for conducting a comprehensive analysis of Ganga River water quality is a critical aspect of our project work. The chosen site represents the diverse characteristics of the river, considering both upstream and downstream regions, urban and rural influences, and potential anthropogenic sources of pollution. Strategic site selection accounts for variations in flow rates and seasonal changes, ensuring a comprehensive evaluation of the river's dynamics. The selected sites for sampling of water are given below in table 6.1.

Table 6.1 The sites selected for the sampling of water samples.

Codes	State	Nearby sites	Latitude (°N)	Longitude (°E)	Altitude (m)
S1	Uttarakhand	Gaumukh	30.7983	79.1542	4023
S2		Gangotri	30.9800	78.9300	3415
S3		Uttarkashi	30.7292	78.4428	1158
S4		Devprayag	30.1500	78.6000	830
S5		Haridwar	29.9667	78.1667	314
S6	Uttar Pradesh	Bijnor	29.3700	78.1300	225
S7		Narora	28.1967	78.3814	174
S8		Budaun	28.0500	79.1200	164
S9		Farrukhabad	27.3700	79.6300	151
S10		Bithoor	26.6127	80.2719	126
S11		Dalmau	26.0700	81.0300	115
S12		Prayagraj	25.4500	81.8500	98
S13		Mirzapur	25.1500	82.5800	80
S14		Varanasi	25.3189	83.0128	81
S15		Ballia	25.7625	84.1519	67

Codes	State	Nearby sites	Latitude (°N)	Longitude (°E)	Altitude (m)
S16	Bihar	Revelganj	25.7800	84.6700	52
S17		Patna	25.6100	85.1414	53
S18		Barh	25.4800	85.7200	47
S19		Bahachouki	25.2975	86.3561	55
S20		Farka	25.2287	87.0949	42
S21	Jharkhand	Sahebganj	25.2500	87.6500	16
S22	West Bengal	Farakka Barrage Township	24.8200	87.9000	30
S23		Murshidabad	24.1800	88.2700	18
S24		Mayapur	23.4250	88.3908	11
S25		Hooghly	22.9089	88.3967	9
S26		Gangasagar	22.1910	88.1905	4

A total of 26 sites have been carefully selected along the banks of the Ganga River. Out of these, five sites are situated in Uttarakhand, while Uttar Pradesh boasts 10 sites (Table 6.1). Bihar contributes five sites, Jharkhand has one, and West Bengal is home to five sites along the river.

PROCEDURE OF WATER COLLECTION

Sampling for Physicochemical Test

Water samples were systematically collected from twenty-six chosen sites spanning the entire stretch of the Ganga River, extending from Gaumukh (Uttarakhand) to Ganganagar (West Bengal). The collection of river water samples employed the grab method, conducted in triplicate using both glass and PTFE (Polytetrafluoroethylene) containers. To maintain sample integrity, they were carefully stored in a cool box filled with ice, maintaining a temperature range of 2-4 degrees Celsius during transportation. The entire process adhered meticulously to the guidelines outlined by the Central Pollution Control Board (CPCB) for water and wastewater analysis, as well as the standards set by the American Public Health Association (APHA) in 2012.

Sampling for microbial analysis

A 20 mL pre-sterilized glass container was employed to gather a water sample from the river. To ensure proper handling of microbiological parameters, the collection process involved wearing gloves. The container was meticulously filled to the brim from a depth ranging between 20 and 30 centimetres below the water's surface. To preserve the integrity of the samples, they were meticulously stored in a refrigerated container filled with ice, maintaining a precise temperature range of 2-4 degrees Celsius throughout the transportation process. The entire procedure strictly adhered to the guidelines stipulated by the Central Pollution Control Board (CPCB) for the analysis of water and wastewater, and it also conformed to the standards established by the American Public Health Association (APHA) in 2012.


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XWVV+Q39, Gangotri, Uttarakhand 249135, India
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Long 78.942583°
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ANALYTICAL METHODS

The methods used for the analysis of physico-chemical parameters of water samples have been furnished in Table 6.2.

Table 6.2 Details of Physico-chemical Analytical Methods

Parameter	Method and Calculation Used	Instrument Used	Reference	Permissible values
Color	Color comparator	-	CPCB	-
Odor	Odor	-	CPCB	-
Temperature	Thermometer	-	CPCB	-
pH	pH meter	PH-009-I	CPCB/WHO	6.5-8.5
Turbidity (NTU)	Nephelometer/turbidimeter	IN LABS India Turbidity meter	WHO	10
Electrical conductivity (µs/cm)	Conductivity meter	Systronics Conductivity TDS meter 308	WHO	400
Dissolved Oxygen (mg/L)	DO Meter or Winkler modified method	Lutron DO-5509	CPCB	6-8
Total Solids/Total Dissolved Solids/ Total Suspended Solids (mg/L)	Gravimetry	TDS-3 Digital meter	CPCB	500
Nitrate-N (mg/L)	Spectrophotometry	Shimadzu Spectrophotometer	BIS	45
Sodium	Flame Photometry	Systronics Flame Photometer 1027	WHO	200
Potassium	Flame Photometry	Systronics Flame Photometer 1027	WHO	55
Biochemical Oxygen Demand (BOD) (mg/L)	DO consumption in 3 days at 27 °C	-	WHO	5
Chemical Oxygen Demand (COD) (mg/L)	Potassium dichromate method	COD Digester	WHO	300
Alkalinity (mg/L)	Titrimetric	-	CPCB	200

Parameter	Method and Calculation Used	Instrument Used	Reference	Permissible values
Total Hardness (mg/L)	Titrimetric	-	CPCB	300
Carbonate as CaCo3 (mg/L)	Titrimetric	-	CPCB	-
Chloride (mg/L)	Argentometric titration	-	CPCB	250
Sulphate (mg/L)	Turbidimetry	INLABS India Turbidity meter	CPCB	200
Fluoride (mg/L)	Ion meter, Colorimetry	-	BIS	0.6-1.2

The microbiological analysis of water samples has been performed by different culture-dependent methods given below (Table 6.3). The details of microbiological instruments used in various methods are listed in Table 6.4.

Table 6.3 Details of Microbiological analysis methods

Name of the Experiment	Name of the culture media	Composition of media	Make	Purpose of Using the Media	Incubation Temp. and Duration	Expected outcome	Reference
Most Probable Number Test	MacConkey Broth	Gelatin peptone, Lactose monohydrate, Dehydrated bile, Bromo cresol purple	Himedia MH083	For the selective enrichment of total coliform and *E. coli*	30-35°C for 18-48 hours	growth and characteristic color change of coliform bacteria, which are indicator organisms for fecal contamination	(Rijal, 2017)
Aerobic Microbial count	Plate Count Agar	Tryptone, Yeast extract, Dextrose (Glucose), Agar	Himedia-M091A	For determining plate counts of microorganisms	35 - 37°C for 18 - 24 hours	total number of live, aerobic bacteria in the sample	(Council, 2024)

Name of the Experiment	Name of the culture media	Composition of media	Make	Purpose of Using the Media	Incubation Temp. and Duration	Expected outcome	Reference
Detection of *E.coli* and fecal Coliform	Eosin Methylene Blue (EMB) Agar	Peptone, Dipotassium hydrogen phosphate, Lactose, Saccharose (Sucrose), Eosin – Y-Methylene blue, Agar	Himedia-M317	For the isolation of Gram-negative enteric bacteria	35 - 37°C for 18 - 24 hours	Lactose-fermenting bacteria produce dark colonies with a metallic sheen, while non-lactose-fermenting bacteria produce colorless colonies	(Lal & Cheeptham, 2007)
Detection of *Salmonella* species	SS Agar (*Salmonella Shigella* Agar)	Peptone, HM peptone B, Lactose, Bile salts mixture, Sodium citrate, Sodium thiosulphate, Ferric citrate, Brilliant green, Neutral red, Agar	Himedia-M108	For the isolation of *Salmonella*	35-37°C for 18-24 hours	isolation and differentiation of *Salmonella* and some *Shigella* species	(SS AGAR, n.d.)
Detection of *Shigella* species	SS Agar (Salmonella Shigella Agar)	Peptone, HM peptone B, Lactose, Bile salts mixture, Sodium citrate, Sodium thiosulphate, Ferric citrate, Brilliant green, Neutral red, Agar	Himedia-M108	For the isolation of *Shigella*	35-37°C for 18-24 hours	isolation and differentiation of *Salmonella* and some *Shigella* species	(SS AGAR, n.d.)

Name of the Experiment	Name of the culture media	Composition of media	Make	Purpose of Using the Media	Incubation Temp. and Duration	Expected outcome	Reference
Detection of *Klebsiella* species	C.L.E.D. Agar w/Bromo Thymol Blue Plate	Peptone, Tryptone, HM Peptone, Lactose, L-Cystine, Bromothymol blue, Agar	Himedia-MP792	For isolation of *Klebsiella* Species	35-37°C for 18-24 hours.	for the isolation, enumeration and differentiation of urinary microorganisms	(Dr. Belouahad loqman, 2024)
Detection of *Enterobacter/ Enterococcus* species	C.L.E.D. Agar w/Bromo Thymol Blue Plate	Peptone, Tryptone, HM Peptone, Lactose, L-Cystine, Bromothymol blue, Agar	Himedia-MP792	For isolation of *Enterobacter/ Enterococcus*	35-37°C for 18-24 hours.	for the isolation, enumeration, and differentiation of urinary microorganisms	(Dr. Belouahad loqman, 2024)
Detection of *Staphylococcus* species:	Mannitol Salt Agar	Peptone, Tryptone, HM Peptone B, Sodium chloride, D-Mannitol, Phenol red, Agar	Himedia-M118	For isolation of *Staphylococcus*	30-35°C for 18-72 hours	differentiation from other *staphylococci* and non-*staphylococcal* bacteria	(Aryal, 2016)
Detection of *Pseudomonas* species:	Cetrimide Agar	Gelatin peptone, Magnesium chloride, Dipotassium sulphate, Cetrimide, Agar	Himedia-MH024	For the selective isolation of *Pseudomonas aeruginosa*	30-35 °C for 18-72 hours	isolation and purification of *Pseudomonas aeruginosa* from contaminated specimens	(Aryal, 2019)

Name of the Experiment	Name of the culture media	Composition of media	Make	Purpose of Using the Media	Incubation Temp. and Duration	Expected outcome	Reference
Detection of *Vibrio* species:	TCBS Agar	Proteose peptone, Yeast extract, Sodium thiosulphate, Sodium citrate, Bile, Sucrose, Sodium chloride, Ferric citrate, Bromo thymol blue, Thymol blue, Agar	Himedia-M870S	For the selective isolation and cultivation of *Vibrio cholerae*	35-37°C for 18-24 hours	selective isolation of *Vibrio cholerae* and other *enteropathogenic* vibrios	(Aryal, 2015)
Antibiotic Sensitivity Test	Nutrient Broth	Peptone, Sodium chloride, HM peptone B, Yeast extract	Himedia-M002	General cultivation of less fastidious microorganisms	35-37°C for 18-48 hours	Cultivation of non-fastidious bacteria	(Gautam, 2021)

Table 6.4 Details of Microbiological Instrumentations used in methods

Name	Make	Purpose	Working Operation
Laminar Airflow	Harrison's Pharma Machinary	Provides a sterile work environment	Uses a continuous, unidirectional flow of filtered air
Autoclave	Salvesion Pharma	Sterilization of equipment and media	Uses high-temperature and pressure steam 121° C, 15 psi `to kill microorganisms
BOD Incubator	Meditech Technologies India Private Limited	Biochemical Oxygen Demand (BOD) testing	Maintains controlled temperature for microbial growth (35-37°C)

Name	Make	Purpose	Working Operation
Colony counter	Prime Vidyo udyog (India)	Enumeration of microbial colonies	Facilitates manual or automated counting of colonies
Hot air oven	Prime Vidyo udyog (India)	Sterilization and drying of glassware	Uses dry heat to achieve high-temperature (100°C) sterilization
Refrigerator	Celfrost Middle by Company USA	Storage of samples, reagents, and cultures	Maintains low temperatures for sample preservation (4°C)
Digital Weighing balance	Contech	Accurate measurement of mass	Utilizes digital sensors and displays for precise weighing
Hot plate	Prime Vidyo udyog (India)	To heat and maintain the temperature of a sample	Based on heating through conduction (80°C)

OVERALL SUITABILITY ANALYSIS OF WATER

The water samples were further classified as the suitability for drinking water, irrigation water or industrial water. In Table 6.5. The details of the said methods have been given below.

Table 6.5 Details of Index measurement to check overall water quality.

S.no.	Type of Water quality	Index Name	Purpose	Calculation	Reference
1	(Drinking water)	NSFWQI	A commonly used method for such evaluations is the Water Quality Index (WQI), which combines various parameters to produce a single numerical value indicating the overall water quality.	$WQI = \sum_{i=1}^{n} QiWi$	Kalagbor I.A. et. al (2019)

S.no.	Type of Water quality	Index Name	Purpose	Calculation	Reference
2	Irrigation Water	SAR	The purpose of SAR calculation for water is to assess its suitability for irrigation and to prevent potential soil problems associated with high sodium levels, ensuring optimal conditions for agriculture	SAR = $Na^{+}/ {}^{2+2+}$	El-Defan, A., et. al (2016)
3	Industrial Water	RSI	These indices help in understanding whether the water will tend to scale, dissolve calcium carbonate, or maintain equilibrium, assisting in the management of water treatment processes to minimize scaling and corrosion issues.	RSI = 2 (pHs) -pH	A. K. Haritash, Shalini Gaur, Sakshi Garg (2016)
Designated Best Use Classification of Surface Water					
S. No.	Designated best use	Quality Class	Primary Water Quality Criteria		
1.	Drinking water source without conventional treatment but with chlorination	A	1. Total coliform organisms (MPN/100 ml) shall 2. be 50 or less 3. pH between 6.5 and 8.5 4. Dissolved Oxygen 6 mg/l or more, and Biochemical Oxygen Demand 2 mg/l or less		
2.	Outdoor bathing (organized)	B	1. Total coliform organisms (MPN/100 ml) shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5 mg/l or more, and 4. Biochemical Oxygen Demand 3 mg/l or less		
3.	Drinking water source with conventional treatment	C	1. Total coliform organisms (MPN/100 ml) shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4 mg/l or more, and 4. Biochemical Oxygen Demand 3 mg/l or less		

S.no.	Type of Water quality	Index Name	Purpose	Calculation	Reference
5.	Propagation of wildlife and fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4 mg/l or more, and 3. Free ammonia (as N) 1.2 mg/l or less		
6.	Irrigation, industrial cooling, and controlled disposal	E	1. pH between 6.0 and 8.5 2. Electrical conductivity less than 2250 micro mhos/cm, 3. Sodium Absorption Ratio less than 26, and Boron less than 2 mg/l.		

Results of water Quality Analysis

Various parameters of water quality were thoroughly examined and are detailed below. The analysis findings were documented state-by-state, encompassing Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal. Furthermore, an overarching water quality index has been compiled and is presented after the report.

01



5
Water Sample Collected

02



5
Suitable for Drinking

03



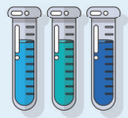
5
Suitable for Irrigation

04



0
Suitable for Industrial use

05



5.02
Avgerage MPN/ ml in Water samples



UTTARAKHAND

Results of water Quality of Uttarakhand

India's northern state of Uttarakhand was once known as Uttaranchal. Because there are so many Hindu temples and pilgrimage sites spread out over the state, it is sometimes referred to as the Devbhumi. The Terai, Bhabhar, and Himalayan natural environments are what make Uttarakhand famous. The whole area of Uttarakhand is 53,483 km^2, of which 86% is made up of mountains and 65% is forest. Glaciers and towering Himalayan peaks encircle the majority of the state's northern region. The major issues regarding the Ganga's pollution in Uttarakhand include receding glaciers, unregulated tourism, discharge of sewage and other waste, illegal mining, and contamination with pesticides and other chemicals. The water quality of the Ganga River was found to be unfit for bathing in most parts of the river, except for upper stretches in Uttarakhand. The pollution of the Ganga River in Uttarakhand has a significant impact on aquatic life. The pollution causes drastic changes in the fauna and flora, the biodiversity of the river ecosystem. The contamination of the Ganga River in Uttarakhand exerts a significant impact on aquatic life, inducing drastic alterations in the fauna and flora, thus affecting the overall biodiversity of the river ecosystem. The discharge of sewage, agricultural runoff, and industrial effluents collectively contribute to the pollution of the river, thereby fostering conditions conducive to waterborne diseases such as cholera and typhoid. Moreover, the impediment of proper vegetation transfers results from the construction of dams and reservoirs, causing the depletion of forests and natural vegetation and consequent soil erosion. Consequently, the pollution of the Ganga River poses a potential health threat to the inhabitants of the region.

ON-SITE ANALYSIS

As shown in On-site parameters (Table 6.6), details of five sites along the Ganges River in Uttarakhand, India, showcasing a remarkable change in environmental conditions from high altitude to the plains.

Table 6.6. Field data of the water samples of Uttarakhand

S.no.	Site name	Site codes	Color	Odor	Foam	Temperature (°C)	pH	TDS (ppm)
1.	Gomukh	S1	Clear	No	No	01.0	6.7	54
2.	Gangotri	S2	Clear	No	No	6.8	7.2	45
3.	Uttarkashi	S3	Clear	No	No	15.8	7.7	35
4.	Devprayag	S4	Green	No	No	24.0	7.4	33
5.	Haridwar	S5	Green	No	No	24.6	8.6	58

At Gaumukh (4023 m), where the river originates, the temperature range is notably chilly, measuring at 01.0°C. As we progress downstream, temperatures gradually increase—reaching 6.8°C at Gangotri and 15.8°C at Uttarkashi. The color of the water sample remains clear throughout this stretch. Upon reaching lower altitudes, specifically at Devprayag (1014 m) and Haridwar (265 m), temperatures significantly soar, registering at 24°C and 24.6°C, respectively. Interestingly, there is no discernible odor, or foam, and the pH levels exhibit an upward trend with the decrease in altitude. Notably, the Total Dissolved Solids exhibit a reverse correlation, decreasing as we ascend in altitude.

LABORATORY ANALYSIS

Oxygen

Natural stream purification processes require adequate oxygen levels to provide for aerobic life forms. As per the results recorded for oxygen concentration measured in three parameters DO, BOD and COD respectively are under the permissible limits. The Fig. 6.1 representing the results for these parameters is shown below:

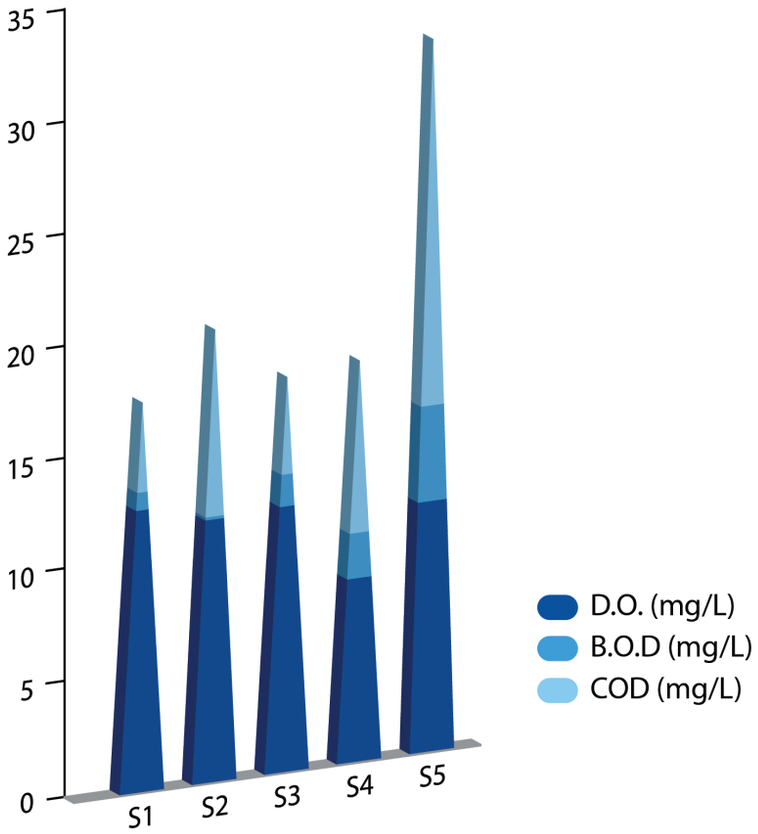


Fig. 6.1 DO, BOD and COD data of water samples obtained from different sample locations of Uttarakhand

The mean values for all three oxygen concentrated parameters are DO (11.17mg/L), BOD (1.744mg/L) and COD (8.132mg/L). In our studies we found DO to be lowest at Devprayag (S4) and highest at Gaumukh (S1) having values 8.20 mg/L and 12.66 mg/L respectively. BOD is marked lowest at Gangotri (S2) having value of 0.13 mg/L and highest at Haridwar (S5) having values 4.26 mg/L. The highest COD is measured at Haridwar, S5(16.33 mg/L) and lowest COD is measured at Gaumukh, S1(4.00 mg/L).

Alkalinity and Electrical conductivity

Electrical conductivity shows a significant correlation with the total alkalinity of water. Alkalinity is measured in terms of the capacity of water to neutralize the acids. The graphical representation of recorded EC and Alkalinity of different sites of Uttarakhand is represented below in Fig. 6.2.

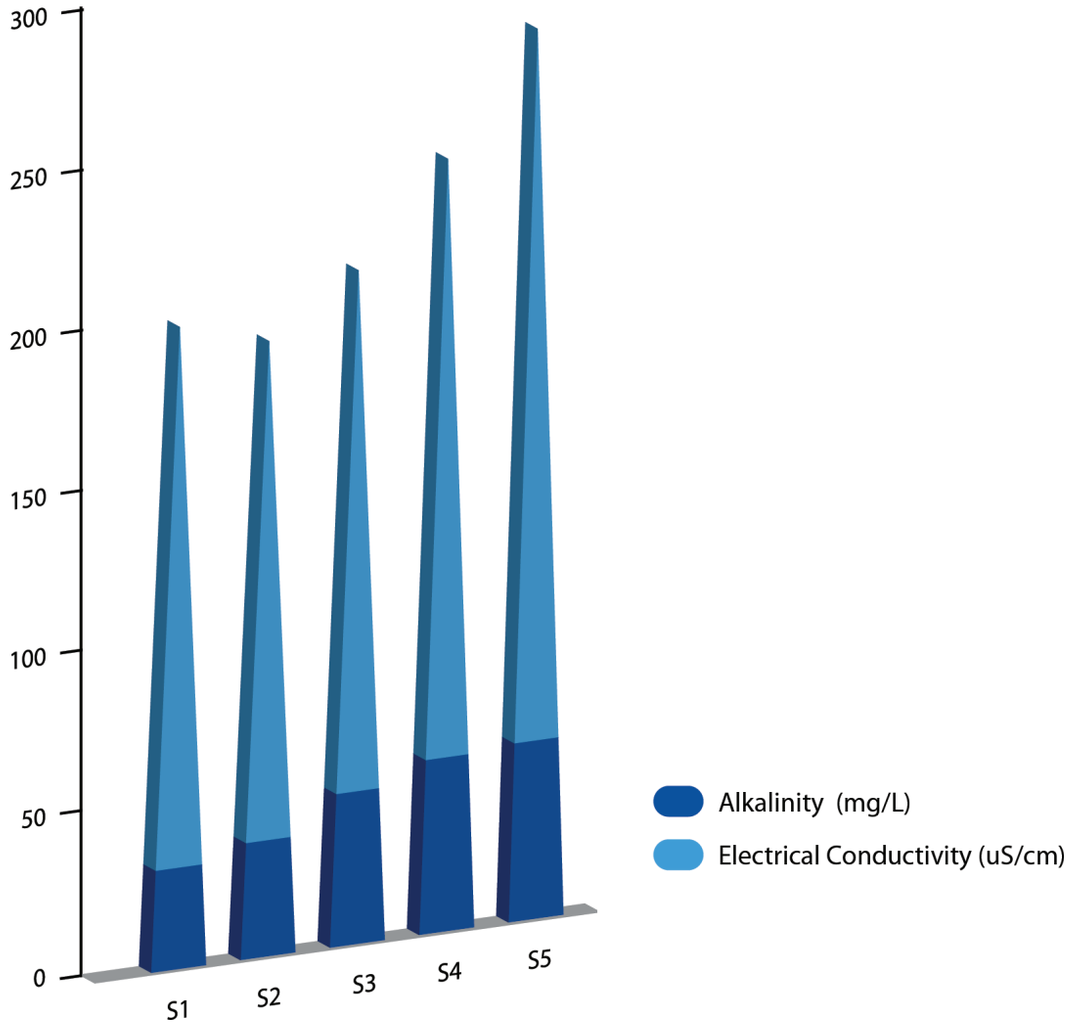


Fig. 6.2 Alkalinity and Electrical Conductivity data of water samples obtained from different sample locations of Uttarakhand.

The alkalinity of the UK is measured highest in Haridwar, S5(56.0mg/L) and lowest in Gaumukh, S1(32.0mg/L) while the mean alkalinity is 45.466mg/L. Similarly, EC an important parameter was recorded to be highest in Haridwar, S5 (222.23 µs/cm) and lowest in Gangotri, S2 (155.80 µs/cm). The mean EC value is calculated to be 179.27uS/cm.

Turbidity, TSS and TDS

Turbidity is caused by the suspended or dissolved particles present in water which makes the physical appearance cloudy or murky. Alkalinity is measured in terms of the capacity of water to neutralize the acids. The graphical representation of recorded Turbidity, TSS, and TDS of different sites of Uttarakhand is represented below in Fig. 6.3.

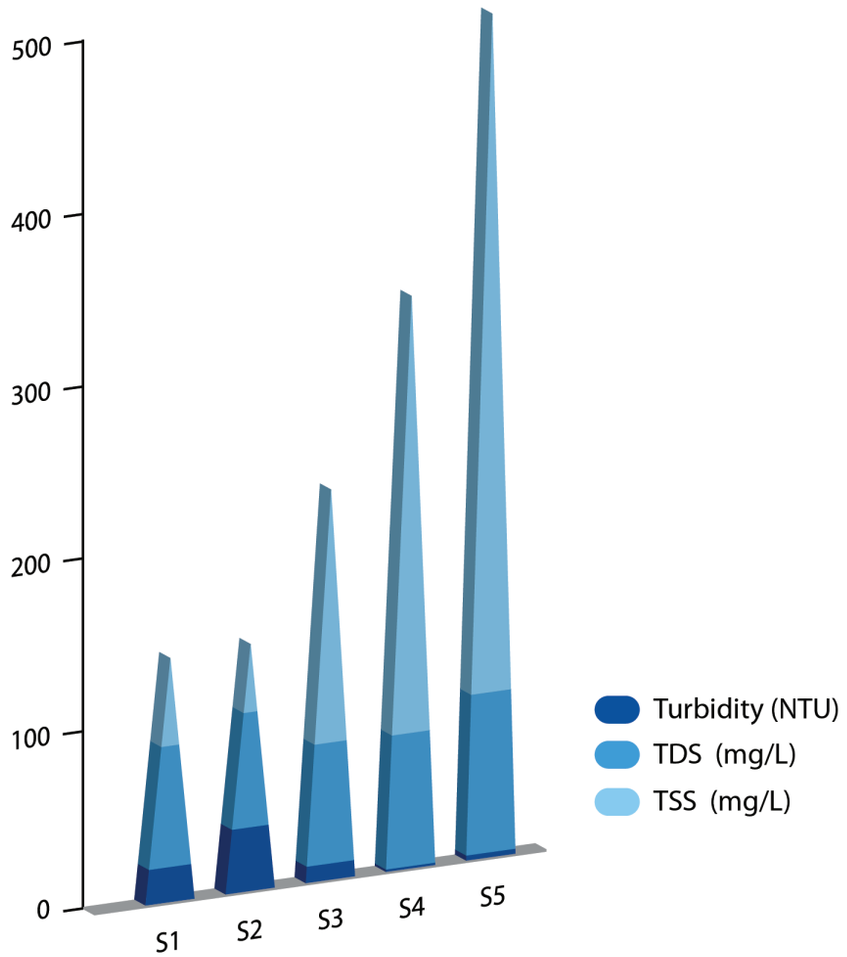


Fig. 6.3 Turbidity, TSS, and TDS data of water samples obtained from different sample locations of Uttarakhand

In this study, the mean turbidity recorded was 14.85 NTU with maxima at Gangotri, S2 (37.53 NTU) and minima at Devprayag, S4 (2.02 NTU). The maximum recorded value

for turbidity was out of the permissible limit given as per the BIS. The values of TDS and TSS are given in mg/L, the mean value recorded is 75.214 mg/L and 176.66 mg/L respectively. The minimum TDS is recorded in Gangotri, S2 (66.54 mg/L), and the maximum in Haridwar, S5 (92.55 mg /L). The TSS values are recorded to be minimum in Uttarkashi, S3 (146.67 mg/L) and maximum in Gaumukh, S1 (50.67 mg/L).

Hardness

Water hardness is defined by the concentration of dissolved Calcium and Magnesium in water. In our research, we meticulously considered calcium hardness, magnesium hardness, and total hardness. The graphical representation of recorded hardness of different sites of Uttarakhand is represented below in Fig. 6.4.

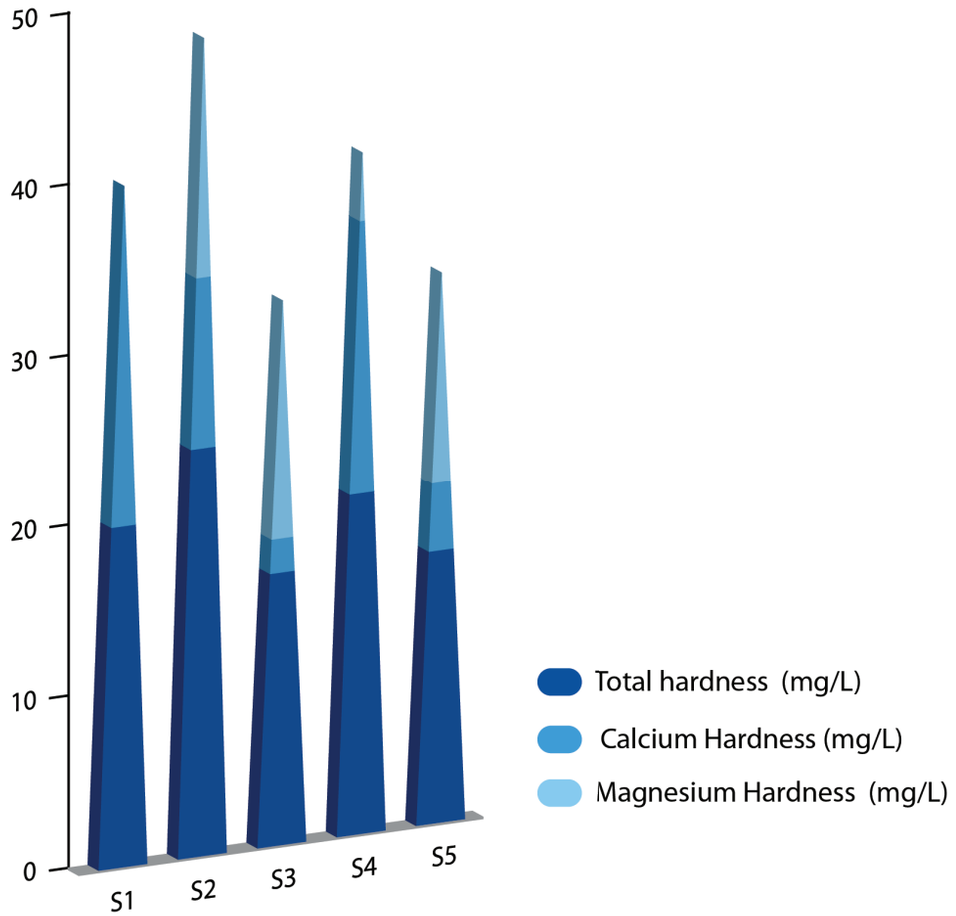


Fig. 6.4 Hardness data of water samples obtained from different sample locations of Uttarakhand

The Calcium hardness in the Uttarakhand region is reported to have an average value of 10.4 mg/L, while the average Magnesium hardness is 8.86 mg/L. The overall mean of total hardness in the region is calculated to be 19.2 mg/L. Notably, Uttarkashi, specifically

site S3, exhibited the minimum calcium hardness at 2.0 mg/L, whereas Gaumukh, site S1, recorded the maximum at 20.0 mg/L. In terms of Magnesium hardness, Gangotri (S2) and Uttarkashi (S3) displayed the highest levels at 14.0 mg/L, while Gaumukh (S1) registered the lowest, with zero magnesium hardness (0.00 mg/L). Similarly, the lowest total hardness values were observed in Uttarkashi (S3) and Haridwar (S5) at 16.0 mg/L, whereas Gangotri (S2) recorded the highest total hardness at 24.0 mg/L.

Nitrate and Sulphate

The concentration of nitrates and sulphates in water may result from the discharge of fertilizers into the water body. The graphical representation of recorded Nitrate and Sulphate of different sites of Uttarakhand is represented below in Fig. 6.5.

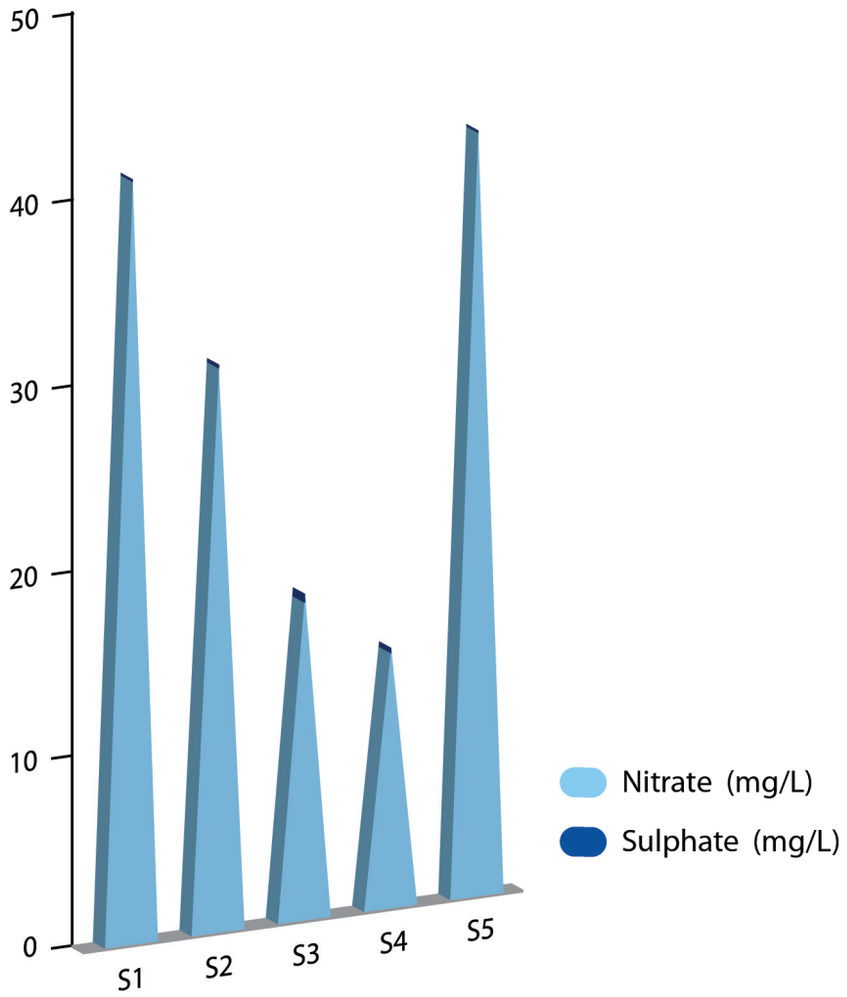


Fig. 6.5 Nitrate and Sulphate data of water samples obtained from different sample locations of Uttarakhand

Our study revealed that the average recorded levels of nitrates and sulphates in Uttarakhand water samples are 0.24 mg/L and 28.79 mg/L, respectively. The minimum nitrate values were observed in samples from Gaumukh (S2) and Haridwar (S5) at 0.14 mg/L, while the maximum nitrate value was found in the Uttarkashi sample (S3) at 0.47 mg/L. Conversely, the highest sulphate concentration was detected in samples from Gaumukh (S1) and Haridwar (S5) at 41.20 mg/L, with the lowest sulphate levels recorded in Devprayag (S4) at 13.81 mg/L.

Ionic Constituent

In our study, we considered four significant ion contributors that is Sodium, Chloride, Fluoride and Potassium. The graphical representation of recorded ionic constituent of different sites of Uttarakhand is represented below in Fig. 6.6.

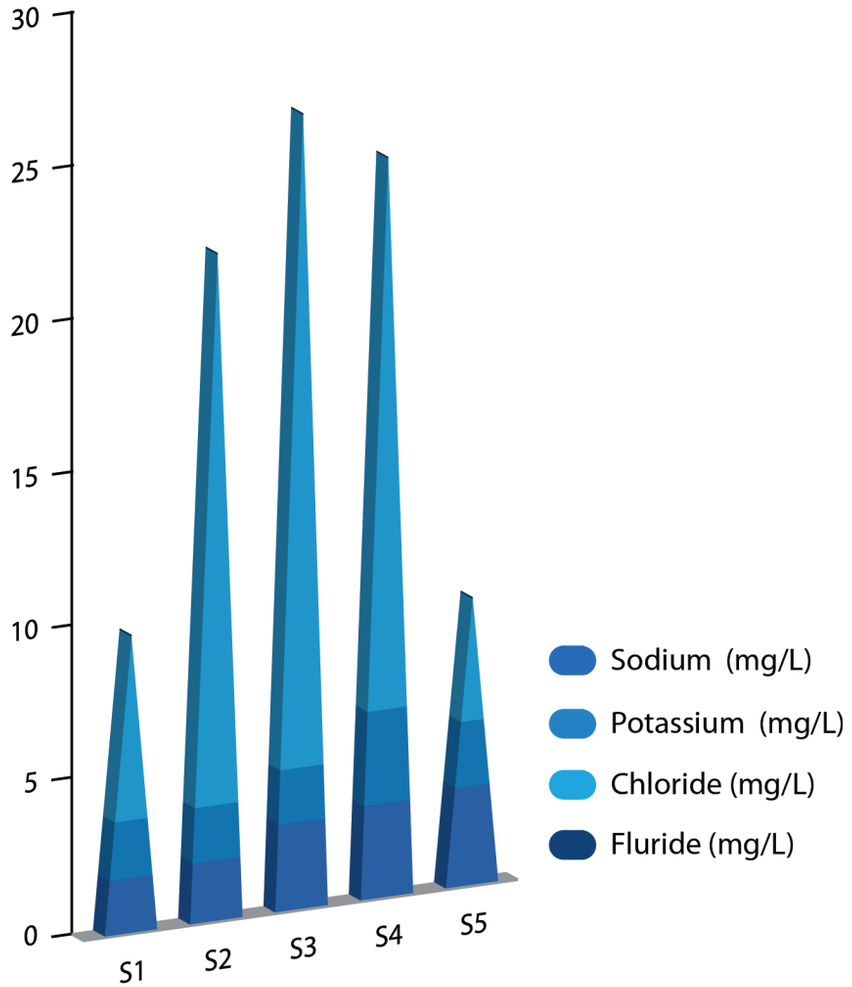


Fig. 6.6 Ionic constituent data of water samples obtained from different sample locations of Uttarakhand

The mean values recorded for Sodium (2.62 ppm), Chloride (13.46 ppm), Fluoride (0.05 ppm) and Potassium is 2.13 ppm. The lowest sodium concentration was observed in Gaumukh, S1 (1.83 ppm), while the highest was found in Haridwar, S5 (3.28 ppm). Potassium exhibited the lowest concentration in Uttarkashi, S3 (1.77 ppm), and the highest in Haridwar, S5 (2.13 ppm). Chloride levels were recorded at their lowest in Haridwar, S5 (4.0 ppm), and the highest in Uttarkashi, S3 (21.33 ppm). Fluoride content remained consistent throughout the river belt in Uttarakhand, with a value of 0.05 ppm.

Total coliform

Total coliforms are a group of bacteria that includes *E. coli* and are commonly used as indicators of water quality. The data obtained from these analyses will be instrumental in evaluating the overall microbial safety and quality of the water in the specified region, as shown in below Fig. 6.7.

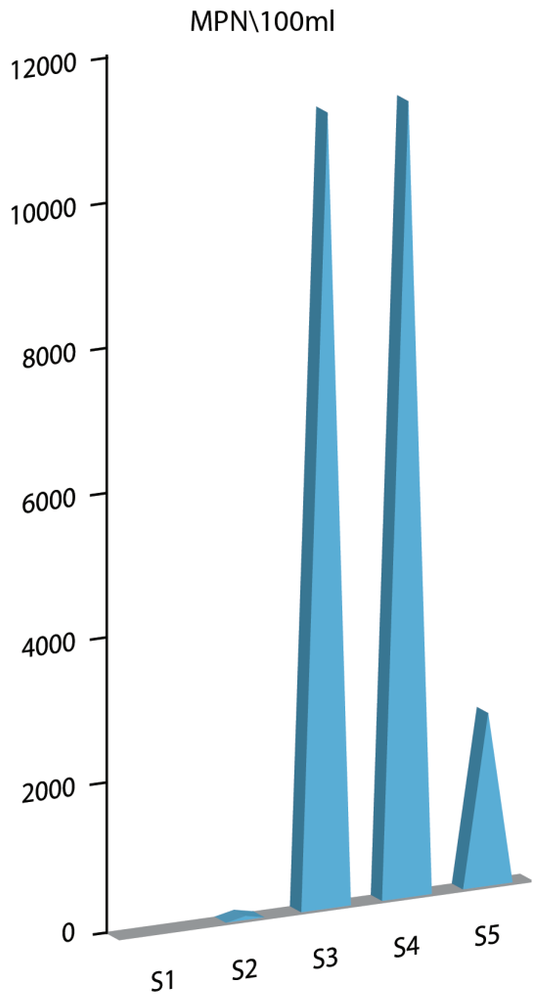


Fig. 6.7 Total coliform data of water samples obtained from different sample locations of Uttarakhand

Notably, S4 and S5 exhibit the highest MPN values, both registering at 11,000 MPN/100ml, with S5 specifically recording a value of 2,400 MPN/100ml. In contrast, S1 and S2 display the lowest MPN values, with S1 indicating an absence (0 MPN/100ml) and S2 showing a minimal count of 74 MPN/100ml. This data highlights significant variations in microbial contamination levels among the sampled locations, emphasizing the importance of continued monitoring and appropriate interventions to ensure water safety.

The Differential Bacterial Count

This count is typically expressed as the number of bacterial colony-forming units (CFUs) per unit volume of the sample, all the values are expressed in Log 10. The total bacterial count remains relatively consistent across all sampling sites, with S2 displaying 8.60, S3 with 9.2, S4 is 8.8, and S5 8.7. Notably, S1 exhibits no detectable bacterial count, registering at 0. Examining total coliform counts reveals minimal variation among the sites as shown in Fig. 6.8. Representative pictures of the isolated bacteria from Uttarakhand are shown in Fig. 6.9.

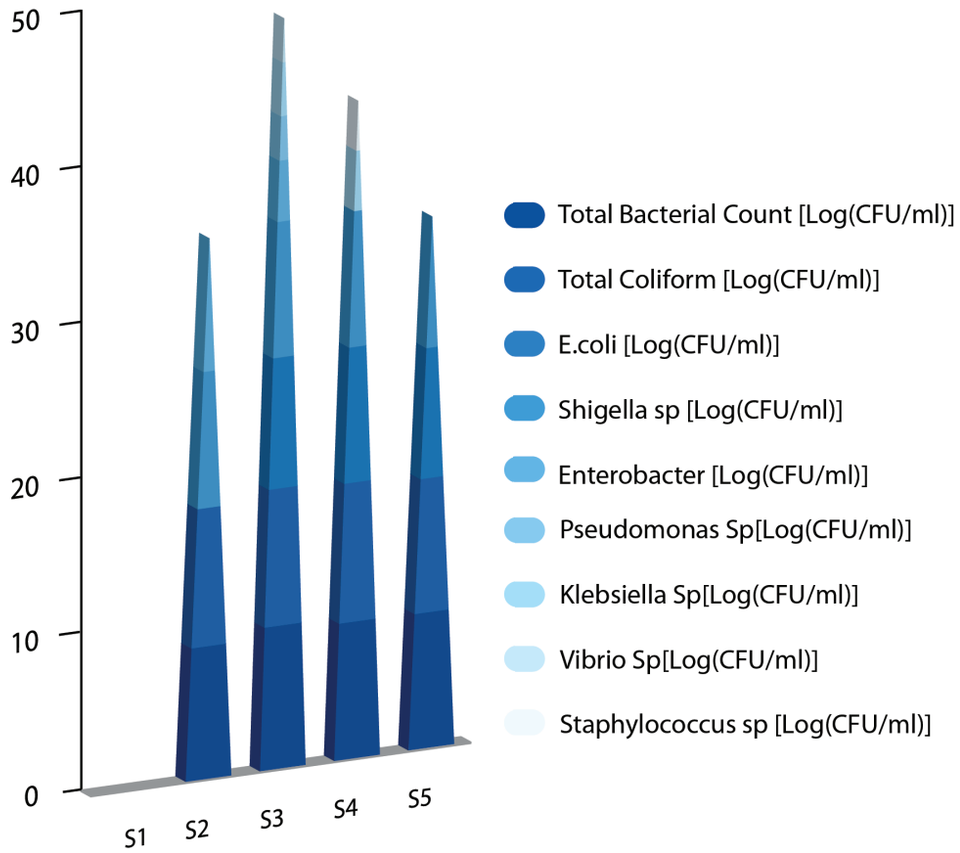
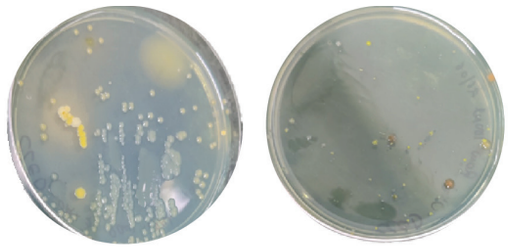


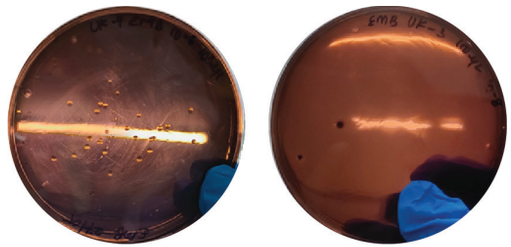
Fig. 6.8 The Differential Bacterial Count data of water samples obtained from different sample locations of Uttarakhand



Analysis of *E. coli* presence shows no detection in S1 and S2, while S3 displays 8.4, S4 at 8.7, and S5 at 8.3. *Shigella* species are present in all sampling sites, excluding S1. The counts are consistent, measuring 8.7 in S2, S3, and S4, while S5 exhibits 8.4. *Enterobacter* is identified solely in S2 and S3, presenting counts of 8.5 and 3.9, respectively. *Pseudomonas* is exclusively found in S3, with a count of 2.8. *Klebsiella* is detected in S3 and S4, registering at 3.4 Log and 3.8, respectively. *Vibrio* species are observed in S3, with a count of 2.8, while *Staphylococcus* species are solely present in S4, recording 3.1.



Cysteine-Lactose-
Electrolyte-Deficient (CLED)



Eosin Methylene
Blue agar (EMB)

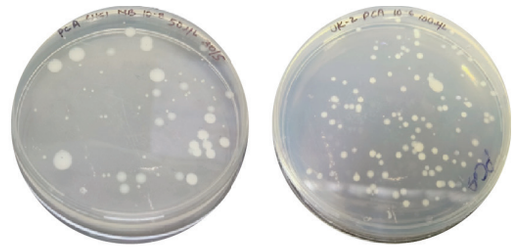
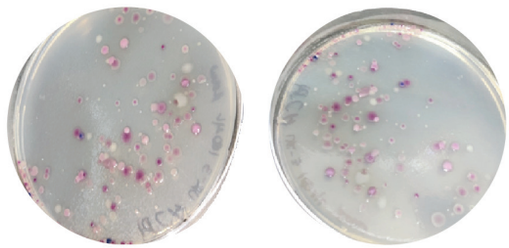
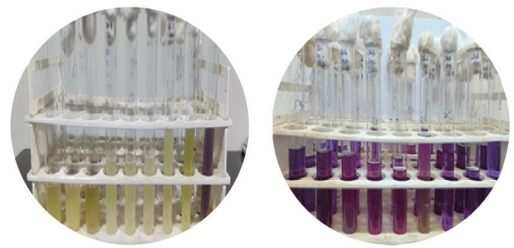


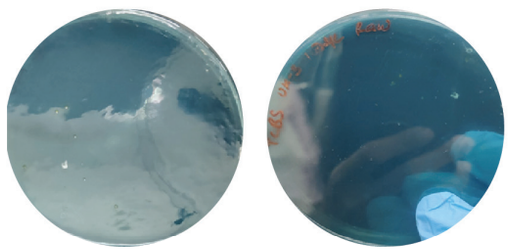
Plate Count
Agar (PCA)



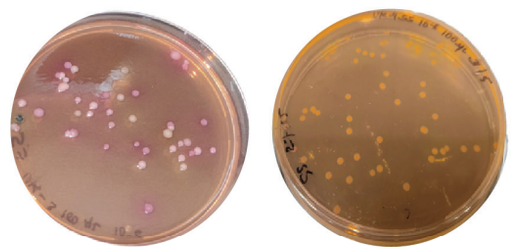
Hichrome Chromogenic
Coliform Agar (HCA)



Most Probable
Number (MPN)



Thiosulfate Citrate Bile



Salmonella-Shigella

Fig. 6.9 Representative pictures of the isolated bacteria from Uttarakhand

01



10
Water Sample Collected

02



4
Suitable for Drinking

03



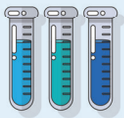
5
Suitable for Irrigation

04



0
Suitable for Industrial use

05



2.22
Avgerage MPN/ ml in Water samples



UTTAR PRADESH

Results of Water Quality of Uttar Pradesh

Uttar Pradesh is the fourth largest Indian state described as the "Heartland of India" by an occupying area of about 2,43,286 sq. km or 93,933 sq. miles comprising over 199,581,477 inhabitants as of the 2011 census, becoming the most populous state in the country. This vast state is divided into 75 districts, 350 tehsils, and 813 community blocks. Geographically, it lies between North latitudes 23o 52′ 23.41′′ to 31o28′ 76.09′′ and East longitudes 77o 03′ 16.32′′ to 84o 39′ 21.23′′ is a part of North-Central of the country India. Uttar Pradesh sits proudly within the Gangetic plain, renowned for its fertile alluvial soils deposited by the Ganga River system flowing down from the Himalayas. This fertile land comprises 9% of India's area yet shelters 16% of the nation's population. (Saxena *et al.,* 2021) In Budaun (S8) and Farrukhabad (S9), the water takes on a pale brown hue, and both sites report no odor or foam. The temperature ranges from 28.4 to 30°C, pH values are 9.3 and 9.2, with TDS concentrations of 70 and 59 ppm, respectively. Bithoor (S10) reveals a light green-brown color with no noted odor or foam. The temperature is 27.6°C, pH is 8.6, and TDS. In recent years, pollution of the Ganga River has been a highly discussed and serious issue, especially due to uncontrolled discharges of untreated home sewage, excessive pollutants from industries, and agricultural runoff. The river has been heavily contaminated, making it extremely dirty. In response to these issues, the Ganga Action Plan (GAP) was launched in 1986 with the goal of restoring water quality to 'Bathing class' levels. GAP efforts to address the issue have included the construction of sewage treatment plants, the establishment of common effluent treatment plants in industrial zones, and the mandate of centralized monitoring systems for individual enterprises. While these efforts have helped to enhance water quality, meeting the appropriate bathing class standards remains a difficult undertaking. According to figures from 2011, 487 of the 764 grossly polluting enterprises discharging into the Ganga River are located in the Kanpur region. As a result, the stretch of the Ganga River upstream and downstream of Kanpur is regarded one of the most polluted. Tanneries, sugar and distillery plants, and pulp and paper mills are the principal polluters of the Ganga River in this industrialized region. Pollutants such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), solids, Total Nitrogen (TN), chromium, sulphide, sulphate, and chloride are released into the river by these enterprises. Furthermore, a substantial portion of the river's catchment region is agricultural land, which leads to nutrient pollution, particularly nitrogen (N) and phosphorous (P), compounding the Ganga River's environmental issues.

The water quality of Uttar Pradesh's Ganges River has generated concerns, with research indicating

that it is unsafe for bathing and drinking in several sites, including Kanpur, Varanasi, and Haridwar. This problem is exacerbated by factors such as decreasing dissolved oxygen (DO), increased biological oxygen demand (BOD), and the discharge of industrial and home trash (Singh, J., et. al 2023). Improvements in water quality were seen during the lockdown, particularly upstream of Kanpur, due to the temporary reduction in industrial pollution caused by factory closures. However, issues such as unregulated discharge of untreated domestic sewage, excessive pollutant discharge from industries, and agricultural runoff continue to exist (Dutta, V., Dubey, D., & Kumar, S. 2020). The Ganges River, which supplies water to 40% of India's population across 11 states, is severely polluted by human waste and industrial pollutants. Regardless of Uttar Pradesh's wealth, Despite Uttar Pradesh's abundant river system, which includes the Ganges and Yamuna, the state faces difficulties such as changing rainfall patterns and future climate change (Santy, S., Mujumdar, P., & Bala, G. 2020).

ON-SITE ANALYSIS

Details about the onsite analysis of water samples from 10 sites in Uttar Pradesh along the Ganges River are provided in Table 6.7, which shows the environmental shift downstream.

Table 6.7 Field data of water samples of Uttar Pradesh

SNo.	Site Name	Site Codes	Color	Odour	Foam	Temperature (C)	Ph	Tds (Ppm)
1	Bijnor	S6	Green	ND	ND	27.9	9.1	69
2	Narora	S7	Green	ND	ND	29.8	9.4	087
3	Budaun	S8	Pale Brown	ND	ND	28.4	9.3	70
4	Farrukhabad	S9	Pale Brown	ND	ND	30	9.2	59
5	Bithoor	S10	Light green-brown	ND	ND	27.6	8.6	110
6	Dalmau	S11	ND	ND	ND	31.5	8.5	146
7	Prayagraj	S12	Green	ND	ND	31.4	8.5	161
8	Mirzapur	S13	ND	ND	ND	28.4	8.4	183
9	Varanasi	S14	Green	ND	ND	32.2	8.6	220
10	Ballia	S15	Green	ND	ND	29	8.5	215

Details about 10 sites of Uttar Pradesh along the Ganges River are provided in Table 5.5, which shows the environmental shift downstream. Starting with Bijnor (S6), the water exhibits a green color with no reported odor or foam. The temperature is recorded at 27.9°C, pH level at 9.1, and a total dissolved solids (TDS) concentration of 69 ppm. Moving to Narora (S7), the water also displays a green color with no reported odor or foam. The temperature is slightly higher at 29.8°C, pH at 9.4, and TDS at 87 ppm. In Budaun (S8) and Farrukhabad (S9), the water takes on a pale brown hue, and both sites report no odor or foam. The temperature ranges from 28.4 to 30°C, pH values are 9.3 and 9.2, with TDS concentrations of 70 and 59 ppm, respectively. Bithoor (S10) reveals a light green-brown color with no noted odor or foam. The temperature is 27.6°C, pH is 8.6, and TDS measures 110 ppm. Dalmau (S11) data is not available (ND) for color, odor, and foam. However, the temperature is recorded at 31.5°C, pH at 8.5, and TDS at 146 ppm. Prayagraj (S12) displays green-colored water with no reported odor or foam. The temperature is 31.4°C, pH at 8.5, and TDS at 161 ppm. Mirzapur (S13) data is not available for color, odor, and foam. The temperature is 28.4°C, pH at 8.4, and TDS at 183 ppm. Varanasi (S14) exhibits green-colored water with no reported odor or foam. The temperature is relatively higher at 32.2°C, pH at 8.6, and TDS at 220 ppm. Ballia (S15) also presents green-colored water with no reported odor or foam. The temperature is 29°C, pH at 8.5, and TDS at 215 ppm. These findings offer a comprehensive overview of the varied water quality parameters across different sites in Uttar Pradesh, highlighting the diverse environmental conditions within the region.

LABORATORY ANALYSIS

Oxygen concentration

Based on the recorded results for oxygen concentration, it is observed that the average dissolved oxygen (DO) value of 7.1 mg/L exceeds the permissible limit. However, biochemical oxygen demand (BOD) and chemical oxygen demand (COD) fall within acceptable limits according to the standards set by CPCB and WHO. A graphical representation of these parameters is depicted below, illustrating the variations in dissolved oxygen, biochemical oxygen demand, and chemical oxygen demand across the different study sites in Uttar Pradesh. The graphical representation of recorded oxygen concentration of different sites in Uttar Pradesh is represented below in Fig. 6.10.

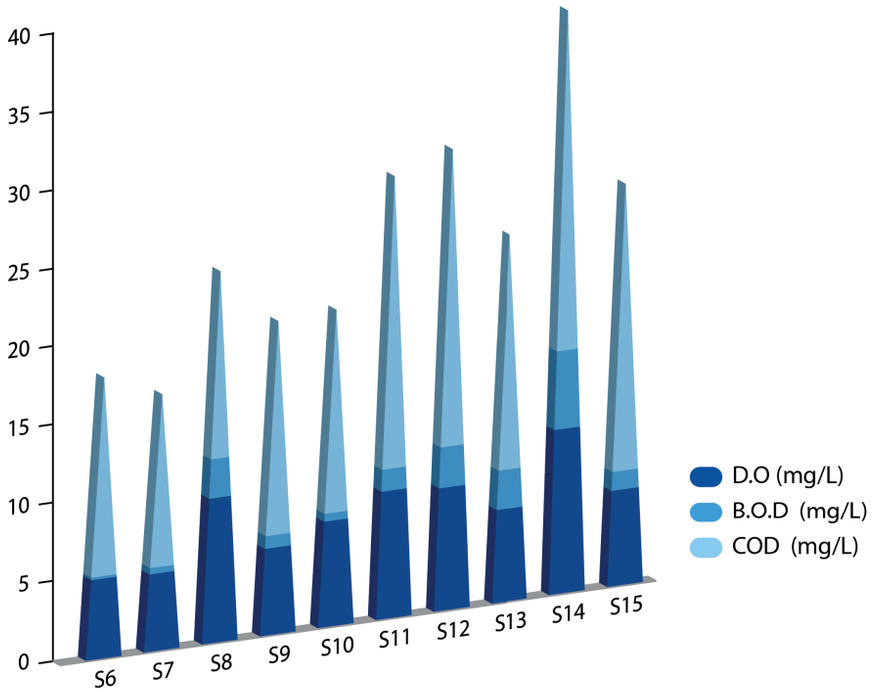


Fig. 6.10 Oxygen data of water samples obtained from different sample locations of Uttar Pradesh

During our investigation, we observed that the dissolved oxygen (DO) concentration varies across the study sites. The lowest recorded DO level is found at Narora (S7), measuring 5.0 mg/L, while the highest is identified at Varanasi (S14), reaching 10.6 mg/L. Biochemical oxygen demand (BOD) levels exhibit a range from a minimum of 0.16 mg/L at Bijnor (S6) to a maximum of 5.0 mg/L at Varanasi (S14). Similarly, the chemical oxygen demand (COD) values fluctuate, with the lowest recorded at Narora (S7) at 11.0 mg/L and the highest observed at Varanasi (S14) at 21.7 mg/L.

Alkalinity and electrical conductivity

Alkalinity, denoting a water's capacity to neutralize acids, is observed to have its highest measurement in Ballia (S15) at 180 mg/L, while the lowest is recorded in Bijnor (S6) at 74.60 mg/L. The mean alkalinity across the sites is calculated to be 125.8 mg/L. The graphical representation of recorded oxygen concentration of different sites in Uttar Pradesh is represented below in Fig. 6.11.

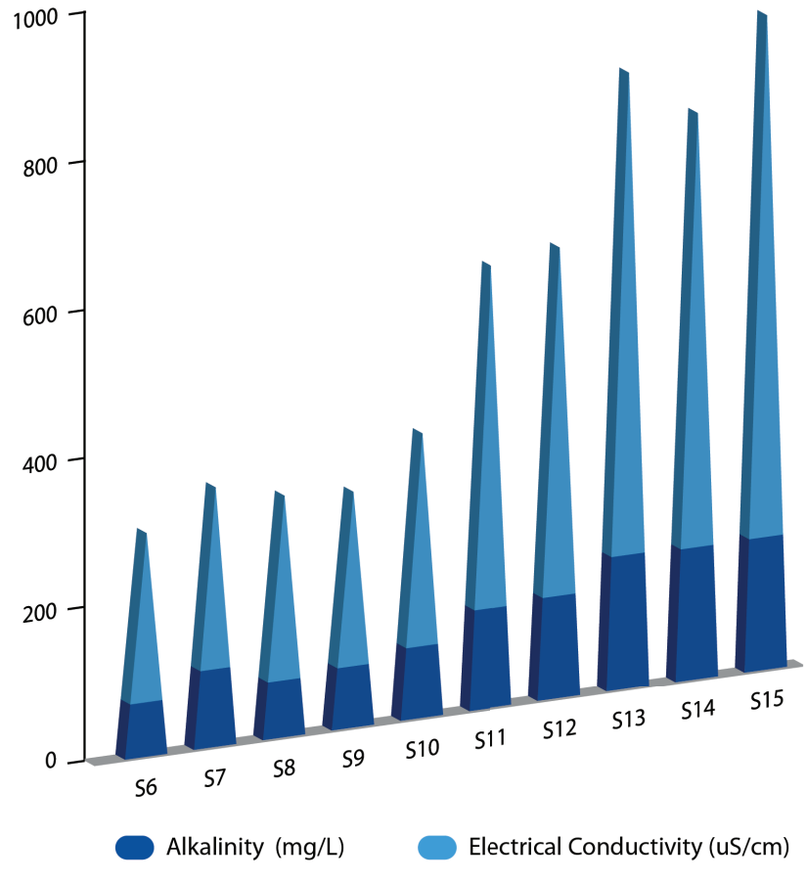


Fig. 6.11 Alkalinity and electrical conductivity data of water samples obtained from different sample locations of Uttar Pradesh

Similarly, the electrical conductivity (EC), a significant parameter, exhibits its highest value in Ballia (S15) at 701.16 µs/cm, and the lowest is noted in Bijnor (S6) at 227.13 µs/cm. The mean EC value is calculated to be 410.0 µS/cm.

Turbidity, TSS and TDS

In our study, the average turbidity, resulting from suspended or dissolved particles in water, is determined to be 22.5 NTU. The highest turbidity is recorded at Varanasi (S14) with a value of 61.31 NTU, while the lowest is observed at Narora (S7) with 2.02 NTU. The graphical representation of recorded oxygen concentration of different sites in Uttar Pradesh is represented below in Fig. 6.12.

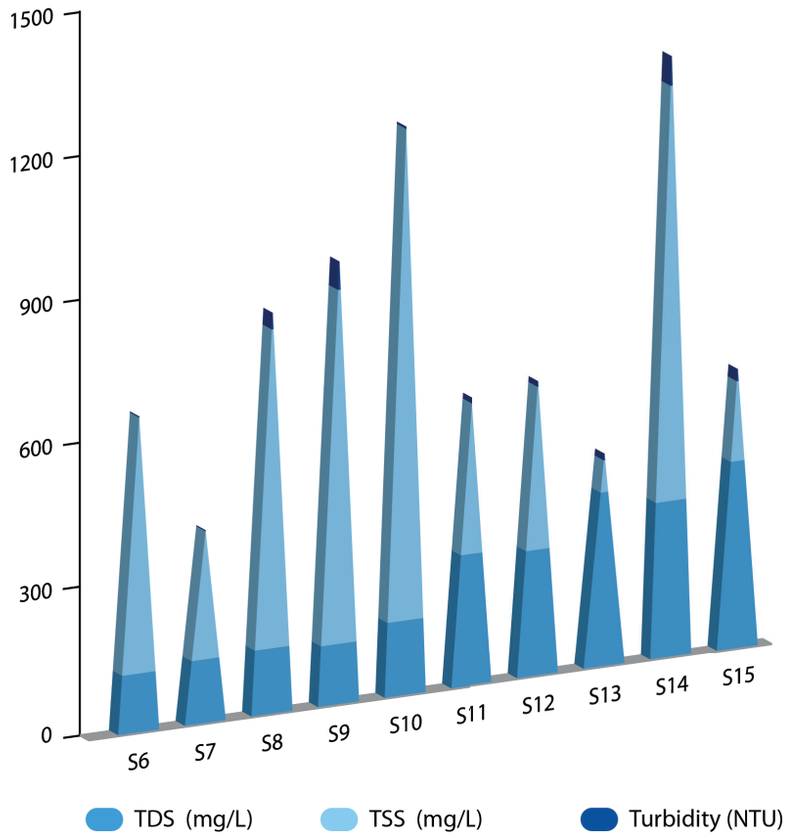


Fig. 6.12 Turbidity, TDS and TSS data of water samples obtained from different sample locations of Uttar Pradesh

The values for Total Dissolved Solids (TDS) and Total Suspended Solids (TSS), measured in mg/L, show mean values of 243.2 mg/L and 498.7 mg/L, respectively. Bijnor (S6) registers the minimum TDS at 124.7 mg/L, whereas Ballia (S15) records the maximum at 392.6 mg/L. For TSS, Mirzapur (S13) reports the minimum value at 66.7 mg/L, and Bithoor (S10) records the maximum at 1026.7 mg/L.

Hardness

The average hardness of the Ganga River in the Uttar Pradesh region falls below the permissible limits set by the World Health Organization (WHO), Central Pollution Control Board (CPCB), and Bureau of Indian Standards (BIS). Calcium hardness shows an average value of 43.6 mg/L, while magnesium hardness has an average of 99.5 mg/L. The calculated mean for total hardness in the UP region is 143.0 mg/L. The graphical representation of recorded oxygen concentration of different sites in Uttar Pradesh is represented below in Fig. 6.13.

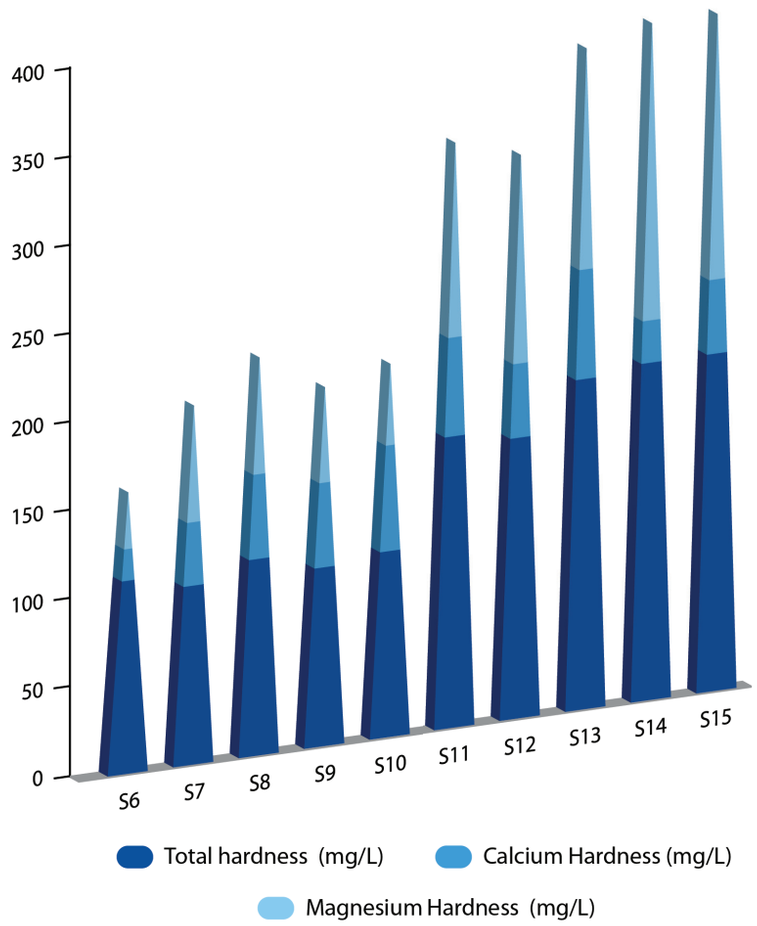


Fig. 6.13 Total, Calcium and Magnesium Hardness data of water samples obtained from different sample locations of Uttar Pradesh

The minimum recorded calcium hardness is observed in Bijnor (S6) at 18.0 mg/L, and the maximum is found in Mirzapur (S13) at 62.0 mg/L. Varanasi (S14) records the highest magnesium hardness at 168.0 mg/L, whereas Bithoor (S10) reports the lowest at 46.0 mg/L. Similarly, the lowest total hardness is noted in Narora (S7) and Farrukhabad (S9) at 102.0 mg/L, while the highest total hardness is recorded in Varanasi (S14) and Ballia (S15) at 192.0 mg/L.

Nitrate and Sulphate

In our investigation, we determined that the average concentrations of nitrates and sulfates in Uttar Pradesh water are 1.7 mg/L and 23.0 mg/L, respectively. These values fall below the permissible limits established by the Central Pollution Control Board (CPCB) and the Bureau of Indian Standards (BIS). The graphical representation of recorded oxygen concentration of different sites in Uttar Pradesh is represented below in Fig. 6.14.

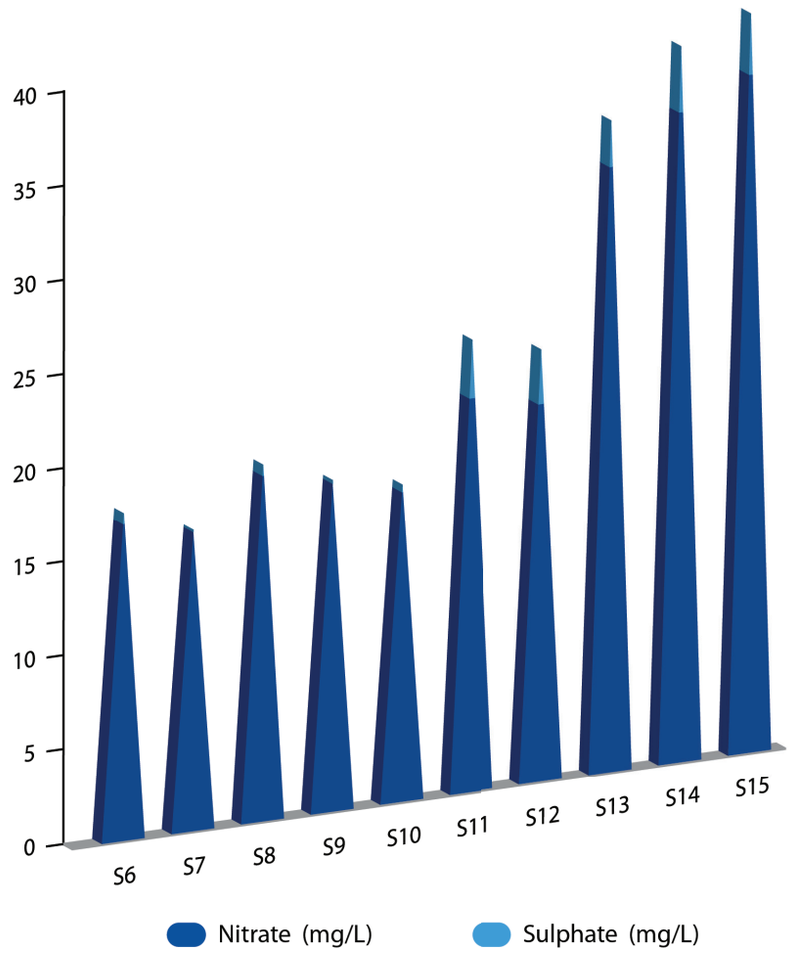


Fig. 6.14 Nitrate and Sulphate data of water samples obtained from different sample locations of Uttar Pradesh

The minimum nitrate concentration is observed in Farrukhabad (S9) samples, registering at 0.197 mg/L. Conversely, Varanasi (S14) exhibits the highest nitrate concentration at 3.5228 mg/L. In terms of sulphate, the maximum value is detected in Ballia (S15) samples, measuring 36.153 mg/L, while the minimum sulphate concentration is found in Narora (S7) at 15.983 mg/L.

Ionic Constituents

In our research, we considered four significant ion contributors, namely Sodium, Chloride, Fluoride, and Potassium, in the Uttar Pradesh region. The mean values recorded for Sodium (20.4 ppm), Chloride (34.3 ppm), and Fluoride (0.05 ppm) are notably low, adhering to the standard limits established by the Central Pollution Control Board (CPCB), Bureau of Indian Standards (BIS), and World Health Organization (WHO). The mean value for Potassium is 5.0 ppm. The graphical representation of recorded oxygen concentration of different sites in Uttar Pradesh is represented below in Fig. 6.15.

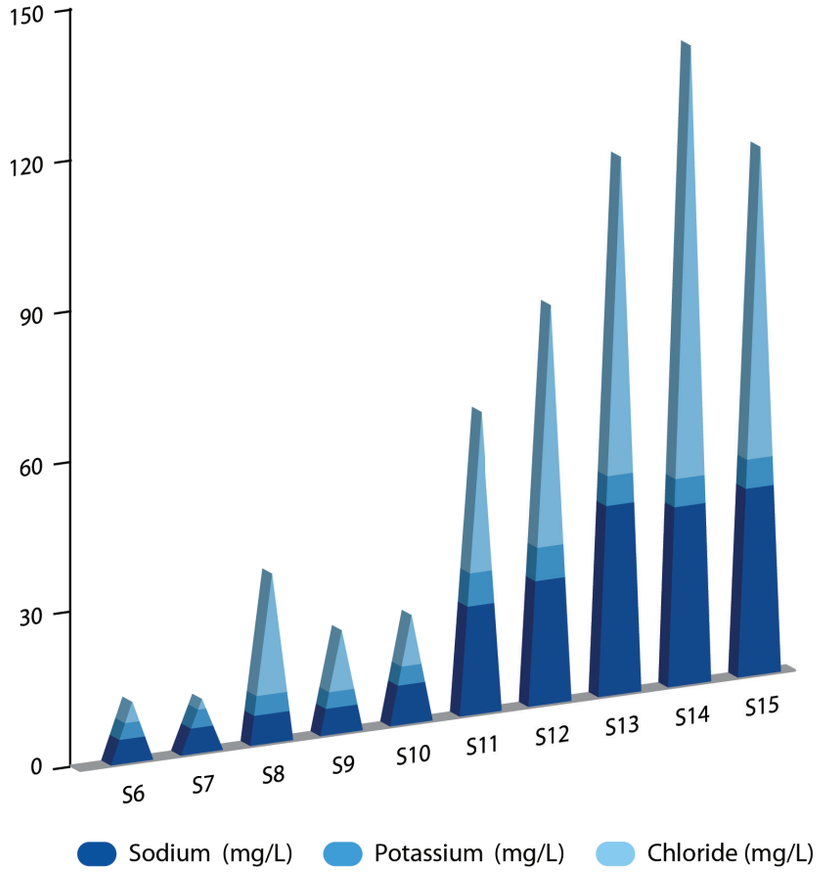


Fig. 6.15 Ionic constituent data of water samples obtained from different sample locations of Uttar Pradesh

The lowest sodium concentration is observed in Bijnor (S6) at 5.07 ppm, while the highest is found in Mirzapur (S13) at 38.08 ppm. For Potassium, the lowest concentration is recorded in Bijnor (S6) at 3.2 ppm, and the highest is in Prayagraj (S12) at 6.61 ppm. Chloride exhibits its lowest value in Narora (S7) at 2.0 ppm, and the highest is observed in Varanasi (S14) at 86 ppm. Fluoride is consistently found at the same concentration throughout the Ganga River belt in Uttar Pradesh, with a value of 0.05 ppm.

Total Coliform

Total coliforms are a group of bacteria that includes *E. coli* and are commonly used as indicators of water quality. The data obtained from these analyses will be instrumental in evaluating the overall microbial safety and quality of the water in the specified region, as shown in Fig. 6.16 below.

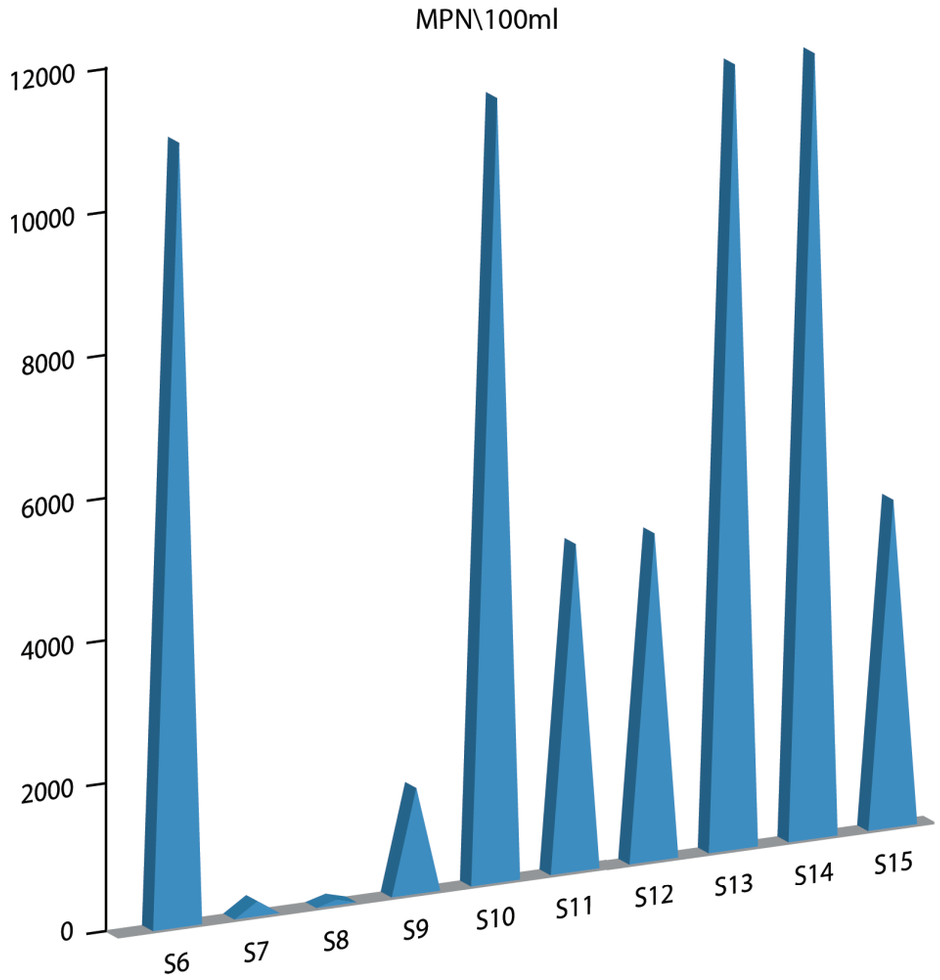


Fig. 6.16 Total coliform data of water samples obtained from different sample locations of Uttar Pradesh

Remarkably, among the sampled locations, S6, S10, S13, and S14 stand out with the most noteworthy levels of MPN (Most Probable Number), all consistently registering at 11,000 MPN/100ml. Notably, S11, S13, and S15 also demonstrate elevated values, recording a specific count of 4600 MPN/100ml. In stark contrast, S7 and S8 exhibit the lowest MPN values in this study, with S7 indicating an absence at 230 MPN/100ml and S8 displaying a minimal count of 94 MPN/100ml. Moreover, S9 presents a distinct MPN value of 1500 MPN/100ml.

Differential Bacterial Count

This count is typically expressed as the number of bacterial colony-forming units (CFUs) per unit volume of the sample, all the values are expressed in Log 10. Examining total bacterial counts variation among the sites of Uttar Pradesh is as shown in Fig. 6.17. Representative pictures of the isolated bacteria from Uttar Pradesh are shown in Fig. 6.18.

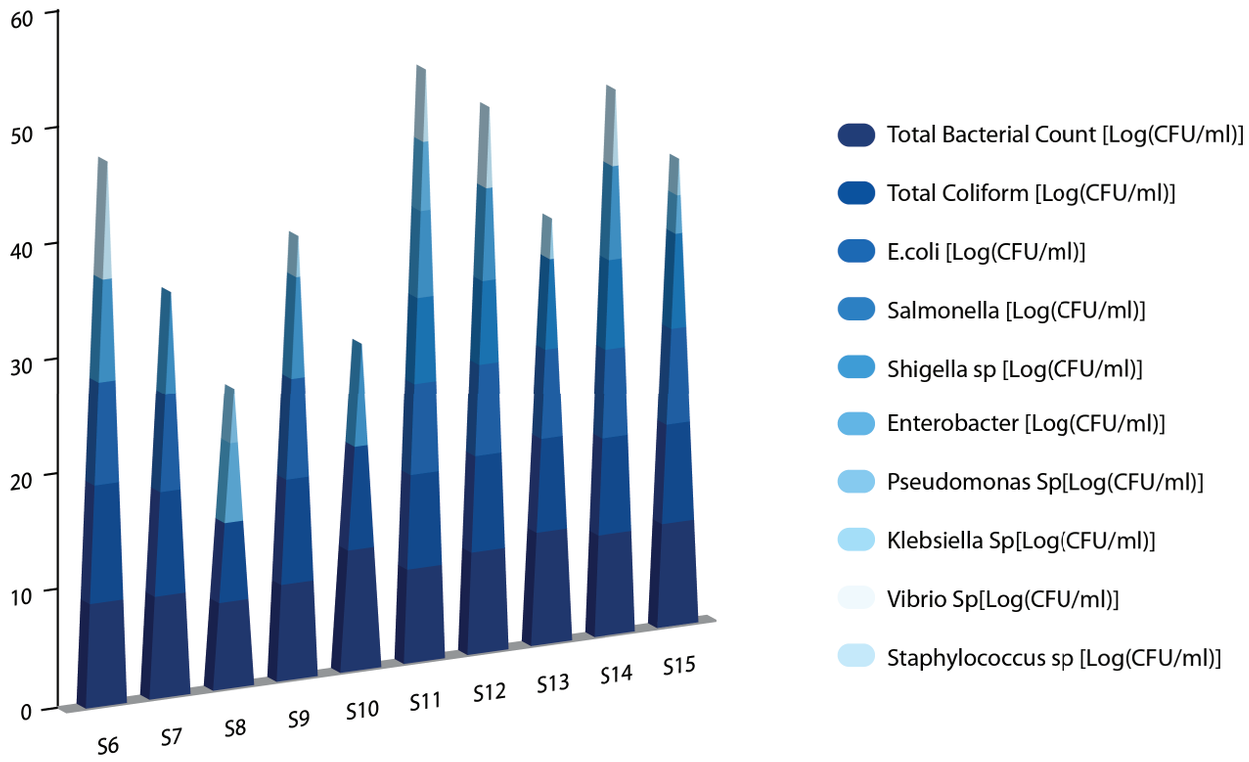


Fig. 6.17 The Differential Bacterial Count data of water samples obtained from different sample locations of Uttar Pradesh

The highest overall bacterial count is observed in sample S10, reaching 10.55. Following closely are samples S6, S13, and S15, with counts of 9.06, 9.8, and 9.0, respectively. Slightly lower counts are noted in samples S7, S9, S11, S12, and S14, displaying 8.9, 8.3, 8.1, 8.8, and 8.8, respectively. The lowest bacterial count is recorded in sample S8, measuring 7.5. This data indicates a clear hierarchy in bacterial counts among the tested samples, with S10 exhibiting the highest and S8 the lowest bacterial load.

The highest concentration of total coliforms is observed in S6, reaching 10.18. Following closely behind is S9 with 9.03, and subsequent samples exhibit decreasing levels, including S7, S10, S11, S12, S13, S14, and S15, registering at 8.9, 8.8, 8.1, 8.2, 8.0, 8.3, and 8.5 respectively. The lowest coliform content is detected in S8, presenting a value of 6.8. This data underscores the varying degrees of microbial contamination across different samples, with S6 exhibiting the highest and S8 the lowest levels of total coliforms. In a parallel manner, the maximum concentration of *E. coli* is observed in S6, reaching 8.9. Following closely are S7 and S15, both displaying 8.3, while S9 records 8.7. On the contrary, S8 and S10 exhibit a complete absence with 0 Log. Similarly, S11, S12, S13, and S14 also demonstrate a negligible presence, each registering zero. Similarly, the maximum concentration of *E. coli* is observed in S6, registering at 8.9. Following closely are S7 and S15, each recording 8.3, while S9 exhibits. Conversely, S8 and S10 show no detectable *E. coli* with 0. Similarly, S11, and S12, exhibit displaying values of 7.8, 7.9, and 7.7 in both S13 and S14. *Salmonella* species were exclusively detected in sites S11, S12, S13, S14, and S15, with bacterial counts recorded at 7.4, 7.2, 7.7, 7.7, and 8.1, respectively. *Shigella* has been detected in samples S6, S7, and S10 at concentrations of 8.8, in S9 at 8.7, and in S14 at 8.0. Meanwhile, its presence is comparatively lower in samples S11 and S12, registering at 7.4 and 7.9. The presence of *Enterobacter* species has been documented in samples S8, S11, and S15, with concentrations measuring 6.8, 5.9, and 3.3. *Pseudomonas* species were exclusively noted in site S8 with a recorded concentration of 4.6. In contrast, *Klebsiella* was identified in multiple locations, specifically S9, S13, and S15, with concentrations of 3.5, 3.4, and 3.1, respectively. Lastly, *Staphylococcus* was detected in varying concentrations across different sites, registering values of 10.1, 6.2, 6.9, and 6.5 in S6, S11, S12, and S14, respectively.

Fig. 6.18 Representative pictures of the isolated bacteria from Uttar Pradesh

01



5

Water Sample Collected

02



5

Suitable for Drinking

03



5

Suitable for Irrigation

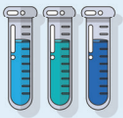
04



0

Suitable for Industrial use

05



5.43

Avgerage MPN/ ml in Water samples



BIHAR

Results of Water Quality of Bihar

Bihar is a state in eastern India, and it faces various water-related challenges. The water quality in Bihar, like in many other parts of India, is influenced by factors such as industrial discharge, agricultural runoff, inadequate sanitation facilities, and the contamination of surface and groundwater sources. The water quality of the Ganga River in Bihar is severely affected by pollution, particularly due to the discharge of untreated sewage and industrial waste. A study conducted in the region around Patna, Bihar, revealed that the water quality of the Ganga River has been severely deteriorated due to the discharge of untreated sewage, rendering it unsuitable for drinking. Industrial pollution is also a major source of pollution, with various industries discharging effluents containing heavy metals, toxic chemicals, and other pollutants into the river (Tiwary, 2018). Overall, the pollution of the Ganga River is a complex issue that requires a multi-faceted approach to address the root causes of pollution and improve the water quality of the river. Several regions in Bihar have been grappling with water pollution issues, including the contamination of rivers and groundwater with pollutants such as heavy metals, pesticides, and fecal matter. The contamination of drinking water sources poses a significant health risk to the population and can lead to waterborne diseases. The government and various non-governmental organizations have been working on initiatives to improve water quality in Bihar. These efforts include implementing water purification projects, promoting better sanitation practices, and creating awareness about the importance of clean water.

ON-SITE ANALYSIS

As shown in On-site parameters (Table 6.8), details of five sites along the Ganges River in Bihar, India, showcasing a remarkable change in environmental conditions from high altitude to the plains.

Table 6.8 Field data of the water samples of Bihar

S.no.	Site Name	Site Codes	Color	Odour	Foam	Temperature (°c)	Ph	Tds (Ppm)
1	Revelganj	S16	Colorless	ND	ND	24.2	8.7	94
2	Patna	S17	Colorless	Fishy	ND	25.8	8.4	196
3	Barh	S18	Colorless	ND	ND	27.1	8.7	186

S.no.	Site Name	Site Codes	Color	Odour	Foam	Temperature (°c)	Ph	Tds (Ppm)
4	Bahachouki	S19	Colorless	ND	ND	28.3	8.4	196
5	Farka	S20	Colorless	ND	Foaming observed along the shore	27.9	8.7	202

As the altitude decreases, there is a corresponding increase in temperature. The sampled water is predominantly colorless, and no noticeable odor is detected across all sampling sites, except site S17 in Patna, where a slight fishy texture is observed. Additionally, at site S20 in Farka, some foaming is noted. The pH levels across the various sampling sites are relatively consistent, with a reading of 8.7. However, there are slight variations in two specific locations; site S18 in Barh and site S19 in Bahachouki show a pH of 8.4. The total dissolved solid varies in every sampling site and is shown in the table. This data suggests a general pattern of temperature increase as altitude decreases, minimal color and odor in the water samples, and minor deviations in pH levels at select locations. Further analysis and consideration of these observations are given below.

LABORATORY ANALYSIS

Oxygen concentration

As per the results recorded for oxygen concentration measured in three parameters DO and BOD are out of permissible limits. The graph representing the results for oxygen concentration is shown below in Fig. 6.19.

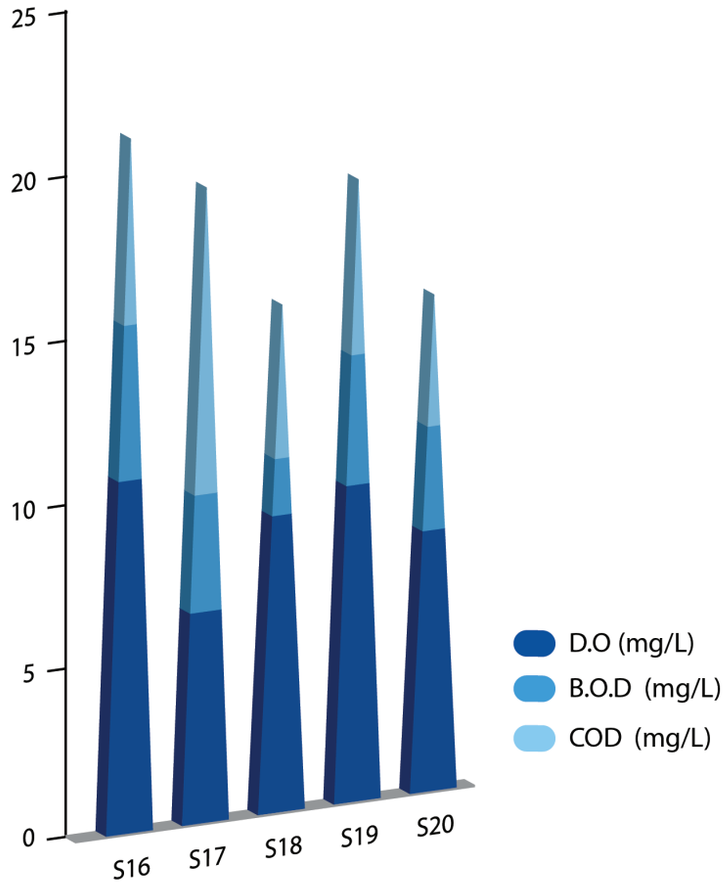


Fig. 6.19 Oxygen concentration data of water samples obtained from different sample locations of Bihar

The mean values for all three oxygen concentration parameters are given as Dissolved Oxygen (DO) at 8.812 mg/L, Biochemical Oxygen Demand (BOD) at 3.436 mg/L, and Chemical Oxygen Demand (COD) at 5.8 mg/L. Upon conducting our studies, we observed that DO exhibit its lowest value in Patna, S17 (6.46 mg/L), and its highest value in Revel Ganj, S16 (10.8 mg/L). For BOD, the lowest recorded value was at Barh, S18 (1.73 mg/L), while the highest was found in Revel Ganj, S16 (4.73 mg/L). As for COD, the highest measurement was observed in Patna, S17 (9.33 mg/L), whereas the lowest was recorded in Farka, S20 (4.00 mg/L).

Alkalinity and Electrical conductivity

The alkalinity is measured in terms of capacity of water to neutralize the acids. The graphical representation of recorded EC and Alkalinity of different sites of Bihar is represented in Fig.6.20.

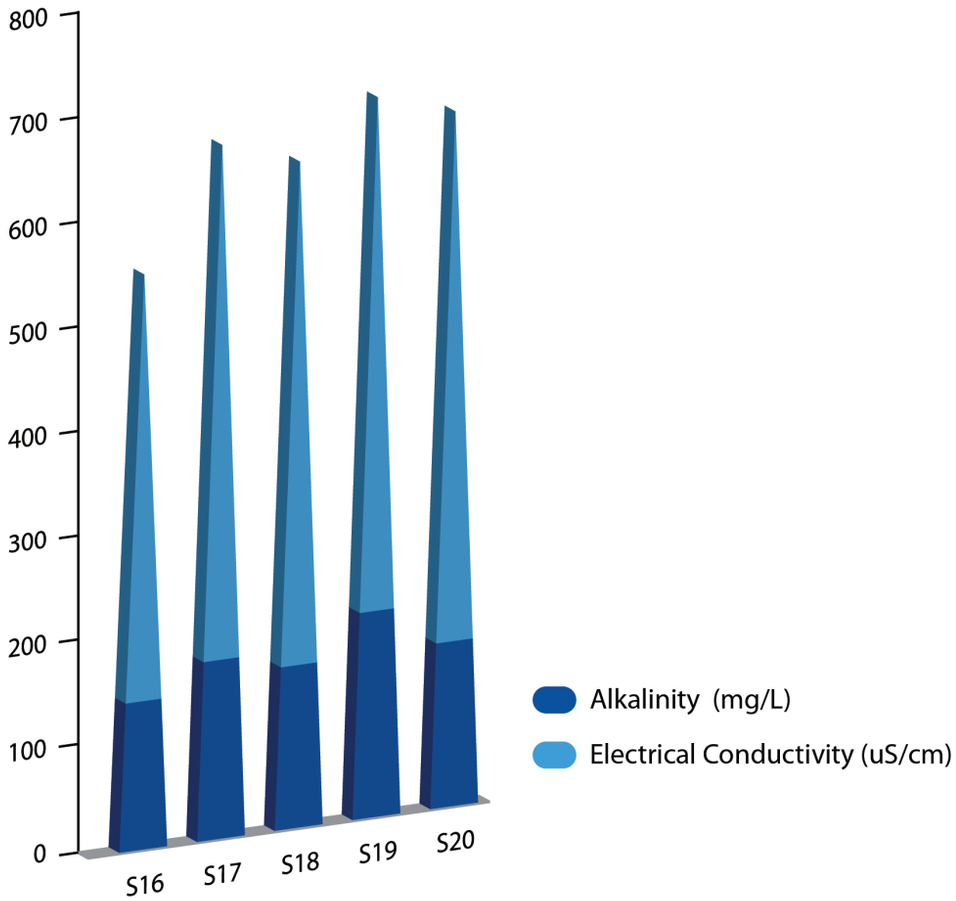


Fig. 6.20 Alkalinity and Electrical conductivity data of water samples obtained from different sample locations of Bihar

The alkalinity levels in Bihar vary across different locations, with the highest recorded in Bahachauki, S19 at 198 mg/L and the lowest in Revel Ganj, S16 at 142.9 mg/L. The overall mean alkalinity for the surveyed areas is calculated to be 165.644 mg/L. Likewise, electrical conductivity (EC), a crucial parameter, exhibits variability among the surveyed locations. The maximum EC was observed in Farka, S20, registering at 506.86 µs/cm, whereas the minimum was recorded in Revel Ganj, S16, at 408.46 µs/cm. The calculated mean EC value for the surveyed regions stands at 476.268 µS/cm.

Turbidity, TSS and TDS

Turbidity is caused by the suspended or dissolved particles present in water which makes the physical appearance cloudy or murky. The graphical representation of recorded EC and Alkalinity of different sites of Bihar is represented in Fig.6.21

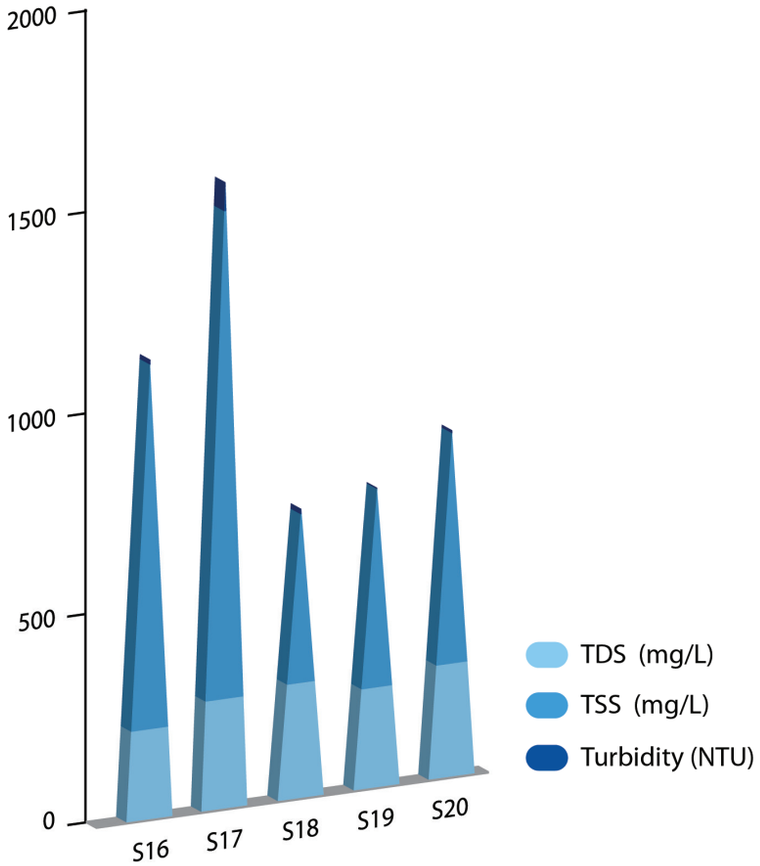


Fig. 6.21 Turbidity, TSS and TDS data of water samples obtained from different sample locations in Bihar

In our current investigation, the average turbidity observed was 21.33 NTU, reaching its highest level in Patna, S17 (71.45 NTU), and its lowest in Bahachouki, S19 (3.16 NTU). Notably, the maximum turbidity value exceeded the permissible limit set by the Bureau of Indian Standards (BIS). The measurements for Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) are presented in milligrams per liter (mg/L). The mean TDS value recorded is 264.25 mg/L, with the lowest TDS concentration found in Revel Ganj, S16 (225.63 mg/L) and the highest in Barh, S18 (287.8 mg/L). In terms of TSS, the average concentration is 721.26 mg/L, with the minimum TSS level detected in Barh, S18 (420 mg/L) and the maximum in Patna, S17 (1213 mg/L). It's important to note that these findings contribute to our understanding of water quality in the studied areas, highlighting instances where certain parameters exceed established standards, particularly in the context of turbidity and its potential implications.

Hardness

In Bihar region, the average hardness of river ganga in is below the permissible limits given by CPCB and BIS. The graphical representation of recorded hardness of different sites of Bihar is represented in Fig. 6.22.

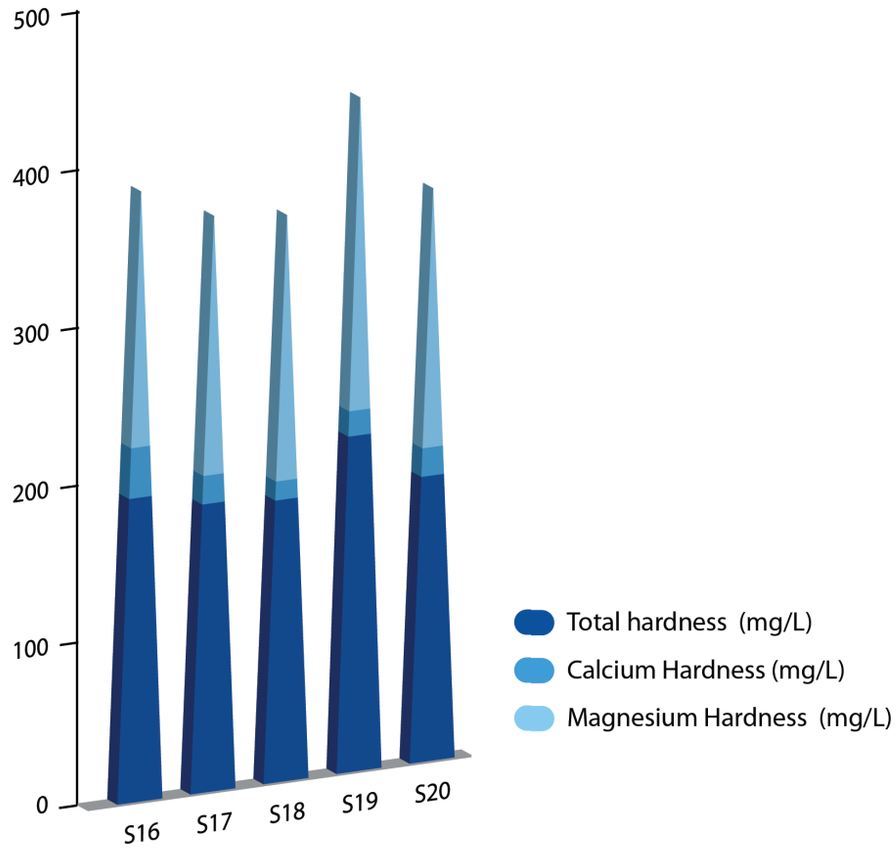


Fig. 6.22 Hardness data of water samples obtained from different sample locations of Bihar

The average value for Calcium hardness is recorded to be 19.2 mg/L and for Magnesium hardness the average value recorded is 171.2mg/L. The mean of total hardness calculated in BH region is 190.8mg/L. The minimum calcium hardness was found to be in Barh, S18 (12.0mg/L) and maximum was found in Revel Ganj, S16 (32.0 mg/L). The Magnesium hardness was found maximum in Bahachauki, S19 having 198.0mg/L whereas the lowest was found in Revel Ganj, S16 having 162 mg/L magnesium hardness. Similarly, the lowest total hardness was recorded in Barh, S18 having a value as 180.0mg/L whereas the highest recorded value for total hardness was recorded in Bahachauki, S19 (214.0mg/L).

Nitrate and sulphate

Nitrate and sulphate are common ions that are often measured in water quality testing to assess the safety and suitability of water for various purposes, including drinking, agriculture, and industrial use. The graphical representation of recorded EC and Alkalinity of different sites of Bihar is represented in Fig. 6.23.

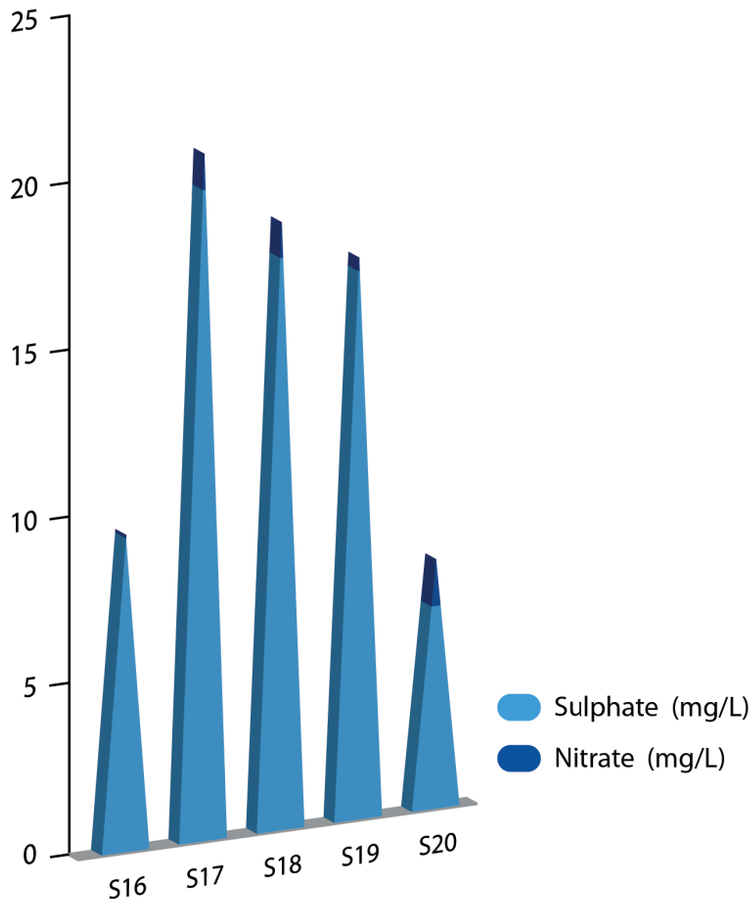


Fig. 6.23 Nitrate and sulphate data of water samples obtained from different sample locations of Bihar

In our investigation, we observed that the average concentrations of nitrates and sulphates in the water of Bihar are recorded at 0.80556 mg/L and 13.75142 mg/L, respectively. These values fall below the permissible limits set by both the Central Pollution Control Board (CPCB) and World health organisation (WHO). Specifically, the lowest nitrate concentration was detected in samples from Bahachauki (S19) at 0.4052 mg/L, while the highest nitrate levels were found in Farka (S20) at 1.38 mg/L. Conversely, the maximum sulphate concentration was observed in Patna (S17) at 19.549 mg/L, and the minimum sulphate concentration was noted in RevelGanj (S16) at 9.45 mg/L.

Ionic constituents

Ionic concentration is a crucial aspect of water quality testing, as it helps assess the levels of various ions present in water. Different ions can have different impacts on the overall quality and usability of water. The graphical representation of recorded ionic constituent of different sites of Bihar is represented in Fig.6.24.

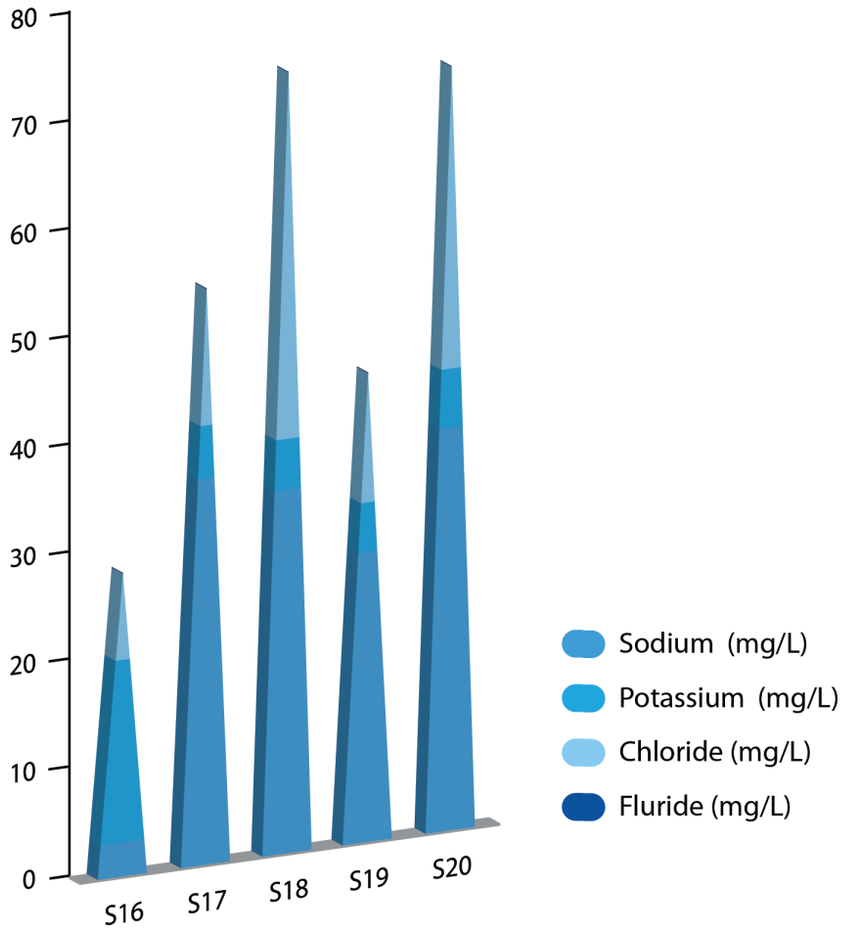


Fig. 6.24 Ionic constituent's data of water samples obtained from different sample locations of Bihar

The mean values recorded ionic constituent considered are Sodium (27.56ppm), Chloride (18.932ppm) and Fluoride (0.05 ppm) in BH region, are very low as per the standard limits given by the CPCB and BIS. The mean value for Pottasium is 7.31 ppm. The lowest sodium was found in Revel Ganj, S16 (3.28 ppm) and highest in Farka, S20 (37.52 ppm). Potassium is recorded lowest in Bahachauki, S19 (3.4.57ppm) and highest in Revel Ganj, S16 (16.9ppm). Chloride in water is found to be at its lowest in Revel Ganj, S16 (8.0 ppm) and highest in Barh, S18 (34 ppm). Fluoride was found to be the same all over the river belt of BH valued as 0.05 ppm.



01

1
Water Sample Collected

02

1
Suitable for Drinking

03

1
Suitable for Irrigation

04

0
Suitable for Industrial use

05

1.88
Avgerage MPN/ml in Water samples

JHARKHAND

Results of Water Quality of Jharkhand

The major sources of pollution in the Ganga River in Jharkhand include the discharge of untreated or partially treated sewage, industrial effluents from sectors such as tanneries, sugar and distillery, and pulp and paper mills, as well as agricultural runoff. The uncontrolled discharge of domestic sewage without treatment, excessive pollutant discharge from industries, and agricultural runoff have significantly contributed to the pollution of the river. The water quality of the Ganga River in Jharkhand state is a concern due to various factors such as industrial discharge, domestic sewage, and agricultural runoff. The Central Pollution Control Board (CPCB) has a network of 57 water quality monitoring stations on the Ganga River, and the water quality data collected under the National Quality Monitoring Program and Assessment of sources of pollution shows that the river's water quality exceeds the criteria in terms of Biochemical Oxygen Demand (BOD) at several locations in Jharkhand. The major industries contributing to the pollution of the Ganga River in Jharkhand are tanneries, sugar and distillery, and pulp and paper mills. These industries are responsible for the discharge of pollutants such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), solids, total nitrogen (TN), chromium, sulfide, sulphate, and chloride into the river. The uncontrolled discharge of industrial effluents from these sectors has significantly contributed to the deterioration of water quality in the Ganga River in Jharkhand.

ON-SITE ANALYSIS

As shown in On-site parameters (Table 6.9), details of one site along the Ganges River in Jharkhand, India, showcasing a remarkable change in environmental conditions from high altitude to the plains.

Table 6.9 Field data of the water samples of Jharkhand

SNo.	Site Name	Site Codes	Color	Odour	Foam	Temperature (ºc)	Ph	Tds (Ppm)
1	Sahebganj	S21	ND	ND	ND	26	8.7	186

The water of Jharkhand rivers exhibits a temperature of 26 degrees Celsius, with a pH level of 8.7 and a Total Dissolved Solids (TDS) concentration of 186. These parameters are crucial indicators of water quality, providing insights into its thermal characteristics, acidity, and dissolved mineral content. It is noteworthy that the 26-degree Celsius temperature falls within the range suitable for various aquatic life forms, contributing to the biodiversity of the region. Additionally, the pH level of 8.7 suggests slightly alkaline conditions, which can impact the overall ecological balance of the aquatic ecosystem.

LABORATORY ANALYSIS

Oxygen concentration

The aerobic life forms in natural streams require adequate oxygen levels. In our studies we have taken three oxygen concentrations into account for study. The graph representing the results for oxygen concentration is shown below in Fig. 6.25.

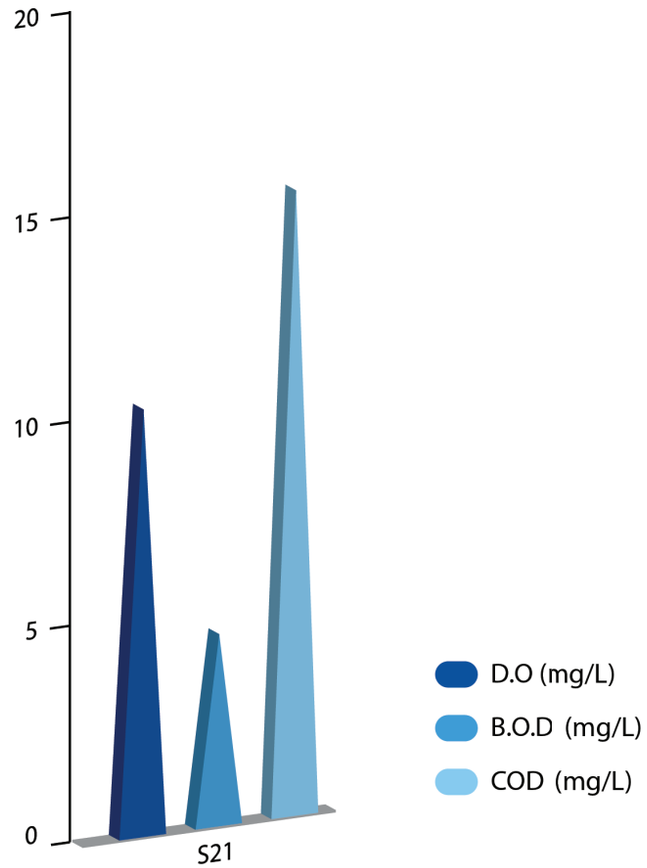


Fig. 6.25 Oxygen concentration data of water samples obtained from Jharkhand.

The recorded values for Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) in these three shows are as follows: DO (10.5 mg/L), BOD (4.73 mg/L), and COD (15.33 mg/L). It is noteworthy that the levels of DO and BOD exceed the permissible limits, as stipulated by regulatory standards. However, it is encouraging to observe that the COD value is within the acceptable range set by both the Central Pollution Control Board (CPCB) and World health organization (WHO). This information underscores the need for immediate attention and remedial measures to address the elevated levels of DO and BOD, while also acknowledging the satisfactory compliance with COD standards.

Alkalinity and electrical conductivity

The alkalinity measured in terms of capacity of water to neutralize the acids shows significant correlation with electrical conductivity. The graph representing the results for alkalinity and electrical conductivity is shown below in Fig. 6.26.

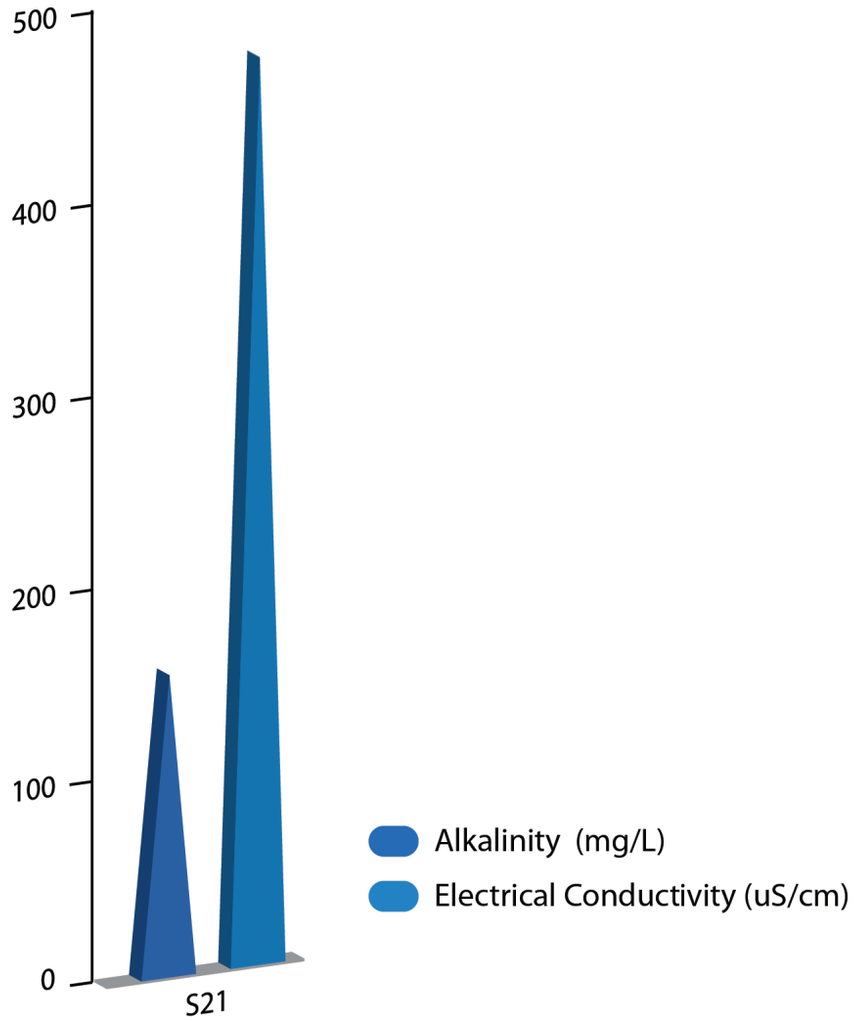


Fig. 6.26 Alkalinity and electrical conductivity data of water samples obtained from Jharkhand.

The alkalinity of JH recorded to be 158mg/L is under the permissible limits as per CPCB. On the other hand, EC an important parameter was recorded to be 472.86µS/cm, which was out of the permissible limits addressed by CPCB. EC value indicates the presence of more salts in river water (Beniwal V. D. et al., 2021).

Turbidity, TSS and TDS

The physical appearance of water sometimes appears to be cloudy or murky due to the presence of suspended and dissolved particles which cause Turbidity in the water system. The graph representing the results for Turbidity, TSS and TDS is shown below in Fig. 6.27.

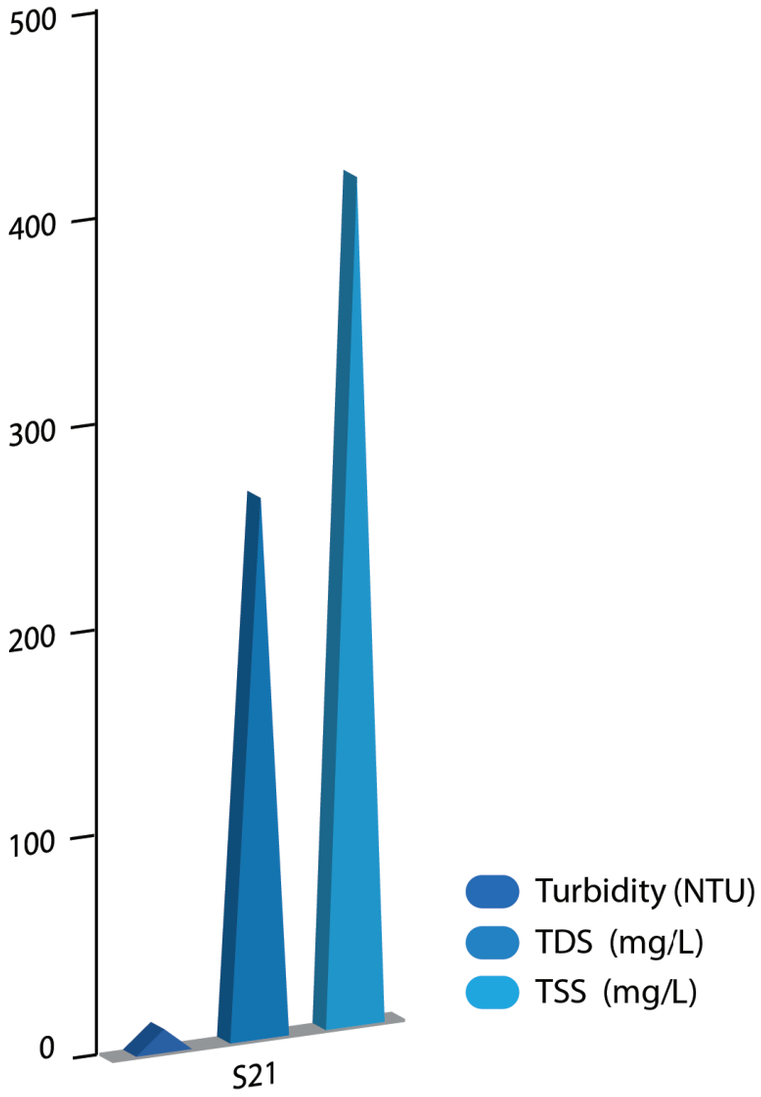


Fig. 6.27 Turbidity, TSS and TDS data of water sample obtained from Jharkhand

In our present study, the turbidity recorded was 12.14 NTU. The recorded value for turbidity was out of the permissible limit given as per the BIS. The values of TDS and TSS given in mg/L are 263.9 and 413.33 respectively. Both values were out of permissible limits as per CPCB and BIS.

Hardness

The amount of Calcium and Magnesium ions dissolved in water describes its hardness. The graph representing the results for hardness is shown below in Fig. 6.28.

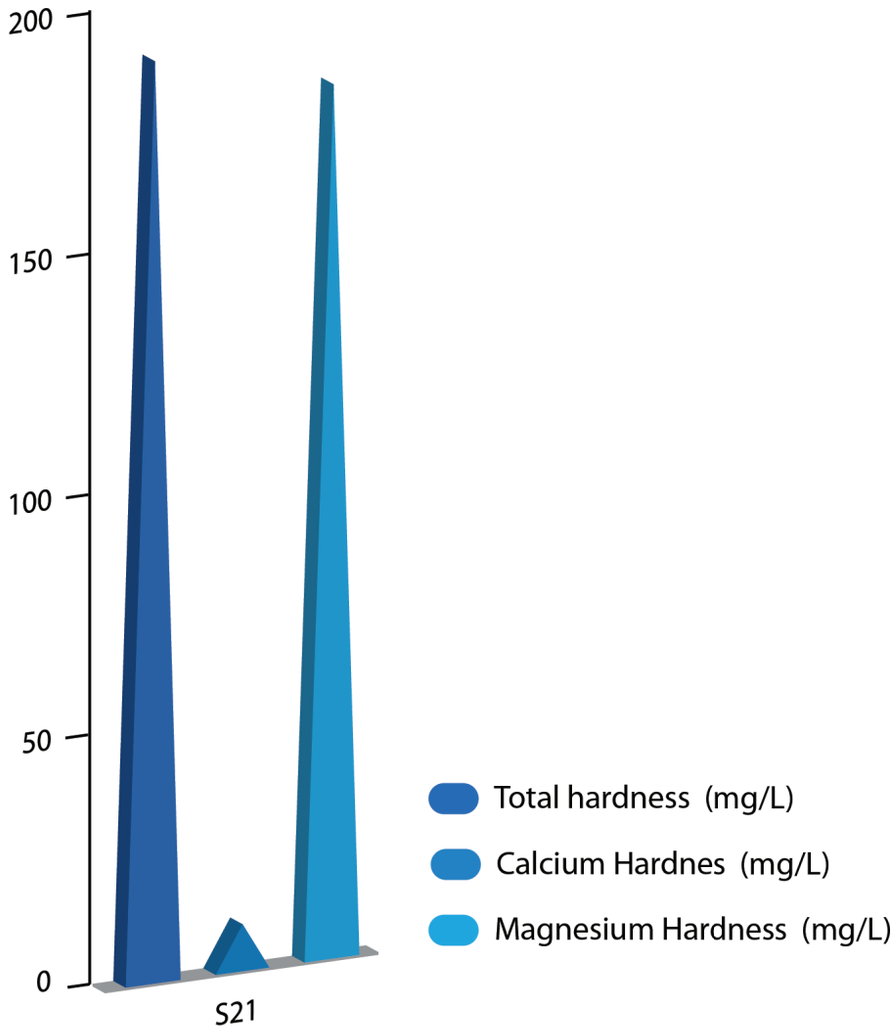


Fig. 6.28 Hardness data of water sample obtained from Jharkhand.

In our studies we have taken calcium hardness, magnesium hardness and total hardness into account. The total hardness and Calcium hardness of river ganga in JH region is below the permissible limits given by WHO, CPCB and BIS. The value for Calcium hardness is recorded to be 10mg/L and for total hardness the value recorded is 192mg/L. The Magnesium hardness recorded in JH region is 182mg/L, which was out of permissible limit.

Nitrate and sulphate

The number of nitrates and sulphates in water may be due to fertilizers discharge into the water body. The graph representing the results for nitrate and sulphate is shown below in Fig. 6.29.

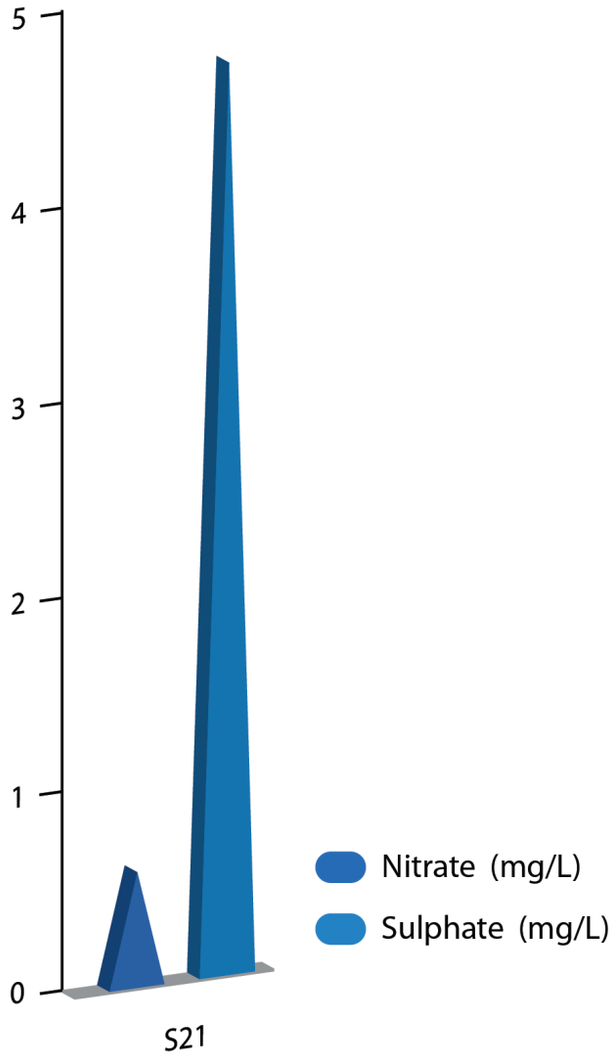


Fig. 6.29 Nitrate and sulphate data of water sample obtained from Jharkhand

In our study, we found the number of nitrates and sulfates present in the JH water is 0.599mg/L and 4.6912mg/L, which is below the permissible limits standardized by CPCB and WHO.

Ionic constituents

In our study, four important ion contributors were considered. The graph representing the results for ionic constituents is shown below in Fig. 6.30.

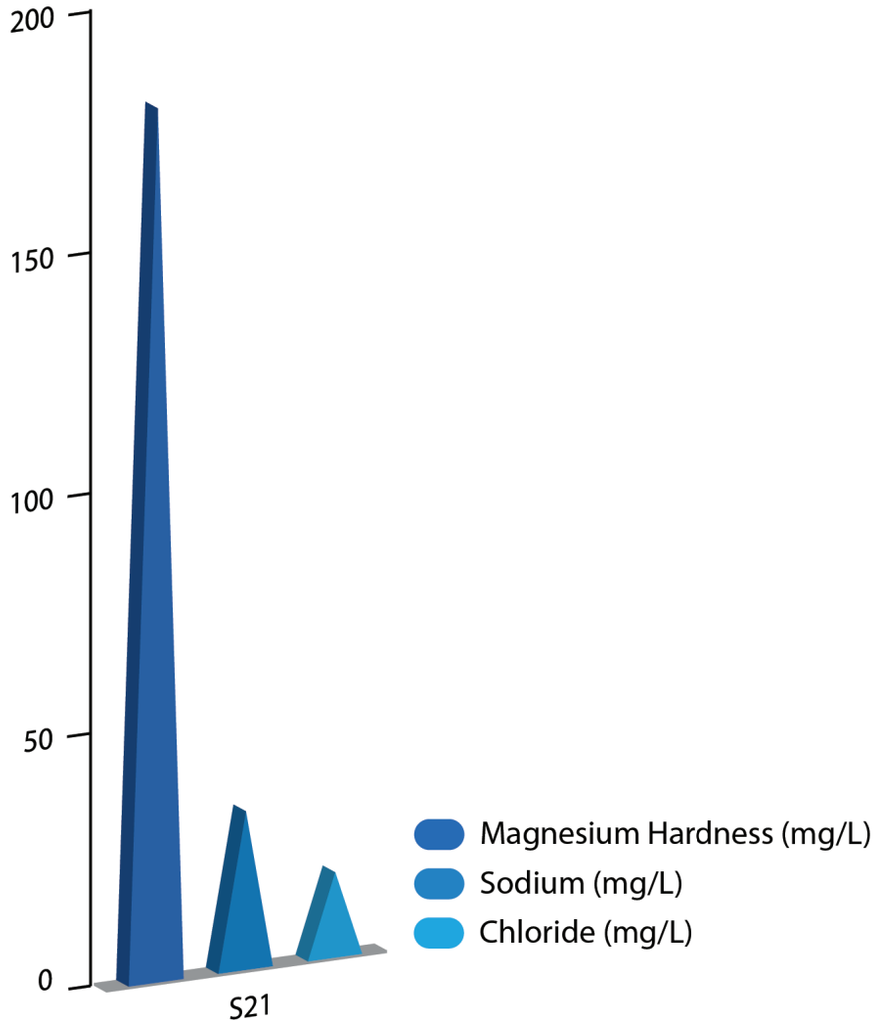


Fig. 6.30 Ionic concentration data of water samples obtained from Jharkhand

The values recorded for Sodium (33.29 ppm), Chloride (18ppm) and Fluoride (0.05 ppm) in JH region, are very low as per the standard limits given by the CPCB, BIS and WHO. The value for Potassium is 5.08 ppm. Fluoride was found to be the same all over the river belt in JH valued at 0.05 ppm. The graph representing the statistical data is shown below: -

Total Coliform

The water quality in the states of Bihar and Jharkhand (Fig. 6.31) in India faces various challenges. The state experiences water stress in the summer and unsafe drinking water during the rainy season, leading to an increase in waterborne diseases like diarrhea and dysentery.

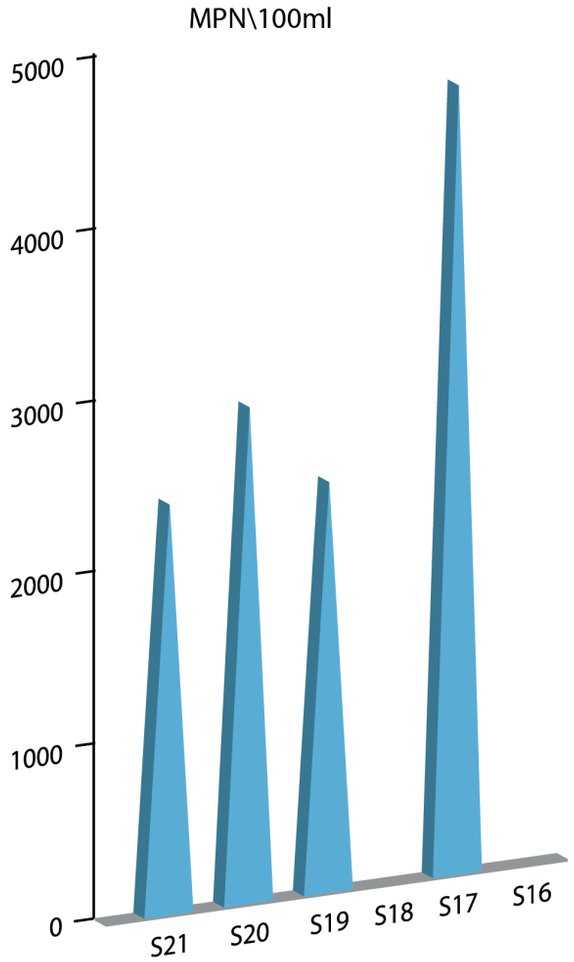


Fig. 6.31 Total coliform data of water samples obtained from Bihar and Jharkhand

The MPN per 100 mL is highest in sample S17, reaching a maximum of 4600 MPN (Most Probable Number) per 100 ml. In comparison, samples S19 and S21 exhibit lower levels with 2400 MPN/100mL each. Sample S20 shows a moderate level of microbial presence, measuring at 2900 MPN per 100 ml. These values indicate varying degrees of microbial contamination in the samples, with S17 having the highest concentration, followed by S20, and then S19 and S21.

The Differential Bacterial Count

This count is typically expressed as the number of bacterial colony-forming units (CFUs) per unit volume of the sample; all the values are expressed in Log 10, as shown in Fig. 6.32. Representative pictures of the isolated bacteria from Bihar Jharkhand are showin in Fig. 6.33

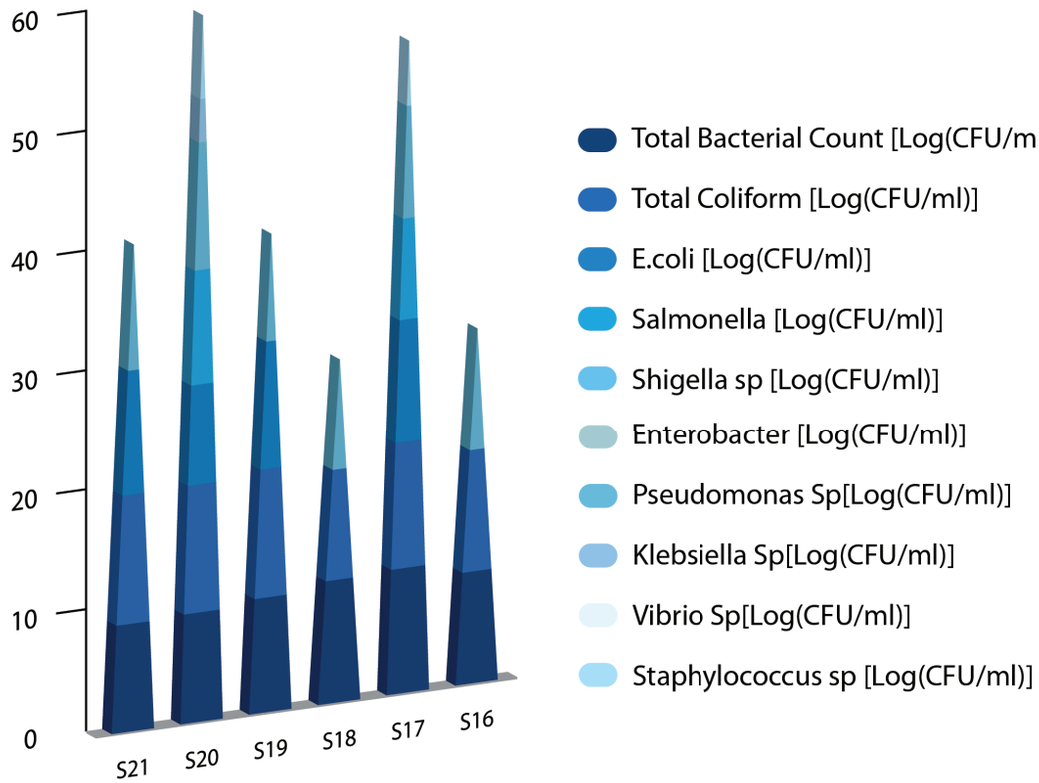


Fig. 6.32 The Differential Bacterial Count data of water samples obtained from Bihar and Jharkhand

The bacterial load across samples varies, as indicated by the total bacterial count in each. Specifically, S16 exhibits a count of 9.4, while S17 demonstrates a slightly higher value at 10.5. Likewise, S18 and S19 exhibit counts of 10.3 and 9.6, respectively. S20 and S21 present slightly lower counts of 9.2 and 9.05. The total coliform count varies across different samples, showcasing a range of bacterial loads. In sample S16, the count is 10.1, indicating a moderate bacterial presence. Similarly, in S17, the count rises slightly to 10.5 signifying a slightly elevated bacterial load. Conversely, sample S18 exhibits a lower count of 9.2, suggesting a comparatively minimal bacterial presence. The bacterial load of *Escherichia coli* (*E. coli*) exhibits variations across different sampling points. In S17, the maximum bacterial count is documented at 10.2 registers a higher load of 10.7, S20 records a lower bacterial count at 8.4, and S21 demonstrates a notable bacterial presence with a load of 10.4. Interestingly, two sampling

points, S16 and S17, show an absence of *E. coli*, indicated by a bacterial count of 0. *Shigella*, a bacterium known for its prevalence and impact on various sites, demonstrates varying concentrations across different locations. In specific sampling sites, namely S16, S17, S18, S19, S20, and S21, the concentrations of *Shigella* are observed to be 10.4, 9.3, 9.2, 8.9, 10.6, and 10.4, respectively. These figures underscore the noteworthy presence of *Shigella* in the sampled areas, with concentrations ranging from 8.9 to 10.6. Concurrently, *Salmonella*, another significant bacterium, manifests itself in the samples, with its presence documented in sites S17 and S20. The concentration of *Salmonella* in these locations is reported as 8.4 and 9.5, respectively. The analysis of bacterial load in samples S20 and S17 revealed noteworthy findings. In S20, the presence of *Klebsiella* and *Staphylococcus* was detected, with concentrations recorded at 3.6 and 6.9, respectively. Meanwhile, in sample S17, the presence of *Staphylococcus* species was identified, with a concentration of 5.4.

Fig. 6.33 Representative pictures of the isolated bacteria from Bihar Jharkhand



01



5
Water Sample Collected

02



4
Suitable for Drinking

03



4
Suitable for Irrigation

04



0
Suitable for Industrial use

05



2.13
Avgerage MPN/ ml in Water samples

WEST BENGAL

Results of Water Quality of West Bengal

West Bengal, located in the eastern part of the country between 21°33′ and 27°14′ N latitude and 86°35′ to 89°53′ E longitude, is one of the most important agriculturally developed states in the country. It spreads from the Himalayas in the north to the Bay of Bengal in the South, Assam, Sikkim, and Bhutan in the northeast, and Odisha in the Southwest. The entire stretch of the eastern part is bounded by Bangladesh and Jharkhand is bound by the western border. The state covers an area of 8.87 M ha representing 2.7% of the total geographical area (TGA) and producing food, fiber, and timber for 7.77 percent of the country's population (Sen, 2016; Department of Industry, Commerce & Enterprises, Government of West Bengal, 2020).

Concerns have been raised about the water quality of West Bengal's Ganges River. According to research, the river's water is contaminated and unsafe to drink in certain West Bengal regions. Over a nine-year period, the eastern section of the river's Water Quality Index (WQI) ranged from 55 to 416 and the Synthetic Pollution Index (SPI) ranged from 0.59 to 3.68. Pollution in the river is caused by factors such as seawater input, geogenic and anthropogenic activity, and industrial and home waste disposal. To overcome this issue, the study suggests implementing water treatment technologies to ensure water potability. Furthermore, the study emphasizes the importance of effective management practices. The water quality of West Bengal's Ganges River is influenced by a variety of causes, including seawater influx, geogenic and anthropogenic activity, and the discharge of industrial and domestic trash. It is critical to make concerted efforts to address these issues and implement water treatment technologies. These activities are critical to ensuring that West Bengal inhabitants have access to clean and safe water. (Ali, S. Y., *et. al* 2021)

ON-SITE ANALYSIS

Details about the onsite analysis of water samples from five sites in West Bengal along the Ganges River are provided in Table 6.10, which shows the environmental shift downstream.

Table 6.10 Field data of the water samples of West Bengal

SNo.	Site Name	Site Codes	Color	Odour	Foam	Temperature (°c)	Ph	Tds (Ppm)
1	Farakka Barrage Township	S22	Bluish-green	Fishy	ND	29.7	8.8	164
2	Murshidabad	S23	Sky blue	Fishy	ND	32.9	8.9	146
3	Mayapur	S24	Sea green	Fishy	ND	28.8	8.9	163
4	Hooghly	S25	Greenish grey	Fishy	ND	29.5	8.5	166
5	Gangasagar	S26	Dirty grey	Fishy	ND	30	8.5	144

In our water quality assessment, various sites along the Ganga River, including Farakka Barrage Township (S22), Murshidabad (S23), Mayapur (S24), Hooghly (S25), and Gangasagar (S26), were examined for several key parameters. Farakka Barrage Township (S22) exhibits a bluish-green color, with a fishy odor and no observable foam. The recorded water temperature is 29.7°C, pH level at 8.8, and a total dissolved solids (TDS) concentration of 164 ppm. Moving to Murshidabad (S23), the water displays a sky-blue color with a fishy odor and no apparent foam. The temperature at this site is 32.9°C, pH at 8.9, and TDS at 146 ppm. Mayapur (S24) presents a sea-green color with a fishy odor and no visible foam. The temperature is recorded at 28.8°C, pH at 8.9, and TDS at 163 ppm. In Hooghly (S25), the water takes on a greenish-grey color, with a fishy odor and no observed foam. The recorded temperature is 29.5°C, pH at 8.5, and TDS at 166 ppm. Gangasagar (S26) exhibits a dirty grey color, a fishy odor, and no apparent foam. The temperature at this site is 30°C, pH at 8.5, and TDS at 144 ppm. These findings provide insights into the visual characteristics and some physicochemical properties of water at different locations along the Ganga River.

LABORATORY ANALYSIS

Oxygen concentration

The recorded results for oxygen concentration indicate that two of the three parameters, Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD), exceed permissible limits. The mean values for these parameters, along with Chemical Oxygen Demand (COD), are recorded as DO (9.708 mg/L), BOD (3.538 mg/L), and COD (10.666 mg/L). A graphical representation of these parameters results is depicted below (Fig. 6.34), illustrating variations in Dissolved Oxygen, Biochemical Oxygen Demand, and Chemical Oxygen Demand across the studied locations. The graphical representation of Oxygen concentration different sites in West Bengal.

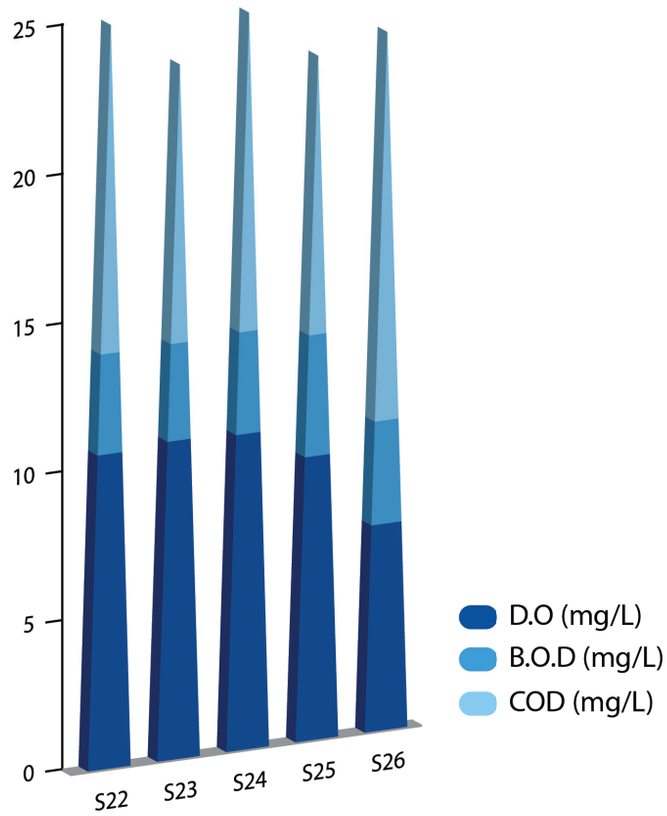


Fig. 6.34 Oxygen concentration data of water samples obtained from West Bengal

In our investigation, the lowest DO concentration is identified at Gangasagar (S26), measuring 6.96 mg/L, while the highest is observed at Murshidabad (S23) with a value of 10.76 mg/L. BOD levels show a minimum value at Murshidabad (S23) with 3.26 mg/L and a maximum at Hooghly (S25) with 4.1 mg/L. The highest COD is measured at Gangasagar (S26) with 13 mg/L, while the lowest COD is recorded at Murshidabad (S23) and Hooghly (S25) with 9.33 mg/L.

Alkalinity and Electrical Conductivity

In our study, alkalinity levels in West Bengal (WB) exhibit variations, with the highest measurement recorded at Hooghly (S25) with 152 mg/L and the lowest at Gangasagar (S26) with 106 mg/L. The mean alkalinity across the sites is calculated to be 136.132 mg/L. Graphical representation of the recorded EC and alkalinity values at various sites in West Bengal is depicted below in Fig. 6.35.

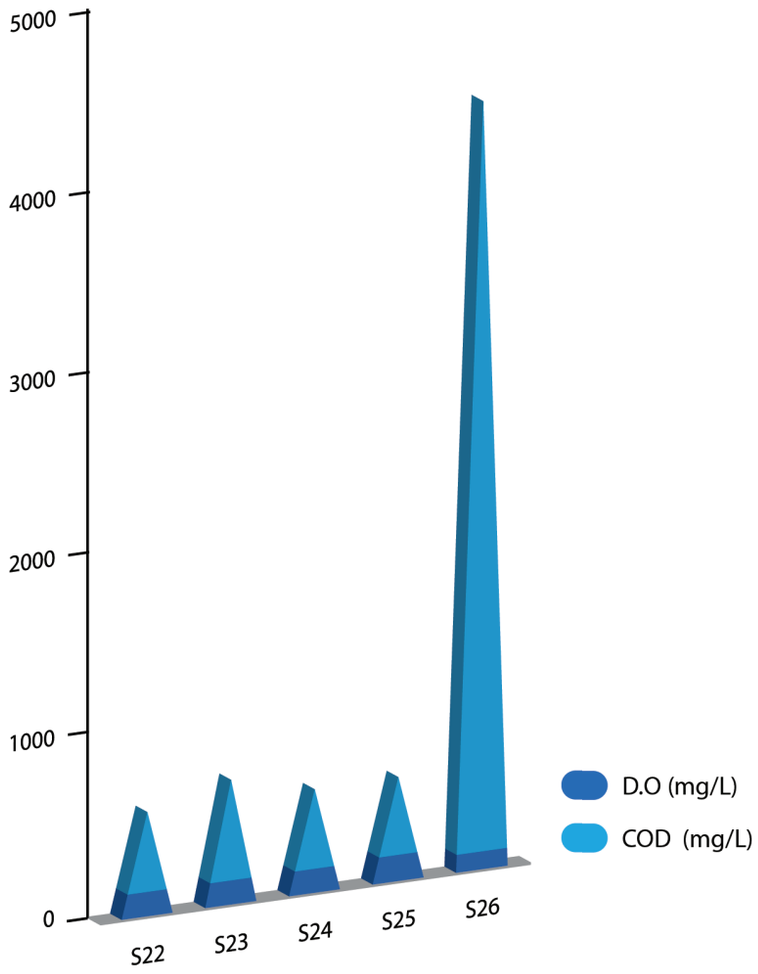


Fig. 6.35 Alkalinity and Electrical Conductivity data of water samples obtained from West Bengal

Similarly, the electrical conductivity (EC), a significant parameter, shows substantial differences, reaching its highest value in Gangasagar (S26) at 4167 µs/cm and the lowest in Hooghly (S25) at 430.3 µs/cm. The calculated mean EC value is 1207.338 µS/cm. However, it's important to note that the permissible limits set by the Central Pollution Control Board (CPCB) indicate that this means EC value exceeds the acceptable limit.

Turbidity, TSS and TDS

In our current study, the mean turbidity recorded is 169.176 NTU, reaching its highest level at Gangasagar (S26) with 694.3 NTU and the lowest at Farakka (S22) with 10.93 NTU. Notably, the recorded turbidity values surpass the permissible limits set by the Bureau of Indian Standards (BIS). The graphical representation below (Fig. 6.36) illustrates the statistical data for these parameters, providing a visual overview of the variations in turbidity, TDS, and TSS across the studied sites.

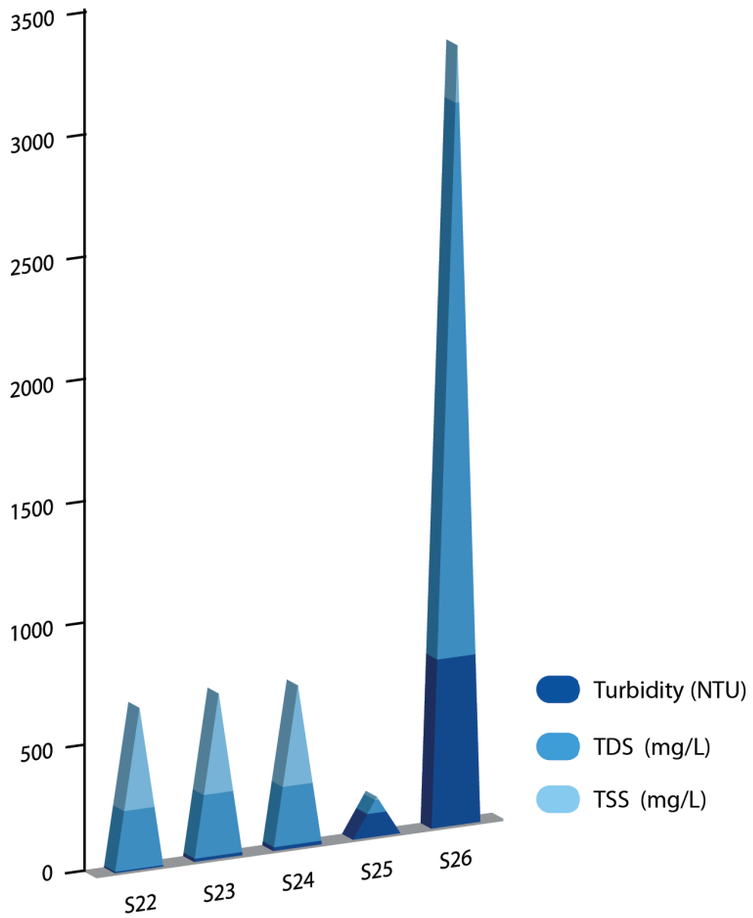


Fig. 6.36 Turbidity, TDS and TSS data of water samples obtained from West Bengal

For Total Dissolved Solids (TDS) and Total Suspended Solids (TSS), measured in mg/L, the mean values are 612.8373 mg/L and 294.3094 mg/L, respectively. The minimum TDS is observed in Hooghly (S25) at 53.06 mg/L, while the maximum is recorded in Gangasagar (S26) at 2271 mg/L. Regarding TSS, the minimum value is noted in Hooghly (S25) at 11.54701 mg/L, and the maximum is observed in Farakka (S22) at 413.333 mg/L.

Hardness

In the West Bengal (WB) region, the average value for Calcium hardness is noted at 20.932 mg/L, and for Magnesium hardness, the average is recorded as 144.864 mg/L. The calculated mean for total hardness in the WB region is 165.598 mg/L. The graphical representation below illustrates these results, providing a visual representation of the variations in calcium hardness, magnesium hardness, and total hardness across the studied sites in West Bengal. The graphical representation of Oxygen concentration on different sites in West Bengal is shown below in Fig.6.37.

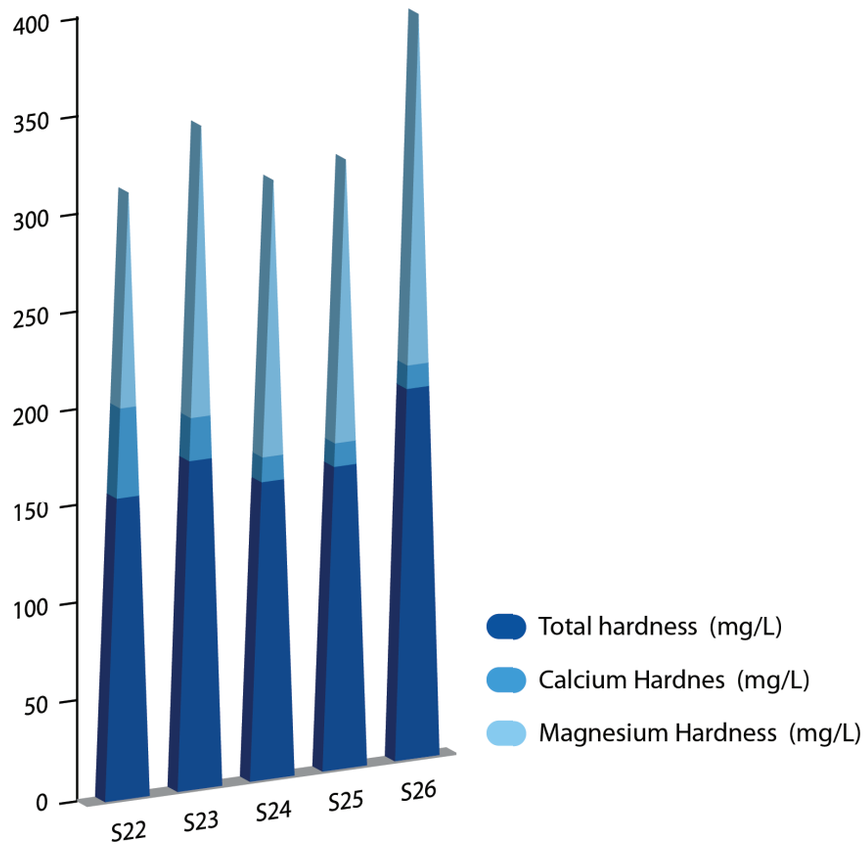


Fig. 6.37 Total, Calcium and Magnesium Hardness data of water samples obtained from West Bengal

The minimum calcium hardness is found in Hooghly (S25) and Gangasagar (S26) at 12.0 mg/L, while the maximum is observed in Farakka (S22) at 46.0 mg/L. For Magnesium hardness, the highest concentration is recorded in Gangasagar (S26) at 179.33 mg/L, whereas the lowest is found in Farakka (S22) with 110 mg/L. Similarly, the lowest total hardness is noted in Mayapur (S24) at 154 mg/L, and the highest recorded value for total hardness is found in Gangasagar (S26) at 191.33 mg/L.

Nitrate and Sulphate

In our research, we determined that the average concentrations of nitrates and sulphates in the West Bengal (WB) water are 0.57448 mg/L and 43.7158 mg/L, respectively. These values fall below the permissible limits established by the Central Pollution Control Board (CPCB), and Bureau of Indian Standards (BIS). A graphical representation (Fig. 6.38) of these findings is illustrated below, providing a visual overview of variations in nitrate and sulphate concentrations across the studied sites in West Bengal.

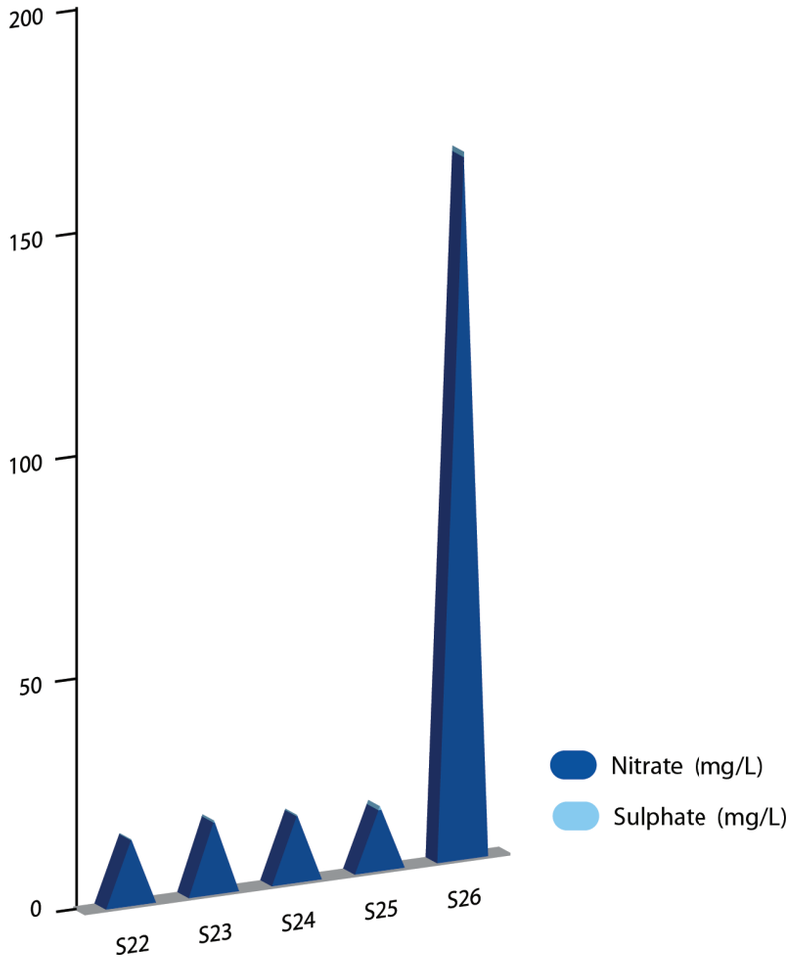


Fig. 6.38 Nitrate and Sulphate data of water samples obtained from West Bengal

The minimum nitrate concentration is observed in Farakka (S22) at 0.1766 mg/L, while the maximum is found in Gangasagar (S26) at 1.1986 mg/L. Conversely, the maximum sulphate concentration is detected in Gangasagar (S26) at 157.82 mg/L, and the minimum sulphate concentration is found in Hooghly (S25) at 14.012 mg/L.

Ionic constituents

The mean values for ionic constituents considered in our study, including Sodium (67.838 ppm), Chloride (175.6 ppm), and Fluoride (0.05 ppm) in the West Bengal (WB) region. The mean value for Potassium is recorded at 9.026 ppm. The graphical representation below (Fig. 6.39) illustrates the statistical data, providing a visual overview of variations in sodium, potassium, chloride, and fluoride concentrations across the studied sites in West Bengal.

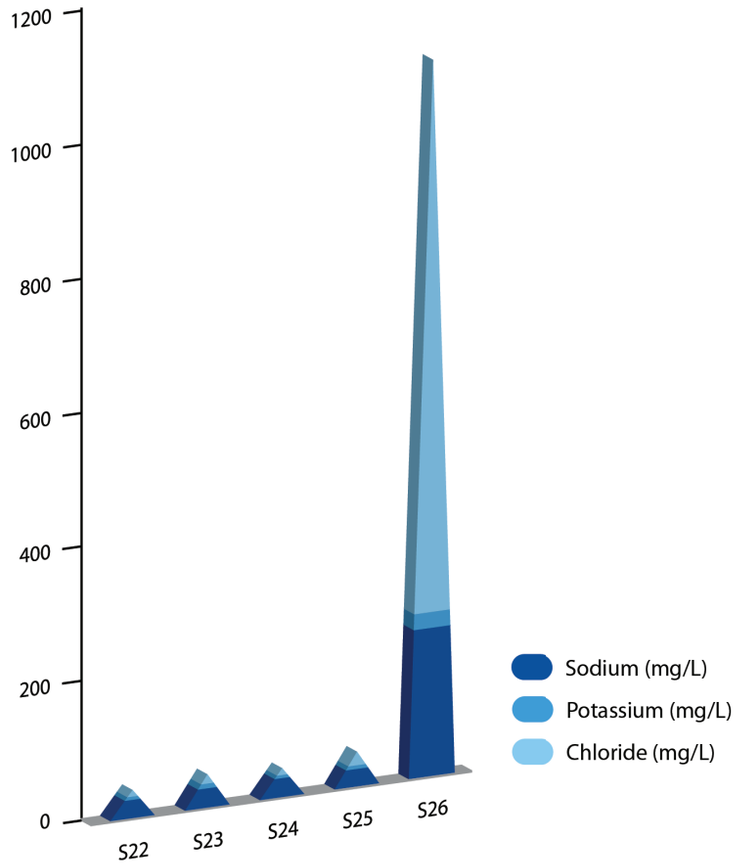


Fig. 6.39 Ionic constituent data of water samples obtained from West Bengal

The lowest sodium concentration is found in Hooghly (S25) at 27.87 ppm, while the highest is observed in Gangasagar (S26) at 222.2 ppm. For Potassium, the lowest concentration is recorded in Farakka (S22) at 4.57 ppm, and the highest is in Gangasagar (S26) at 23.56 ppm. Chloride concentrations in water range from a minimum in Farakka (S22) and Mayapur (S24) at 10 ppm to a maximum in Gangasagar (S26) at 824 ppm. Fluoride is consistently found at the same concentration throughout the Ganga River belt in West Bengal, valued at 0.05 ppm.

Total Coliform

The water quality in West Bengal, India, is a concern due to various factors such as industrial discharge, domestic sewage, and groundwater contamination. Many districts of West Bengal suffer from contaminated drinking water, containing various substances. The data obtained from these analyses will be instrumental in evaluating the overall microbial safety and quality of the water in the specified region, as shown in below Fig. 6.40.

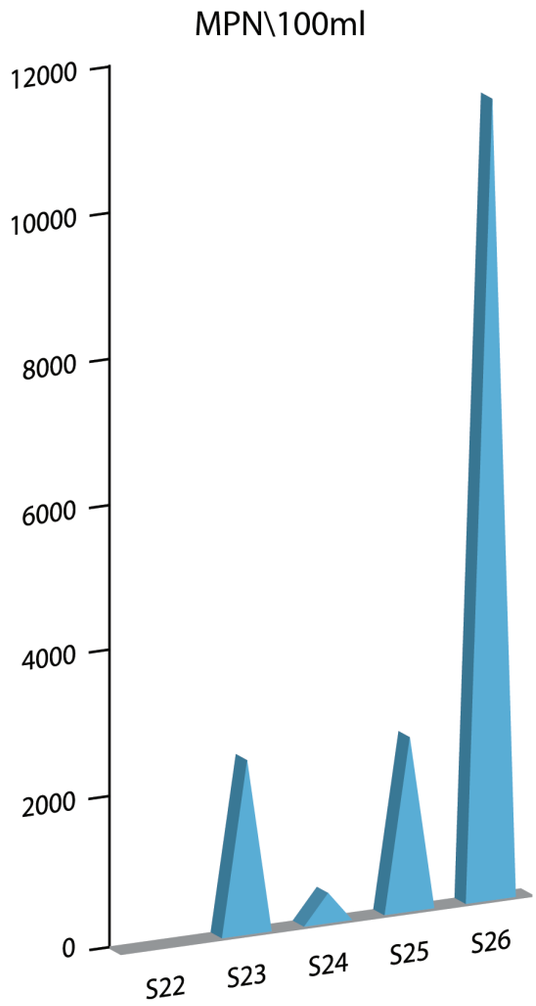


Fig. 6.40 Total coliform data of water samples obtained from West Bengal

Sample S26 demonstrates the highest bacterial load, reaching a maximum of 1100 MPN per 100 ml. In contrast, samples S23 and S25 display comparatively lower levels, each recording 2400 MPN/100mL. Sample S24 exhibits a moderate presence of microbes, registering at 430 MPN per 100 ml. It's worth highlighting that sample S22 showed no detectable bacteria with a reading of 0 MPN/100mL.

The Differential Bacterial Count

Total bacterial count is typically expressed as the number of bacterial colony-forming units (CFUs) per unit volume of the sample, all the values are expressed in Log 10. Examining total coliform counts reveals minimal variation among the sites as shown in Fig. 6.41. Representative pictures of the isolated bacteria from West Bengal are shown in Fig. 6.42.

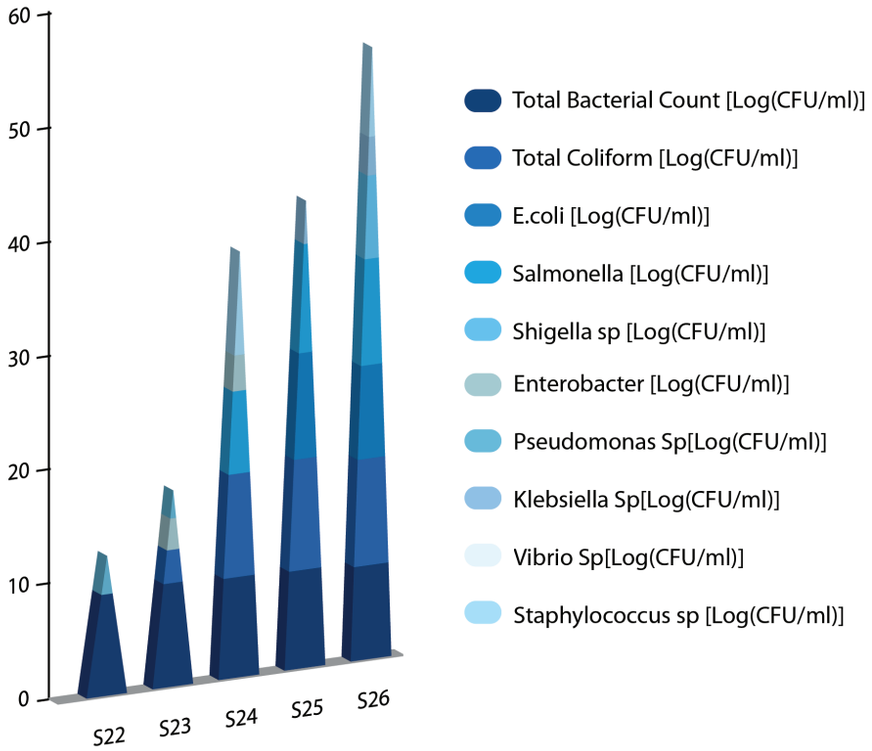


Fig. 6.41 The Differential Bacterial Count data of water samples obtained from West Bengal

Specifically, S22 exhibits a count of 8.9, S23 shows a higher count of 9.16, S24 records 8.8, S25 registers 8.7, and S26 displays a slightly lower count of 8.3. The recorded total coliform levels exhibit variations across different samples, with S22 displaying an absence (0 Log), S23 at 2.9 l, S24 at 9.0, S25 at 9.7, and S26 at 9.3.

Notably, *E. coli* is detected solely in samples S25 and S26, registering concentrations of 9.3 and 8.2, respectively. The concentrations of *Shigella* species in samples S24, S25, and S26 were recorded at 7.3, 9.5, and 9.3, respectively. Additionally, sample S26 exhibited the presence of *Salmonella* species at a concentration of 7.3.

Enterobacter species were detected in samples S23 and S24 at 2.7 and 3.1, respectively. *Pseudomonas* was identified in samples S22 and S23 with concentrations of 3.3 and 2.4, respectively. *Klebsiella* was observed in samples S25 and S26, registering concentrations of 3.7 and 3.3. *Staphylococcus* was found in samples S24 and S26 at 9.0 and 7.8, respectively.

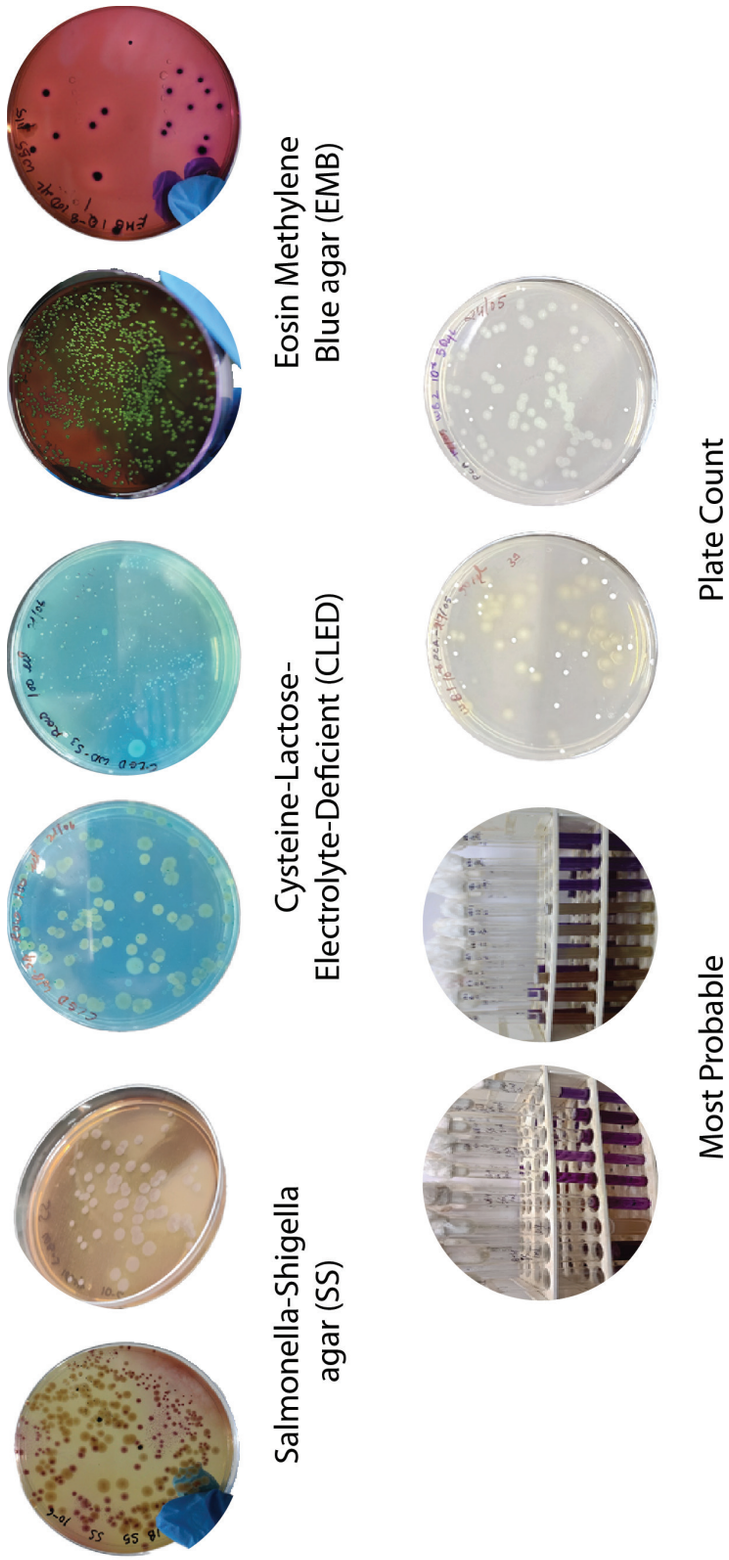
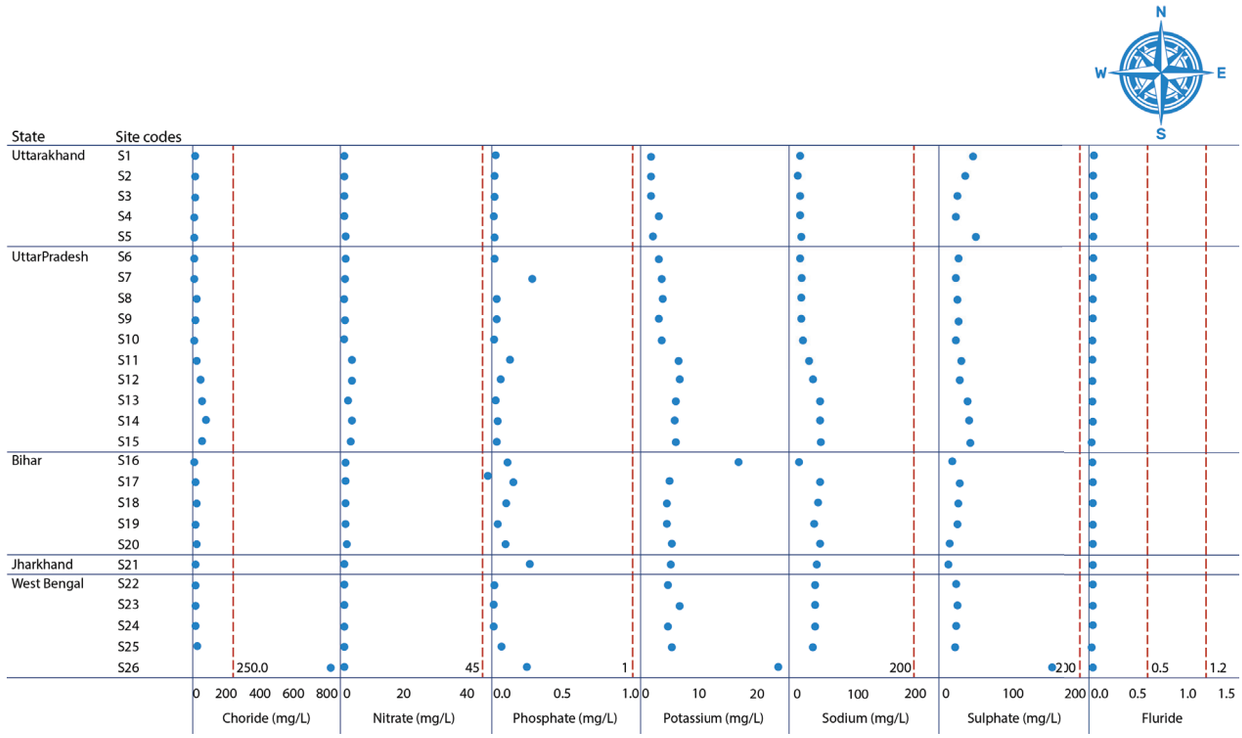


Fig. 6.42 Representative pictures of the isolated bacteria from West Bengal

Comparison of Different Sites According to the Different Water Parameters

The comparison of different sites comprising of five states along with the prescribed limit by WHO, CPCB and BIS has been given below in Fig. 6.43-6.46.

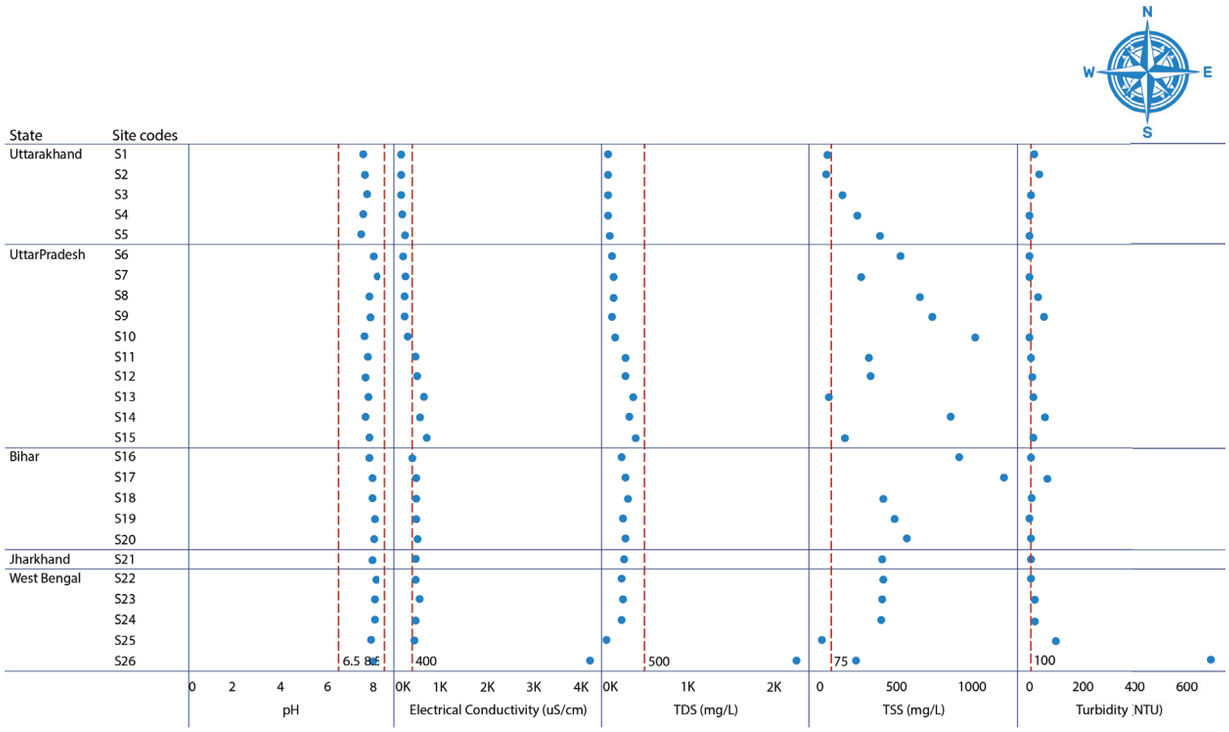


The value of the dotted line (permissible limit) has been adopted from WHO/BIS/CPCB

Fig. 6.43 Ionic Concentration of water Samples along with permissible limits

The analysis reveals that the ionic concentration in water samples generally adheres to the permissible limits set forth by regulatory bodies such as CPCB, BIS, and WHO.

Specifically, for chloride and sodium, a noteworthy 96% of samples register concentrations well within the permissible limits, 4% which exhibits elevated concentrations for both elements. On the other hand, nitrate, phosphate, potassium, sulfate, and fluoride levels consistently fall within the acceptable range stipulated by regulations.

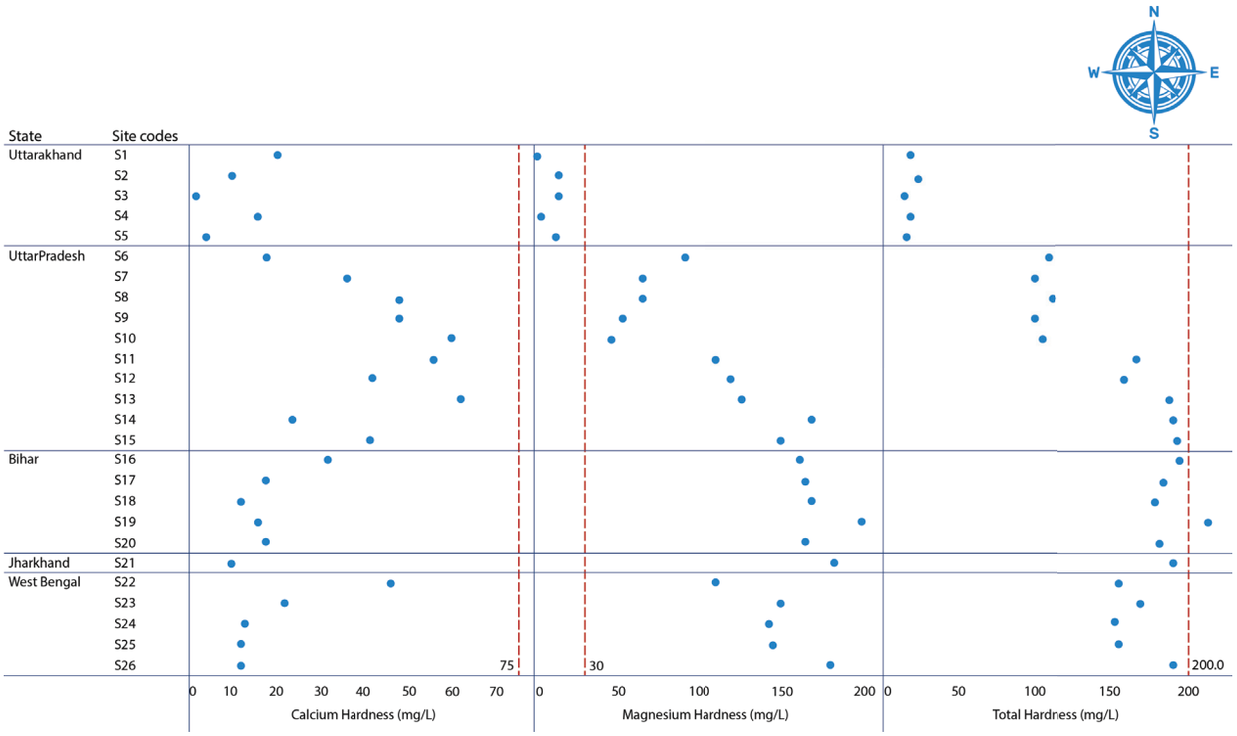


The value of the dotted line (permissible limit) has been adopted from WHO/BIS/CPCB

Fig. 6.44 Physicochemical parameters of water Samples along with permissible limits

The pH levels of all water samples fall within the accepted range of 6.5 to 8.5. However, 15.38% of the samples are slightly below the permissible limit while the remaining 84.6% exceed this limit. In terms of total suspended solids (TSS), 15.38% of the samples meet the permissible limit, while 84.6% exceed it. In the case of Electrical conductivity (EC) only 10 samples (38.4%) samples are within the prescribed range.

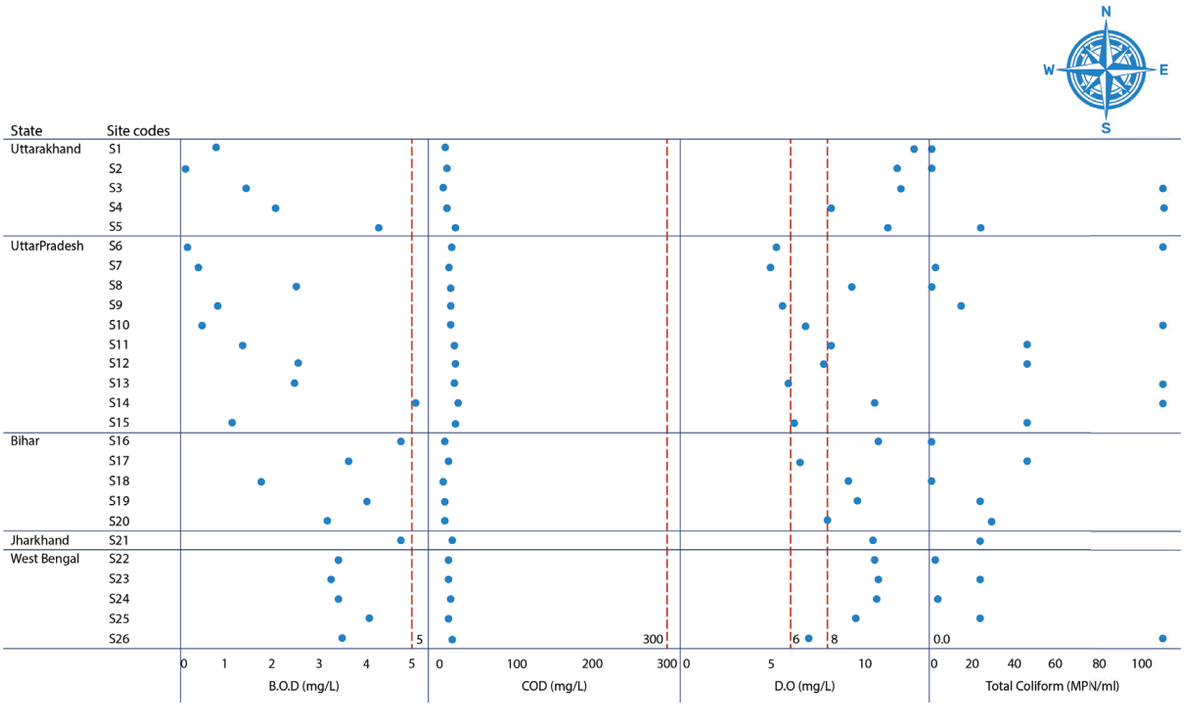
When it comes to turbidity, 34.6% of the samples surpass the permissible limit, with the remaining 65.4% falling within acceptable levels. It's noteworthy that for Total dissolved solids (TDS), 96% of the samples are below the permissible limit, and only 4% exceed it, indicating generally good compliance with the set standards.



The value of the dotted line (permissible limit) has been adopted from WHO/BIS/CPCB

Fig. 6.45 Hardness of water Samples along with permissible limits

The hardness of water is determined by factors such as Calcium hardness, Magnesium hardness, and Total hardness. In the case of calcium hardness, all samples were found to be within the permissible limits set by CPCB, BIS, and WHO. For magnesium hardness, 19.2% of the total samples met the permissible limit, while the remaining 80.8% exceeded it. Additionally, only 3.8% of the samples surpassed the permissible limit for total hardness, with the remaining 96.2% falling below the specified threshold.



The value of the dotted line (permissible limit) has been adopted from WHO/BIS/CPCB

Fig. 6.46 BOD, COD, DO, and Total coliform of water Samples along with the permissible limit

In the water samples analyzed, 96.2% exhibited Biochemical Oxygen Demand (BOD) levels below the permissible limit, while the remaining 3.8% were within the permissible range*. Concerning Chemical Oxygen Demand (COD), all the samples are within the prescribed limit. In terms of Dissolved Oxygen (DO), 11.5% registered levels below the permissible limit, 30.7% fell within the acceptable range, and 57.8% surpassed the permissible limit. As per the guidelines set forth by the World Health Organization, the absence of any detectable *E. coli*, with a count of zero per 100 ml of water, is deemed to be within the safe parameters for drinking, approximately 30.7% of water samples fall within the range of 20 in the total coliform graphical representation, while the remaining 69.3% exceed this range.

Suitability Analysis of the Water Samples

When evaluating the quality of water for irrigation, industry, and drinking, suitability examination of water samples is crucial. This analysis aids in determining whether the water is suitable for industrial, agricultural, or drinking uses. The water samples have been categorized based on their suitability, as indicated in table 6.11. The proportion of samples as drinking, irrigation, and industrial qualities of the water along with the justification were also covered in the part that followed.

Table 6.11 Suitability of the water samples

States	Sites	Site codes	Drinking Water Quality	Irrigation Water Quality	Industrial Water quality
Uttarakhand	Gomukh	S1	Totally suitable	Totally Suitable	Totally Unsuitable
	Gangotri	S2	Suitable	Totally Suitable	Totally Unsuitable
	Uttarkashi	S3	Medium Suitable	Totally Suitable	Totally Unsuitable
	Devprayag	S4	Medium Suitable	Totally Suitable	Totally Unsuitable
	Haridwar	S5	Medium Suitable	Totally Suitable	Totally Unsuitable
Uttar Pradesh	Bijnor	S6	Medium Suitable	Totally Suitable	Totally Unsuitable
	Narora	S7	Medium Suitable	Totally Suitable	Not suitable
	Budaun	S8	Medium Suitable	Totally Suitable	Not suitable
	Farrukhabad	S9	Medium Suitable	Totally Suitable	Not suitable
	Bithoor	S10	Medium Suitable	Totally Suitable	Not suitable
	Dalmau	S11	Medium Suitable	Medium suitable	Not suitable
	Prayagraj	S12	Medium Suitable	Medium suitable	Not suitable

States	Sites	Site codes	Drinking Water Quality	Irrigation Water Quality	Industrial Water quality
	Mirzapur	S13	Lower-Medium Suitable	Medium suitable	Not suitable
	Varanasi	S14	Totally Unsuitable	Medium suitable	Not suitable
	Ballia	S15	Medium Suitable	Medium suitable	Not suitable
Bihar	Revelganj	S16	Medium Suitable	Medium suitable	Not suitable
	Patna	S17	Lower-Medium Suitable	Medium suitable	Totally Unsuitable
	Barh	S18	Medium Suitable	Medium suitable	Totally Unsuitable
	Bahachouki	S19	Medium Suitable	Medium suitable	Totally Unsuitable
	Farka	S20	Medium Suitable	Medium suitable	Totally Unsuitable
Jharkhand	Sahebganj	S21	Lower-Medium Suitable	Medium suitable	Totally Unsuitable
West Bengal	Farakka	S22	Medium Suitable	Medium suitable	Not suitable
	Murshidabad	S23	Lower-Medium Suitable	Medium suitable	Not suitable
	Mayapur	S24	Medium Suitable	Medium suitable	Totally Unsuitable
	Hooghly	S25	Lower-Medium Suitable	Totally Suitable	Totally Unsuitable
	Gangasagar	S26	Totally Unsuitable	Not suitable for irrigation	Totally Unsuitable

Drinking Water Quality: NSFWQI Index

This method was developed by (Brown, et.al 1970) to provide a standardized method for comparing the water quality of various bodies of water using nine water quality parameters. These are pH, temperature, turbidity, fecal coliform, dissolved

oxygen (DO), biochemical oxygen demand (BOD), total phosphates, nitrate, and total solids according to (Kumar, D., & Alappat, B. J. 2009). In this study, NSFWQI was found in the range of 47.2–84.2. As per (Shweta et al., 2013) NSFWQI value falling within the range of 91–100 corresponds to excellent water quality, 71 and 90 good water quality, 51 to 70 suggests medium water quality, 26–50 poor water quality, and values between 0 and 25 signify very bad water quality.

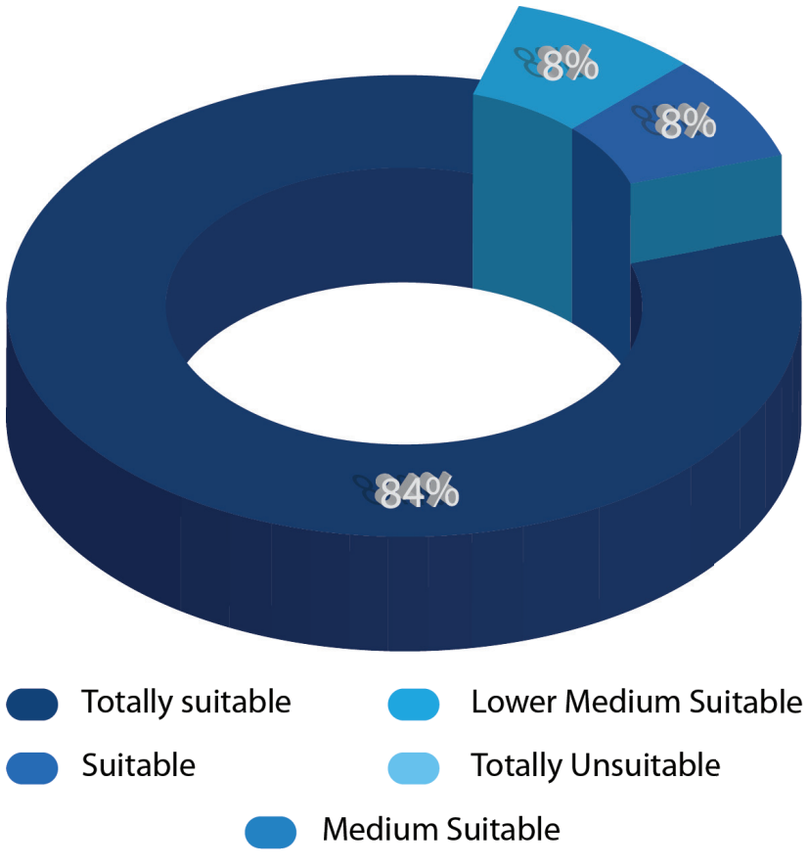


Fig.6.47 NSFWQI index of water quality (Drinking water)

The review of several sites shows a distribution of ratings based on their performance. Two (8%) of the total sites surveyed were rated as "Good," indicating positive elements or satisfactory performance. The vast majority, 22 sites (84%) fall into the "Medium" category, indicating a mixed or average degree of performance across these locations. Meanwhile, two sites (8%) are rated "Bad," indicating concerns that may need to be addressed or improved. This rating diversity emphasizes the importance of conducting a thorough examination of individual comments linked with each v site, which will allow for focused actions to improve overall performance and satisfaction (Fig. 6.47).

The data on drinking water quality in different states presents a diverse picture of suitability across regions (Table 6.11). In Uttarakhand, most places are classified as

totally suitable (20%), suitable (20%), and medium suitable (80%), indicating a generally favorable drinking water quality. Uttar Pradesh exhibits a predominantly medium suitable (80%) classification of drinking water quality, with a few areas falling into the lower-medium suitable category (10%) and one marked as totally unsuitable (10%). Bihar's drinking water quality is characterized by a mix of medium suitable (80%) and lower-medium suitable (20%) classifications. Jharkhand and West Bengal show a range of suitability, with some areas marked as lower-medium suitable (50%), medium suitable (33%), and, in the case of West Bengal, a region identified as totally unsuitable (17%). The data underscores the importance of monitoring and addressing water quality variations to ensure the provision of safe and suitable drinking water across different states, especially in regions flagged as unsuitable.



Irrigation water Quality: SAR Index

SAR, or Sodium Adsorption Ratio, serves as an indicator of potential sodium hazards by assessing the proportion of sodium to calcium and magnesium in water (Interpreting Water Quality Test Results First Edition NSW DPI Agriculture Water Unit, 2016). The sodium adsorption ratio is a measure of the tendency of irrigation water to participate in cation exchange reactions within the soil. When there is an excess of sodium, it adheres to soil particles, leading to alterations in soil properties and a decrease in permeability (Ayers and Bronson 1975). In this study, SAR was found in the range of 0.91–87.43. As per Richards (1954), water with SAR range of 0–10e is considered very good, 10–18 range good, 18–26 range marginal, and values exceeding 26 falls into the harmful category.

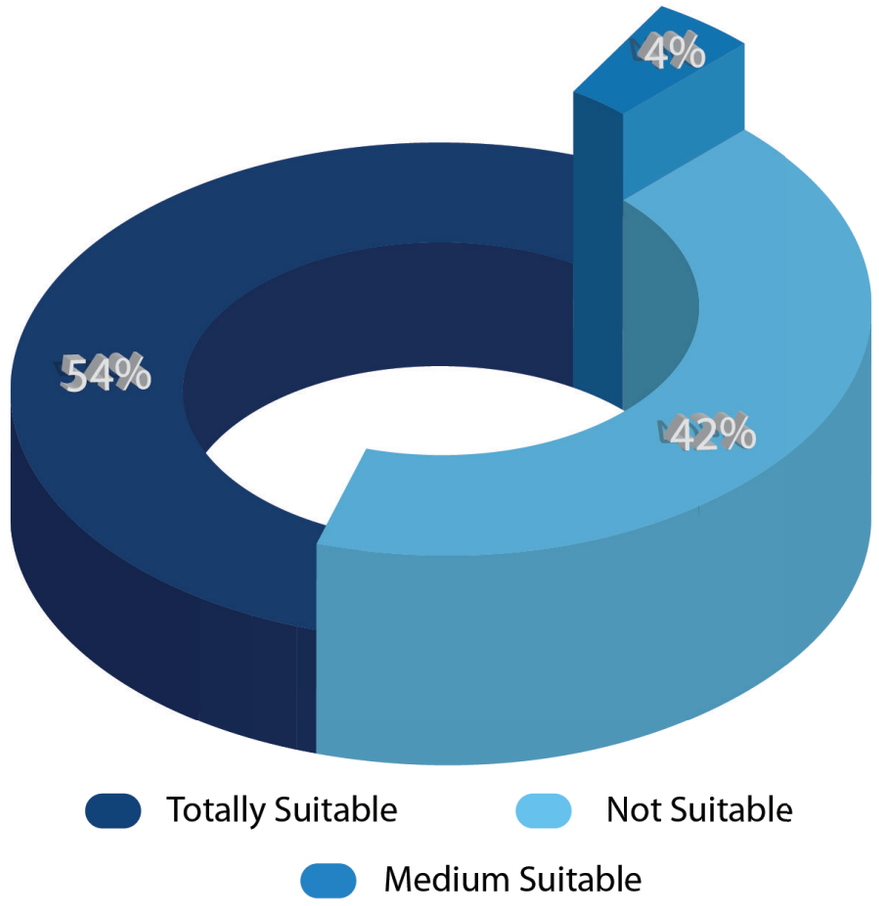


Fig. 6.48 SAR index of water quality (Irrigation water)

The evaluation of water quality categorizes it into different groups based on sodium content, each assigned a corresponding score. Water exhibiting low sodium levels, identified at 16 locations, receives the highest score of 16 (62%), indicating excellent overall water quality. This preference for low-sodium water underscores its

positive impact. In contrast, water with moderate sodium content, observed at 6 locations, earns a middle score of 6 (23%). While not as favorable as low-sodium water, it still contributes significantly to the overall water quality. High-sodium water, present at 3 locations, receives a lower score of 3 (11%), indicating a less desirable impact on overall water quality. Of concern is water with very high sodium levels at 1 location, receiving the lowest score of 1 (4%). This signals an excessive sodium presence, posing a significant challenge to water quality at that specific site.

The provided data outlines the Sodium Absorption Ratio (SAR) for various locations in states such as Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal (Table 6.11), Fig. 6.48. In Uttarakhand, places like Gomukh, Gangotri, Uttarkashi, Devprayag, and Haridwar are consistently classified as totally suitable (100%) in terms of SAR. Similarly, in Uttar Pradesh, Bijnor, Narora, Budaun, Farrukhabad, and Bithoor demonstrate total suitability (80%). However, a transition to medium suitability (50%)is observed in places like Dalmau, Prayagraj, Mirzapur, Varanasi, and Ballia. Bihar's locations, including Revelganj, Patna, Barh, Bahachouki, and Farka, fall into the medium suitability range (100%). Jharkhand's Sahebganj and West Bengal's Farakka, Murshidabad, Mayapur (66%), and Hooghly are also classified as medium suitable (17%). Notably, Gangasagar in West Bengal is marked as not suitable for irrigation (17%). The data underscores variations in SAR across different regions, highlighting the importance of water quality monitoring and management practices, especially in areas with deviations from total suitability.

Industrial water Quality: RSI Index

The Ryznar index (RSI) is employed as a predictive tool to assess the probability of calcium carbonate scale formation in each water sample (Corrosionpedia 2018). The RSI indicates the water's scaling tendency based on factors like pH, temperature, and conductivity. The Ryznar Stability Index specifically assesses the potential for scale formation by comparing the saturation pH (the pH at which the water is at equilibrium with calcium carbonate) to the actual system pH. These indices help in understanding whether the water will tend to scale, dissolve calcium carbonate, or maintain equilibrium, assisting in the management of water treatment processes to minimize scaling and corrosion issues. In this study, RSI was found in the range of 7.57– 12.05. The Ryznar Stability Index (RSI), as per Ryznar's findings in 1944, provides insights into water characteristics. With an RSI below 5.5, heavy-scale formation is anticipated. In the range of 5.5–6.2, scale formation is expected. Within 6.2–6.8, no difficulties are foreseen. Moving to 6.8–8.5, the water is deemed aggressive, and an RSI above 8.5 suggests the water is very aggressive.

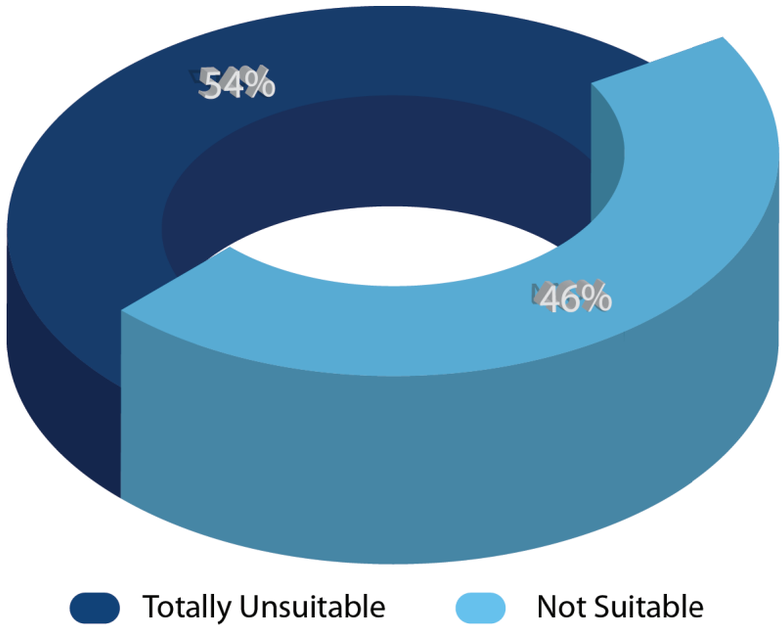


Fig. 6.49 RSI index of water quality (Industrial water)

Water can be labelled as "Aggressive" or "Very Aggressive," and these labels correspond to different scores in the water assessment. "Aggressive water" receives a score of 12, indicating that it has some reactivity or potential for difficulties. On the other side, "Very Aggressive water" has a higher score of 14, suggesting that it is more reactive or has a larger risk of producing problems. Simply defined, Very Aggressive water is totally unsuitable for industrial purpose whereas aggressive water is also not suitable but can be processed with proper remediation.

Over all 54% of all tested water samples are very aggressive that denotes it is completely unsuitable for industrial purpose. Whereas rest 46% can be used for industrial purpose but not without remediation (Fig. 6.49). The summarized results based on the RSI data in table 6.11, reveal significant concerns regarding water quality in multiple states and their respective locations. In Uttarakhand, including Gomukh, Gangotri, Uttarkashi, Devprayag, and Haridwar, all places are classified as totally unsuitable(100%). Uttar Pradesh exhibits varying levels of unsuitability, with locations such as Bijnor marked as totally unsuitable (10%), while Narora, Budaun, Farrukhabad, Bithoor, Dalmau, Prayagraj, Mirzapur, Varanasi, and Ballia are classified as not suitable (90%). In Bihar, Revelganj is labeled as unsuitable (20%), whereas Patna, Barh, Bahachouki, and Farka are deemed totally unsuitable (80%). Jharkhand's Sahebganj and West Bengal's Farakka, Murshidabad, Mayapur, Hooghly, and Gangasagar are also classified as either not suitable (33%) or totally unsuitable (67%). These results emphasize the urgent need for water quality management and remedial actions in the identified areas to ensure a safe and suitable water supply.

Classification of Water Samples

As we have taken the surface or sub-surface water samples from the river Ganga. The significance of the water quality classes designated by the Central Pollution Control Board (CPCB) in India is paramount for effective water management and environmental conservation. Class A signifies water bodies suitable for direct consumption without conventional treatment, emphasizing the provision of safe drinking water. Class B ensures organized outdoor bathing activities occur in water bodies that meet specified quality standards, promoting public health and safety. Class C is crucial for the supply of drinking water, necessitating conventional treatment processes. Class D focuses on the preservation of wildlife and fisheries, safeguarding aquatic ecosystems. Lastly, Class E is dedicated to non-potable uses such as irrigation, industrial cooling, and controlled disposal, establishing standards to prevent adverse impacts on agriculture, industries, and the environment. These classifications play a vital role in guiding water resource management practices, safeguarding human health, supporting ecosystems, and promoting sustainable water use in diverse sectors (P. Bhawan, 2007). Thus, the classification for the best use surface water as prescribed by the Central Pollution Control Board (CPCB 1978) needs to be considered According to the classification given, the 26 water samples are classified and drafted below (Table 6.12).

Table 6.12 Categorization of Water Samples from Respective Sites Based on CPCB Classifications

States	Near By sites	Site Codes	Classification with Designated Usage				
			Class A	Class B	Class C	Class D	Class E
			Drinking water source without conventional treatment but with chlorination	Outdoor bathing (organized)	Drinking water source with conventional treatment	Propagation of wildlife and fisheries	Irrigation, industrial cooling, and controlled disposal
Uttarakhand	Gaumukh	S1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	Gangotri	S2	Not Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	Uttarkashi	S3	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Devprayag	S4	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Haridwar	S5	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
Uttar Pradesh	Bijnor	S6	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Narora	S7	Not Acceptable	Acceptable	Acceptable	Not Acceptable	Acceptable
	Budaun	S8	Not Acceptable	Acceptable	Acceptable	Not Acceptable	Acceptable
	Farrukhabad	S9	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Acceptable
	Bithoor	S10	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Dalmau	S11	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Acceptable
	Prayagraj	S12	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Acceptable
	Mirzapur	S13	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Varanasi	S14	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Ballia	S15	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Acceptable

States	Near By sites	Site Codes	Classification with Designated Usage				
			Class A	Class B	Class C	Class D	Class E
			Drinking water source without conventional treatment but with chlorination	Outdoor bathing (organized)	Drinking water source with conventional treatment	Propagation of wildlife and fisheries	Irrigation, industrial cooling, and controlled disposal
Bihar	Revelganj	S16	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Patna	S17	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Barh	S18	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	Bahachouki	S19	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Farka	S20	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
Jharkhand	Sahebganj	S21	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
West Bengal	Farakka	S22	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Murshidabad	S23	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Mayapur	S24	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
	Hooghly	S25	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Acceptable
		S26	Not Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable

The water quality assessment across states in India reflects encouraging results with detailed percentage values of acceptability at various sites (Fig. 6.50).

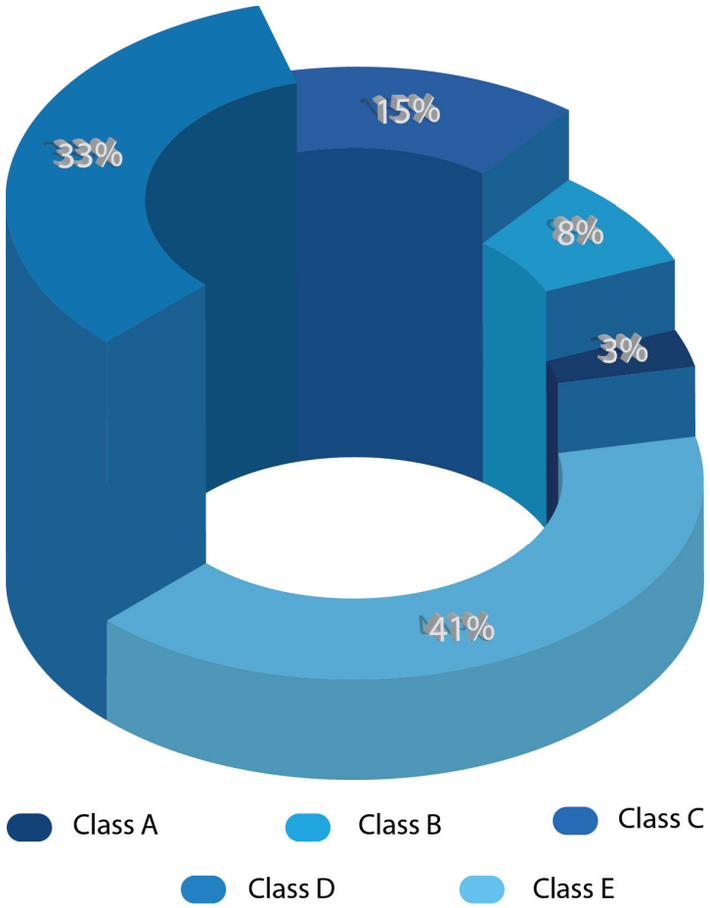


Fig. 6.50 The classification of water samples according to the different classes of possible usage

Overall, Class A water cross ponds to only 3% whereas Class B is 8%, Class C is 15%, Class D is 33% and Class E corresponds to 41%.

In Uttarakhand, sites S1 to S5 showcase exemplary performance, achieving 100% acceptability across all classes (A to E) for their designated best uses, indicating an optimal environmental status. Uttar Pradesh demonstrates overall favorable conditions, with S6 to S15 sites exhibiting acceptability percentages ranging from 80% to 100% across different classes. Particularly noteworthy is S9, achieving a perfect 100% acceptability across Classes B, C, D, and E, emphasizing its reliability as a drinking water source. Bihar's S16 to S20 sites consistently register a commendable 100% acceptability across all designated classes, reflecting a robust water quality profile. In Jharkhand, the singular site S21 attains 100% acceptability across the specified classes, reinforcing positive environmental conditions. West Bengal's S22 to S25 sites also maintain a perfect 100% acceptability rate, while S26 achieves a respectable 66.67% acceptability for Classes A and B. This comprehensive analysis underscores the overall high water quality standards in these states, portraying a positive outlook for diverse water use categories and environmental conservation.

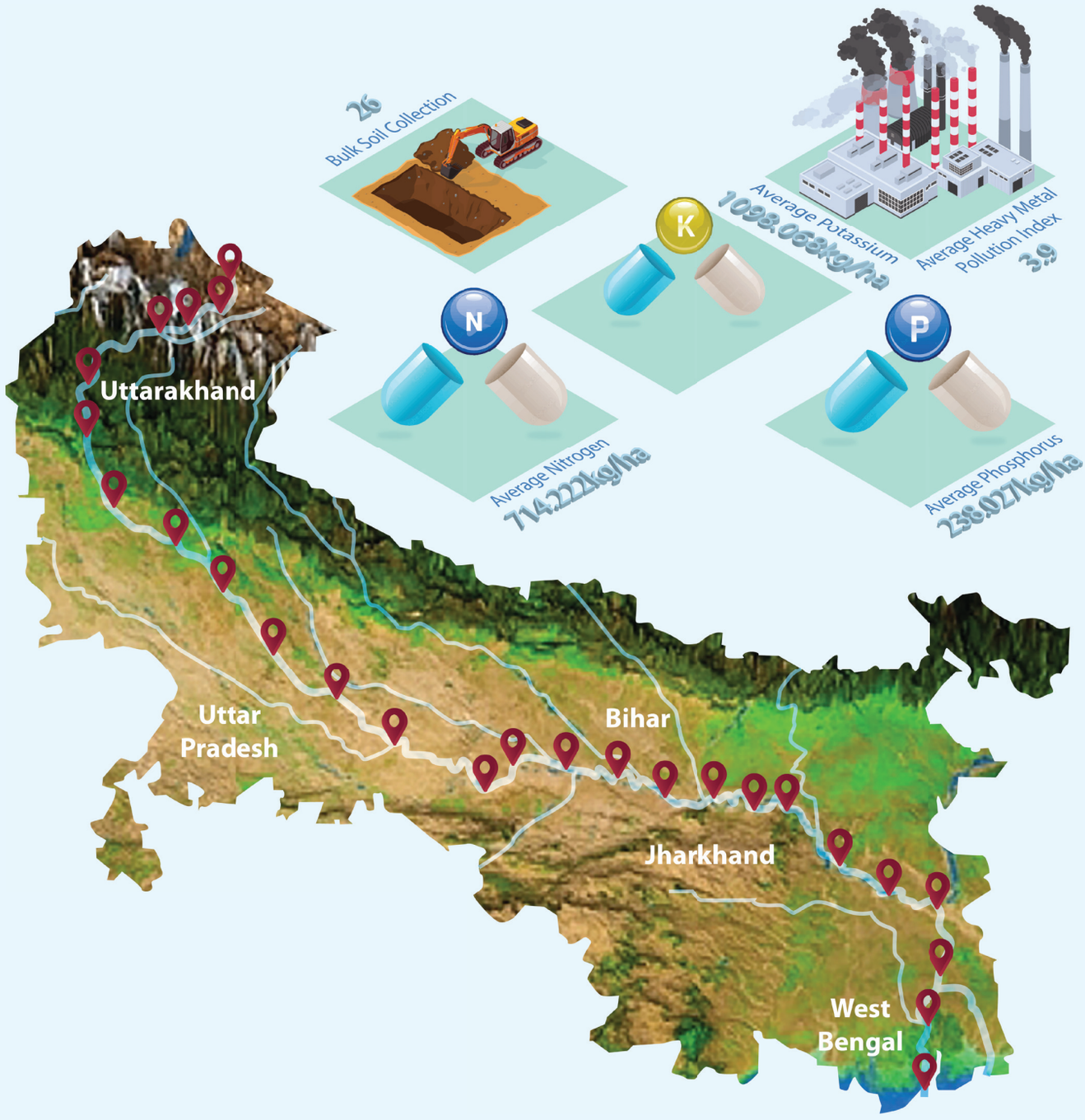
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Section-VII

Soil Quality Analysis



The soil quality in the Ganga region states varies due to the diverse nature of the Ganga basin. The high Himalayas in the north experience continuous soil erosion, while the Gangetic plain and the Ganges River deltaic region have their own unique soil characteristics. The Ganga basin is the largest river basin in India, with a catchment area of 861,404 sq. km, and it encompasses a wide variety of soils. Some areas in the region face severe constraints such as drought, salinity, and waterlogging, which affect the soil and land qualities. Additionally, the heavily industrialized Kanpur region is known for excessive pollutant discharge, making it the most polluted stretch of the Ganga River. This industrial pollution, along with agricultural runoff and other factors, has significantly impacted the water quality in this area. The soil and land quality in the Ganga region is a complex and multifaceted issue, influenced by natural and anthropogenic factors (Dimri et al., 2021). In the Ganga Valley region, soil quality testing plays a significant role in assessing the fertility of the land and the impact of various human activities on the soil. Some key aspects of soil quality testing in this region include: The Ganga River is of immense importance for supporting the livelihoods of many people, and monitoring its water quality is essential for ensuring its purity and safety (Goyal et al., 2022). In the Himalayan region, soil quality varies under different types of land use, such as cultivation, deforestation, and heavy rainfall. Studying soil quality under these conditions helps in understanding the impact of human activities on the soil and finding ways to improve its health. Assessing soil quality in the Ganga Valley region is also important for understanding the effects of climate change on agriculture and the environment (Małgorzata Kijowska-Strugała et al., 2022). The Ganga River has been found to contain antibiotic-resistant bacteria, which indicates the presence of these bacteria in the watersheds and the potential spread of drug-resistant infections (Jr & Chaudhary, 2019).

In summary, soil quality testing in the Ganga Valley region is essential for understanding the health and productivity of the soil, assessing the impact of human activities on the environment, and addressing the challenges posed by climate change and the spread of antibiotic-resistant bacteria.

Material and Methods

The following section comprise the different analytical procedure for determining the Physicochemical, heavy metal content of the soil samples. Also the heavy metal index as well as soil quality index measurement has been detailed below.

SITE SELECTION

The sites selected for the sampling of soil samples have been furnished in Table 7.1.

Table 7.1 The table represents the site description

S.No.	Name	Codes	Coordinates		Altitude (m)
			Latitude (°N)	Longitude (°E)	
1.	Gaumukh	S1	30.5679	79.030813	3794
2.	Gangotri	S2	31.0392	78.746554	2506
3.	Uttarkashi	S3	30.74619	78.483766	1232
4.	Devprayag	S4	30.13581	78.30477	1014
5.	Haridwar	S5	29.91694	78.088639	265
6.	Bijnor	S6	29.28574	78.104133	217
7.	Narora	S7	28.1465	78.439386	179
8.	Badaun,	S8	27.93941	78.85346	162
9.	Farrukhabad	S9	27.41044	79.62818	136
10.	Bithoor	S10	26.61589	80.276996	113
11.	Dalmau	S11	26.34853	81.12184	91
12.	Prayagraj	S12	25.25373	81.5315054	91
13.	Mirzapur	S13	25.85879	82.3243184	91
14.	Varanasi	S14	25.15181	83.1314688	65
15.	Ballia	S15	25.35455	83.5611997	67

S.No.	Name	Codes	Coordinates		Altitude (m)
			Latitude (°N)	Longitude (°E)	
16.	Revelganj	S16	25.43876	84.49599	69
17.	Patna	S17	25.38077	85.12415	36
18.	Barh	S18	25.23107	85.59791	30
19.	Bahachoki	S19	25.17823	86.20763	18
20.	Farka	S20	25.23225	87.090834	23
21.	Sahibganj	S21	25.14606	87.39595	17
22.	Farraka	S22	24.82274	87.910668	30
23.	Hazarduari	S23	23.99688	88.221339	14
24.	Mayapur	S24	23.41293	88.38087	8
25.	Hooghly	S25	22.84913	88.389494	9
26.	Gangasagar	S26	22.17743	88.195856	3

There are a total of 26 sites selected along the Ganga River. Among them five sites were from Uttarakhand; 10 sites were from Uttar Pradesh; 5 sites were from Bihar; 1 site was from Jharkhand and 5 sites were from West Bengal.

PROCEDURE OF SOIL COLLECTION

The samples were collected by choosing the points in a zig-zag manner for each location of sampling. For this, all the grass and litter were removed from the soil surface using a khurpi/Trowel. Then, a 15 cm V-shaped pit was dug and from the sides of the pit, 1.5 to 2.5 cm of soil was collected. In this way, soil from 8-10 points should be collected that represent the area of the soil. Grass, stones, pebbles, and other extras were taken out, and the soil was then equally spread out across the plastic or sack. The same was cut into four equal pieces, with the opposite pieces being eliminated, and the remaining pieces being aseptically stored in plastic zip-lock bags with the appropriate labeling (Bania & Sheoran, 2021). Additionally, temperature, coordinates, altitude, and geotagged pictures of the location were taken.


GPS Map Camera
Terasiya, Bihar, India
Terasiya, Bihar, India
Lat 25.634598°
Long 85.206957°
17/03/23 10:03 AM GMT +05:30
Google
GPS Map Camera
Patna, Bihar, India
Mahatma Gandhi Setu, Muzafferpur Patna Marg, Mahatma Gandhi Setu, Patna, Bihar 844101, India
Lat 25.631313°
Long 85.210166°
17/03/23 07:55 AM GMT +05:30
Google
GPS Map Camera
Chak Bansberia, West Bengal, India
Putul Factory Bus Stop, Bansberia, Chak Bansberia, West Bengal 712502, India
Lat 22.961343°
Long 88.388478°
22/03/23 04:56 PM GMT +05:30
Google
GPS Map Camera
Bhatpara, West Bengal, India
R9XQ+RV4, Jagatdal, Bhatpara, West Bengal 743125, India
Lat 22.849114°
Long 88.389512°
23/03/23 12:32 PM GMT +05:30
Google
GPS Map Camera
Farakka Barrage Township, West Bengal, India
RW69+C36, Farakka Barrage Twp, West Bengal 742212, India
Lat 24.810538°
Long 87.917851°
25/03/23 11:21 AM GMT +05:30
Google
GPS Map Camera
Diamond Harbour, West Bengal, India
55GW+VFP, Diamond Harbour, West Bengal 743331, India
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Long 85.130537°
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ANALYTICAL METHODS

The details of the analytical methods have been furnished in table 7.2.

Table 7.2 Details of Analytical methods

Testing Parameters	Methods	Instrument Used	Reference
pH	Potentiometry	Systronics pH system 316	ICAR (Singh and Praharaj, 2017)
Electrical conductivity (µS/ppm)	Conductometry	Conductivity TDS meter 308	ICAR (Singh and Praharaj, 2017)
Total Moisture content (%)	Oven-dried method	Hot air oven	ICAR (Singh and Praharaj, 2017)
Bulk Density (g/cm^3)	Graduated cylinder method	-	ICAR (Singh and Praharaj, 2017)
Organic Carbon (%)	Titrimetric method (Walkley and Black, 1934)	-	ICAR (Singh and Praharaj, 2017)
Organic Matter (%)	Titrimetric method (Walkley and Black, 1934) Soil organic matter % = organic carbon % x 1.724	-	ICAR (Singh and Praharaj, 2017)
Available Nitrogen (kg/ha)	Kjeldhal Method	Kjeldhal [Gerhardt VAPODEST 200)]	ICAR (Singh and Praharaj, 2017)
Available Phosphorous (kg/ha)	Colorimetric methods	UV-VIS Spectrophotometer (UV-1900i Shimadzu)	ICAR (Singh and Praharaj, 2017)
Available Potassium (kg/ha)	Flame photometer method (1986)	Systronics Flame photometer 1027	ICAR (Singh and Praharaj, 2017)
Available Sulphur (kg/ha)	Colorimetric methods	UV-VIS Spectrophotometer (UV-1900i Shimadzu)	ICAR (Singh and Praharaj, 2017)
Metal Content (mg/Kg)	Optical Emission Spectrometry Optical Emission Spectrometry	ICP-MS (iCAP Qc, Thermo Fisher Scientific, Bremen)	(CPCB, 2012)

SOIL QUALITY INDICATORS & THE PRESCRIBED VALUES

The following soil quality indicators have been taken to validate its quality for organic farming (Table 7.3). The physicochemical parameters values have been taken from ICAR (Bhattacharyya et al., 2017), GOI whereas the heavy metal values have been taken from WHO (WHO, 2020).

Table 7.3 Prescribed limits of the different parameters of soil samples

Indicator	Scoring curve	Lower threshold	Upper threshold	Source of limits
Bulk density (Mg/m3)	Less is bett	1	2	(Bhattacharyya et al., 2017)
pH	Optimum	4.5	9	(Bhattacharyya et al., 2017)
Electrical conductivity (dS/m)	Less is better	2	12	(Bhattacharyya et al., 2017)
Organic carbon (g/kg)	More is better	0	12	(Bhattacharyya et al., 2017)
Available nitrogen (kg/ha)	More is better	0	400	(Bhattacharyya et al., 2017)
Bray's phosphorus (kg/ha)	More is better	0	50	(Bhattacharyya et al., 2017)
Available potassium (kg/ha)	More is better	0	400	(Bhattacharyya et al., 2017)
Zinc (mg/kg)	More is better	0	50	(WHO, 2020)
Copper (mg/kg)	More is better	0	36	(WHO, 2020)
Manganese (mg/kg)	More is better	0	20	(WHO, 2020)
Chromium	Less is better	0	100	(WHO, 2020)
Arsenic	Less is better	0	20	(WHO, 2020)
Cadmium	Less is better	0	0.8	(WHO, 2020)
Mercury	Less is better	0	0.1	(WHO, 2020)
Lead	Less is better	0	85	(WHO, 2020)
Nickle	Less is better	0	75	(WHO, 2020)

METAL POLLUTION INDEX

The metal pollution index has been calculated according to the method of Matta et al. 2020 (Matta et al., 2020). The metals considered here for calculation were Cr, Cu, Zn, As, Cd. Hg, Pb and Ni. The prescribed limit has been taken from Table 7.3. The calculation was done by the following equation.

$$MPI = \sum \frac{Cn}{Pn}$$

Where C_n is the measured concentration of individual heavy metals whereas P_n is the prescribed limit for the respective heavy metals.

After calculation of MPI the categorization of the places was done according to the following manner. <0.3= Very Pure; 0.3-1= Pure; 1-2= Slightly Effected; 2-4= Moderately Effected; 4-6= Seriously Effected; >6 = Strongly Effected (Matta et al., 2020).

Overall Soil Quality Index Measurement

A Soil Quality Index (SQI) is a tool used to assess and quantify the overall health and fertility of a soil system. It provides a single numerical value that reflects the combined impact of various soil properties on its quality. The additive method is one approach to calculate the Soil Quality Index, where individual soil properties are assigned, weights based on their relative importance, and these weighted values are summed to generate the overall index.

Here Soil Quality Index was calculated using the Additive Method. The generalized procedure is given below. The soil quality assessment utilized the Simple Additive Soil Quality Index (SQI) method, following the approach outlined by (Mukherjee & Lal, 2014). Threshold values for soil parameters were established based on a thorough literature review and expert opinions. Mineral soil property thresholds, interpretations, and associated soil index values were systematically determined. The SQI for each individual soil sample was then calculated by summing the individual index values according to Equation 1.

$$\Sigma \text{ SQ1} = \Sigma \textit{ Individual soil parameter index values} \quad (1)$$

To ensure comparability across the datasets, a scaled SQI (%) was computed using Equation 2:

$$SQI\ (\%) = (\Sigma SQI - SQI_{Min}) / (SQI_{Max} - SQI_{Min}) \quad (2)$$

whereas SQI_{Min}=Minimum value of SQI, and SQI_{Max}=Maximum value of SQI from the total dataset.

Results of Soil Quality Analysis

Different parameters of soil quality were analyzed and reported below. The analysis report was documented State wise (Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal). The overall soil quality index has also been produced at the end of the report.

01



5
Bulk Soil Collection

02

7
N
Nitrogen

193.512kg/ha
Average Nitrogen

03

19
K
Potassium

230.706kg/ha
Average Potassium

04

15
P
Phosphorus

82.416kg/ha
Average Phosphorus

05



3.18
Heavy Metal Index



UTTARAKHAND

RESULTS OF SOIL QUALITY OF UTTARAKHAND

Uttarakhand is one of the hilly states in the Indian Himalaya Region (IHR), located in northern India between the latitudes 28°43′ N and 31°27′ N and the longitudes 77°34′ E and 81°02′ E, and covering an area of 53,483 square kilometers (Ruhela et al., 2018; https://sbb.uk.gov.in/files/Documents/AR-2021-2022.pdf). The state has a vast range of physiography, climate, geology, and natural vegetation, all of which contribute to the production of a diverse range of soils. Uttarakhand's unique geographical features, which include a predominantly mountainous region along with the Tarai and Ganga plain regions, make it a unique place where a variety of crops can be grown. With an altitude gradient varying from 250 m to 7,187 m above MASL, a combination of geographical factors determines the climatic conditions favorable for farming.

The state's major soil zones are Hill Soils, Bhabhar Soils, and Tarai Soils. However, agricultural land is confined, especially in Udham Singh Nagar and the southern parts of Dehradun, Nainital, and Haridwar districts, which are known as the Bhabhar and Tarai regions. Hill soils are brown to grayish brown and dark grey and moderately acidic to neutral in reaction. The major soil limitations of hill soils are highly porous with low moisture retention capacity, moderate to severe erosion-prone, and terrace cultivation at steep slopes. The Bhabhar (which means coarse stony and porous material) soils are shallow with loamy sand to loam textures containing abundant quantities of gravel and stones on the surface. Water percolation through profile is very rapid; nutrient and moisture retention capacity are low. Tarai soils are thick and very fertile with medium to heavy texture, imperfect to moderate drainage, dark colored and high in organic matter, cation exchange capacity, and nutrient holding capacity. Taxonomically these soils belong to great groups of Mollisols, Inceptisols, Entisols, and Alfisols soil orders. Cultivation is mainly confined to Kharif season but on the availability of irrigation, Rabi crops are also grown. In recent years, acreage under micronutrient deficiency has increased due to imbalanced use of fertilizers, low use of organic manure, and poor replenishment as compared to crop demand. Now the deficiency of zinc (Zn), iron (Fe), and manganese (Mn) have been emerging and posing threats to sustain food productivity (Shukla et al., 2015). To manage soil nutrient deficiencies and toxicity there is a need to understand the level of Macro and micronutrients in soil, which in turn results in sustainable agriculture.

ON-SITE ANALYSIS

As shown in On-site parameters (Table 7.4), details of five sites along the Ganges River in Uttarakhand, India, showcasing a remarkable change in environmental conditions from high altitude to the plains.

Table 7.4 Field data of the soil samples of Uttarakhand

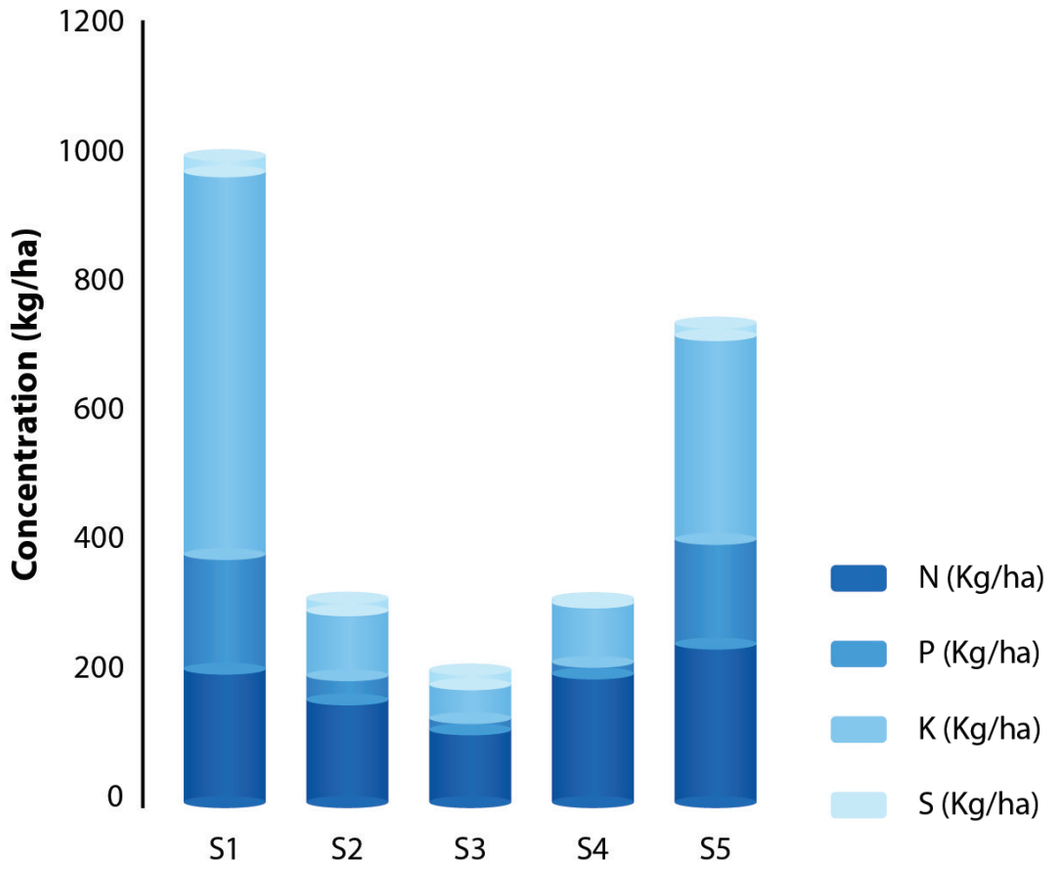
S.No.	Site Code	Corresponding Sites	Altitude (m)	Temperature (°C)	Sunlight	Moisture	Soil Colour
1	S1	Gaumukh	3794	9	High^{+}	Dry^{+}	Black
2	S2	Gangotri	2506	17	Low	Dry^{+}	Light Brown
3	S3	Uttarkashi	1232	18	Low	Dry	Yellowish Brown
4	S4	Devprayag	1014	23	Normal	Nor Dry^{+}	Brown
5	S5	Haridwar	265	34	High-	Nor	Dark Brown

At Gaumukh (3794 m), near the river's source, temperatures are chilly (9°C), sunlight is abundant, and black soil dominates. As we move downstream, temperatures rise (17°C at Gangotri, 18°C at Uttarkashi), sunlight decreases, and soil color shifts to lighter browns. Moisture remains dry or slightly dry through Uttarkashi. Finally, at Devprayag (1014 m) and Haridwar (265 m), temperatures soar (23°C, 34°C), sunlight becomes moderate, and soil takes on a darker brown hue. This downstream journey thus reveals a transition from cold, high-altitude dryness to warm, sun-drenched plains.

LABORATORY ANALYSIS

Nitrogen, Phosphorus, Potassium and Sulphur

The analysis of available nutrients across five sites along the Ganges River revealed significant variations as shown in Fig. 7.1, in which available Nitrogen of these sites were 215.34 kg/ha (S1), 168.09 kg/ha (S2), 122.09 kg/ha (S3), 207.81 kg/ha (S4) and 254.23 kg/ha (S5) with an average value of 193.512 kg/ha.



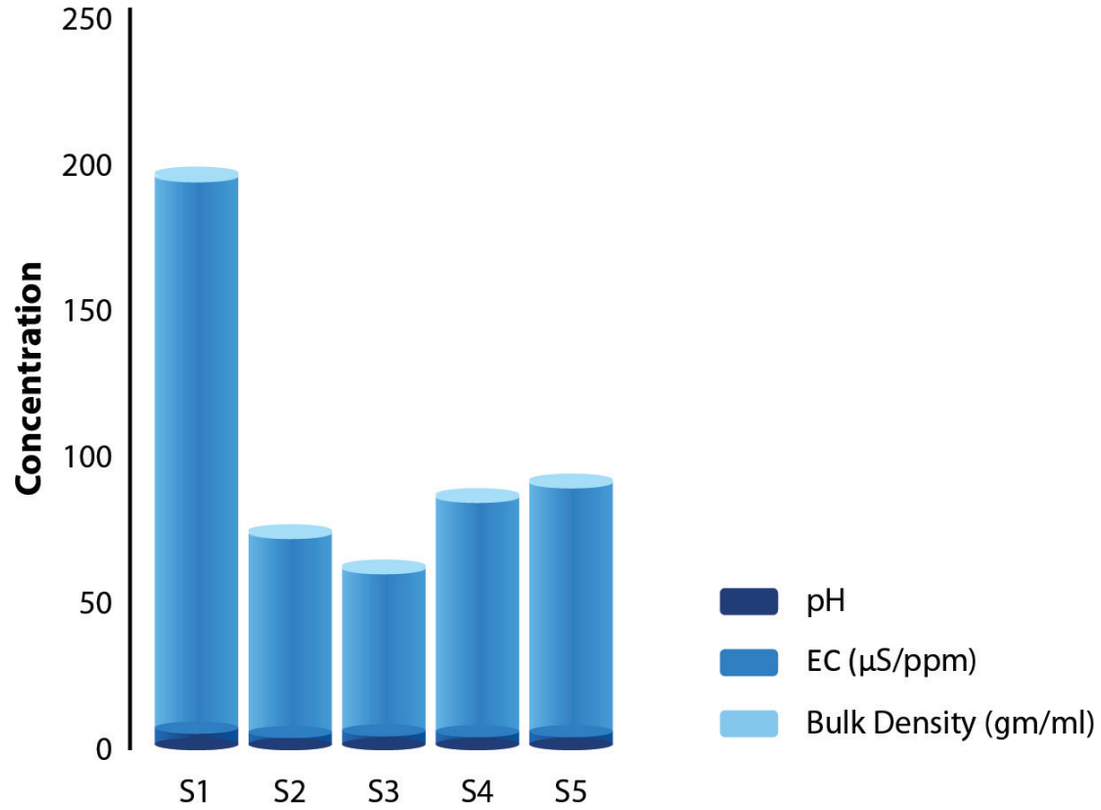
N: Nitrogen; P: Phosphorus; K: Potassium; S: Sulphur

Fig. 7.1 NPK & S data of soil samples obtained from different sample locations of Uttarakhand

The maximum was found in Haridwar (S5) while the minimum was found in Uttarkashi (S3); availability of Phosphorous in these sites were 177.64 kg/ha (S1), 36.96 kg/ha (S2), 17.19 kg/ha (S3), 18.47 kg/ha (S4) and 161.82 kg/ha (S5) with the mean value of 82.416 kg/ha in which the maximum was found in Gaumukh (S1) and minimum in Uttarkashi (S3); available Potassium found in these sites were 592.74 kg/ha (S1), 100.84 kg/ha (S2), 52.23 kg/ha (S3), 91.58 kg/ha (S4) and 316.14 kg/ha (S5) with an average of 230.706 kg/ha where, the maximum was found in Gaumukh (S1) and minimum in Uttarkashi (S3); availability of Sulphur found in these sites were 24.73 kg/ha (S1), 19.51 kg/ha (S2), 22.87 kg/ha (S3), 6.81 kg/ha (S4) and 19.23 kg/ha (S5) with a mean of 18.63 kg/ha in which the maximum was found in Gaumukh (S1) and the minimum in Devprayag (S4).

pH, Electrical Conductivity, and Bulk Density

From the results as shown in Fig. 7.2, it was observed that the soil pH of different sample sites ranges from neutral to acidic, which includes S1 (7.67), S2 (6.23), S3 (6.77), S4 (6.46) and S5 (6.45).



EC: Electrical Conductivity; BD: Bulk Density

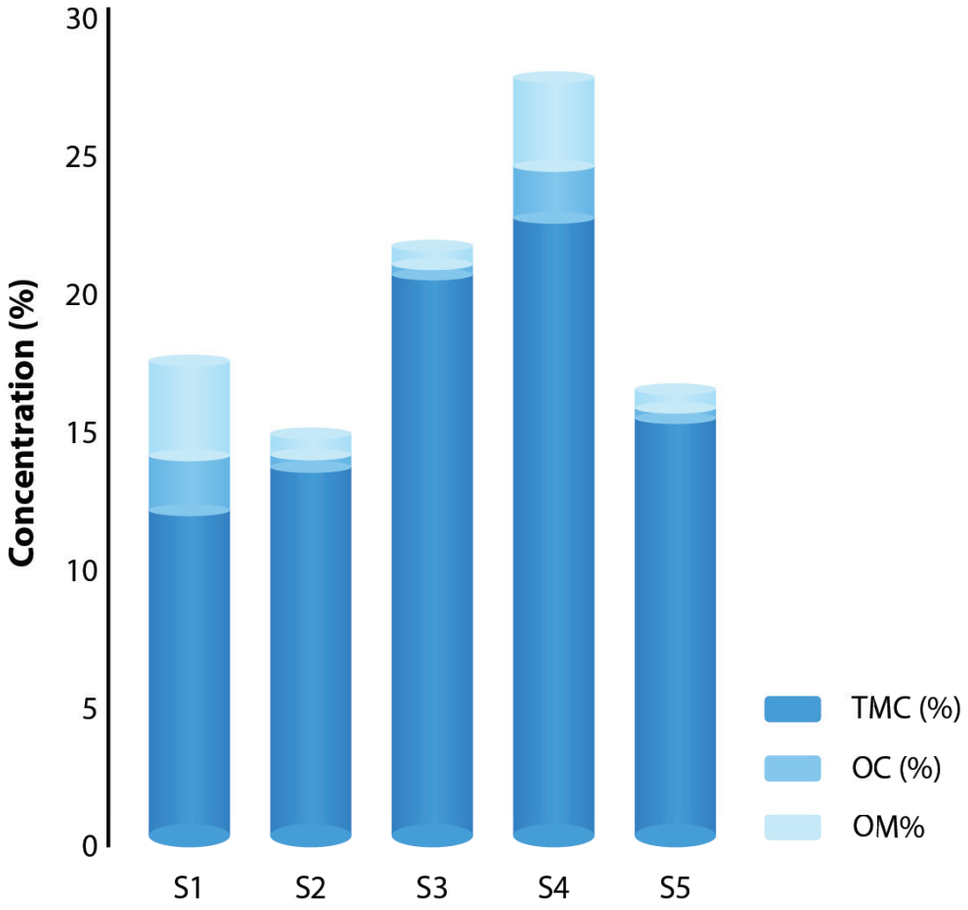
Fig. 7.2 pH, E.C. and B.D. data of soil samples obtained from different sample locations in Uttarakhand

The average pH of Uttarakhand is 6.71, where the maximum was found in Haridwar (S5) while the minimum was found in Gangotri (S2). Electrical Conductivity of these sites were 189.23 µS/ppm (S1), 68.22 µS/ppm (S2), 55.48 µS/ppm (S3), 80.38 µS/ppm (S4) and 85.27 µS/ppm (S5). The average E.C. of the Uttarakhand region was 95.716 µS/ppm, where the maximum was found in Gaumukh (S1) while the minimum was found in Uttarkashi (S3). The Bulk Density found in these five sites were 0.95 g/cm^3(S1), 0.91 g/cm^3(S2), 0.95 g/cm^3(S3), 0.77 g/cm^3(S4) and 0.95 g/cm3(S5). The average was 0.906 g/cm^3 where the maximum was found in Gaumukh (S1), Uttarkashi (S3), and Haridwar (S5) while the minimum was found in Devprayag (S4).

Total Moisture Content, Organic Carbon, and Organic Matter

The Total Moisture Content, Organic Carbon, and Organic Matter of these sites are shown in Fig. 7.3.

According to the results, the total moisture content found in these 5 sites was 12.23 % (S1), 13.8 % (S2), 20.77 % (S3), 22.83 % (S4) and 15.57 % (S5) with the average of 17.04 % where the maximum was found in Devprayag (S4) while the minimum was found in Gaumukh (S1). The organic carbon % of these sites were 1.99 % (S1), 0.45 % (S2), 0.38 % (S3), 1.87 % (S4), 0.38 % (S5) with an average of 1.014 % where the maximum was found in Gaumukh (S1) while the minimum was found in Uttarkashi (S3) and Haridwar (S5). As per the study, the organic matter % of these sites were 3.43 % (S1), 0.77 % (S2), 0.66 % (S3), 3.22 % (S4), and 0.66 % (S5). The average OM% of Uttarakhand sites was 1.748 %, where the maximum was found in Gaumukh (S1) and the minimum in Uttarkashi (S3) and Haridwar (S5).



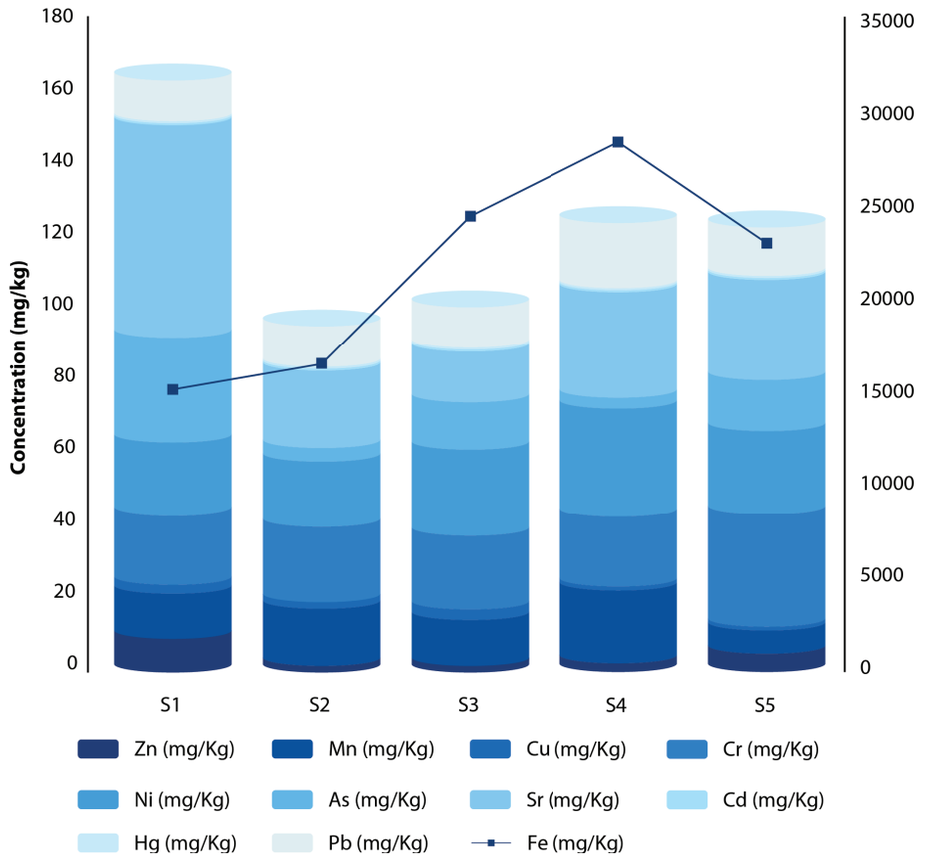
TMC: Total Moisture Content; OC: Organic Carbon; OM: Organic Matter

Fig. 7.3 TMC, OC, and OM data of soil samples obtained from different sample locations of Uttarakhand

Metals Constituents

The study analysed the levels of different metals such as zinc, iron, manganese, copper, chromium, nickel, arsenic, strontium, cadmium, mercury, and lead in different sites of Uttarakhand (Fig 7.4).

The results showed that the average value of these metal constituents found at these sites of Uttarakhand is 3.914 mg/kg (Zn), 21716.31 mg/kg (Fe), 13.726 mg/kg (Mn), 1.868 mg/kg (Cu), 22.362 mg/kg (Cr), 23.096 mg/kg (Ni), 12.726 mg/kg (As), 30.408 mg/kg (Sr), 0.166 mg/kg (Cd), 0.1 mg/kg (Hg) and 12.222 mg/kg (Pb). Fe was found in huge amounts in all sites of Uttarakhand, which is crucial for chlorophyll production and plant growth but exceeding permissible levels can limit nutrient uptake and harm beneficial soil microbes. Hg was found in very low quantity in all sites of Uttarakhand. These metal nutrients play a complex role in agriculture, with both beneficial and detrimental effects. Understanding the optimal range and site-specific variations of these metals is crucial for sustainable agricultural practices in Uttarakhand.



Zn: Zinc; Mn: Manganese; Cu: Copper; Cr: Chromium; Ni: Nickel; As: Arsenic; Sr: Strontium; Cd: Cadmium; Hg: Mercury; Pb: Lead; Fe: Iron

Fig. 7.4 Metal constituents of soil samples obtained from different sample locations of Uttarakhand



01

10
Bulk Soil Collection

02

7
N
Nitrogen

81.912kg/ha
Average Nitrogen

03

19
K
Potassium

227.854kg/ha
Average Potassium

04

15
P
Phosphorus

24.273kg/ha
Average Phosphorus

05

3.4
Heavy Metal Index

UTTAR PRADESH

RESULTS OF SOIL QUALITY OF UTTAR PRADESH

Uttar Pradesh is the fourth largest Indian state described as the "Heartland of India" by an occupying area of about 2,43,286 sq. km or 93,933 sq. miles comprising over 199,581,477 inhabitants as of the 2011 census, becoming the most populous state in the country. This vast state is divided into 75 districts, 350 tehsils, and 813 community blocks. Geographically, it lies between North latitudes 23° 52′ 23.41′′ to 31°28′ 76.09′′ and East longitudes 77° 03′ 16.32′′ to 84° 39′ 21.23′′ is a part of North-Central of the country India. Uttar Pradesh sits proudly within the Gangetic plain, renowned for its fertile alluvial soils deposited by the Ganga River system flowing down from the Himalayas. This fertile land comprises 9% of India's area yet shelters 16% of the nation's population. The state boasts an impressive cropping intensity of 153%. Variations in topography, rainfall, vegetation, climate, and soil parent materials have led to a diverse range of soil types across the region. The extremely fertile alluvial soils range from sand to clayey loam. The soils within the southern part of the state are generally mixed red and black or red-to-yellow (Saxena et al., 2021).

The most prevalent type of soil in Uttar Pradesh is alluvial soil, also known as alluvium, which covers over half of the state and is deposited as slits by the Ganges and its confluence. Because Uttar Pradesh receives a significant portion of the Indo-Gangetic plain, most of the area is covered with a vast blanket of alluvium distributed by the wave action of the Ganges system's slow-moving rivers. Alluvium, an exceptionally fertile soil rich in humus, is typically a deep brown hue with a loamy texture that might be clayey or sandy. As it is loamy, the soil is also porous, allowing for good drainage and other agricultural conditions (U.P. Govt. Department of Land Development and Water Resources, 2009; Kullu et al., 2021).

The soil of Uttar Pradesh is divided into six distinct groups based on geographical formation and pedogenic characteristics: Vindhyan soils, Alluvial soils, Bhabar soils, Bundelkhand soils, Tarai soils, and Alluvial soils; each of which has developed under the combined influence of a wide range of pedogenic (soil formation) factors. The availability of iron in these 6 kinds of soil is in the descending order of Aravali > Alluvial > Vindhyan > Bundelkhand > Tarai > Bhabar. Low iron status soils are found in Unnao, Hardoi, and Farukhabad. Nitrogen availability in soils is very poor in most districts of Uttar Pradesh, whereas Phosphorus availability is low in 41 districts and medium in 14 districts. Potassium status is low in 29 districts, but medium in 17; Potassium availability is excellent in only four districts. The sulfur level of recent alluvium soil found in the Gangetic Plains and its uplands, central lowlands, Kanpur, and Yamuna uplands is very high. Similarly, zinc availability is low in Basti, Juanpur, Ghazipur, Azamgarh, and other districts, but high in Varanasi, Deoria, and Gorakhpur. Zinc deficiency exists in the soils of Meerut,

Hamirpur, Bulamdshar, and other cities (Mathur, 2020; Kullu et al., 2021). An estimated 65% of the state's land is alkaline, with pH ranging from 7.5 to 9.5, while the region covered by acidic soil is quite low (4.5-6.5 pH), accounting for around 10-12% of the total area. Similarly, between 20 and 25% of soil is neutral. The new and ancient alluvial soils are known locally as 'Bhangar' and 'Khadar', respectively. Various soils in southern Uttar Pradesh are known as 'Maad', 'Regur', 'Rakad', 'Monta', 'Red', and 'Padwa' (Kullu et al., 2021).

ON-SITE ANALYSIS

Details about the onsite analysis of soil samples from 10 sites in Uttar Pradesh along the Ganges River are provided in Table 7.5, which shows the environmental shift downstream.

Table 7.5. Field data of soil samples of Uttar Pradesh

S.No.	Site Code	Corresponding Sites	Altitude (m)	Temperature (°C)	Sunlight	Moisture	Soil Colour
1.	S6	Bijnor	217	29°C (±1)	Low^{+}	Normal	Grey
2.	S7	Narora	179	31	Low^{+}	Normal	Grey
3.	S8	Badaun,	162	25	Low^{+}	Dry	Grey
4.	S9	Farrukhabad	136	27	Normal	Dry	Grey
5.	S10	Bithoor	113	28	Normal	Wet^{+}	Grey
6.	S11	Dalmau	91	31	Low+	Dry^{+}	Grey
7.	S12	Prayagraj	91	33	Low+	Wet^{-}	Light Brown
8.	S13	Mirzapur	91	32	Low-	Wet^{+}	Light Brown
9.	S14	Varanasi	65	38	Low+	Dry^{+}	Greyish Brown
10.	S15	Ballia	67	34	Low+	Wet	Light Brown

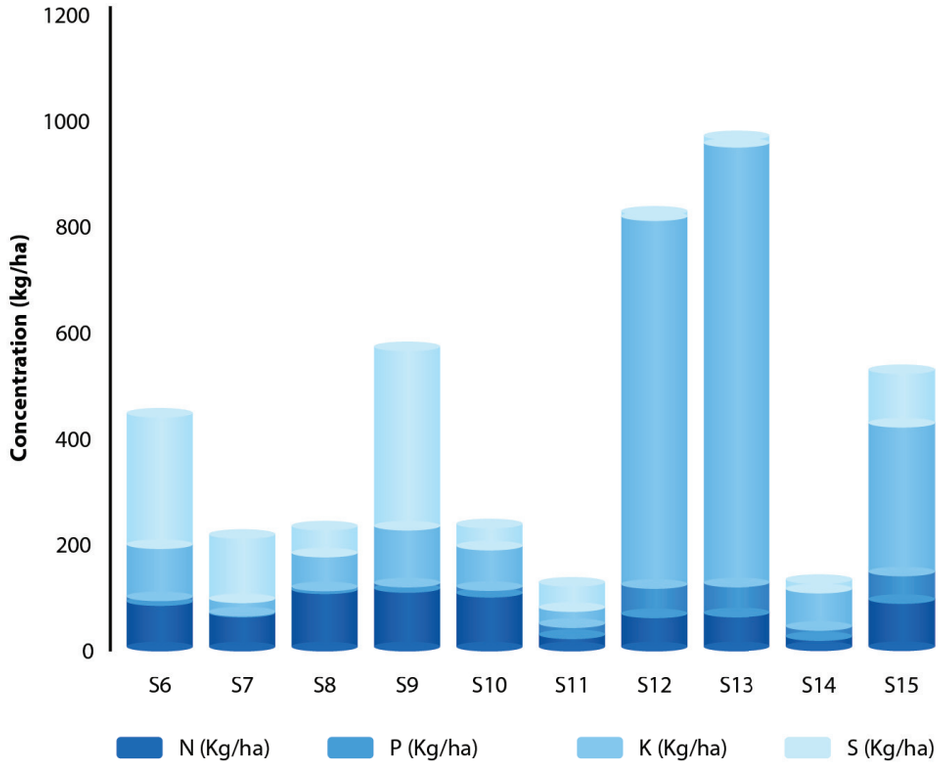
Details about 10 sites of Uttar Pradesh along the Ganges River are provided in Table 6.4, which shows the environmental shift downstream. Starting at Bijnor (217 m), temperatures remain warm (29°C) with decreasing sunlight and mostly grey soil. Moving further, sites like Narora and Badaun experience similar temperatures, while dryness increases, and moisture levels fluctuate. Farrukhabad and Bithoor exhibit slightly lower temperatures and varying moisture levels, with Bithoor standing out for its wetter soil. Dalmau and Prayagraj share similar temperatures and dryness but differ in soil color (Prayagraj being light brown). Mirzapur boasts a similar temperature but higher moisture with light brown soil. Varanasi brings another shift, with higher temperatures and a return to dryness, while Ballia marks the end with slightly

lower temperatures and higher moisture content. Overall, the downstream journey reveals a gradual shift from warm, dry conditions to a mix of wet and dry depending on location, with consistent grey or light brown soil dominating the landscape.

LABORATORY ANALYSIS

Nitrogen, Phosphorus, Potassium and Sulphur

Soil quality analysis across Uttar Pradesh revealed significant differences in nutrient levels (Available Nitrogen, Phosphorus, Potassium, and Sulphur) across different regions as showcased in Fig. 7.5.



N: Nitrogen; P: Phosphorus; K: Potassium; S: Sulphur

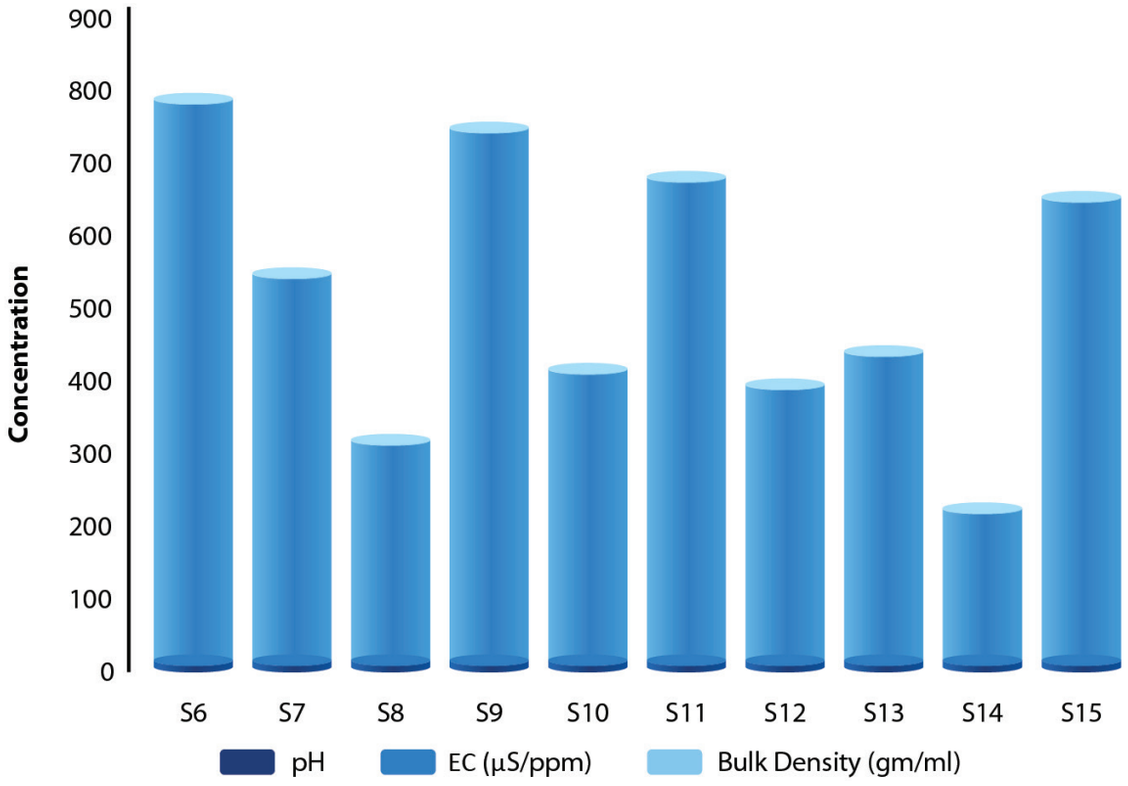
Fig. 7.5 NPK & S data of soil samples obtained from different sample locations of Uttar Pradesh

Results revealed that the available Nitrogen content in different sites of Uttar Pradesh was 94.92 kg/ha (S6), 73.17 kg/ha (S7), 117.08 kg/ha (S8), 120 kg/ha (S9), 110.81 kg/ha (S10), 32.2 kg/ha (S11), 71.92 kg/ha (S12), 73.17 kg/ha (S13), 28.01 kg/ha (S14) and 97.84 kg/ha (S15) with an average of 81.912 kg/ha, in which highest nitrogen was found in Farrukhabad (S9) and lowest in Varanasi (S14). The amount of Phosphorus found in these sites were 8.33kg/ha (S6), 1.8 kg/ha (S7), 5.75 kg/ha (S8), 10.01 kg/ha (S9), 12.25 kg/

ha (S10), 20.91 kg/ha (S11), 55.25 kg/ha (S12), 56.75 kg/ha (S13), 19.41 kg/ha (S14) and 52.27 kg/ha (S15) with the mean value of 24.273 kg/ha. Where maximum phosphorus was found in Mirzapur (S13) and the minimum in Narora (S7). The available potassium content found in these sites was 99.34 kg/ha (S6), 25.5 kg/ha (S7), 63.58 kg/ha (S8), 106.03 kg/ha (S9), 76.61 kg/ha (S10), 30.69 kg/ha (S11), 694.74 kg/ha (S12), 830.26 kg/ha (S13), 70.52 kg/ha (S14) and 281.27 kg/ha (S15) with the mean of 227.854 kg/ha. It was observed that the maximum was found in Mirzapur (S13) and the minimum was found in Narora (S7). As per the results, the available sulfur present in these sites were 247.8 kg/ha (S6), 121.29 kg/ha (S7), 50.59 kg/ha (S8), 339.87 kg/ha (S9), 41.72 kg/ha (S10), 47.09 kg/ha (S11), 9.47 kg/ha (S12), 13.77 kg/ha (S13), 17.5 kg/ha (S14), 100.99 kg/ha (S15) with an average of 99.009 kg/ha, in which maximum was found in Farrukhabad (S9) and minimum was in Prayagraj (S12).

pH, Electrical Conductivity, and Bulk Density

The results revealed that the soil pH of different regions of Uttar Pradesh ranges from neutral to alkaline as shown in Fig. 7.6.



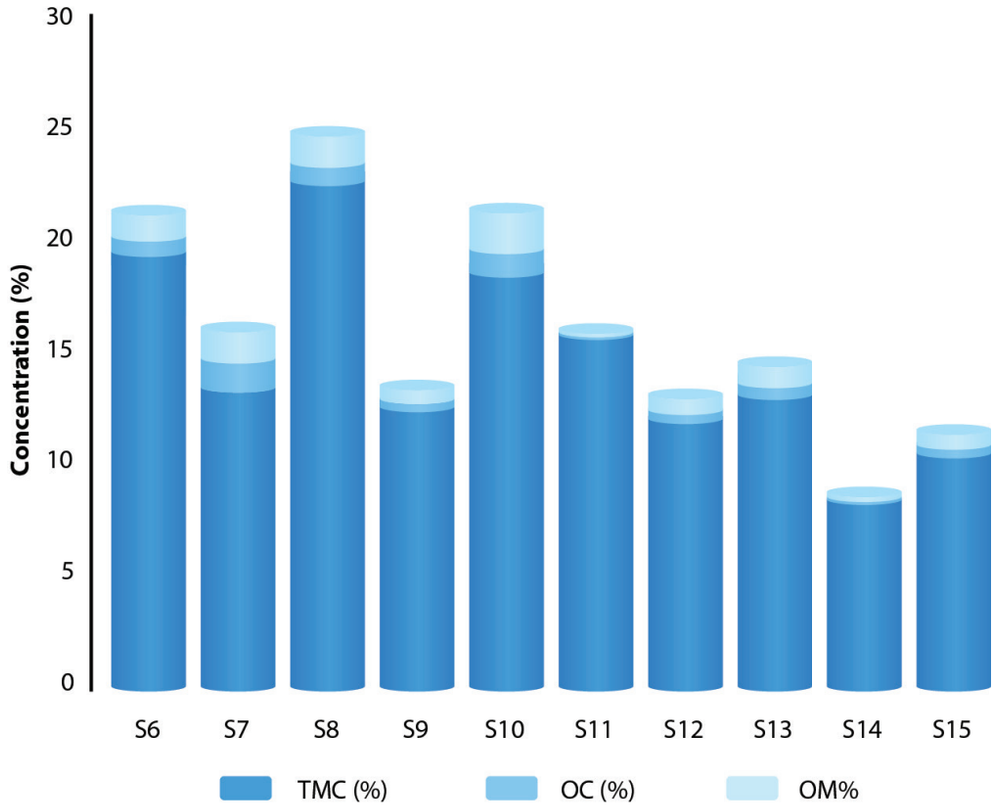
EC: Electrical Conductivity; BD: Bulk Density

Fig. 7.6 pH, EC, and BD of soil samples obtained from different sample locations of Uttar Pradesh

The pH of these sites was 7.14 (S6), 7.35 (S7), 7.69 (S8), 7.5 (S9), 7.59 (S10), 8.84 (S11), 8.12 (S12), 7.89 (S13), 8.83 (S14) and 8.2 (S15) with the mean of 7.915, in which maximum was found in Dalmau (S11) and minimum in Bijnor (S6). The Electrical conductivity of U.P. sites was 789.7 µS/ppm (S6), 549.3 µS/ppm (S7), 319.6 µS/ppm (S8), 750.03 µS/ppm (S9), 409.33 µS/ppm (S10), 680.53 µS/ppm (S11), 395.63 µS/ppm (S12), 441.93 µS/ppm (S13), 223.53 µS/ppm (S14) and 653.7 µS/ppm (S15) with the average of 521.328 µS/ppm. The maximum E.C. was found in Bijnor (S6) and minimum in Varanasi (S14). According to the results bulk density found in these sites were 0.95 g/cm3 (S6), 0.95 g/cm3 (S7), 0.87 g/cm3 (S8), 0.82 g/cm3 (S9), 0.94 g/cm3 (S10), 1 g/cm3 (S11), 0.91 g/cm3 (S12), 0.91 g/cm3 (S13), 1.43 g/cm3 (S14) and 0.85 g/cm3 (S15) with the mean value of 0.963 g/cm3, in which highest was found in Varanasi (S14) and lowest was in Farrukhabad (S9).

Total Moisture Content, Organic carbon, and Organic matter

According to the study, as given in Fig. 7.7, the TMC % of different regions of U.P. were 19.56 % (S6), 13.94 % (S7), 22.75 % (S8), 12.57 % (S9), 18.63 % (S10), 15.83 % (S11), 12.04 % (S12), 13.12 % (S13), 8.39 % (S14) and 10.5 % (S15) with the mean of 14.73%, in U.P. highest T.M.C. % was found in Badaun (S8) and lowest in Varanasi (S14).



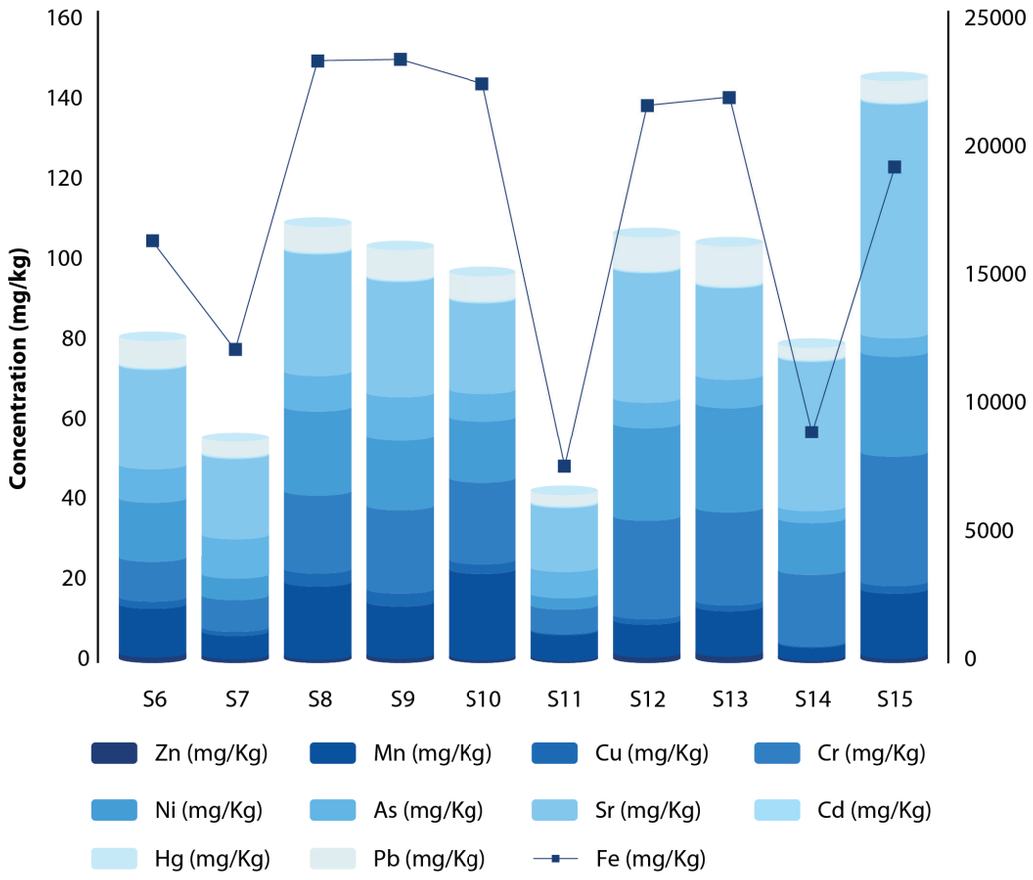
TMC: Total Moisture Content; OC: Organic Carbon; OM: Organic Matter

Fig. 7.7 TMC, OC, and OM of soil samples obtained from different sample locations of Uttar Pradesh

Results also revealed that the average OC (%) of sites of U.P. were 0.69 % (S6), 0.82 % (S7), 0.82 % (S8), 0.36 % (S9), 1.05 % (S10), 0.1 % (S11), 0.41 % (S12), 0.54 % (S13), 0.13 % (S14) and 0.39 % (S15). The average OC % of U.P. was 0.531 %, in which the maximum was found in Bithoor (S10) and the minimum was found in Dalmau (S11). The OM % found were 1.18 % (S6), 1.41 % (S7), 1.41 % (S8), 0.62 % (S9), 1.81 % (S10), 0.17 % (S11), 0.7 % (S12), 0.94 % (S13), 0.22 % (S14) and 0.66 % (S15), with the mean value of 0.912 %. The highest OM % was found in Bithoor (S10) and the lowest in Dalmau (S11).

Metals Constituents

Across this comprehensive research, we analyze metal constituents across the diverse landscapes of Uttar Pradesh. This report presents a detailed overview as shown in Fig. 7.8 of metals like zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As), strontium (Sr), cadmium (Cd), mercury (Hg) and lead (Pb) that were present in U.P. regions.



Zn: Zinc; Mn: Manganese; Cu: Copper; Cr: Chromium; Ni: Nickel; As: Arsenic; Sr: Strontium; Cd: Cadmium; Hg: Mercury; Pb: Lead; Fe: Iron

Fig. 7.8 Metal constituents of soil samples obtained from different sample locations of Uttar Pradesh

The average of these metals was 0.816 mg/kg (Zn), 17811.24 mg/kg (Fe), 11.69 mg/kg (Mn), 1.69 mg/kg (Cu), 18.252 mg/kg (Cr), 17.312 mg/kg (Ni), 6.389 mg/kg (As), 29.318 mg/kg (Sr), 0.108 mg/kg (Cd), 0.1 mg/kg (Hg) and 6.322 mg/kg (Pb). The maximum Zn was found in Mirzapur (S13) i.e., 1.38 mg/kg and minimum in Dalmau (S11) i.e., 0.41 mg/kg; maximum Fe was found in Farrukhabad (S9) i.e., 23553.72 mg/kg and minimum in Dalmau (S11) i.e., 7657.25 mg/kg; maximum Mn was found in Bithoor (S10) i.e., 21.53 mg/kg and minimum in Varanasi (S14) i.e., 3.23 mg/kg; maximum Cu was found in Farrukhabad (S9) i.e., 3.23 mg/kg and minimum in Dalmau (S11) i.e., 0.22 mg/kg; maximum Cr was found in Ballia (S15) i.e., 32.28 mg/kg and minimum in Dalmau (S11) i.e., 6.16 mg/kg; maximum Ni was found in Mirzapur (S13) i.e., 26.25 mg/kg and minimum in Dalmau (S11) i.e., 6.64 mg/kg; maximum As was found in Farrukhabad (S9) i.e., 10.9 mg/kg and minimum in Dalmau (S11) i.e., 2.8 mg/kg; maximum Sr was found in Ballia (S15) i.e., 58.37 mg/kg and minimum in Dalmau (S11) i.e., 15.82 mg/kg; maximum Cd was found in Ballia (S15) i.e., 0.17 mg/kg and minimum 0.1 mg/kg was found in all sites except S12 and S15; Hg in all sites was same i.e., 0.1 mg/kg; maximum Pb was found in Mirzapur (S13) i.e., 10.27 mg/kg and minimum in Dalmau (S11) i.e., 3.07 mg/kg.





01

5
Bulk Soil Collection

02

7 N Nitrogen

144.508 kg/ha
Average Nitrogen

03

19 K Potassium

212.612kg/ha
Average Potassium

04

15 P Phosphorus

36.438kg/ha
Average Phosphorus

05

3.49
Heavy Metal Index

BIHAR

RESULTS OF SOIL QUALITY OF BIHAR

Bihar is the twelfth largest state area-wise, situated in the north-eastern region of the country located between 24°20′10″ N and 27°31′15″ N latitudes and between 83°19′50″E and 88°17′40″E longitudes. The total area of Bihar is 94,163 km^2. Nepal is in the north, Jharkhand is in the south, Uttar Pradesh is in the east, and West Bengal is in the west. The state's climate is diverse. The average temperature of the state is 27°C and the average precipitation is 1,200 mm. The climate of the state is sub-tropical. The average elevation of Bihar above the mean sea level is 53 m. The Ganga River is the major river in the state. It flows from the west to the east and divides the state into two parts. All other rivers join the river Ganga from the north and south. Gandak, Bagmati, Kosi, and Kali join the river Ganga from the north, while Sone, Phalgu, and Punpun join from the south (https:// state.bihar.gov.in) (Shukla, 2021).

The majority of Bihar's territory lies in the Ganga basin plain. As a result, most of the area has alluvium soil and is suitable for agriculture. Bihar is classified into three regions based on physical and structural characteristics: the Shivalik range region, the Bihar plain region, and the southern plateau region. The Shivalik region is situated in the northern part of the West Champaran district. The Bihar Plain is spread between the Himalayas and the Chhota Nagpur plateau. The area of the Bihar plain is 90,650 km^2. It is a part of the bed of the Tethys Sea, which was filled by the deposition of the rivers that originated from the Himalayas and the Chhota Nagpur plateau. The northern region of Bihar is mostly a plain area, whereas in the plain of the south region Gaya, Rajgir, Kaimur, and Kharagpur, hills are found. The North Bihar plain is formed by the deposits of the rivers, namely Gandak, Kosi, Bagmati, Mahananda, Kamla-Balan, and their tributaries. East and West Champaran districts are located in the northern part of the North Bihar plain, which has a higher elevation and is known as the Terai area. Due to this, the soils are porous and have a higher percolation rate (Shukla, 2021).

Bihar is located on the world's most fertile alluvial plain, the Gangetic Valley, which extends from the foothills of the Himalayas in the north to a few miles south of the river Ganges as it flows through the State from the west to the east. Variations in relief, precipitation, vegetation, and parent rocks have resulted in various soil varieties due to the region's relief features. (Singh et al., 2021). Soils in the northern plain are formed by the deposition of rivers like Gandak and Burhi Gandak flowing on the north side. Piedmont swamp soil, Terai soil, and Gangetic alluvium soil are the types of soil found in the northern plain of Bihar (Ranjan and Kumar, 2013). Piedmont swamp soil is brown to grey and found in the north-west region of West Champaran. This type of soil is mostly clayey and contains organic matter. Terai soil is found in the northern part of Bihar near the Nepal border, and it is grey to yellow. The Gangetic alluvial soil is loamy with varying thickness. It is thicker in the north and thinner in the south. In the upland area, this soil is

known as the 'Bhangar soil', while in the lowland area, it is known as the 'Khadar soil'. The Bhangar soil is rich in carbonaceous compounds, and it has a high clay content. The Khadar soil has less carbonaceous compounds and a lesser clay content. The soil in the southern plain is mainly formed by the deposition of rivers (Falgu, Sone, and Punpun). Karail-kewal soil, Tal soil, and Balthar soil are the major soil types found in the southern plain of Bihar (Ranjan and Kumar, 2013). Karail-kewal soil is found in some different districts (Gaya, Munger, and Bhagalpur) of Bihar. These types of soil have a higher clay content and the color varies from brown to yellow. Tal soil is found in the region from the Buxar to the Banka district. This soil is light grey to dark grey. Balthar soil is found from the south of the Ganga Plain to the Chhota Nagpur Plain. This type of soil has less water absorption capacity with its color being red. The soils of Bihar's southern plateau are red and yellow, formed by the disintegration of igneous and metamorphic rocks, respectively. These are found in the districts of Gaya, Nawada, Banka, and Aurangabad, whereas the soil in the Kaimur and Rohtas districts has a higher concentration of sand known as red sandy soil (Shukla, 2021).

ON-SITE ANALYSIS

The details of the on-site analysis of soil samples obtained from 5 sites in Bihar are given in Table 7.6, showcasing further environmental variations from Revelganj to Farka.

Table 7.6. Field data of the soil samples of Bihar

S.No.	Site Code	Corresponding Sites	Altitude (m)	Temperature (°C)	Sunlight	Moisture	Soil Colour
1.	S16	Revelganj	69	25	Low^{+}	Dry^{+}	Light Brown
2.	S17	Patna	36	25	Low	Dry^{+}	Light Brown
3.	S18	Barh	30	28	High^{-}	Dry	Light Brown
4.	S19	Bahachoki	18	30	Low	Dry^{+}	Brown
5.	S20	Farka	23	25	Normal	Dry^{+}	Light Brown

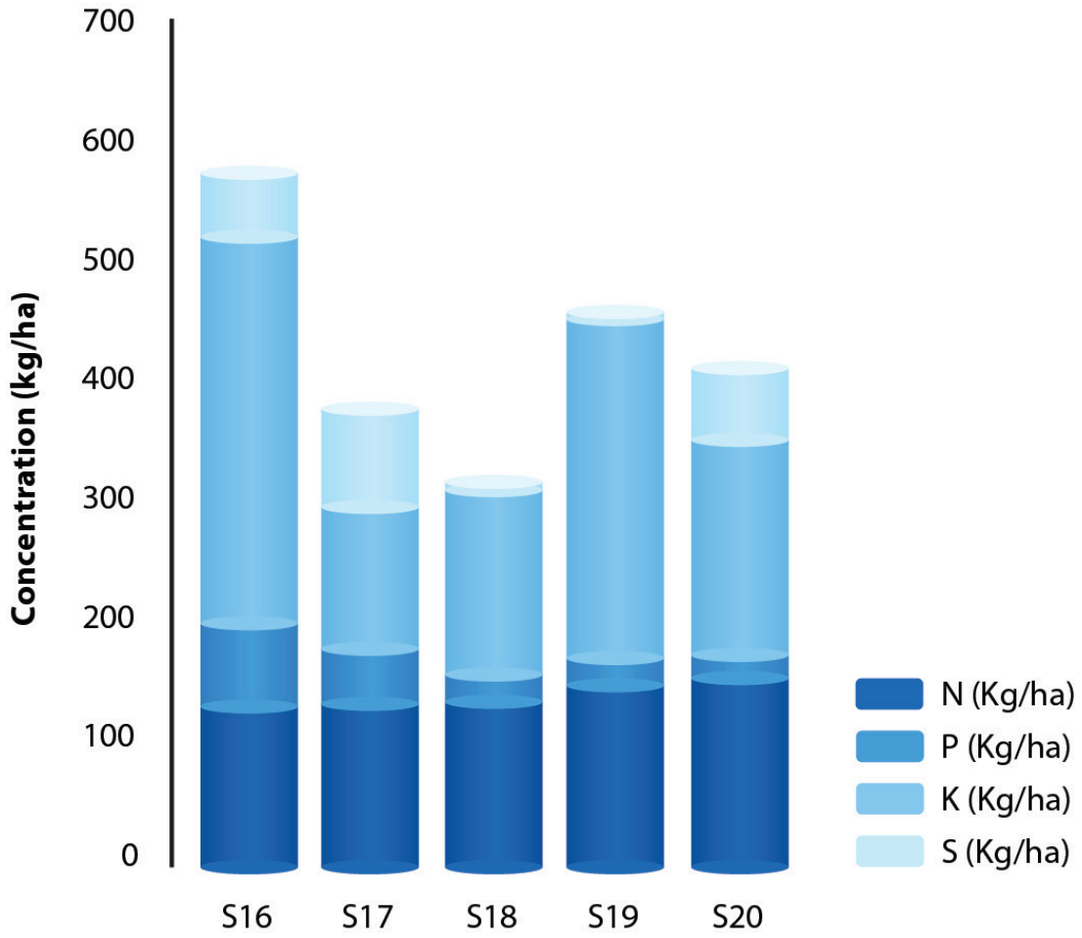
Revelganj and Patna, both at low altitudes (69 m and 36 m respectively), experience similar temperatures (around 25°C) with limited sunlight and largely dry conditions. Light brown soil dominates these landscapes. As we move further downstream, Barh exhibits a slight increase in temperature (28°C) and becomes sunnier but remains dry with light brown soil. Bahachoki, located at an even lower altitude (18 m), sees a jump in temperature (30°C) but retains limited sunlight and continues the trend of dry conditions with brown soil. Finally, Farka marks a shift in temperature, returning

to a more moderate 25°C. Sunlight remains normal, and while dryness persists, the soil color transitions back to light brown. This suggests a subtle change in the environment, possibly due to local factors or proximity to the Ganges distributaries.

LABORATORY ANALYSIS

Nitrogen, Phosphorus, Potassium and Sulphur

The levels of Nitrogen, Phosphorous, Potassium and Sulphur in the rich plains of Bihar show different patterns of soil health as shown in Fig. 7.9.



N: Nitrogen; P: Phosphorus; K: Potassium; S: Sulphur

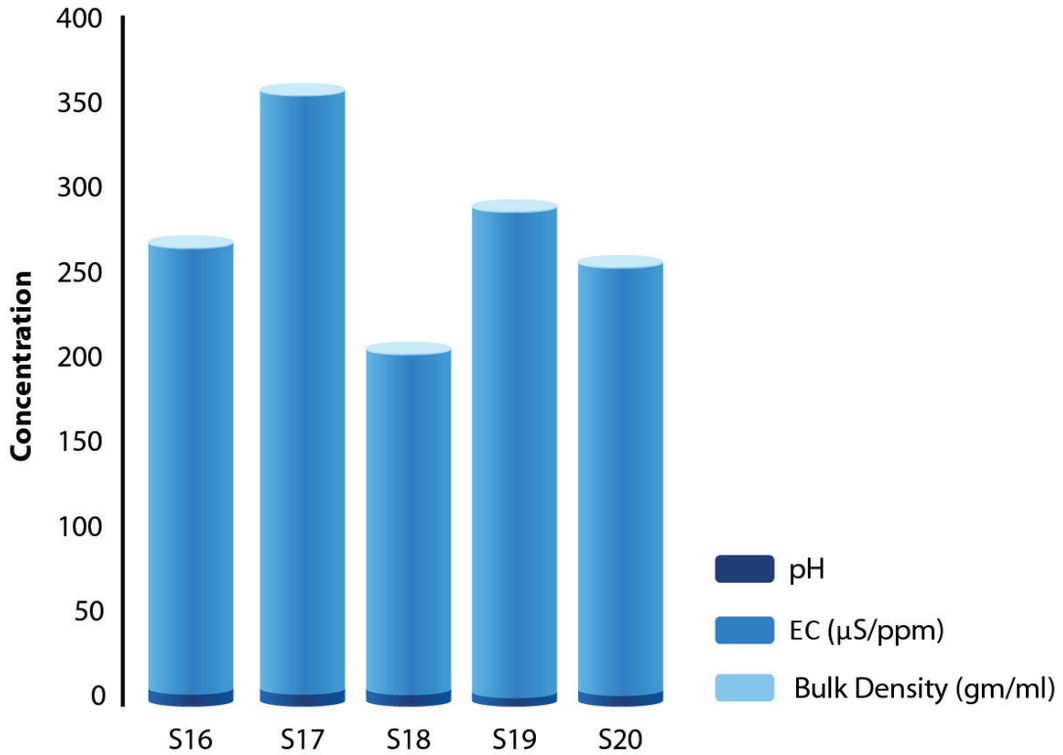
Fig. 7.9 Available NPK & S data of soil samples obtained from different sample locations of Bihar

The Nitrogen levels found in different sites of Bihar were 135.06 kg/ha (S16), 137.15 kg/ha (S17), 138.82 kg/ha (S18), 152.62 kg/ha (S19) and 158.89 kg/ha (S20) with the mean value of 144.508 kg/ha, where highest was found in Farka (S20) and lowest in Revelganj

(S16). The Phosphorous levels were 70.19 Kg/ha (S16), 46.29 Kg/ha (S17), 23.15 Kg/ha (S18), 23.15 Kg/ha (S19), and 19.41 Kg/ha (S20) with the average of 36.438 Kg/ha, in which maximum was found in Revelganj (S16) and minimum in Farka (S20). As per the results, Potassium level of these sites was 324.05 kg/ha (S16), 118.72 kg/ha (S17), 154.82 kg/ha (S18), 284.59 kg/ha (S19) and 180.88 kg/ha (S20), with the mean of 212.612 kg/ha, where the highest level was found in Revelganj (S16) and lowest level in Patna (S17). The levels of Sulphur were 53.9 kg/ha (S16), 82.6 kg/ha (S17), 6.63 kg/ha (S18), 5.79 kg/ha (S19), and 59.83 kg/ha (S20) with the mean of 41.75 kg/ha, in which maximum was found in Patna (S17) and minimum in Bahachoki (S19).

pH, Electrical Conductivity, and Bulk Density

The pH of Bihar was acidic to neutral in different regions as shown in Fig. 7.10. According to the results, the pH of different sites of Bihar were 6.83 (S16), 6.89 (S17), 6.58 (S18), 6.53 (S19) and 7.81 (S20) with an average of 6.928.



EC: Electrical Conductivity; BD: Bulk Density

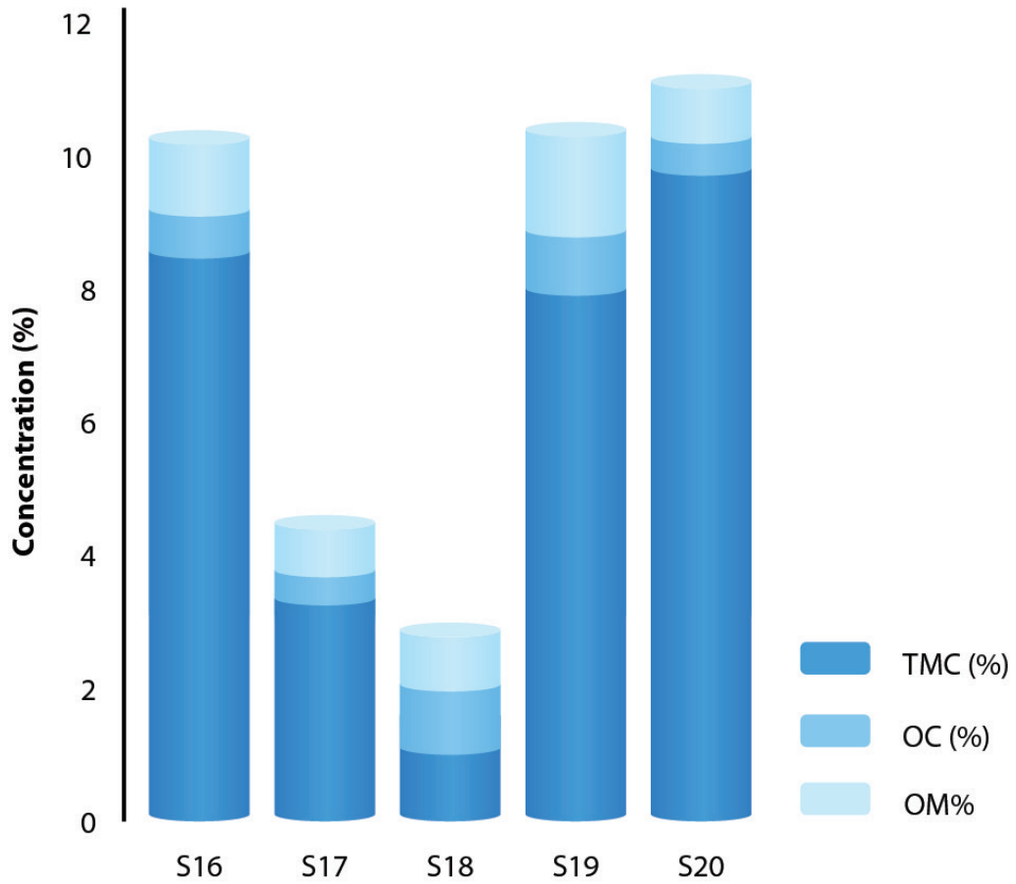
Fig. 7.10 pH, EC, and BD of soil samples obtained from different sample locations of Bihar

The maximum was found in Farka (S20) and minimum in Bahachoki (S19). The Electrical conductivity of these sites was 262.9 µS/ppm (S16), 352.87 µS/ppm (S17), 200.47 µS/ppm (S18), 284.5 µS/ppm (S19) and 250.37 µS/ppm (S20) with the mean of 270.222 µS/ppm, in which highest was found in Patna (S17) and lowest in Barh (S18). Bulk density found

in Bihar regions were 0.97 g/cm^3 (S16), 0.95 g/cm^3 (S17), 0.95 g/cm^3 (S18), 0.91 g/cm^3 (S19) and 0.91 g/cm^3 (S20) with an average of 0.938 g/cm^3, where maximum was found in Revelganj (S16) and minimum in Bahachoki (S19) and Farka(S20).

Total Moisture content, Organic Carbon, and Organic Matter

The study revealed that the TMC % of different regions of Bihar as given in Fig. 7.11, which were 8.45 % (S16), 3.24 % (S17), 1.48 % (S18), 7.89 % (S19) and 9.7 % (S20) with an average of 6.152 %.



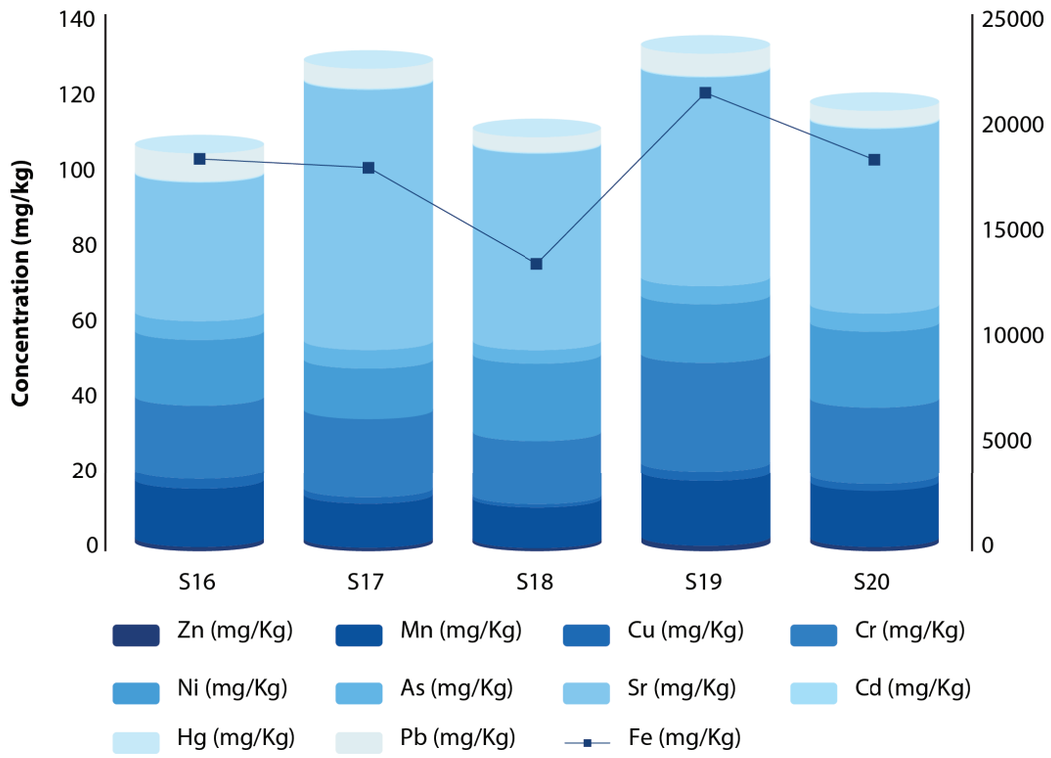
TMC: Total Moisture Content; OC: Organic Carbon; OM: Organic Matter

Fig. 7.11 TMC, OC, and OM of soil samples obtained from different sample locations of Bihar

The highest TMC % was found in Farka (S20) and lowest in Barh (S18). The organic carbon % of Bihar sites were 0.63 % (S16), 0.42 % (S17), 0.47 % (S18), 0.88 % (S19), and 0.48 % (S20) with a mean of 0.576 %, in which maximum was observed in Bahachoki (S19) and minimum in Patna (S17). According to the results, the organic matter % of these sites was 1.08 % (S16), 0.72 % (S17), 0.81 % (S18), 1.52 % (S19), and 0.83 % (S20) with an average of 0.992 %, where the maximum was found in Bahachoki (S19) and minimum in Patna (S17).

Metals Constituents

This extensive study examines the distribution of various metals across the varied landscapes of Bihar (Fig 7.12). It provides a thorough analysis of the presence of different metals, including zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As), strontium (Sr), cadmium (Cd), mercury (Hg) and lead (Pb) within the state's regions as shown in Fig. 7.12.



Zn: Zinc; Mn: Manganese; Cu: Copper; Cr: Chromium; Ni: Nickel; As: Arsenic; Sr: Strontium; Cd: Cadmium; Hg: Mercury; Pb: Lead; Fe: Iron

Fig. 7.12 Metal constituents of soil samples obtained from different sample locations of Bihar

The average levels of these metals found across Bihar regions were 1.026 mg/kg (Zn), 18187.494 mg/kg (Fe), 14.048 mg/kg (Mn), 1.944 mg/kg (Cu), 21.436 mg/kg (Cr), 17.412 mg/kg (Ni), 4.618 mg/kg (As), 52.51 mg/kg (Sr), 0.106 mg/kg (Cd), 0.15 mg/kg (Hg), 5.514 mg/kg (Pb). According to the Study, the maximum Zn was found in Bahachoki (S19) i.e., 1.35 mg/kg and the minimum in Barh (S18) i.e., 0.8 mg/kg; the maximum Fe was found in Bahachoki (S19) i.e., 21787.68 mg/kg and the minimum in Barh (S18) i.e., 13675.29 mg/kg; the maximum Mn was found in Bahachoki (S19) i.e., 17.3 mg/kg and the minimum in Barh (S18) i.e., 10.79 mg/kg; the maximum Cu was found in Bahachoki (S19) i.e., 2.64



mg/kg and the minimum in Barh (S18) i.e., 0.88 mg/kg; the maximum Cr was found in Bahachoki (S19) i.e., 28.9 mg/kg and the minimum in Barh (S18) i.e., 16.97 mg/kg; the maximum Ni was found in Barh (S18) i.e., 20.56 mg/kg and the minimum in Patna (S17) i.e., 13.18 mg/kg; the maximum As was found in Revelganj (S16) i.e.,5.03 mg/kg, and the minimum in Barh (S18) i.e., 3.63 mg/kg; the maximum Sr was found in Patna (S17) i.e., 69.08 mg/kg, and the minimum in Revelganj (S16) i.e., 36.72 mg/kg; the maximum Cd was found in Farka (S20) i.e., 0.13 mg/kg, and minimum 0.1 mg/kg in all other sites; the maximum Hg was found in Patna (S17) i.e., 0.35 mg/kg, and minimum 0.1 mg/kg in all other sites; the maximum Hg was found in Patna (S17) i.e., 0.35 mg/kg, and minimum 0.1 mg/kg in all other sites; the maximum Pb was found in Revelganj (S16) i.e., 7.59 mg/kg, and the minimum in Barh (S18) i.e., 4.23 mg/kg.





01

1
Bulk Soil Collection

02

7
N
Nitrogen

135.06 kg/ha
Average Nitrogen

03

19
K
Potassium

214.29 kg/ha
Average Potassium

04

15
P
Phosphorus

55.25 kg/ha
Average Phosphorus

05

4.17
Heavy Metal Index

JHARKHAND

RESULTS OF SOIL QUALITY OF JHARKHAND

Jharkhand is a state in eastern India. The state is bordered by West Bengal in the east, Uttar Pradesh and Chhattisgarh in the west, Bihar in the north, and Odisha in the south. It is one of the richest mineral zones in the world and boasts 40% and 29% of India's mineral and coal reserves, respectively. Due to its large mineral reserves, mining, and mineral extraction are the major industries in the state (Jharkhand, 2022).

Jharkhand is well-known for its abundant mineral resources, which include Uranium, Mica, Bauxite, Granite, Gold, Silver, Graphite, Magnetite, Dolomite, Fireclay, Quartz, Feldspar, Coal (32% of India), Iron, Copper (25% of India), and others. The Chota Nagpur Plateau is the source of the Koel, Damodar, Brahmani, Kharkai, and Subarnarekha rivers, the upper basins of which are in Jharkhand. The forest still covers a large portion of the state. The soil content of the Jharkhand state mainly consists of soil formed from the disintegration of rocks and stones (https://www.jharkhand.gov.in/home/AboutState).

The soil found here can be classified into five types. They are red soil, black soil, sandy soil, laterite soil, and red micaceous soil. Red soil is commonly found in the Damodar Valley and Rajmahal areas. They are formed by the decomposition of crystalline metamorphic rocks such as granite and gneiss. The color of the soil is mostly chocolate dark except for a few places where it is red. They are porous and possess enough lime and potash but lack nitrogen, phosphorus, and humus. Sandy soil is found in east Hazaribagh and Dhanbad. It is formed by the gradual decomposition of sandy loam and sandy soil. It is yellowish and has a low humus content.

Black soil is found in the Rajmahal areas and contains basalt, kaolin, potash, and iron oxide. It contains a very high proportion of clay and thus has a very high water-retaining capacity. The areas with higher elevation have a thin layer of black soil with light grey colour whereas those with lower elevation have a thick layer of soil having darker shades. Laterite soil is found in the western part of Ranchi, Palamu, and parts of Santhal Parganas and Singhbhum. It is mostly composed of aluminum, iron oxide, and manganese oxide, although it is deficient in phosphorus, nitrogen, and potash. It has a limited yield since it is susceptible to acid reactions. Red micaceous soil (including mica) is most common in Koderma, Mandu, Jhumri Telaiya, and Barkagaon (Shukla, 2021).

ON SITE ANALYSIS

The onsite analysis of soil sample obtained in Sahibganj (S21) details has been given in Table 7.7, which shows that it at a low altitude of 17 meters, breaks the dry trend observed upstream with its moderate 25°C temperature and limited sunlight.

Table 7.7. Field data of soil sample of Jharkhand

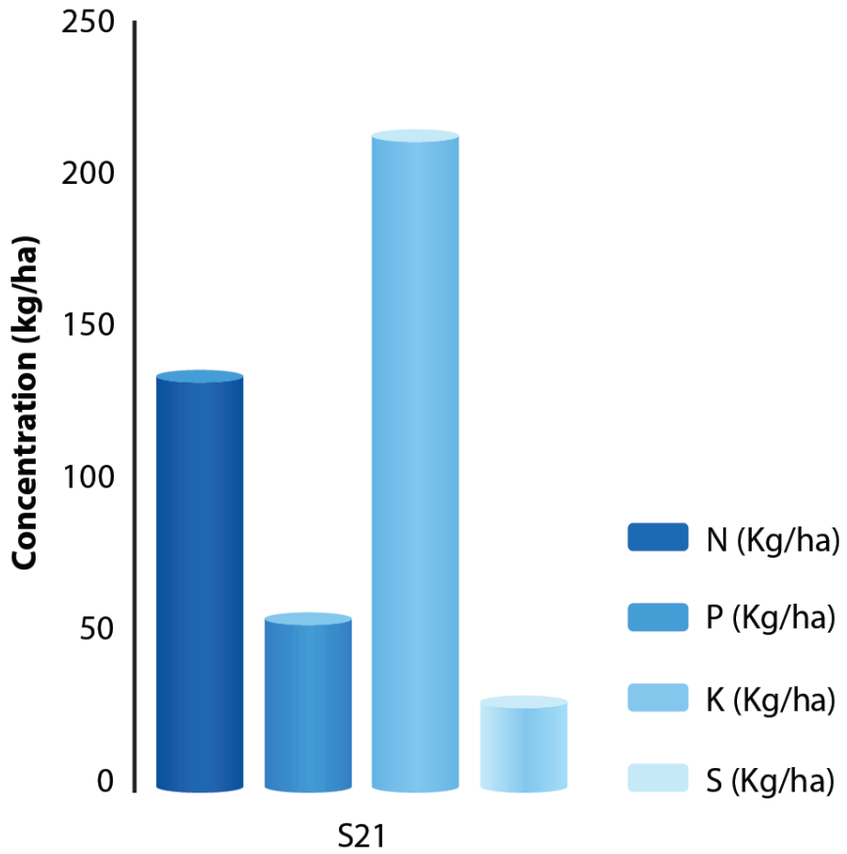
S.No.	Site Code	Corresponding Sites	Altitude (m)	Temperature (°C)	Sunlight	Moisture	Soil Colour
1.	S21	Sahibganj	17	25	Low	Wet	Light Brown

While the soil color is light brown, the shift towards moisture suggests a unique microclimate or potential influence from the Ganges distributaries in this low-lying area.

LABORATORY ANALYSIS

Nitrogen, Phosphorus, Potassium and Sulphur

Soil quality analysis across Jharkhand revealed significant differences in nutrient levels (Available Nitrogen, Phosphorus, Potassium, and Sulphur) across Sahibganj regions as showcased in Fig. 7.13.



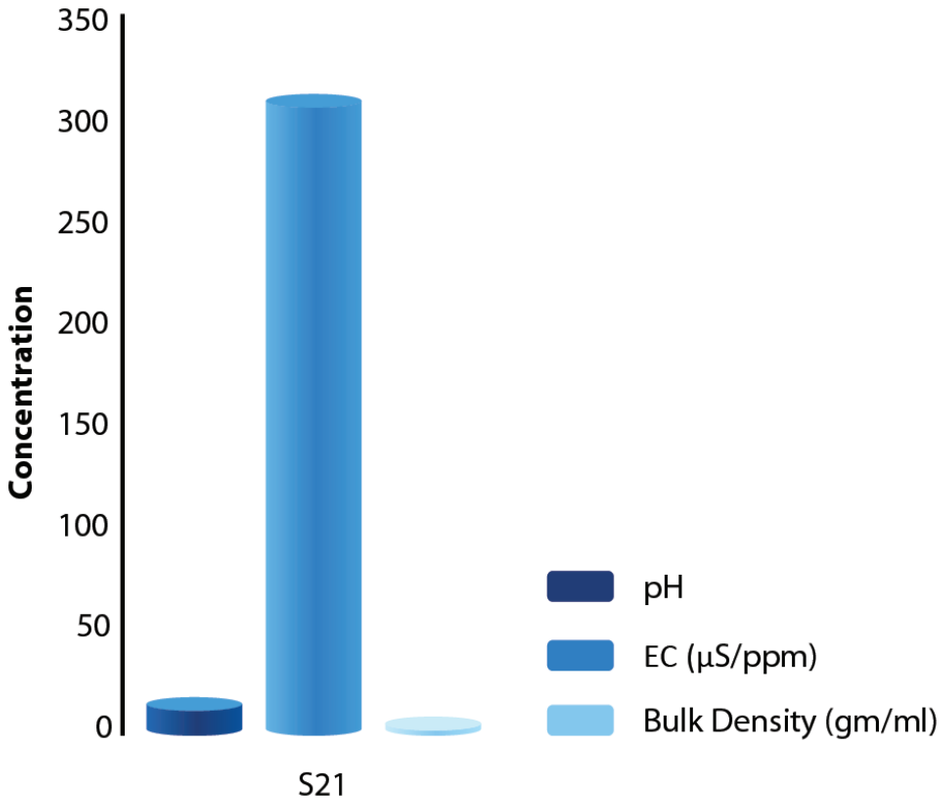
N: Nitrogen; P: Phosphorus; K: Potassium; S: Sulphur

Fig. 7.13 Available NPK & S data of soil samples obtained from different sample locations of Jharkhand

Results revealed that the available NPK and S content in Sahibganj (S21) was 135.06 kg/ha, 55.25 kg/ha, 214.29 kg/ha, and 27.81 kg/ha respectively.

pH, Electrical Conductivity, and Bulk Density

The pH level of Sahibganj (S21) was alkaline (7.84) in nature, while the electrical conductivity of this site was 306.67 µS/ppm (Fig. 7.14).



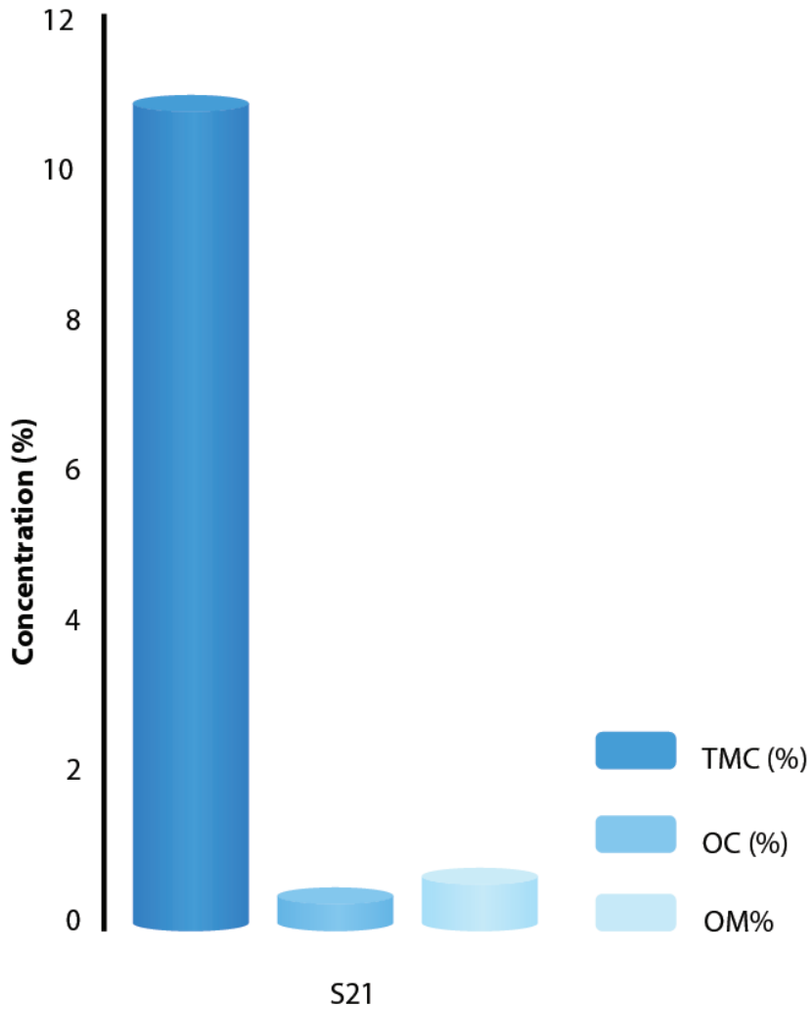
EC: Electrical Conductivity; BD: Bulk Density

Fig. 7.14 pH, EC, and BD of soil samples obtained from different sample locations of Jharkhand

The bulk density found in S21 was 0.93 g/cm^3 as given in Fig. 7.14.

Total Moisture content, Organic Carbon, and Organic Matter

According to the results as shown in Fig. 7.15, the total moisture content found in Sahibganj (S21) was 10.93%. The organic carbon and organic matter present in Sahibganj (S21) were 0.36 % and 0.62% respectively.

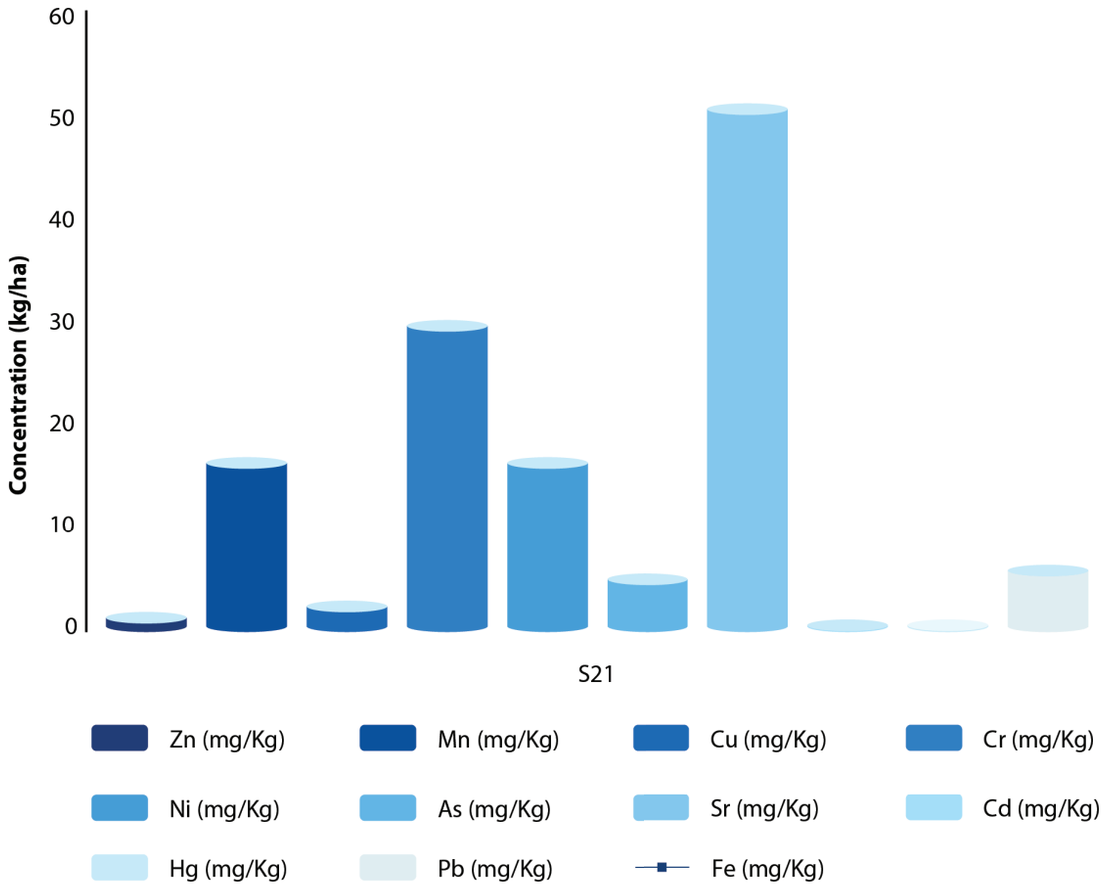


TMC: Total Moisture Content; OC: Organic Carbon; OM: Organic Matter

Fig. 7.15 TMC, OC, and OM of soil samples obtained from different sample locations of Jharkhand

Metals Constituents

Through this extensive research, we analyze metal constituents across the region of Jharkhand (Fig. 7.16).



Zn: Zinc; Mn: Manganese; Cu: Copper; Cr: Chromium; Ni: Nickel; As: Arsenic; Sr: Strontium; Cd: Cadmium; Hg: Mercury; Pb: Lead; Fe: Iron

Fig. 7.16 Metal constituents of soil samples obtained from different sample locations of Jharkhand

The results present a detailed overview of metals like zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As), strontium (Sr), cadmium (Cd), mercury (Hg) and lead (Pb) as given in Fig. 7.16. The level of these metals in Sahibganj (S21) were 0.82 mg/kg (Zn), 21063.2 mg/kg (Fe), 16.06 mg/kg (Mn), 1.94 mg/kg (Cu), 29.6 mg/kg (Cr), 16.11 mg/kg (Ni), 4.61 mg/kg (As), 50.89 mg/kg (Sr), 0.1 mg/kg (Cd), 0.1 mg/kg (Hg) and 5.49 mg/kg (Pb).



01

5
Bulk Soil Collection

02

7 N Nitrogen

159.23 kg/ha
Average Nitrogen

03

19 K Potassium

212.61 kg/ha
Average Potassium

04

15 P Phosphorus

39.65 kg/ha
Average Phosphorus

05

5.7
Heavy Metal Index

WEST BENGAL

RESULTS OF SOIL QUALITY OF WEST BENGAL

West Bengal, located in the eastern part of the country between 21°33' and 27°14' N latitude and 86°35' to 89°53' E longitude, is one of the most important agriculturally developed states in the country. It spreads from the Himalayas in the north to the Bay of Bengal in the South, Assam, Sikkim, and Bhutan in the northeast, and Odisha in the Southwest. The entire stretch of the eastern part is bounded by Bangladesh and Jharkhand is bound by the western border. The state covers an area of 8.87 M ha representing 2.7% of the total geographical area (TGA) and producing food, fiber, and timber for 7.77 percent of the country's population (Sen, 2016; Department of Industry, Commerce & Enterprises, Government of West Bengal, 2020).

West Bengal has abundant natural resources of minerals and favorable agro-climatic conditions for agriculture, horticulture, and fisheries (IBEF, 2022). Physio-graphically, the state is divided into three broad regions viz. Eastern Himalaya (in the north), Eastern plateau and Indo-Gangetic plains. The Eastern Himalaya in the north, comprises the mountainous terrain of Darjeeling (except Siliguri sub-division) and the northern fringes of the Jalpaiguri district. Eastern plateau or Chotanagpur plateau - a tertiary and post-tertiary peneplain surface in the west and south-west, encompasses the western part of Barddhaman, Paschim Medinipur, Bankura, Birbhum and the whole of Puruliya district. The other physiographic region is the Indo-Gangetic alluvial plain, which is further subdivided into Tista-Mahananda alluvial plains, which cover Jalpaiguri, Koch Behar, north and south Dinajpur and Maldah districts; Bengal basin, which includes Murshidabad, Nadia, Hugli, the eastern part of Barddhaman, Birbhum, Bankura, Purba Medinipur, North 24 Parganas and South 24 Parganas excepting coastal areas of Sundarbans and southeastern part of Purba Medinipur district and coastal areas of North 24 Parganas and South 24 Parganas (Sen, 2016).

Soil-related restrictions vary by physiographic area. The problem of severe erosion on high hill slopes is widespread in the north; whereas problems related to the acidity are very common in Tista- Mahananda alluvial plains. Nutrient deficiency, poor soil fertility, and soil acidity are the major constraints in the Eastern Plateau. Drainage congestion, low-lying areas in the Bengal basin; salinity, acidity, and water logging in the coastal plains are the major bottlenecks for agriculture in the state (Singh et al., 2015).

As per the report of ICAR-NBSS & LUP, the tremendous pace of agricultural expansion in West Bengal over the last fifty to sixty years has led to heavy nutrient mining and a variety of soil-related concerns. Excessive nitrogenous fertilizer use depletes the supply of phosphorus, potassium, and other micronutrients. The areas under the poor balance of multi-nutrients have increased out of proportion. The extent and severity of acidity and erosion increased in the rice bowl alluvial plains of West Bengal. Apart from zinc, the deficiency of micro-nutrients like boron and molybdenum

has been reported in many parts of the state. However, nutrient imbalances did not exist equally across the state or region. It differed between and within physiographic regions based on geology and land use. Zinc deficiency was found in 25 to 60% of the tested samples in West Bengal, whereas boron deficiency was found in 50 to 90% of the samples. A deficiency of molybdenum was found in 25-50% of the samples. The extent and intensity of the deficiency are high in the eastern plateau and the Tista-Mahananda alluvial plains as compared to other parts of the state (Singh et al., 2015).

ON-SITE ANALYSIS

The details on site analysis of soil samples obtained from the final section (West Bengal) of the Ganges journey showcased in Table 7.8, revealed the diverse environmental contrasts.

Table 7.8. Field data of the soil samples of West Bengal

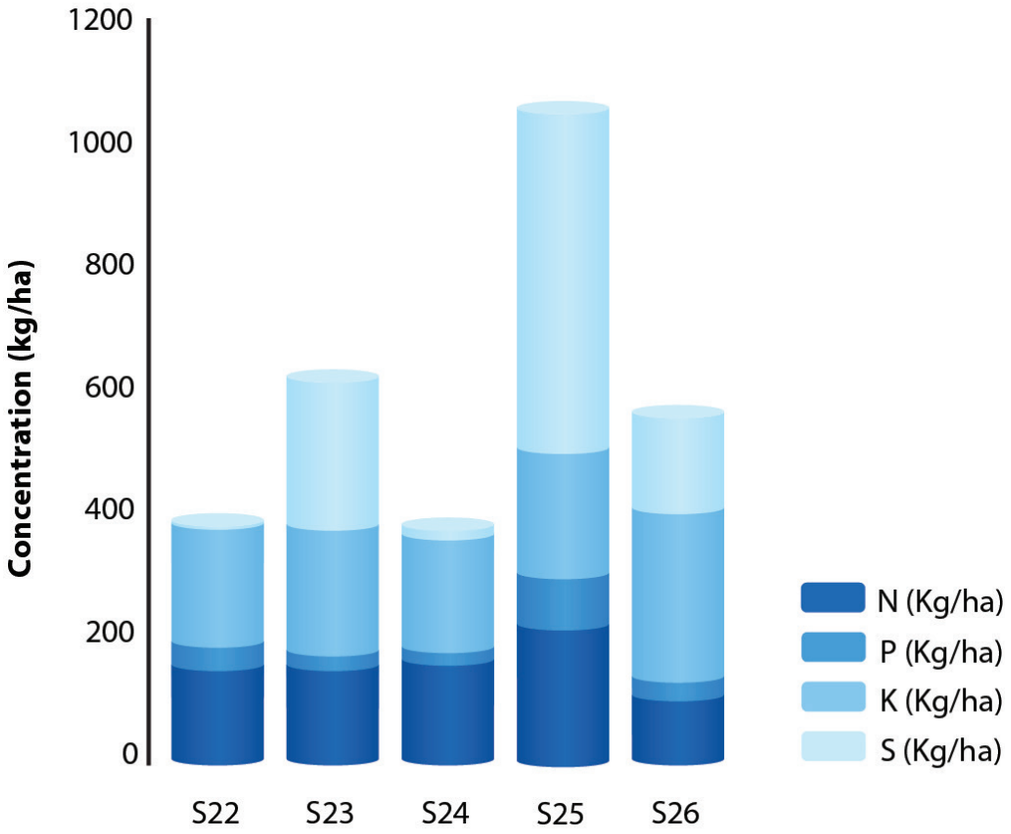
S.No.	Site Code	Corresponding Sites	Altitude (m)	Temperature (°C)	Sunlight	Moisture	Soil Colour
1.	S22	Farraka	30-35	28	Low	Dry +	Light Brown
2.	S23	Hazarduari	14	30	Normal	Dry	Light Brown
3.	S24	Mayapur	8	27	Low	Wet	Brown
4.	S25	Hoogly	9	30	Low	Dry +	Black
5.	S26	Gangasagar	3	31	Low	Wet+	Greyish Brown

Farraka experiences a temperature of 28°C with low sunlight and dryness, despite its higher altitude compared to other sites. Hazarduari, with its moderate 30°C and normal sunlight, continues the dry trend with light brown soil. Mayapur, located at the lowest altitude (8m), breaks the pattern with lower temperatures (27°C), wet conditions, and brown soil. Hoogly, at a slightly higher altitude (9m), returns to the dry trend with moderate sunlight and black soil. Finally, Gangasagar, at the river's mouth, sees the highest temperature (31°C) alongside low sunlight, wetness, and greyish-brown soil. This final stretch highlights the influence of tidal dynamics and the Ganges delta on the river's environmental parameters, showcasing a dynamic and diverse landscape before its confluence with the Bay of Bengal.

LABORATORY ANALYSIS

Nitrogen, Phosphorus, Potassium and Sulphur

The analysis of available nutrients across five sacred sites along the Ganges River revealed significant variations as shown in Fig. 7.17, in which available Nitrogen of these sites are 153.45 kg/ha (S22), 153.45 kg/ha (S23), 162.24 kg/ha (S24), 222.87 kg/ha (S25) and 104.12 kg/ha (S26) with average value of 159.23 kg/ha, .



N: Nitrogen; P: Phosphorus; K: Potassium; S: Sulphur

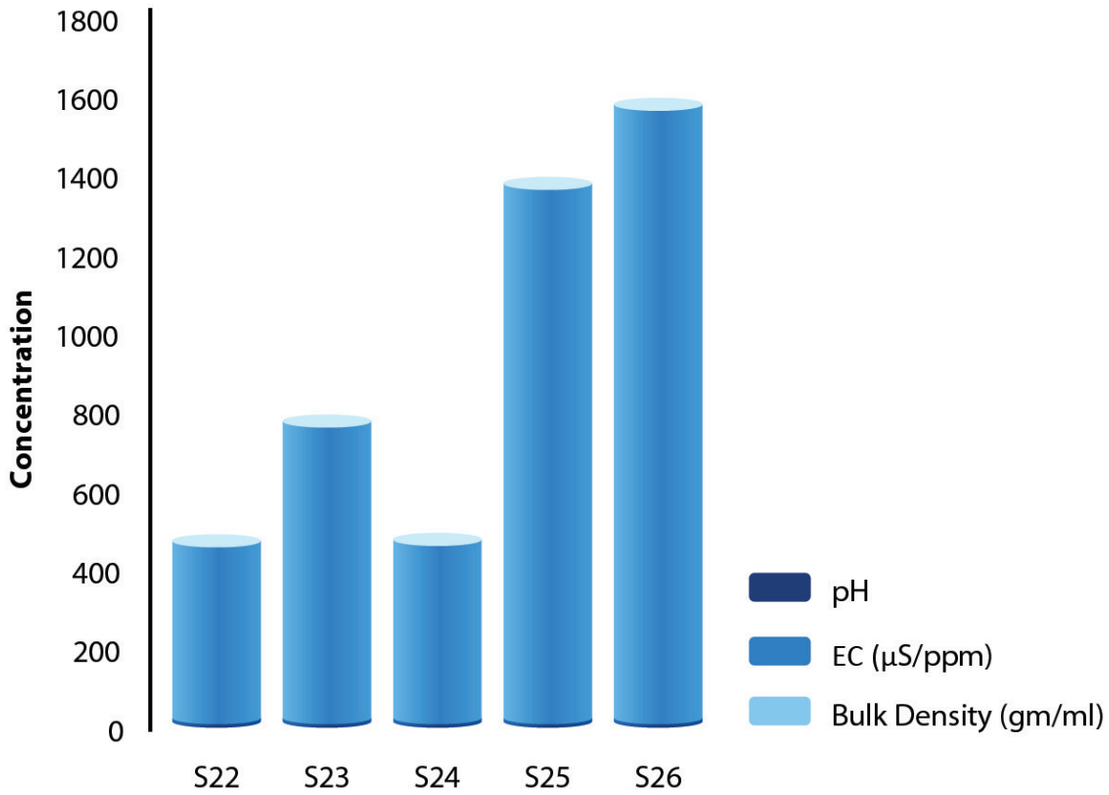
Fig. 7.17 Available NPK & S data of soil samples obtained from different sample locations of West Bengal

The maximum was found in Hooghly (S25) while the minimum was found in Gangasagar (S26); availability of Phosphorous in these sites are 38.74 kg/ha (S22), 24.11 kg/ha (S23), 20.65 kg/ha (S24), 84.11 kg/ha (S25) and 30.63 kg/ha (S26) with the mean value of 39.65 kg/ha in which maximum was found in Hooghly (S25) and minimum in Mayapur (S24); available Potassium found in these sites are 192.53 kg/ha (S22), 205.67 kg/ha (S23), 184.39 kg/ha (S24), 204.81 kg/ha (S25) and 275.63 kg/ha (S26) with the average of 212.61 kg/ha where the maximum was found in Gangasagar (S26) and minimum in Mayapur (S24); availability of Sulphur found in these sites are

5.72 kg/ha (S22), 242.54 kg/ha (S23), 16.51 kg/ha (S24), 555.53 kg/ha (S25) and 156.90 kg/ha (S26) with the mean of 195.44 kg/ha in which maximum was found in Hoogly (S25) and minimum in Farraka (S22).

pH, Electrical Conductivity, and Bulk Density

From the results as shown in Fig. 7.18, it was observed that the soil pH of different sample sites ranges from neutral to alkaline, which includes 6.75 (S22), 7.97 (S23), 7.92 (S24), 7.77 (S25) and 7.86 (S26).



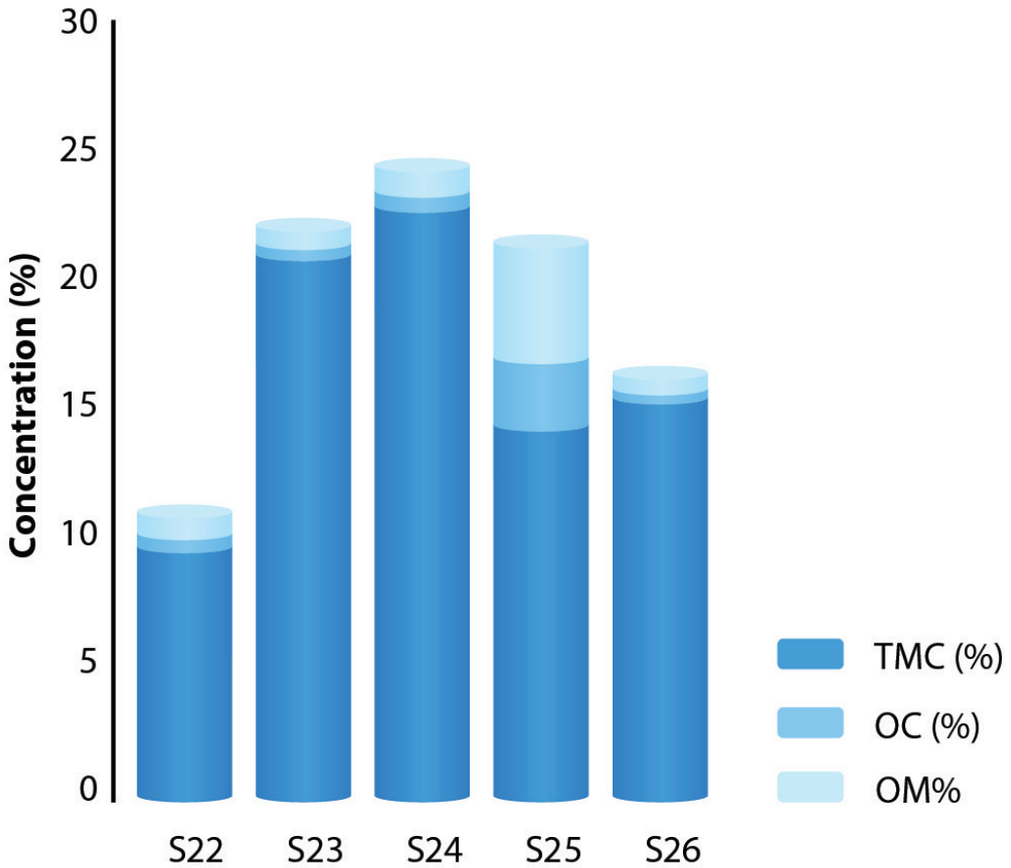
EC: Electrical Conductivity; BD: Bulk Density

Fig. 7.18 pH, EC, and BD of soil samples obtained from different sample locations of West Bengal

The average pH of West Bengal is 7.65, where the maximum was found in Hazarduari (S23) while the minimum was found in Farraka (S22). The electrical Conductivity of these sites is 449.43 µS/ppm (S22), 752.23 µS/ppm (S23), 451.8 µS/ppm (S24), 1354.33 µS/ppm (S25), and 1554.67 µS/ppm (S26). The average E.C. of West Bengal is 912.49 µS/ppm, where the maximum was found in Gangasagar (S26) while the minimum was found in Farraka (S22). The Bulk Density (gm/ml) found in these 5 sites are 0.95 gm/ml (S22), 0.83 gm/ml (S23), 0.91 gm/ml (S24), 0.8 gm/ml (S25) and 0.87 gm/ml (S26). The average was 0.87 gm/ml where the maximum was found in Farraka (S22) while the minimum was found in Hooghly (S25).

Total Moisture Content, Organic Carbon, and Organic Matter

The total Moisture Content, Organic Carbon, and Organic Matter of these sites are shown in Fig. 7.19.



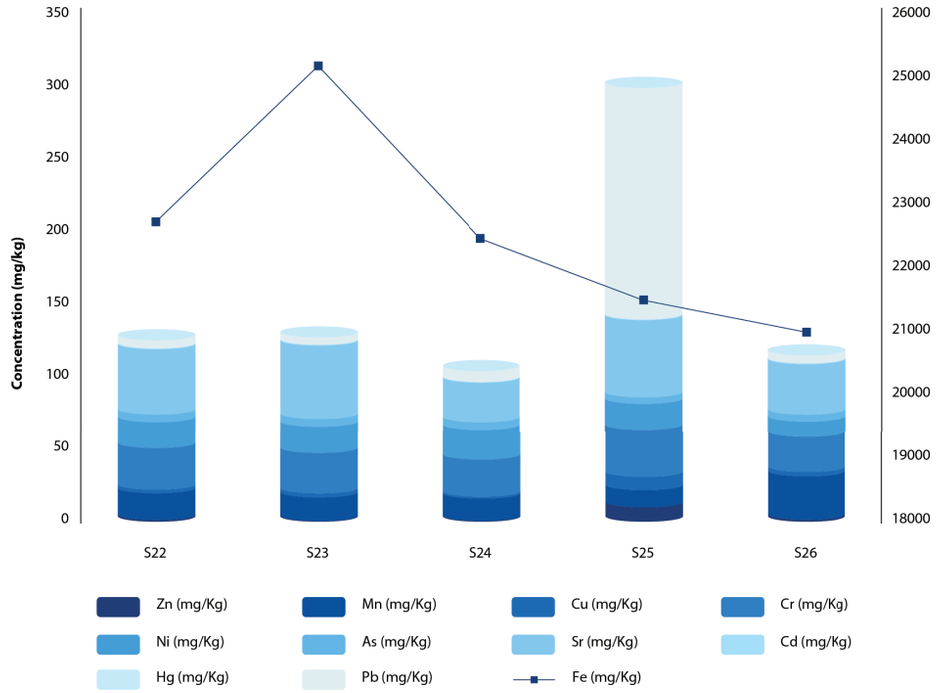
TMC: Total Moisture Content; OC: Organic Carbon; OM: Organic Matter

Fig. 7.19 TMC, OC, and OM of soil samples obtained from different sample locations of West Bengal

The total moisture content found in these 5 sites is 9.73 % (S22), 21.13 % (S23), 23.03 % (S24), 14.47 % (S25) and 15.53 % (S26). The average TMC % is 16.78 % where the maximum was found in Mayapur (S24) while the minimum was found in Farraka (S22). According to the results, the organic carbon % of these 5 sites are 0.51 % (S22), 0.43 % (S23), 0.59 % (S24), 2.64 % (S25) and 0.37 % (S26) with an average of 0.91 % where the maximum was found in Hooghly (S25) while the minimum was found in Gangasagar (S26). According to the results, the organic matter % of these 5 sites is 0.87 % (S22), 0.73 % (S23), 1.01 % (S24), 4.54% (S25) and 0.63 % (S26) with an average of 1.56 % where the maximum was found in Hoogly (S25) while the minimum was found in Gangasagar (S26).

Metals Constituents

The study analysed the presence of various metals such as zinc (Zn), iron (Fe), manganese (Mn), copper (Cu), chromium (Cr), nickel (Ni), arsenic (As), strontium (Sr), cadmium (Cd), mercury (Hg), and lead (Pb) at different sites in West Bengal (Fig. 7.20).



Zn: Zinc; Mn: Manganese; Cu: Copper; Cr: Chromium; Ni: Nickel; As: Arsenic; Sr: Strontium; Cd: Cadmium; Hg: Mercury; Pb: Lead; Fe: Iron

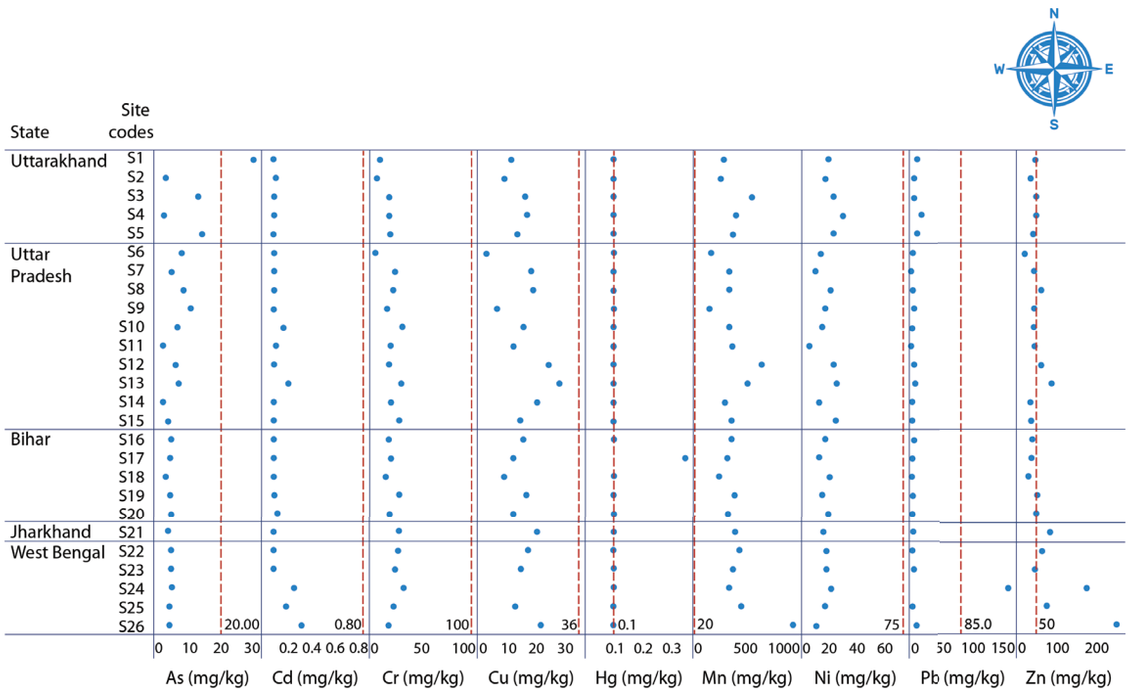
Fig. 7.20 Metal constituents of soil samples obtained from different sample locations of West Bengal

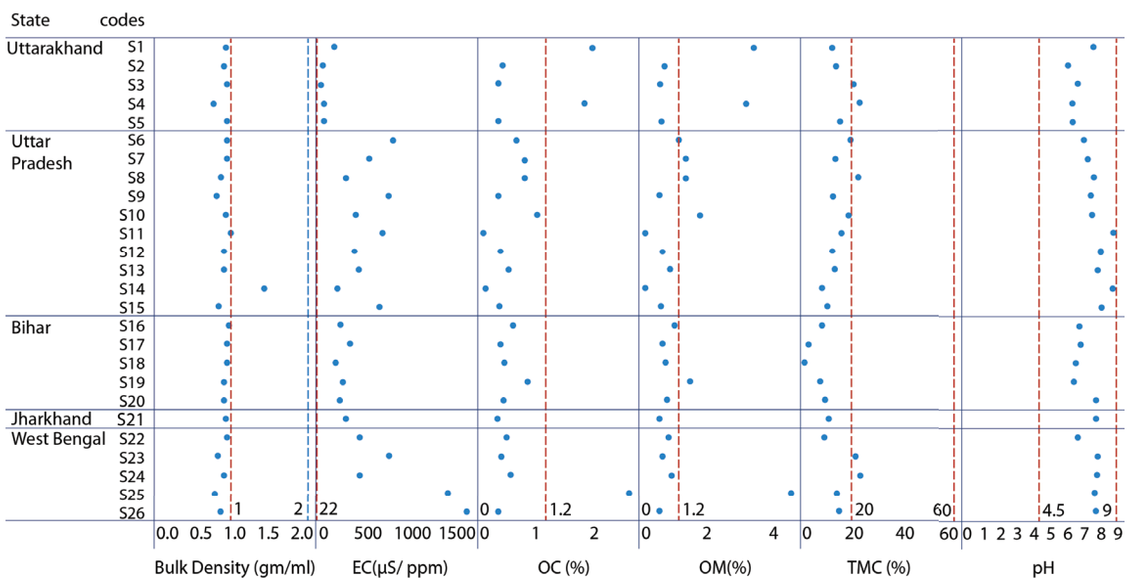
The average values of these metal constituents at the sites in Uttarakhand were also observed. The results showed significant variations in the presence of these metals at different sites. For example, maximum zinc was found in Hooghly (S25) and minimum in Mayapur (S3). Similarly, other metals showed varying levels at different sites.
The study emphasized the importance of understanding the optimal range and site-specific variations of these metals for sustainable agricultural practices in West Bengal.

The search results provide information about the toxicity, health effects, and distribution of heavy metals, including zinc, iron, copper, chromium, nickel, and cadmium. They also discuss the levels of heavy metals in fish and their potential health implications. Additionally, the results highlight that while some heavy metals are essential in small amounts, they can be toxic in larger quantities. Furthermore, the results explain that heavy metals are often considered toxic, but many of them are vital for humans in small quantities and are called essential trace elements.

SOIL QUALITY INDICATORS

As the primary criteria of soil testing is to validate the possibility of organic farming in the ganga region, thus standards and their threshold limits as directed by Indian Counsil for Agriculture Research, GOI regarding the same has been taken into consideration (Bhattacharyya et al., 2017). The Figure (7.21 A, B, C) shows below could highlight the prescribed limit of the parameters.





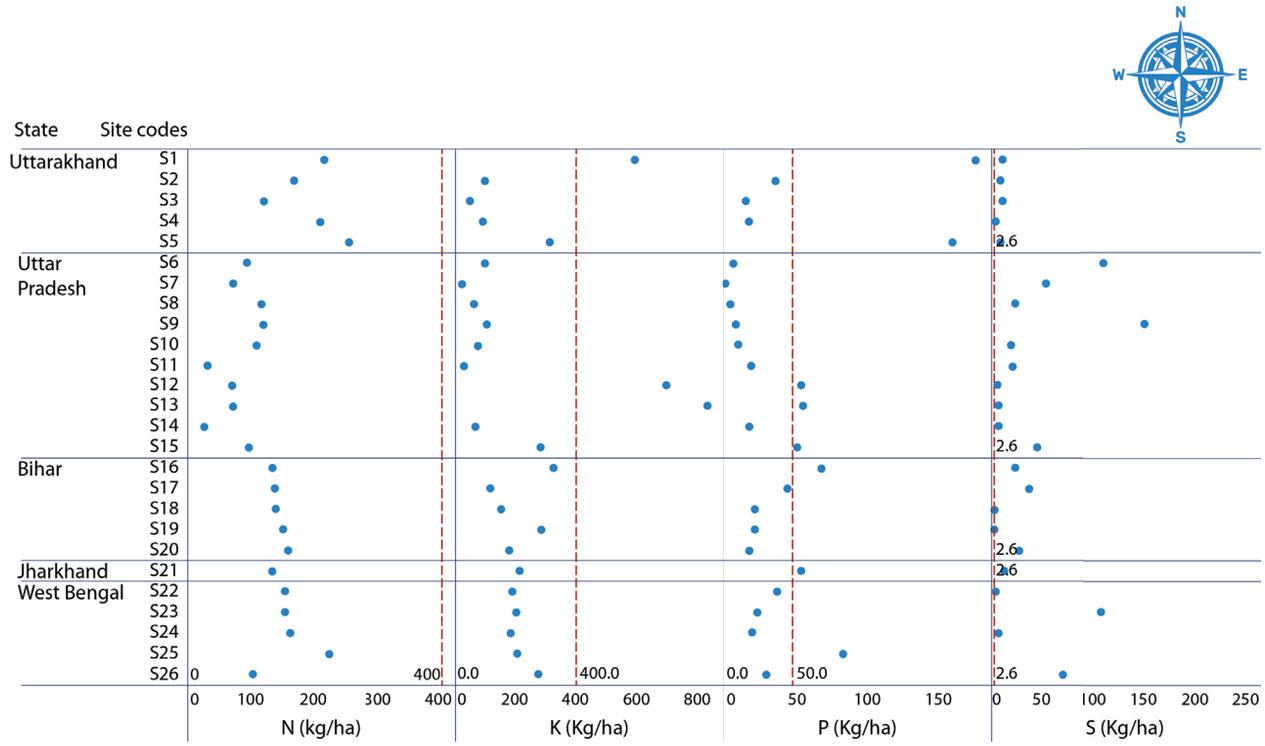


Fig 7.21(A-C) Distribution of sites according to the soil parameters with prescribed values

According to the quality standard prescribed by WHO/ FAO 1996 given in table 6.3 the physicochemical parameters vary greatly among the sampling points. The prescribed value for Nitrogen content is 400kg/ ht, and all samples are within the limit. For available Phosphorus content, the prescribed value is 0-50kg/ ht, and about 30% of all the tested samples were beyond the limit. However, according to the valuation, the "more is better" in this case, so no threat exists. For available Potassium content, the prescribed value is 400kg/ ht, and about 11.5% of all the tested samples were beyond the limit. But according to the valuation, the "more is better" in this case, so no threat exists. The prescribed value for pH of the soil is 4.5-9, and all samples were within the limit. However, in the case of Electrical conductivity of the soil, the prescribed value is 2-12 µS/ppm, and all the tested samples were beyond the limit. According to the valuation, the "less is better" in this case, so a threat exists in every sample. The prescribed value for bulk density of the soil is 1-2gm/ cm3, and only one sample was beyond the limit. But according to the valuation, the "less is better" in this case, so no threat exists. The prescribed value for Organic carbon (%) of the soil is 0-1.2%, and only two samples were beyond the limit. But according to the valuation, the "more is better" in this case, so no threat exists. The prescribed value for Total Moisture Content (%) of the soil is 20%-60%, and only 19.23% of all tested samples were beyond the limit. For individual heavy metals, only

one sample is beyond the limit for Arsenic, whereas for Mercury, all samples are in the reference range. For Mn, all the values are beyond the limit except one sample. For the rest of the heavy metals, all the soil sample values are within range.

METAL POLLUTION INDEX

As per metal pollution index calculation, most of the soil samples are slightly affected (61%). Apart from that 31 % samples are moderately affected region whereas only 8% of the samples are seriously affected region (Fig .7.22)

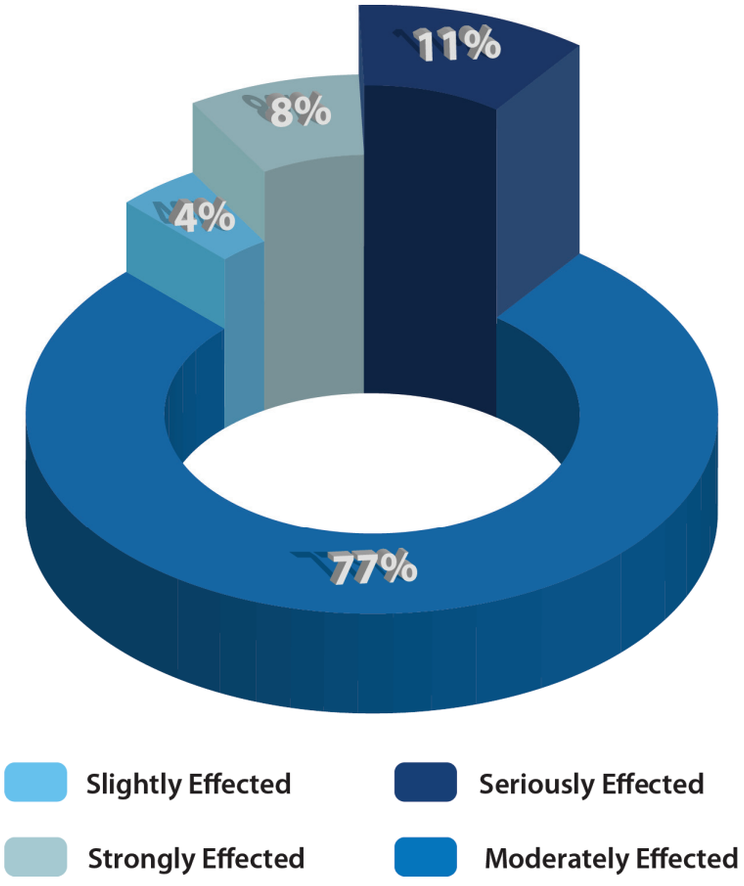


Fig. 7.22 Categorization of the samples according to the Metal Pollution Index score (Matta et al., 2020)

OVERALL SOIL QUALITY INDEX

The Soil Quality Index (SQI) values vary across the Ganga River sampling sites in different states (Fig 7.23).

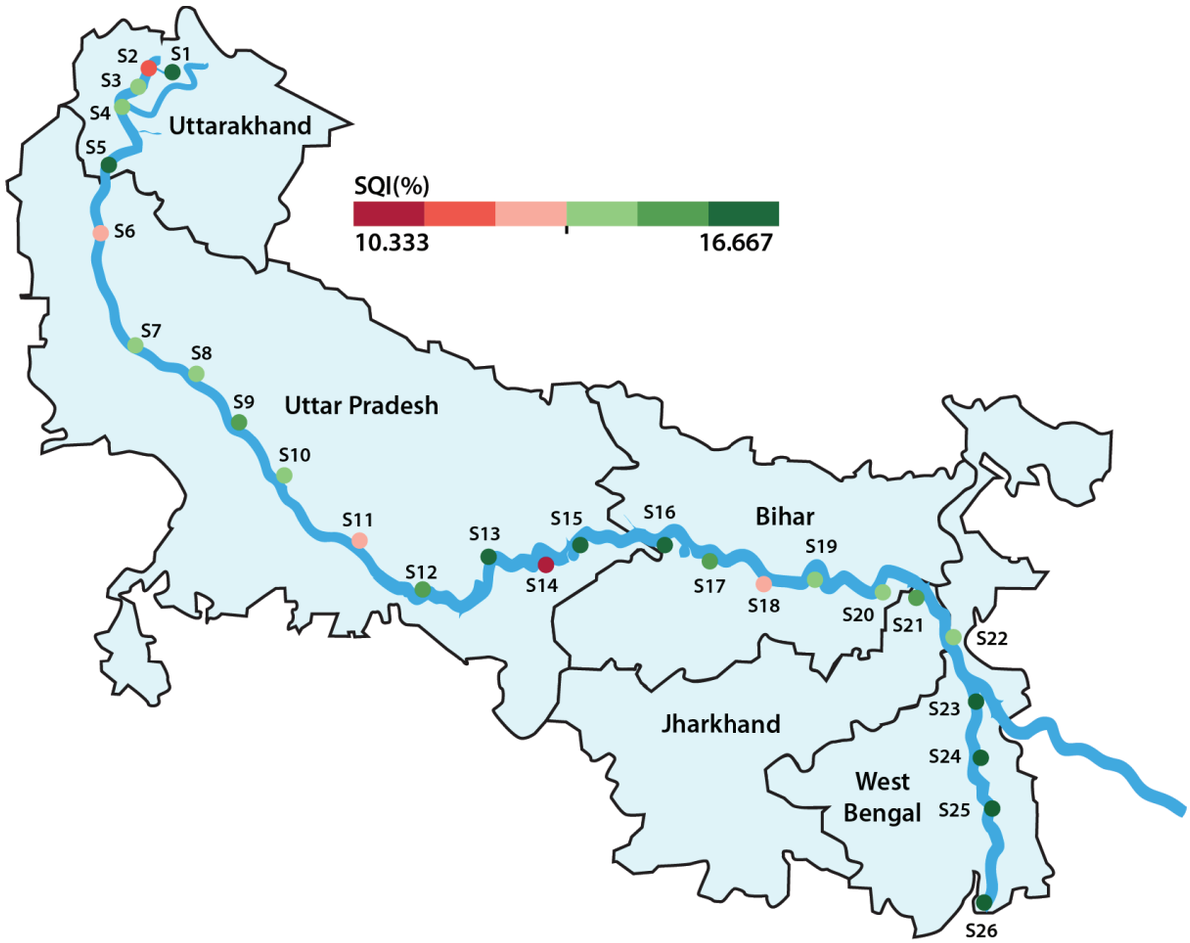


Fig 7.23 Soil quality Index of sampling sites in different states

In Uttarakhand, Gaumukh (S1) has the highest SQI at 16.33%, indicating robust soil quality, while Varanasi (S14) in Uttar Pradesh presents a lower SQI of 10.33%, suggesting potential soil challenges. In Uttar Pradesh, Prayagraj (S12) stands out with an SQI of 14%. Bihar sites, including Revelganj (S16) and Patna (S17), show moderate to high soil quality with SQI values ranging from 13% to 15.67%. West Bengal exhibits notable variations, with Hooghly (S25) displaying the highest SQI at 16.67%. These SQI assessments provide insights into regional soil health disparities and can contribute to targeted soil management strategies for sustainable land use along the Ganga River.

The study provides a comprehensive assessment of soil quality across different states along the Ganga River, offering valuable insights into the varying degrees of soil health and fertility in the region.

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Section-VIII

Plant-Microbe Interaction



Plant-microbe interactions are diverse and play a crucial role in the growth, performance, and stress tolerance of plants. These interactions can be mutualistic, neutral, or harmful. Mutualistic interactions, such as mycorrhizal symbiosis and nitrogen fixation, are beneficial for plant growth and performance. On the other hand, some microbes help break down organic matter in the soil, protect plants from diseases, or release toxins that kill plant-eating insects. Understanding the intimate mechanisms of plant-microbe interactions is essential for sustainable agriculture, as these interactions are important for promoting plant growth, suppressing diseases, and environmental health. The study of plant-microbe interactions is an evolving field with implications for food production, environmental sustainability, and disease resistance (Mine et al 2014; Wu et al., 2009).

Rhizosphere bacteria are microorganisms that inhabit the narrow region of soil directly influenced by root secretions. The rhizosphere is enriched in bacteria, fungi, and other microbes that play crucial roles in plant growth, nutrient cycling, and disease suppression. Rhizosphere bacteria are highly diverse and can solubilize metals, fix nitrogen, produce hormones, and suppress soilborne pathogens (Ling et al., 2022). They can also be used for bioremediation of contaminated sites. The diversity and composition of the rhizosphere bacterial community are influenced by both plant species and soil conditions. Rhizosphere colonization involves the attachment of microbes to the root surface and the opening of the line at the root surface. Understanding the functions and mechanisms of rhizosphere bacteria is essential for sustainable agriculture, as it can help improve plant growth, suppress diseases, and promote environmental health (Lynch et al., 2001; Saeed et al., 2021).

Rhizosphere bacteria play an important role in the medicinal properties of plants. The rhizosphere is enriched in bacteria, fungi, and other microbes that promote plant growth, nutrient cycling, and disease suppression. Rhizosphere bacteria can produce cytokinins, which are plant hormones that regulate growth and stress responses. They can also produce antibiotics, siderophores, and hydrogen cyanide to suppress soilborne pathogens and protect plants from diseases. Rhizosphere bacteria can improve the utilization rate of nutrients in the soil, thereby affecting the growth and development of plants and stress resistance and promoting good plant health and

soil quality (Köberl et al., 2013). The diversity and composition of the rhizosphere bacterial community are influenced by both plant species and soil conditions. Understanding the functions and mechanisms of rhizosphere bacteria is essential for sustainable agriculture, as it can help improve plant growth, suppress diseases, and promote environmental health. Therefore, the study of rhizosphere bacteria is important for the medicinal properties of plants (Zhou et al.,2022).

Importantly, the interaction between rhizosphere bacteria and plants extends beyond basic physiological functions, influencing the bioactive compounds synthesized by plants. Many medicinal plants owe their therapeutic properties to the intricate interplay between rhizosphere bacteria and the host plant. These bacteria can stimulate the production of secondary metabolites, such as alkaloids, flavonoids, and terpenoids, which often possess pharmacological significance (Morgan et al., 2005).

Understanding the role of rhizosphere bacteria in modulating the medicinal properties of plants has implications for agriculture, pharmaceuticals, and environmental sustainability. Harnessing this knowledge may lead to the development of innovative agricultural practices, bio-fertilizers, and plant-based medicines. The intricate dance between plants and rhizosphere bacteria offers a promising avenue for enhancing the quality and quantity of medicinal compounds derived from plants, ultimately benefiting both agriculture and human health.

Studying plant-microbe interactions in the rhizosphere, with a specific focus on bacteria, provides valuable insights for optimizing the cultivation of medicinal plants. This knowledge can be applied to develop sustainable and efficient agricultural practices that support the production of high-quality medicinal herbs with potential therapeutic benefits. Thus, with the above justification the objective of the study is the following.

- To quantify the total cultivable rhizosphere bacteria among the selected medicinal plants
- To elucidate the differential count of isolated rhizosphere bacteria

Material and Methods

SELECTION OF PLANTS

In the process of selecting plants for cultivation or conservation, a crucial criterion is the occurrence of these plants in a specific geographic region. This criterion is fundamental in ensuring the adaptation and resilience of chosen species to the local environment. By focusing on plants that naturally occur in the region, we leverage their inherent ability to thrive in the prevailing climate, soil conditions, and ecosystem. This approach also aligns with principles of ecological sustainability, as native plants are often well-integrated into the local biodiversity. Through a careful assessment of the occurrence of medicinal plants, stakeholders can make informed decisions that contribute to the preservation of regional flora, promote ecosystem health, and harness the inherent benefits of plants adapted to the unique ecological niches of a particular area as shown in Table 8.1. As *Ranunculus sceleratus* is mostly growing in watery places so Instead of *Ranunculus sceleratus, Polygonum plebeium* has been selected for for lant-microbe interactions.

Table 8.1 Medicinal selected plant with their medicinal property

Name of the Selected Plant	Common and Vedic name	Type	Family	Ayurvedic	Medicinal Uses	Pharmacological activities	Reference
Achyranthes aspera L.	Kubja (Sanskrit); Chirchita, Latjira Apamarg(Hindi) अपामार्गक: खरमञ्जिक: (Apāmārgakaḥ kharamañjikaḥ)	Herb	Arecaceae	Yes	Bleeding, bronchitis, and wound healing.	Anti-inflammatory and analgesic	(Balkrishna A., (2022)
Boerhavia diffusa L.	Shothagni, Survari, Thikri, (Hindi) पुनर्नवक: रक्तकाण्ड: (Punarnavakaḥ raktakāṇḍaḥ)	Herb	Nyctaginaceae	Yes	Dropsy and hyperuricemia.	Anti-inflammatory and anti-aging	(Balkrishna A., (2022)
Croton bonplandianus Baill.	Bana tulasī, Ban tulsi, Haldi, Kala bhangra (Hindi); मुक्ततन्तुक: अरोमवृन्त: (Muktatantukaḥ aromavṛntaḥ)	Shrub	Euphorbiaceae	No	Insomnia, abdominal dropsy, and infectious disorders.	Anti-inflammatory and antipyretic	(Balkrishna A., (2022)
Cynodon dactylon (L.) Pers.	Vīrataramv, Vīraṇam (Sanskrit); Baramuḍā grāsa, Doob ghas, Drub, Dubala, Kabbar, Doob, Hariali (Hindi) दूर्विका शत पर्वा (Dūrvikā śataparvā)	Grass	Poaceae	Yes	Convulsions, diuretic and expectorant.	Antimicrobial and antipyretic	(Balkrishna A., (2022)

Name of the Selected Plant	Common and Vedic name	Type	Family	Ayurvedic	Medicinal Uses	Pharmacological activities	Reference
Ficus racemosa L.	Ambar, Domoor, Dumar, Gular, Phagoora, Udumbara, Umar, Umba (Hindi); पयोवृक्षक: उदुम्बर: (Payovṛkṣakaḥ udumbaraḥ)	Tree	Moraceae		Diabetes, liver disorders, inflammatory conditions, hemorrhoids, respiratory and urinary diseases.	Anti-inflammatory	(Balkrishna A., (2022)
Polygonum plebeium R.Br.	Machhaichhie, Machichi, Muniyaara, Choti (Hindi); पयोवृक्षक: उदुम्बर: (Purusandhikaḥ aśiraḥ)	Herb	Polygonaceae	No	Pneumonia, bowel complaints, diarrhea, dysentery, and eczema	Anti-inflammatory, analgesic and antipyretic	(Balkrishna A., (2022)
Ricinus communis L.	Erand, Erandi, Irandia, Grundi, Jrandia (Hindi); एरण्डक: पञ्चाङ्गुल: (Eraṇḍakaḥ pañcāṅgulaḥ)	Shrub	Euphorbiaceae	Yes	Laxative, emollient, constipation, skin disorders, and arthritis.	Anti-cancer	(Balkrishna A., (2022)
Solanum nigrum L.	Kamuni, Mako, Makoi, Makoy, Mukko, Palpotan, Uda-mako], Mokoi (Hindi); युक्पञ्चकम् कृष्णफलम् (Yukpañcakam kṛṣṇaphalam)	Herb	Solanaceae	Yes	Pneumonia, aching teeth, stomach ache, tonsillitis, and inflammation.	Hepatoprotective	(Balkrishna A., (2022)

Name of the Selected Plant	Common and Vedic name	Type	Family	Ayurvedic	Medicinal Uses	Pharmacological activities	Reference
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Anjan, Anjani, Arjun sadado, Kaugach, Khawa, Koara, Kohera, Kowa, Arjan, Kahu, Koha, Arjun (Hindi); वीरक: अर्जुन: (Vīrakaḥ arjunaḥ)	Tree	Combretaceae	Yes	Atherosclerosis, and myocardium necrosis.	Cardiotonic and anti-inflammatory	(Balkrishna A., (2022)
Tridax procumbens L.	Ghamra[WS1], Kalal, Khai-Muriya, Taimuriya, Pabula-ka-mocha, Pebul-ka-mocha, Pilo-bayoni (Hindi); सदाहरित्क: बाणपत्र: (Sadāharitkaḥ bāṇapatraḥ)	Herb	Asteraceae	No	Hyperuricemia and bacterial infections.	Antioxidant, Anti-coagulant, Anti-microbial	(Balkrishna A., (2022)

Occurrence of Plants in the Present Study

Selecting plants based on their occurrence in a state involves a comprehensive process that begins with researching the state's climate, soil conditions, and native vegetation. Understanding the unique ecosystems within the region and identifying native plants adapted to local conditions is crucial. Consideration of plant hardiness zones, site-specific factors, and potential microclimates further refines the selection. Collaboration with local authorities and experts, such as botanical gardens or agricultural extension offices, can provide valuable insights. Prioritizing native species supports biodiversity and ecological balance, while vigilance against invasive species helps maintain a healthy ecosystem. Adapting choices to urban or garden settings, planning for diversity, and conducting small-scale trials contribute to successful plant selection. Documentation and ongoing observation facilitate learning and enhance future landscaping endeavors for a sustainable and thriving plant environment. The selected plant is listed based on their occurrence as given in Table 8.2

Table 8.2 Occurrence of the selected plant along the study area

States	Uttarakhand		Uttar Pradesh										Jharkhand	Bihar					West Bengal					
Boerhavia diffusa L.	√	√	√	√	√	√		√	√	√	√	√	√	√		√	√							
*Croton bonplandianus*Baill.		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√						
Cynodon dactylon (L.) Pers.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√			
Achyranthes aspera L.		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√							
Ficus racemosa L.		√		√		√	√	√	√	√	√	√	√	√				√						√
Polygonum plebeium R.Br.	√	√	√			√		√					√		√	√	√	√				√		
Ricinus communis L.	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√				√		
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.		√	√	√	√			√	√	√	√	√	√	√		√	√	√	√					
Tridax procumbens L.	√	√	√		√		√	√	√	√	√	√	√		√	√		√				√		
Solanum nigrum L.	√	√	√		√	√	√	√	√	√	√	√	√	√	√		√					√		

Here S4 represent (Devprayag), S5 (Haridwar), S6 (Bijnor), S7 (Narora), S8 (Badaun), S9 (Farrukhabad), S10 (Bithoor), S11 (Dalmau), S12 (Prayaraj), S13 (Mirzapur), S14 (Varanasi), S15 (Ballai), S16 (Sahibganj), S17 (Revelganj), S18 (Patna, S19 (Barh), S20 (Bahachoki), S21 (Farka), S22 (Faraka), S23 (Hazarduari), S24 (Mayapur), S25 (Hoogly) and S26 (Gangasagar).

COLLECTION OF RHIZOSPHERE SOIL SAMPLES

Soil samples from the rhizosphere of ten different plants were procured from diverse locations spanning the vast geographical expanse from Gaumukh to Gangasagar. The collection sites, each characterized by distinct Latitude and Longitude values, are detailed in Table 8. 3. Notably, the state of Uttarakhand presented occurrences in Devprayag (S4) and Haridwar (S5), while Uttar Pradesh featured locations such as Bijnor (S6), Narora (S7), Badaun (S8), Farrukhabad (S9), Bithoor (S10), Dalmau (S11), Prayaraj (S12), Mirzapur (S13), Varanasi (S14), and Ballia (S15). Additionally, Bihar hosted sites in Revelganj (S16), Patna (S17), Barh (S18), Bahachoki (S19), and Farka (S20). In Jharkhand, the collection site was limited to Sahibganj (S21), while West Bengal encompassed Farraka (S22), Hazarduari (S23), Mayapur (S24), Hoogly (S25), and Gangasagar (S26). The soil sampling procedure involved careful excavation around plant roots to a depth of 15 cm using a tool. Subsequently, a 100-gm wet soil specimen was delicately collected on paper from this depth and placed in an open area for drying under a fan. After 30 minutes, the soil achieved moisture-free status, underwent meticulous debris removal, and fine soil separation from the residue using filter paper.


GPS Map Camera
Bithoor, Uttar Pradesh, India
J79H+29C Bithoor Ganga Bridge, Pariyar Road, Bithoor, Uttar Pradesh 209203, India
Lat 26.61587°
Long 80.276986°
22/03/23 01:31 PM GMT +05:30
Google
GPS Map Camera
जैतिया, बिहार, भारत
P44J+56X, जैतिया, बिहार 841101, भारत
Lat 25.705137°
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जैतिया, बिहार, भारत
P44J+56X, जैतिया, बिहार 841101, भारत
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Rudrapara P, West Bengal, India
C97J+C86, Rudrapara P, West Bengal 741302, India
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Mahatma Gandhi Setu, Muzafferpur Patna Marg, Mahatma Gandhi Setu, Patna, Bihar 844101, India
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Long 85.210166°
17/03/23 07:54 AM GMT +05:30
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GPS Map Camera
Bhatpara, West Bengal, India
R9XQ+RV4, Jagatdal, Bhatpara, West Bengal 743125, India
Lat 22.849128°
Long 88.389503°
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GPS Map Camera
Bhatpara, West Bengal, India
V98Q+M5G, ESD Machinery, Jagatdal, Bhatpara, West Bengal 743132, India
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Long 88.387778°
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Patna, Bihar, India
Mahatma Gandhi Setu, Muzafferpur Patna Marg, Mahatma Gandhi Setu, Patna, Bihar 844101, India
Lat 25.63132°
Long 85.210168°
17/03/23 07:54 AM GMT +05:30
Google

Table 8.3 Site name with their Latitude and Longitude

S.No.	States	Nearby Location	Site Code	Latitude (°N)	Longitude(°E)
1.	Uttarakhand	Devprayag	S4	30.13581	81.12184
2.		Haridwar	S5	29.91694	81.53151
3.	Uttar Pradesh	Bijnor	S6	29.28574	82.32432
4.		Narora	S7	28.14650	83.13147
5.		Badaun	S8	27.93941	83.56120
6.		Farrukhabad	S9	27.41044	84.49599
7.		Bithoor	S10	26.61589	85.12415
8.		Dalmau	S11	26.34853	85.59791
9.		Prayagraj	S12	25.25373	86.20763
10.		Mirzapur	S13	25.85879	87.09083
11.		Varanasi	S14	25.15181	87.39595
12.		Ballia	S15	25.35455	87.91067
13.	Bihar	Revelganj	S16	25.43876	88.22134
14.		Patna	S17	25.38077	88.38087
15.		Barh	S18	25.23107	88.38949
16.		Bahachoki	S19	25.17823	88.19586
17.		Farka	S20	25.23225	78.85346
18.	Jharkhand	Sahibganj	S21	25.14606	79.62818
19.	West Bengal	Farraka	S22	24.82274	80.27700
20.		Hazarduari	S23	23.99688	81.12184
21.		Mayapur	S24	23.41293	81.53151
22.		Hooghly	S25	22.84913	82.32432
23.		Gangasagar	S26	22.17743	83.13147

CULTIVATION OF BACTERIAL POPULATION

Cultivable rhizosphere bacterial populations represent a key component of the intricate web of interactions that occur within the rhizosphere, the soil zone surrounding plant roots. This dynamic microbial community is characterized by its cultivability, implying that these bacteria can be isolated and grown in laboratory conditions. The study of cultivable rhizosphere bacteria is essential for unraveling the multifaceted roles they play in supporting plant health and influencing various ecological processes (Hakim et al., 2021). The rhizosphere serves as a hotspot for microbial activity due to the release of root exudates, organic compounds released by plant roots. These exudates attract and sustain a diverse array of bacteria, forming a unique and dynamic ecosystem. Cultivable rhizosphere bacteria, once isolated and studied, provide valuable insights into the functional diversity of this microbial community. Researchers can explore their metabolic capabilities, nutrient-cycling activities, and interactions with plants. Understanding cultivable rhizosphere bacterial populations has practical implications for agriculture, as these bacteria play pivotal roles in nutrient mobilization and acquisition, disease suppression, and the promotion of plant growth. Moreover, the cultivation and study of these bacteria contribute to the development of bio-fertilizers and microbial-based solutions for sustainable agriculture (Mendes et al., 2013). The cultivable rhizosphere bacterial population's exploration not only sheds light on their ecological significance but also unveils their potential applications in various fields, including agriculture, environmental management, and biotechnology. As we delve deeper into the intricacies of these microbial communities, we gain valuable knowledge that can be harnessed for optimizing plant-microbe interactions and fostering more sustainable and resilient agricultural practices (Gao et al., 2019). The culture media and instruments used for the isolation of bacteria are depicted in Tables 8. 4 and 8. 5.

Table 8.4 **Culture Mediums Used for cultivation of Bacteria**

Name of the culture media	Constituents	Make	Purpose of Using the media	Incubation Temp and Duration	Expected outcome	Reference
Nutrient Agar	Peptone, Beef Extract, Agar, Sodium Chloride, and Yeast extract	HiMedia (M002)	Total Bacterial Count **(TBC)**.	37°C and 16 hr	Turbidity indicates bacterial growth; no turbidity indicates no growth Gray white, round, completely hemolytic, opaque, flat, drying, medium-sized colony.	(Ma, Q et al., 2023)
MacConkey Agar	Peptone, Lactose, Bile Salts, Neutral Red and Agar	HiMedia (M008S)	Total Feacal Count **(FC)**.	30 °C and 48 days	Lactose-fermenting bacteria produce pink colonies, and non-lactose fermenting produces colorless colonies.	(Jung, B., and Hoilat, G. J. 2022)
Eosin methylene Agar	Peptic digest of animal tissue, Dipotassium phosphate Peptone, Lactose, Eosin Y, and Methylene Blue and Agar	HiMedia (M317)	Fecal Coliform **(TC)**.	30 °C and 2 days	E. coli produces a green metallic sheen, and other lactose-fermenting bacteria produce pink colonies.	(Lal, A., & Cheeptham, N. 2007)
Aleksandrow Medium	Magnesium sulfate, Calcium carbonate, Potassium aluminum silicate, Dextrose (Glucose), Ferric chloride, Calcium phosphate and Agar	HiMedia (M1997)	Potassium-Mobilizer Bacteria **(PMB)**.	30 °C and 7 days	Growth of bacteria indicated by the presence of colonies on the agar Color of colonies, pigmentation: white, buff, red, purple.	(Singh et al., 2018)

Name of the culture media	Constituents	Make	Purpose of Using the media	Incubation Temp and Duration	Expected outcome	Reference
Zinc Solubilizing Medium	Dextrose (Glucose), Ammonium sulphate, Potassium chloride, Dipotassium hydrogen phosphate, Magnesium sulphate, heptahydrate and Zinc oxide	HiMedia (M2023)	Zinc Solubilizing Bacteria **(ZSB)**.	28±2 °C and 14 days	Clear zones around colonies indicate zinc solubilization, Cream to white homogeneous free-flowing powder.	(Yasmin et al., 2021)
Rhizobium Medium	Yeast extract, Mannitol, Dipotassium phosphate, Magnesium sulphate, Sodium chloride, Congo red and Agar	HiMedia (M408)	Rhizobium Bacteria **(RZB)**.	28±2 °C and 5 days	Growth of Rhizobium bacteria indicated by the presence of colonies on the agar yellow with creamy margins, convex, round.	(Koskey et al., 2018)
Azotobacter Agar	Magnesium sulphate, Sodium chloride, Ferrous sulphate, Soil extract, Mannitol and Agar	HiMedia (M1944)	Azotobacter Bacteria **(AZB)**.	28±2 °C and 6 days	Growth of Azotobacter indicated by the presence of colonies on the agar flat, slimy, paste-like colonies	(Sumbul et al., 2020)

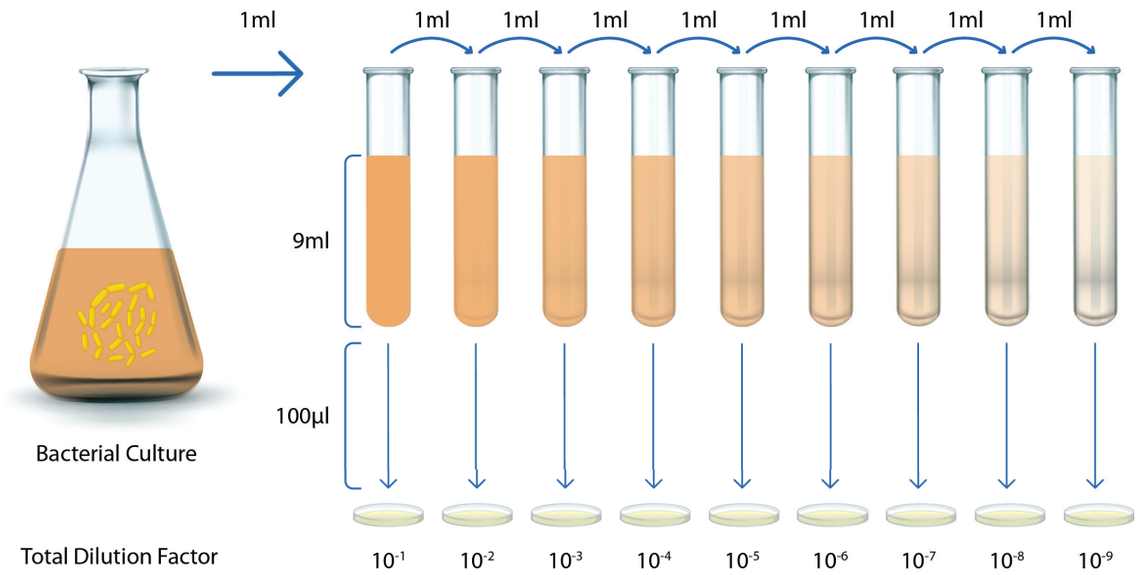
Name of the culture media	Constituents	Make	Purpose of Using the media	Incubation Temp and Duration	Expected outcome	Reference
Azospirillum Medium w/o Agar	**Part A:** Malic acid, Dipotassium hydrogen phosphate, Ferrous sulphate, Manganese sulphate, Magnesium sulphate, Sodium chloride, Bromo thymol blue, Sodium molybdate, Calcium chloride and Agar **Part B:** Potassium hydroxide	HiMedia (M1720- + M1720)	Azospirillum bacteria **(AZO)**.	36±1 °C and 6 days	Growth of Azospirillum indicated by the presence of colonies on the agar colonies with flat morphology, glossy, large, scarlet-red coloring, with circular and regular edges.	(Hong, et al., 2019)
Pikovskaya's Broth	Yeast Extract, Dextrose, Calcium Phosphate, Ammonium Sulphate, Potassium Chloride, Magnesium Sulphate, Manganese Sulphate, Ferrous Sulphate and Agar	HiMedia (GM1719)	Phosphate-Solubilizing Bacteria (KSB).	28±2 °C and 14 days	Clearing around colonies indicates phosphate solubilisation, White to light yellow homogeneous free-flowing powder.	(Gupta et al., 2022)

Table 8.5 Instruments used in execution of the study.

Name	Make	Purpose	Working Operation
Laminar Airflow	Harrison's Pharma Machinery	Provides a sterile work environment	Uses a continuous, unidirectional flow of HEPA filtered air
Autoclave	Salvesion Pharma	Sterilization of equipment and media	Uses high-pressure steam to kill microorganisms at (121°C, 15 lb pressure for 15 minutes)
BOD Incubator	Meditech Technologies India Private Limited	Biochemical Oxygen Demand (BOD) testing	Maintains controlled temperature (37°C) for microbial growth
Incubator-Shaker	Biogen scientific	Agitation of liquids for culturing	Oscillating or orbital motion to promote cell growth
Colony counter	Prime Vidyo udyog (India)	Enumeration of microbial colonies	Facilitates manual or automated counting of colonies
Hot air oven	Prime Vidyo udyog (India)	Sterilization and drying of glassware	Uses dry heat to achieve high-temperature sterilization (1.5 to 2 hours at 160 °C (320 °F) 6 to 12 minutes at 190 °C (374 °F)).
Refrigerator	Celfrost Middle by Company USA	Storage of samples, reagents, and cultures	Maintains (4°C) low temperatures for sample preservation
Digital Weighing balance	Contech	Accurate measurement of mass	Utilizes digital sensors and displays for precise weighing

QUANTIFICATION OF CULTIVABLE BACTERIAL CONCENTRATION

The quantification of cultivable bacterial concentration through Colony Forming Units (CFU) involves the use of culture-based counting methods. The standard unit of measure for CFU is the number of culturable bacteria present per 1 mL of culture (CFU/mL) determined by serial dilution and spread plating techniques. This method provides a direct measurement of bacterial cell counts and is achieved by performing a 1:10 dilution series (10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6}) of the batch culture and spread plating a specific volume of each dilution. CFU counting tends to undercount the actual number of bacteria, as it only detects those that can grow on specific solid media, excluding unculturable, live, inactive, or damaged bacterial cells. Therefore, while CFU enumeration is a widely used method, it has limitations in capturing the total bacterial population as depicted in Fig 8.1 (Van Alst et al., 2016).



$$\text{Colony Forming Units per ml (CFU/ml)} = \frac{\text{Number of Colonies}}{\text{Total Dilution Factor}}$$

Fig. 8.1 Serial dilution method for cultivation & quantification Bacteria

METHODOLOGY ADOPTED FOR THE CULTIVATION OF BACTERIA

The bacterial concentration has been measured by the standard method of the American Society of Microbiology (Reynolds, 2005). Briefly, the protocol has been stated below.

1. Dilute the batch culture through serial dilutions of 1:10 by transferring 1 mL of the previous dilution into the subsequent tube containing 9 mL of sterile, distilled water
2. Pipette and spread 100 µL onto agar plates of the correct growth medium using a cell spreader 3. Label plates with the Dilution Factor (DF) and incubate overnight (or as necessary).

(DF = total volume of dilution/ sample volume)

1. Choose a plate with a reasonable number of colonies (between 30 and 300 colonies)
2. Time to do some cell counting! Count how many colonies you can see on each plate.
3. Once you have the CFU for each plate, perform the following calculations:

Volume plated (mL) x DF of the plate = Total Dilution Factor

Number of colonies counted (CFU) / Total Dilution Factor =

Total CFU / mL

4. All the calculated CFU values were converted to Log_{10} values, such as Log_{10} $(3x10^6) = 18$

Results and Discussion

The results and discussion section of obtained cultivable bacteria and their features have been represented statewise. In the present study, there were 26 sites dispersed in five states (Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal).

01



16
Total Rhizosphere Soil Collection

02



6.94 CFU/ml
Average Rhizosphere Bacterial Concentration

03



***Solanum nigrum* L.**
Maximum Bacteria Found

04



4.82 CFU/ml
Average Rhizosphere Pathogenic Bacteria Concentration

05



1.3
Benficial Bacteria Ratio Total



UTTARAKHAND



According to the search results, several studies have reported the presence of rhizosphere bacteria in Uttarakhand, India. One study isolated Bacillus strains from the rhizosphere of a common bacteria growing in Uttarakhand Himalaya, which showed potential plant growth-promoting properties (Kumar et al., 2012). Another study explored soil bacterial diversity in different micro-vegetational habitats of Dachigam National Park in North-western Himalaya and identified certain species of Bacillus in the soil (Mushtaq et al., 2023) A comparative analysis of rhizospheric bacteria associated with four amla plant soils in Uttarakhand was also undertaken (Jyotirmayee et al., 2021). Additionally, a study isolated a *Pseudomonas* sp. from the rhizospheric soil of a medicinal plant Bergenia ciliata from Uttarakhand (Thakur et al., 2023). Finally, a study characterized bacterial cultures isolated from hot springs in Uttarakhand, including Bacillus and Paenibacillus species (Pandey et al., 2015).

Selected Sites: S4 (Devprayag) and S5 (Haridwar).

Plants Collected: Total 10 plant is collected *Achyranthes aspera* L., *Croton bonplandianus* Baill., *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Solanum nigrum* L., *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn, *Tridax procumbens* L., and *Boerhavia diffusa* L.

In the context of Uttarakhand's rich botanical diversity, the presence of various medicinal plants, including *Achyranthes aspera* L., *Croton bonplandianus* Baill., *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Solanum nigrum* L., *Terminalia arjuna* R.Br. (Roxb. ex DC.) Wight & Arn, *Tridax procumbens* L., and *Boerhavia diffusa* L. were investigated. These plant species are notably distributed across different ecological niches within the region. *Achyranthes aspera*, commonly known as Prickly Chaff Flower, is obtained in diverse habitats, from plains to hilly regions (Mengie et al., 2021; Soorgani, N. R., 2023). *Croton bonplandianus*, recognized for its therapeutic properties, is prevalent in lower altitudes. *Cynodon dactylon*., or Bermuda Grass, is ubiquitous in both cultivated and uncultivated areas (Ghosh, T., 2018; Dutta, S., and Chaudhuri, T. K. 2018).) *Ficus racemosa*, *Polygonum plebeium*, *Ricinus communis*, *Solanum nigrum*, *Terminalia arjuna*, *Tridax procumbens*, and *Boerhavia diffusa* exhibit adaptability to varied elevations, showcasing their resilience across Uttarakhand's diverse landscapes. This distribution and adaptability underscore the ecological significance of these plants and form the basis for further exploration of their medicinal properties, ecological roles, and potential applications in traditional and modern healthcare practices (Nagori, B. P., and Solanki, R. 2011 and Ahmed, F., and Urooj, A. 2010).) The rhizospheric bacteria were Isolated and colony morphology was identified. Nine distinct bacteria were identified from a soil sample collected in various locations (ur Rehman et al, 2018). Different bacteria, including total bacterial count, total fecal and coliform bacteria, Zinc-solubilizers, Rhizobium, *Azotobacer*, *Azospirillum*, potash mobilizers, and Phosphate-solubilizers, are

isolated using different media. The distinct strains of isolated bacteria have different colony morphologies, such as cream-colored, white colonies with smooth, wavy, and branching margins, green colonies with a metallic sheen, and red colonies with some bacteria-producing zones that show an inhibition zone (Ahsan et al., 2018).

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Achyranthes aspera* L.

Achyranthes aspera is a highly medicinal plant known for its microbial content and its given value expressed in Log_{10}. In S5 (Haridwar), there is an observed higher total bacterial count (8.47)], indicating a potentially more abundant microbial presence. The elevated total coliform counts (4) raise concerns about potential contamination. The increased counts of *Azotobacter* (7.52) and *Rhizobium* (7.50) suggest an enhanced capacity for nitrogen fixation, contributing to improved soil fertility. Moreover, the higher count of potash-mobilizing bacteria (3.47) may contribute to an augmented availability of potassium in the soil. The phosphate-solubilizing bacteria, with a count of (3.60), may enhance phosphate availability in the soil as shown in Fig 8.2. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

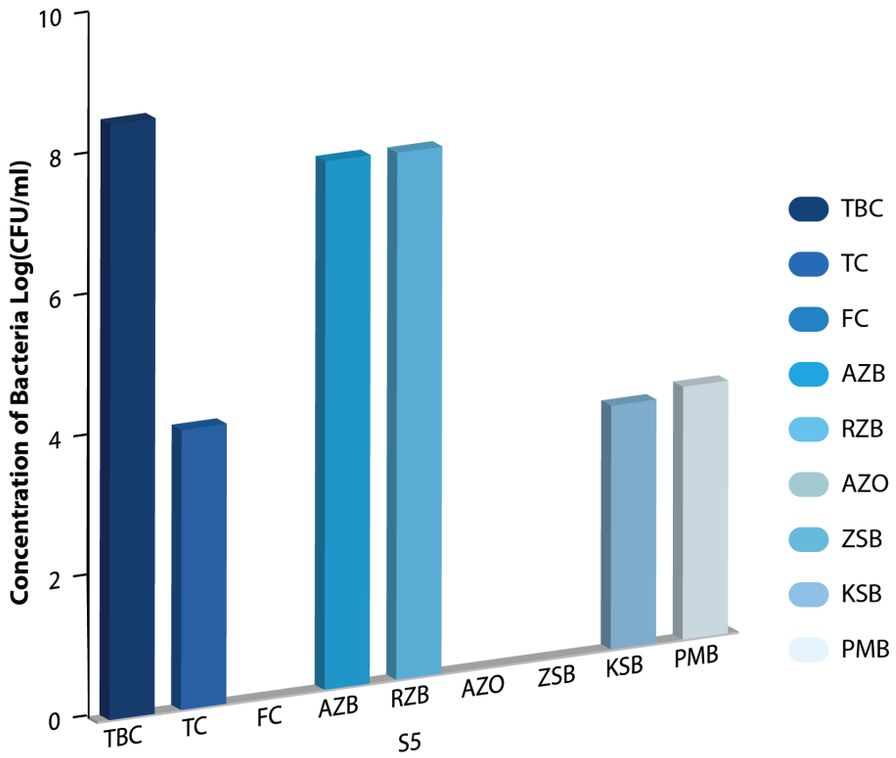


Fig. 8.2 Total and differential bacterial count of *Achyranthes aspera* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Croton bonplandianus* Baill.

The highly therapeutic plant *Croton bonplandianus* Baill. has a high microbial content as shown in Fig. 8.3. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

The higher total bacterial count of (4.29) in S5 (Haridwar), suggests a possible higher microbial presence. Concerns regarding water quality are highlighted by a reported fecal coliform count of (3.18), and elevated total coliform counts (3.18) that suggest the possibility of contamination. Improved soil fertility is suggested by the higher *Azotobacter* (3.60) and *Rhizobium* (7.70) counts, which indicate improved nitrogen-fixing abilities. Additionally, the soil may contain more potassium due to the higher count of potash-mobilizing bacteria (4.47) and more phosphate due to the higher count of phosphate-solubilizing bacteria (5.43), and all values are expressed in $Log_{10.}$

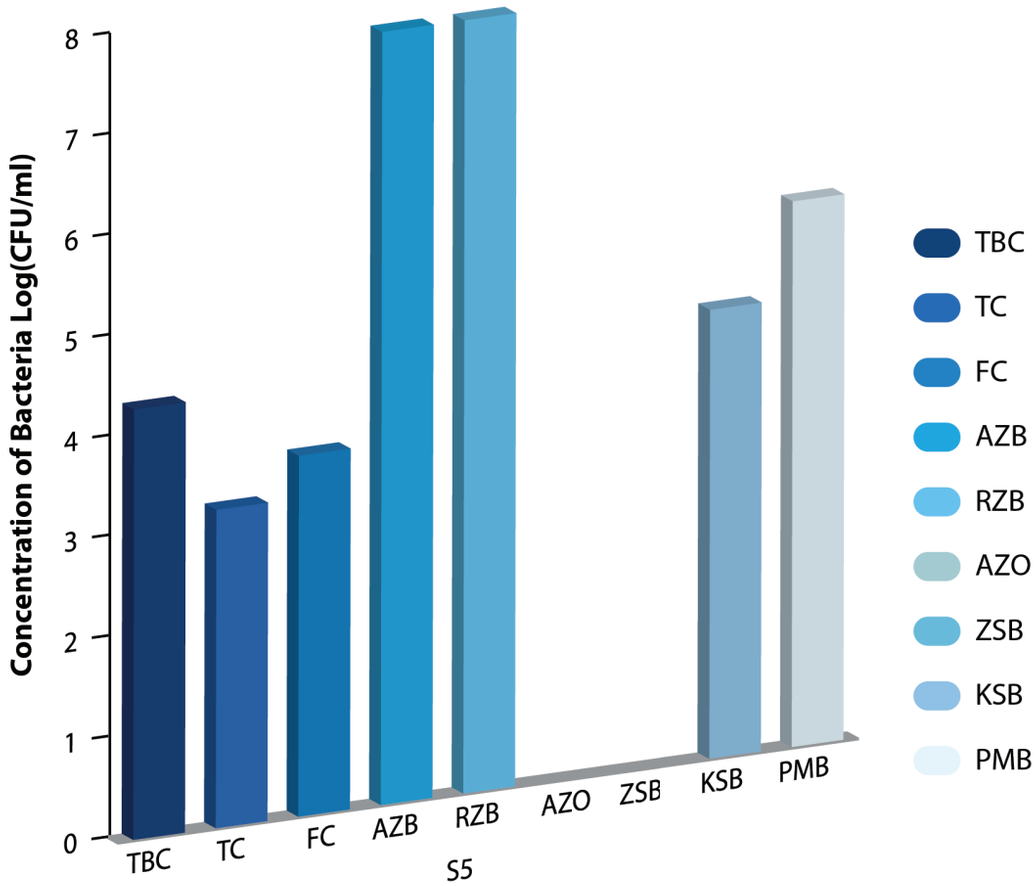


Fig. 8.3 Total and differential bacterial count of *Croton bonplandianus* Baill.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Cynodon dactylon* (L.) Pers.

Significant differences in microbial counts between S5 (Haridwar) and S4 (Devprayag) in *Cynodon dactylon* (L.) Pers. as shown in Fig.8.4. and given values expressed in $Log_{10.}$ The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

S5 exhibits a higher total bacterial count (7.38) compared to S4 (4.83), indicative of a potentially greater microbial presence in S5. Elevated total coliform counts (7.33) in S5 suggest the possibility of contamination. Furthermore, S5 reports a fecal coliform count of (3.10), emphasizing potential water quality concerns. The higher counts of *Azotobacter* (8.19) and *Rhizobium* (8.37) in S5 compared to S4 (Azotobacter: 6.17, Rhizobia: 7.94) suggest enhanced nitrogen-fixing capabilities, contributing to improved soil fertility. Additionally, a higher count of *Azospirillum* (5.77) in S5 indicates potential benefits for plant growth. The zinc-solubilizing bacteria count (1.72) in S5 suggests a role in making zinc available to plants, while the higher potash-solubilizing bacteria count (4.40) may contribute to increased potassium availability in soil. Higher counts of beneficial bacteria in S5, such as *Azotobacter* and *Rhizobium*, could contribute to improved soil fertility. However, the absence of certain data for S4 limits a comprehensive comparison.

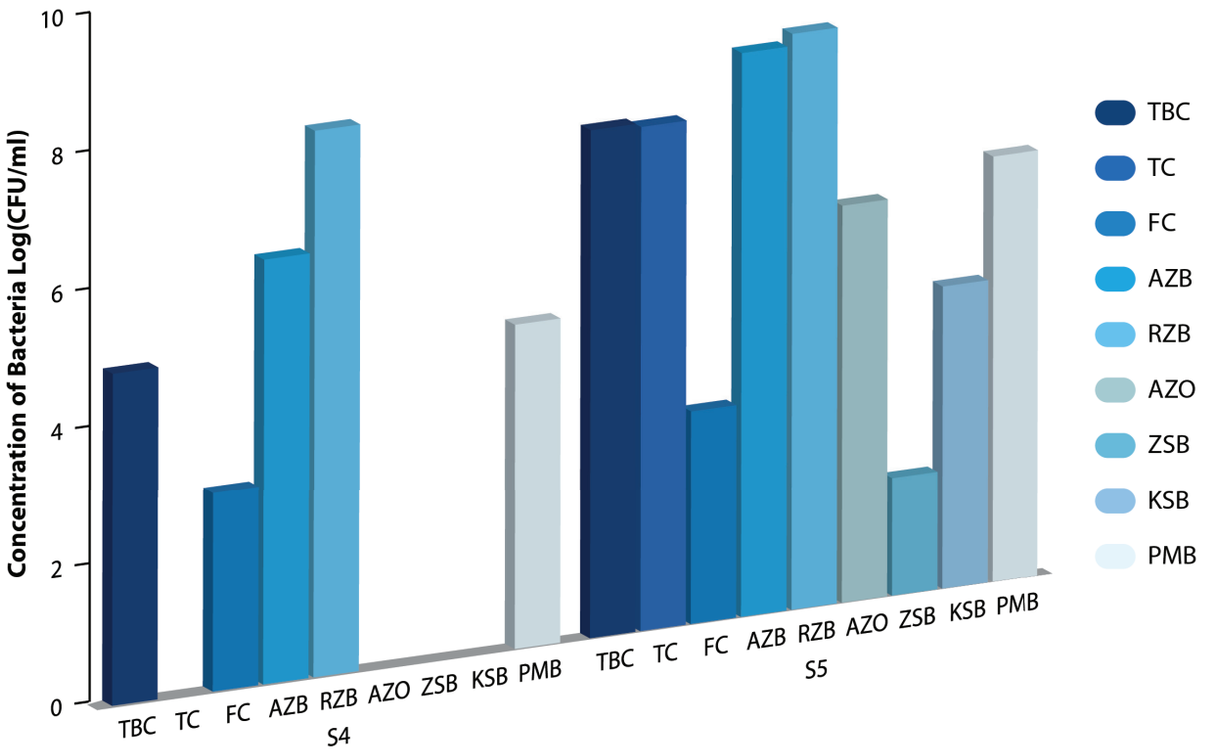


Fig. 8.4 Total and differential bacterial count of *Cynodon dactylon* (L.) Pers.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Ficus racemose* L.

A highly medicinal plant with microbial properties is *Ficus racemose* L. S5 (Haridwar), which has a higher total bacterial count of (5.40), which suggests that there may be more microbes there. Increased levels of total coliform (3.30) indicate a potential for contamination. S5 also reports a fecal coliform count of (3.69), highlighting possible issues with the quality of the water. Increased nitrogen-fixing capacity is suggested by the higher *Azotobacter* (4.70) and *Rhizobium* (5.34) counts, which improve soil fertility. Furthermore, a higher *Azospirillum* count (3.17) in S5 suggests possible advantages for plant growth. Furthermore, the higher potash-mobilize bacteria count (4.23) might be a factor in the soil's increased potassium availability. The higher phosphate availability in soil may be attributed to the Phosphate solubilizing bacteria of (2.95) as shown in Fig. 8.5 and their value expressed in $Log_{10.}$ The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

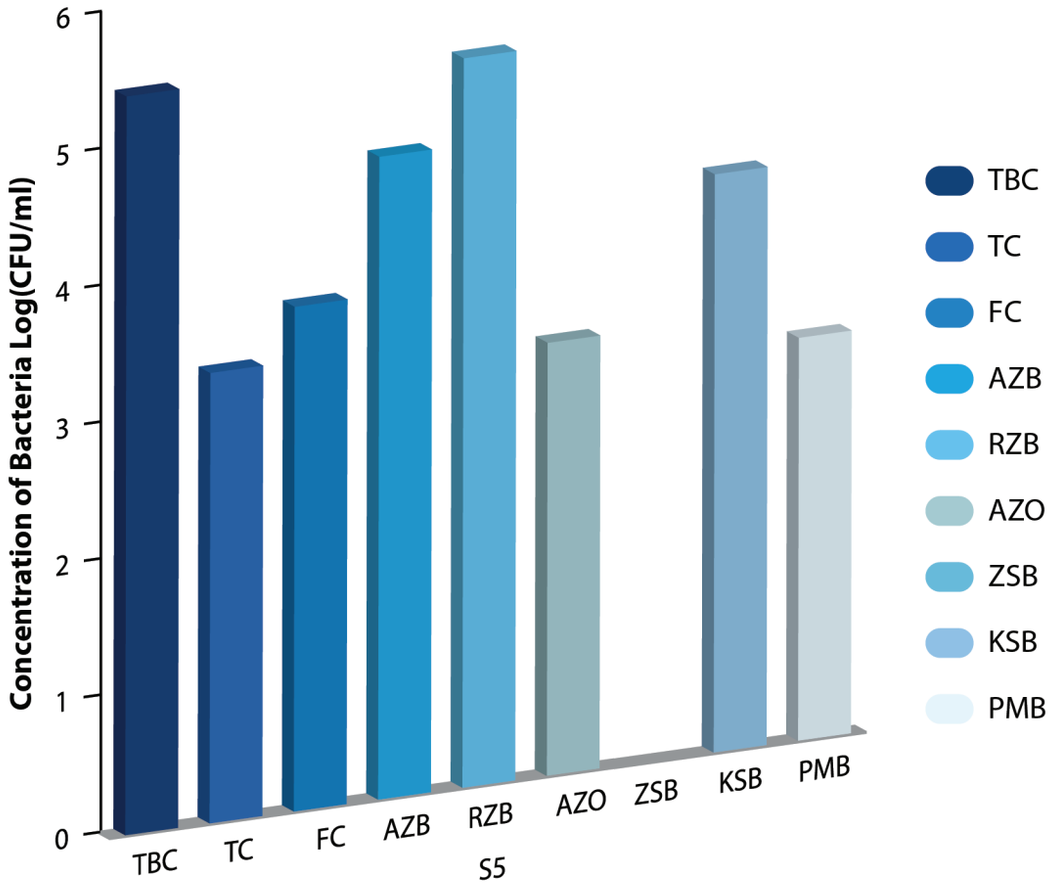


Fig. 8.5 Total and differential bacterial count of *Ficus racemose* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Polygonum plebeium* R.Br.

Research from S4 (Devprayag) and S5 (Haridwar), offers fascinating new perspectives on the microbial ecology of *Polygonum plebeium* R.Br. as shown in Fig. 8.6 and values mentioned in $Log_{10.}$ The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

Compared to S4 (7.69), S5 has a slightly higher total bacterial count (8.13), indicating a comparatively richer microbial presence. Significantly lower than in S4 (Total Coliform: 6.67, Fecal Coliform: 6.75) are the counts of total and fecal coliform in S5 (Total Coliform: 3.77, Fecal Coliform: 3.77), suggesting that contamination levels may be lower there. S4 has marginally higher concentrations of advantageous bacteria, such as *Rhizobium* and *Azotobacter*, which suggests a higher capacity for nitrogen fixation. *Azospirillum* is a plant growth-promoting bacterium that is obtained in greater abundance in S4 (5.78) than in S5 (4.53). Zinc-solubilizing bacteria counts are comparable, while S4 has higher counts of potash mobilizers and phosphate-solubilizing bacteria.

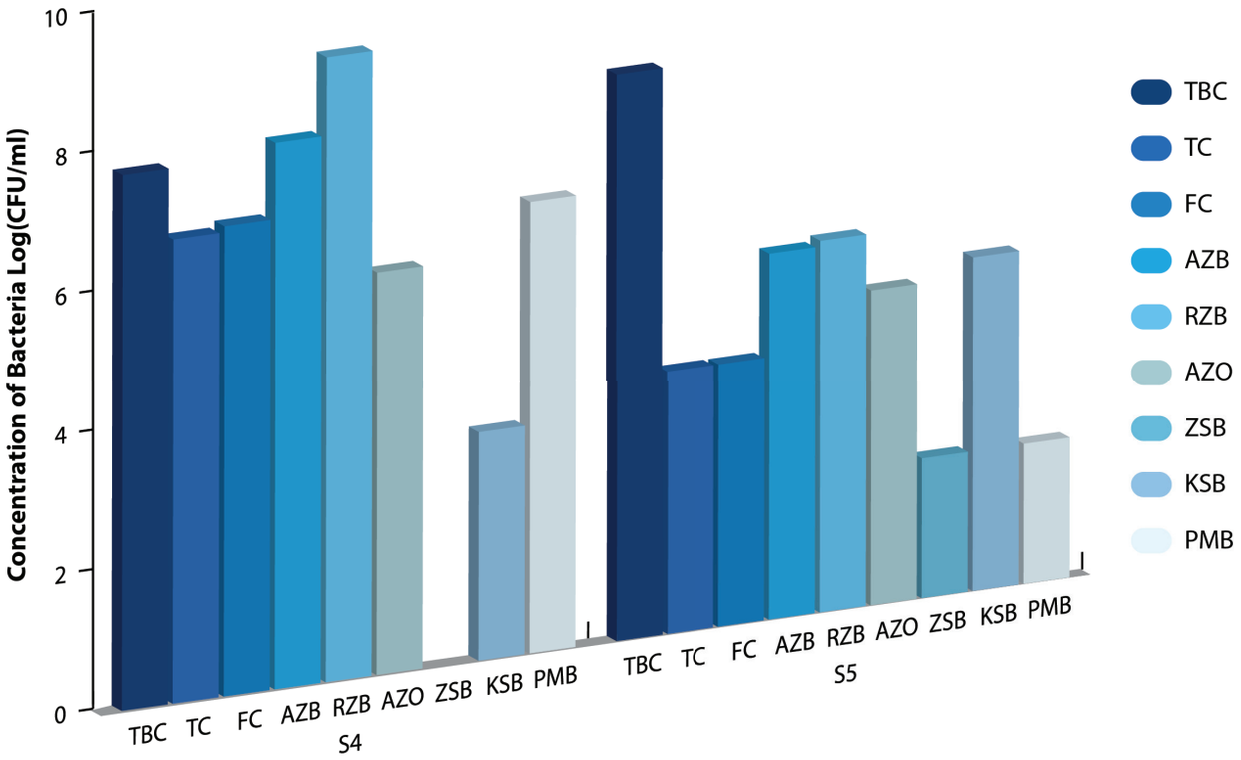


Fig. 8.6 Total and differential bacterial count of *Polygonum plebeium* R.Br.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Ricinus communis* L.

Significant differences in the soil microbiota are revealed by the scientific study of *Ricinus communis* L. in S4 (Devprayag) and S5 (Haridwar), based on the supplied microbial data as shown in Fig. 8.7. and values mentioned in $Log_{10.}$ The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

In comparison to S4 (8.15), S5 has a slightly higher total bacterial count (8.28), indicating a slightly more abundant microbial presence. There may be variations in contamination levels in S5 as evidenced by the slightly higher total and fecal coliform counts (6.16). Notably, significant populations of advantageous bacteria, like *Rhizobia* and *Azotobacter*, which are important for nitrogen fixation and soil fertility, are obtained in both regions. Higher levels of *Azospirillum*, a bacterium known to stimulate plant growth, have been obtained in S5, suggesting possible benefits for plant health. Variations in the availability of nutrients are indicated by the presence of bacteria that can dissolve zinc in S4 and potash in S5.

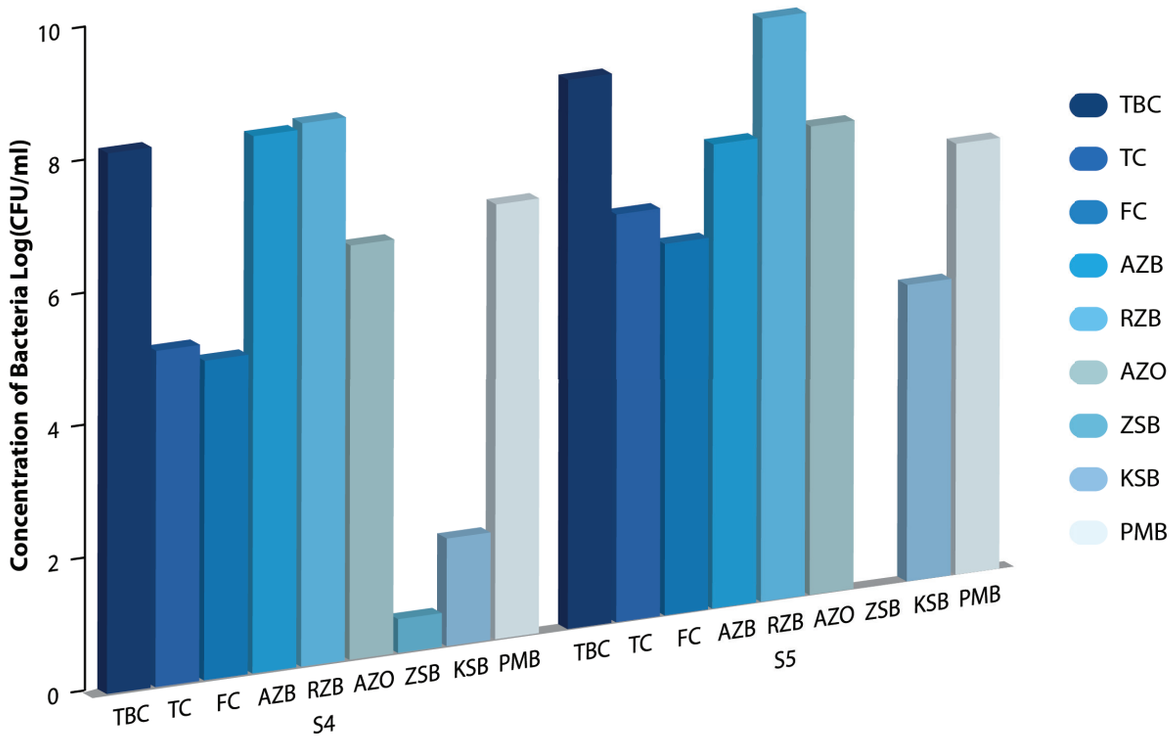


Fig. 8.7 Total and differential bacterial count of *Ricinus communis* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn.

A highly beneficial plant with microbiological properties is *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn. as shown in Fig.8.8. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

There may be more microorganisms in S5 (Haridwar), because of its higher total bacterial count of (6.722). The fecal coliform count of (4.18) reported by S5 further highlights possible issues with water quality. An increase in *Rhizobium* (6.72) and *Azotobacter* (8.21) counts suggests that the soil is more capable of fixing nitrogen, which improves fertility.

Furthermore, the increased availability of potassium in soil may be attributed to the higher potash-mobilize bacteria count (3.247). Phosphate availability in soil may be enhanced by the Phosphate solubilizing bacteria, which has a (6.34) pH value for all the given values expressed in $Log_{10.}$

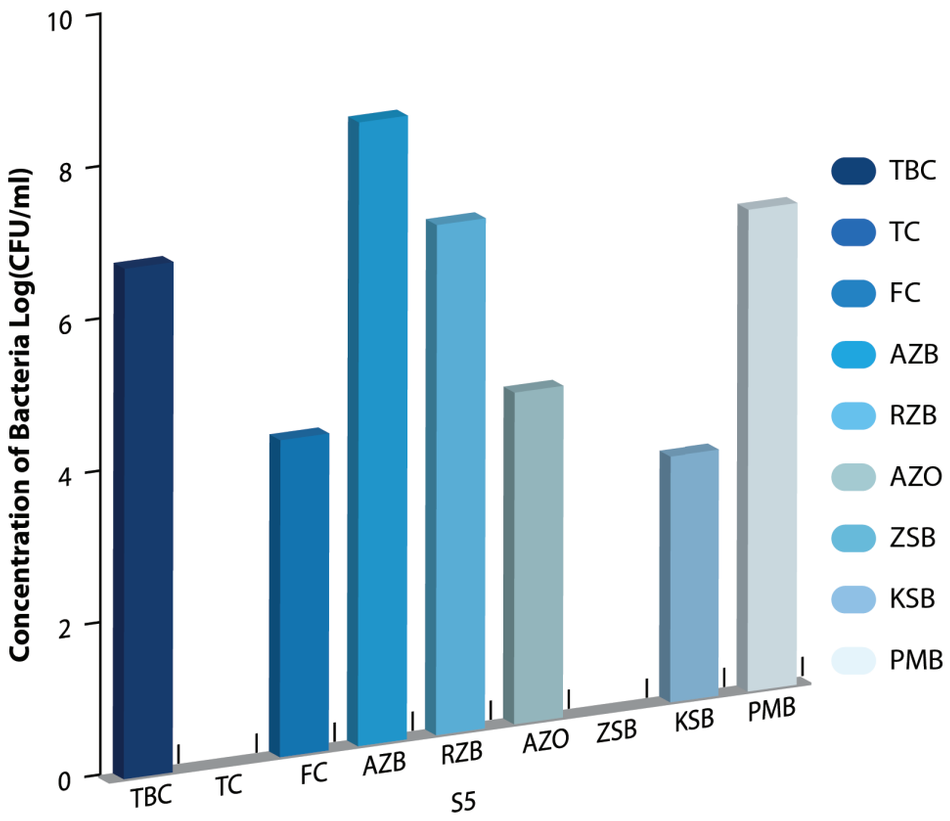


Fig. 8.8 Total and differential bacterial count of *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Tridax procumbens* L.

Based on the available microbial data, the scientific evaluation of *Tridax procumbens* L. in S4 and S5 (Haridwar), reveals different microbial compositions in these areas as shown in Fig 8.9 and values given in Log_{10}. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

Although there are notable differences in other parameters, the total counts of bacteria between S4 (6.77) and S5 (6.84) are comparable. In comparison to S5 (6.01), S4 exhibits a lower total coliform count (3.72), which may indicate lower levels of contamination in S4. The presence of fecal coliform counts (5.72) in S5 alone suggests that fecal contamination may exist in this area. S4 (8.90) has higher levels of *Azotobacter* than S5 (5.97), indicating differences in the nitrogen-fixing bacteria that support soil fertility. S4 has somewhat higher *Rhizobium* counts, which may indicate that legumes have a higher capacity for fixing nitrogen. *Azospirillum*, known for promoting plant growth, exhibits comparable counts in both regions. Zinc-sulfate bacteria are more abundant in S4, whereas S5 shows higher counts of potash-solubilizing bacteria.

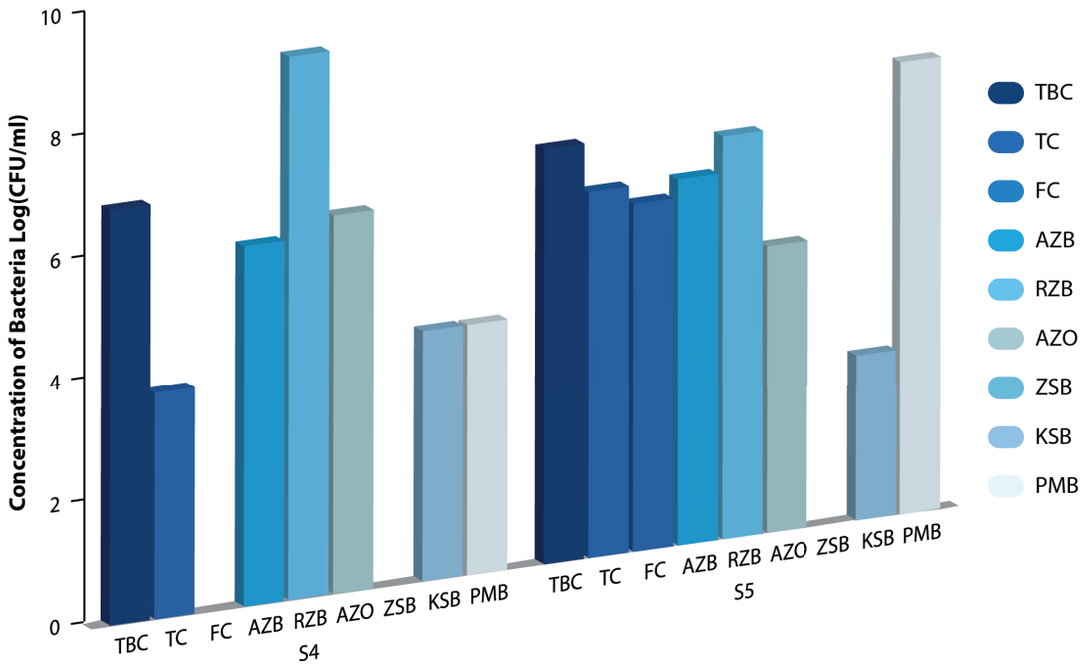


Fig. 8.9 Total and differential bacterial count of *Tridax procumbens* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Boerhavia diffusa* L.

The analysis of *Boerhavia diffusa* L. in S4 and S5 (Haridwar), based on the provided microbial data shows distinct patterns in microbial communities as shown in Fig. 8.10. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

S4 exhibits a higher total bacterial count (6.99) compared to S5 (4.93), indicating a potentially more diverse microbial population in S4. The absence of fecal coliform data in S4 and the presence of fecal coliforms in S5 (5.51) may suggest potential contamination issues in S5. *Azotobacter* counts are slightly higher in S4 (5.96) than in S5 (6.43), indicating comparable nitrogen-fixing capabilities in both regions.

Rhizobium counts are notably higher in S4 (8.02), suggesting a potentially more favorable environment for nitrogen fixation in legumes. *Azospirillum* shows higher counts in S4 (7.23) compared to S5 (2.52), and zinc-sulfate bacteria counts are also higher in S4, while S5 exhibits higher counts of potash-solubilizing bacteria and values are mentioned in Log_{10}.

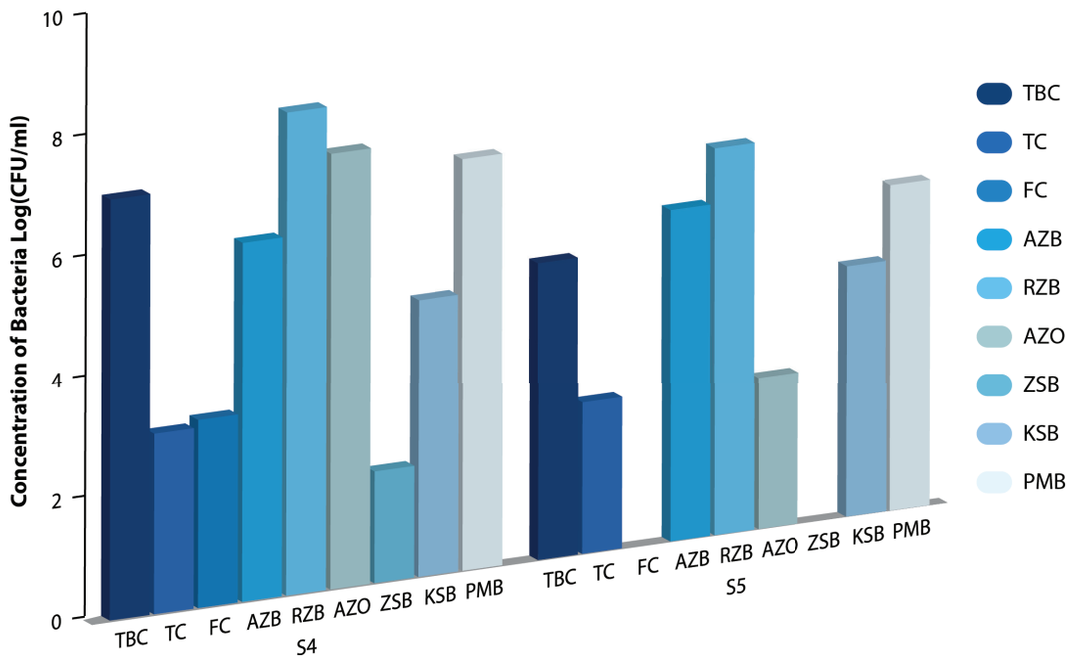


Fig. 8.10 Total and differential bacterial count of *Boerhavia diffusa* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Solanum nigrum* L.

The microbial analysis of *Solanum nigrum* L. in states S4 and S5 (Haridwar), reveals distinctive characteristics in the soil composition as shown in Fig. 8.11. and their value is given in Log_{10}. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

S4 exhibits a higher total bacterial count of (8.91) compared to S5 with a count of (7.16), indicating a potentially richer microbial community in S4. The absence of total coliform count in S5 and the presence of fecal coliforms in S4 (3.60) suggest variations in contamination levels between the two states. S4 shows notable counts of *Azotobacter* (7.58) and *Rhizobium* (7.87), indicating robust nitrogen-fixing capabilities that contribute to enhanced soil fertility. *Azospirillum* counts are similar in both states, suggesting comparable contributions to plant growth promotion. Zinc sulfate bacteria, with a count of (1) in S4, may play a role in zinc availability, while S5 exhibits a higher count of potash-solubilizing bacteria (6.52), contributing to increased potassium availability in the soil. Phosphate-solubilizing bacteria, with counts of (4.15) in S4 and (4.27) in S5, may enhance phosphate availability in the soil.

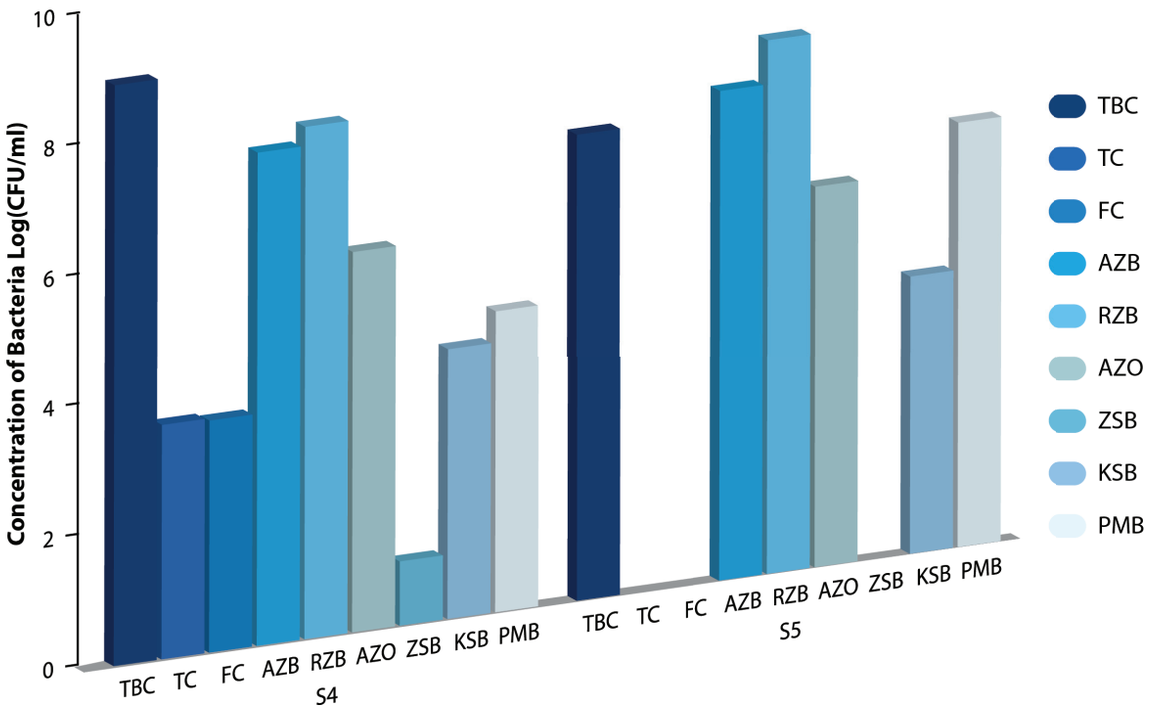


Fig. 8.11 Total and differential bacterial count of *Solanum nigrum* L.

Below, in Fig. 8.12, are some representative images of the isolated bacteria from the selected Uttarakhand sites.

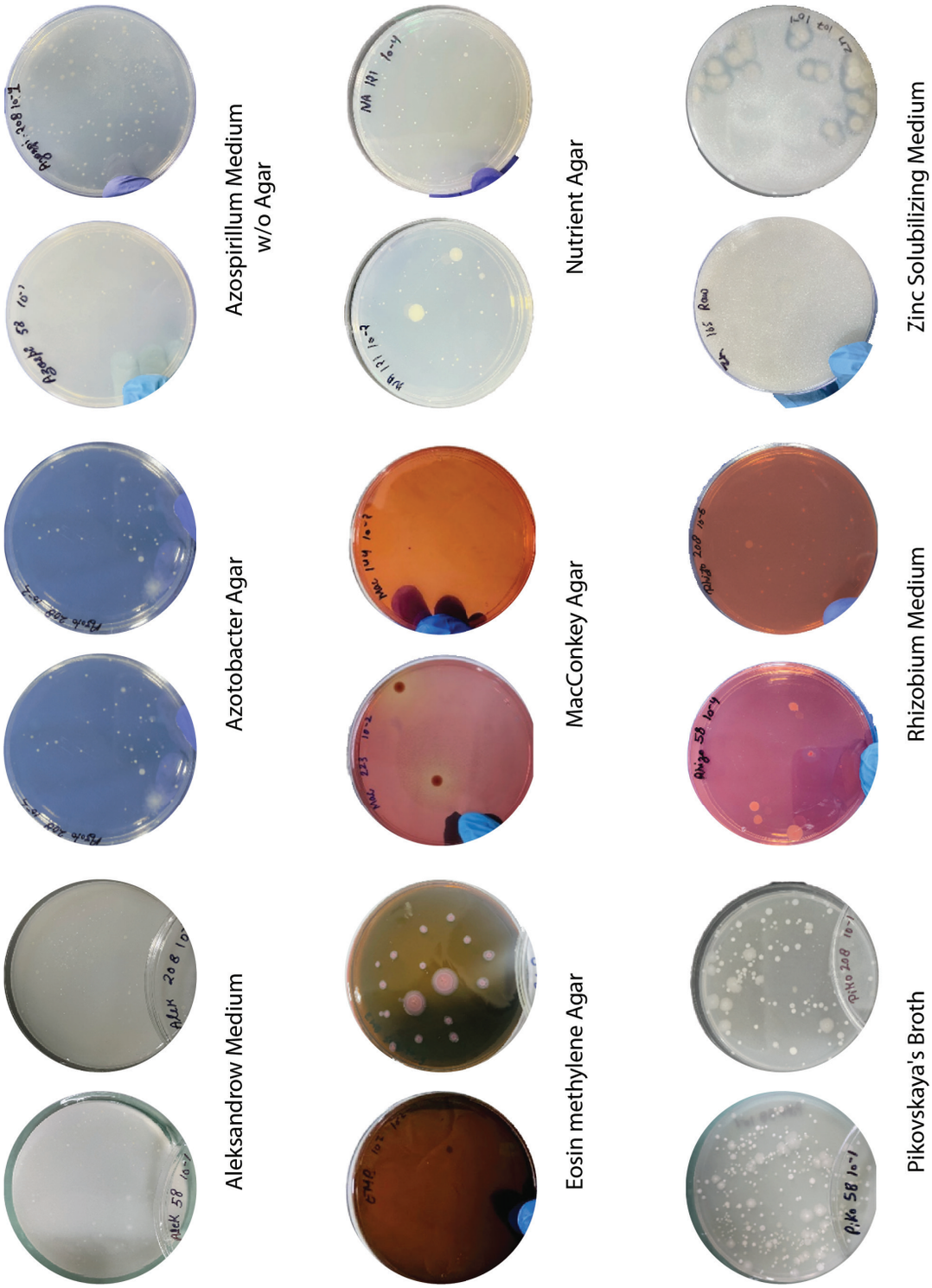


Fig. 8.12 Representative pictures of the isolated bacteria of Uttarakhand



01



85
Total Rhizosphere Soil Collection

02



6.46CFU/ml
Average Rhizosphere Bacterial Concentration

03



***Achyranthes aspera* L.**
Maximum Bacteria Found

04



5.318CFU/ml
Average Rhizosphere Pathogenic Bacteria Concentration

05



1.2
Benficial Bacteria Ratio Total

UTTAR PRADESH

Several studies have reported the presence of rhizosphere bacteria in Uttar Pradesh, India. One study focused on the core microbiota of wheat rhizosphere under the Upper Indo-Gangetic plains and their response to soil physicochemical properties. The study identified significant variation in bacterial diversity among the sites and reported the presence of *Proteobacteria, Chloroflexi*, *Actinobacteria, Bacteroidetes*, and *Acidobacteria* in the wheat rhizospheric soil samples collected from 20 different locations in Uttar Pradesh (Kumar et al., 2023). This study provides insights into the microbial community structure in the wheat rhizosphere along the Upper Indo-Gangetic plains.

Selected Sites: S6 (Bijnor), S7 (Narora), S8 (Badaun), S9 (Farrukhabad), S10 (Bithoor), S11 (Dalmau), S12 (Prayagraj), S13 (Mirzapur), S14 (Varanasi) and S15 (Ballia).

Plants Collected: Total 10 plant is collected *Achyranthes aspera* L., *Croton bonplandianus* Baill., *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Solanum nigrum* L., *Terminalia arjuna* R.Br. (Roxb. ex DC.) Wight & Arn, *Tridax procumbens* L., and *Boerhavia diffusa* L.

In the context of Uttar Pradesh, rich botanical diversity, the presence of various medicinal plants, including *Achyranthes aspera* L., *Croton bonplandianus* Baill., *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Solanum nigrum* L., *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn, *Tridax procumbens* L., and *Boerhavia diffusa* L. were investigated. These plant species are notably distributed across different ecological niches within the region. *Achyranthes aspera*, commonly known as Prickly Chaff Flower, is obtained in diverse habitats, from plains to hilly regions (Mengie et al., 2021; Soorgani, N. R., 2023). *Croton bonplandianus*, recognized for its therapeutic properties, is prevalent in the lower altitudes. *Cynodon dactylon*., or Bermuda Grass, is ubiquitous in both cultivated and uncultivated areas (Ghosh, T., 2018; Dutta, S., and Chaudhuri, T. K. 2018).) *Ficus racemosa*, *Polygonum plebeium*, *Ricinus communis*, *Solanum nigrum*, *Terminalia arjuna*, *Tridax procumbens*, and *Boerhavia diffusa* exhibit adaptability to varied elevations, showcasing their resilience across Uttar Pradesh diverse landscapes. This distribution and adaptability underscore the ecological significance of these plants and form the basis for further exploration of their medicinal properties, ecological roles, and potential applications in traditional and modern healthcare practices (Nagori, B. P., and Solanki, R. 2011 and Ahmed, F., and Urooj, A. 2010).) The rhizospheric bacteria were Isolated and colony morphology was identified. Nine distinct bacteria were identified from a soil sample collected in various locations (Rehman et al, 2018). Different bacteria, including total bacterial count, total fecal and coliform bacteria, Zinc-solubilizers, Rhizobium, *Azotobacer*, *Azospirillum*, potash mobilizers, and Phosphate-solubilizers, are isolated using different media. The distinct strains of isolated bacteria

have different colony morphologies, such as cream-colored, white colonies with smooth, wavy, and branching margins, green colonies with a metallic sheen, and red colonies with some bacteria-producing zones that show an inhibition zone (Ahsan et al., 2018).

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Achyranthes aspera* L.

Achyranthes aspera, is a highly medicinal plant. The total bacterial count across different sites reveals variations, with S14 (Varanasi) displaying the highest count at (7.382) and S6 (Bijnor) registering the lowest at (6.032). Concerns about potential contamination arise as S15 (Ballia) shows the highest total coliform count at (6.99), while S7 (Narora) records the lowest count at (4.000). Notably, S7 (Narora) also exhibits the highest total fecal coliform count at (5.715), emphasizing the need for further investigation into potential water quality issues. In contrast, S6 (Bijnor) and S13(Mirzapur) both register lower fecal coliform counts at (3.539). Examining specific bacterial types, S8 (Badaun) stands out with the highest *Azotobacter* bacteria at (9.074), indicating a robust population of nitrogen-fixing bacteria. S12 (Prayagraj), with the lowest *Azotobacter* at (5.422), suggests variations in nitrogen-fixing microbial communities. S10 (Bithoor) displays the highest total *Rhizobium* count at (8.514), while S11 (Dalmau) records the lowest at (6.148). In terms of *Azospirillum* counts, S14(Varanasi) exhibits the highest at (7.201), showcasing its potential for promoting plant growth. S11 (Dalmau) has the lowest *Azospirillum* count at (4.897), indicating differences in the availability of plant growth-promoting bacteria. For zinc-solubilizing bacteria, S7(Narora)has the highest count at (5.055), underscoring its role in making zinc more available to plants. S13 (Mirzapur) records the lowest count at (0.761), suggesting potential variations in zinc availability across sites. Regarding potash mobilizer bacteria, S14 (Varanasi) exhibits the highest count at (7.334), emphasizing its crucial role in making potassium more available to plants. S12 (Prayagraj) records the lowest count at (3.589), warranting further investigation into factors influencing potash mobilizer bacteria. S13 (Mirzapur) has the highest count for phosphate-solubilizing bacteria at (6.935), contributing to phosphorus availability. S8 (Badaun) records the lowest count at (6.057), all these values is given in Log_{10} as depicted in Fig 8.13. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

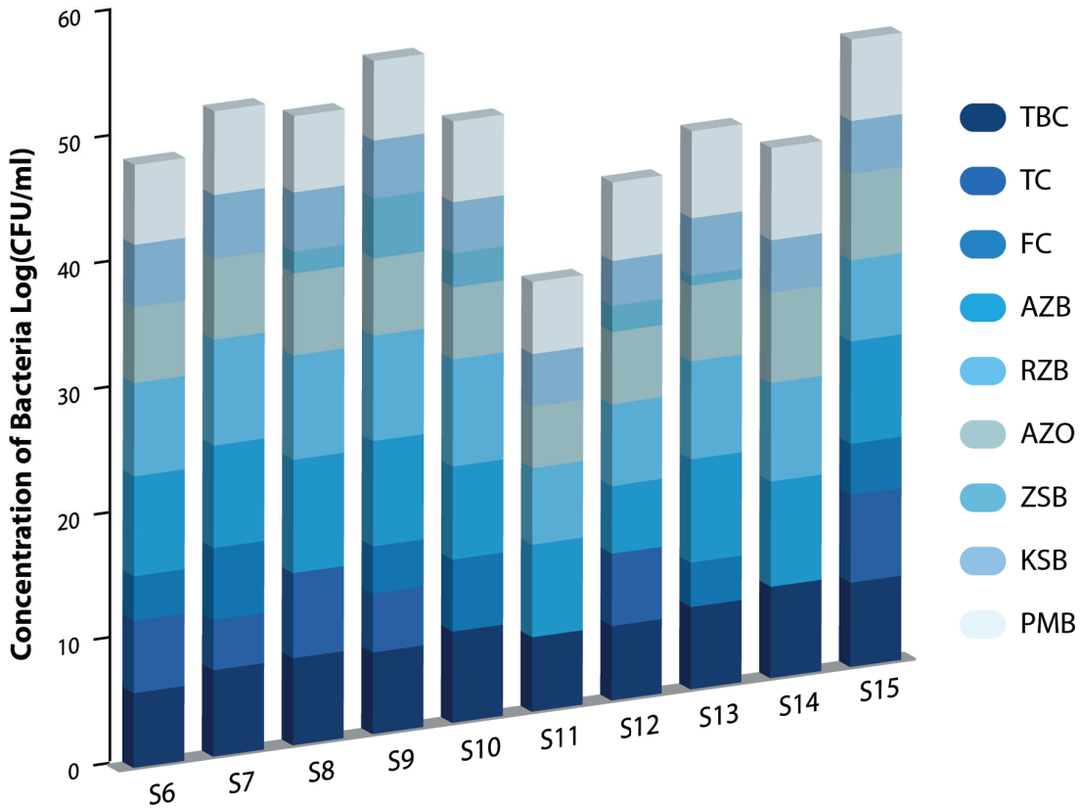


Fig. 8.13 Total and differential bacterial count of *Achyranthes aspera* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Croton bonplandianus* Baill.

S9 (Farrukhabad) boasts the highest total bacterial count at (6.943), indicating a thriving bacterial population in the soil, while S7(Narora) exhibits the lowest total bacterial count at (5.720).The given value in $\log_{10}$. In total coliform count, S10(Bithoor) records the highest at (5.439), with S15 (Ballia) having the lowest at (2.439). For total fecal coliform bacteria, S10 (Bithoor) leads with the highest count at (6.577), while S6(Bijnor) & S11 (Dalmau) show the lowest at (3.439). In terms of Total *Azotobacter* bacteria, S10 (Bithoor) stands out with the highest count at (8.793), reflecting a robust nitrogen-fixing bacterial population. Conversely, S6(Bijnor) has the lowest Azotobacter bacteria at (5.877). S7 (Narora) also exhibits the highest *Rhizobium* bacteria at (8.724), whereas S13(Mirzapur) records the lowest at (4.889). S11(Dalmau) displays the highest *Azospirillum* bacteria at (7.011), while S7 (Narora) shares the lowest count at (3.439) in this category. In zinc-solubilizing bacteria, S10(Bithoor) records the highest count at (1.724), with S12 (Prayagraj), S14(Varanasi) & S15 (Ballia) having the lowest at (0.762). For potash-mobilizing bacteria, S14(Varanasi) leads with the highest count at (5.042), while S11(Dalmau) has the lowest at (3.005). In phosphate-solubilizing bacteria, S12 (Prayagraj) exhibits the highest count at (7.769), whereas S13

(Mirzapur) shows the lowest at (5.402) and given value in log_{10}. as shown in Fig 8.14. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

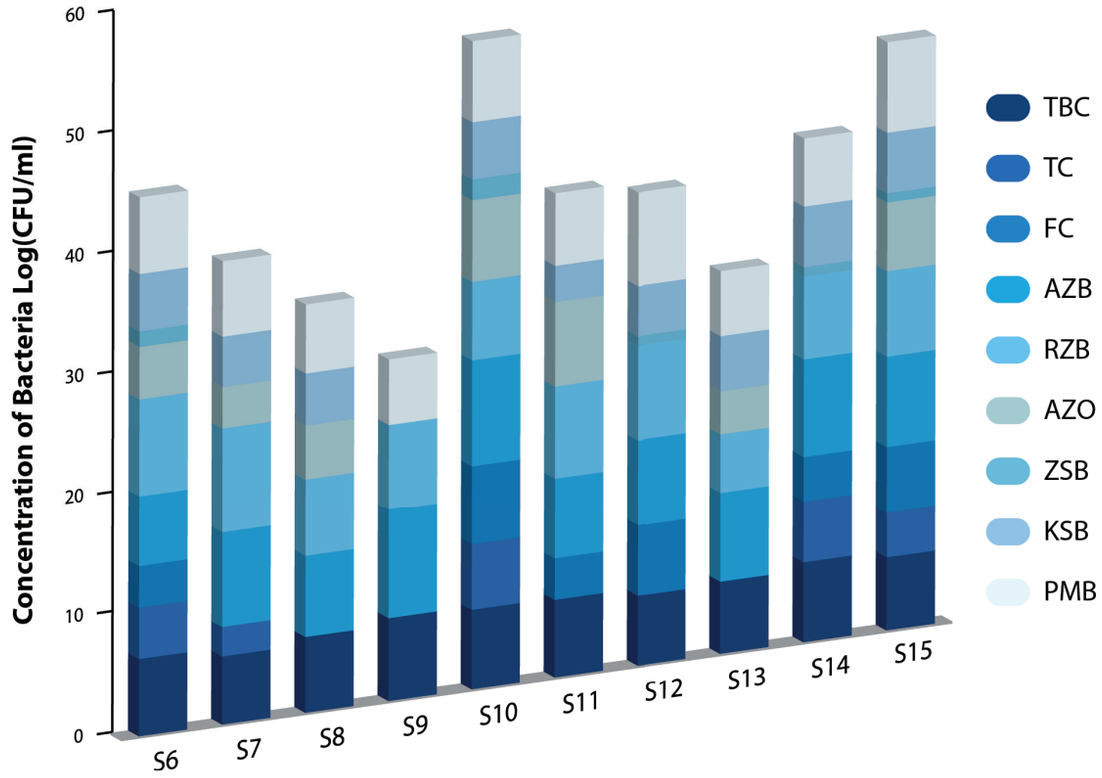


Fig. 8.14 Total and differential bacterial count of *Croton bonplandianus* Baill.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Cynodon dactylon* (L.) Pers.

Significant differences in microbial counts S9 (Farrukhabad) boasts the highest total bacterial count at (7.87), indicating a robust bacterial presence, while S8 (Badaun) has the lowest at (4.68). S14 (Varanasi) leads in total coliform count with (5.44), and S8 (Badaun) shows the lowest at (3.72). S9 (Farrukhabad) records the highest total fecal coliform bacteria at (8.83), while S12 (Prayagraj) has the lowest at (2.44). In total *Azotobacter* bacteria, S10 (Bithoor) excels with (8.94), while S8 (Badaun) has the lowest at (6.15). S9 (Farrukhabad) also tops in total *Rhizobium* bacteria at (8.78), and S11(Dalmau) has the lowest at (2.68). S14 (Varanasi) dominates in *Azospirillum* bacteria at (4.44), while S8 (Badaun) and S9 (Farrukhabad) show no presence. S7 (Narora) leads in zinc solubilizing bacteria at (3.85), and S12 (Prayagraj) records the lowest at (0.48). S12 (Prayagraj) has the highest potash-mobilizing bacteria at (4.68), and S14 (Varanasi) has the lowest at (4.18). In phosphate-solubilizing bacteria, S15 (Ballia) excels at (5.77), and S12 (Prayagraj) has the lowest at (4.89), and given value in log_{10},

as depicted in Fig 8.15. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

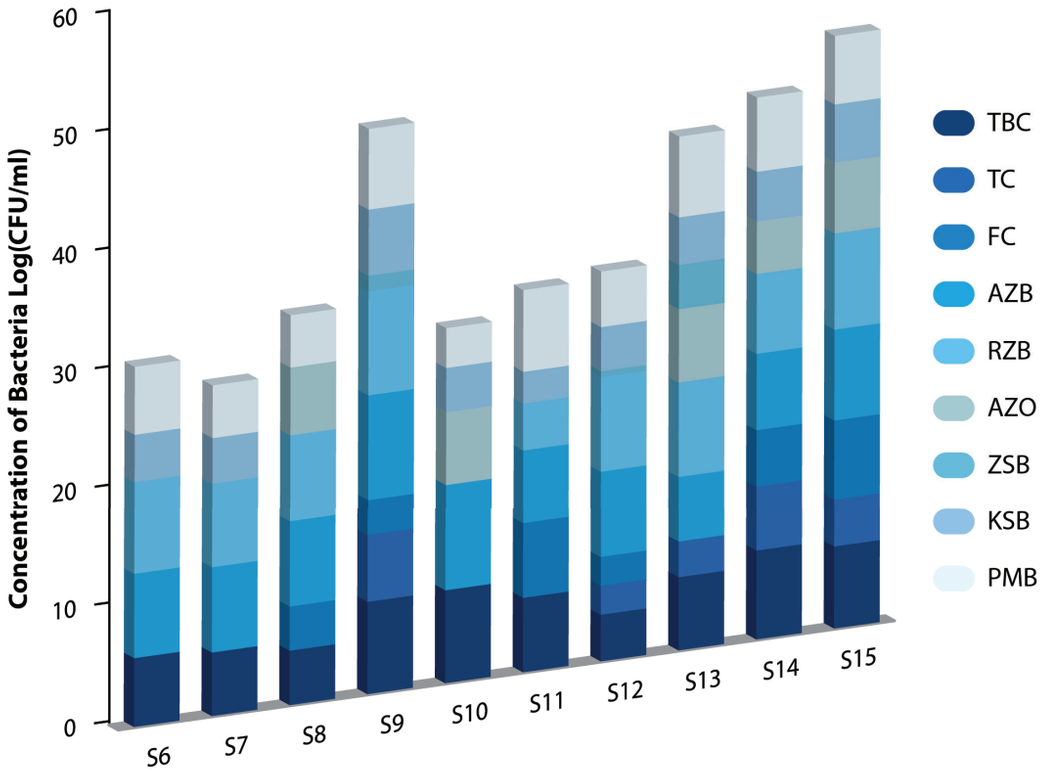


Fig. 8.15 Total and differential bacterial count of *Cynodon dactylon* (L.) Pers.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Ficus racemose* L.

Site S11 (Dalmau) displays the highest total bacterial count at (8.14), indicating a thriving microbial population, while site S9 (Farrukhabad) has the lowest total bacterial count at (4.69). For total coliform count, S11 (Dalmau) has the highest at (3.70), signaling an elevated presence of coliform bacteria, while S13 (Mirzapur) has the lowest, suggesting a lower contamination risk. In total fecal coliform count, S15 (Ballia) records the highest at (7.91), indicating potential fecal contamination and S8(Badaun) has the lowest at (4.45). S11 (Dalmau) leads in total *Azotobacter* bacteria at (6.69), showcasing a robust nitrogen-fixing bacterial population, whereas S10 (Bithoor) has the lowest at (3.72). S9 (Farrukhabad) exhibits the highest *Rhizobium* bacteria at (7.36), suggesting favorable conditions for this bacterium, while S10 (Bithoor) records the lowest at (3.72). S9 (Farrukhabad) showcases the highest *Azospirillum* bacteria at (5.51), indicating a potentially robust plant growth-promoting bacteria population, with S10 (Bithoor) recording the lowest at (3.72). For zinc solubilizing bacteria, S7 (Narora) displays the highest at (2.44), suggesting an active population making zinc more available to

plants, and S13 (Mirzapur) records the lowest at 3.72). In potash-mobilizing bacteria, S9 (Farrukhabad) leads with (5.51), showcasing potential nutrient-mobilizing bacteria, while S12 (Prayagraj) has the lowest at (1.30). For phosphate-solubilizing bacteria, S9 (Farrukhabad) again exhibits the highest at (5.40), emphasizing a potentially rich phosphate-solubilizing bacteria population, with S10 (Bithoor) having the lowest at (3.69) and given value in $\log_{10}$, as shown in Fig. 8.16. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

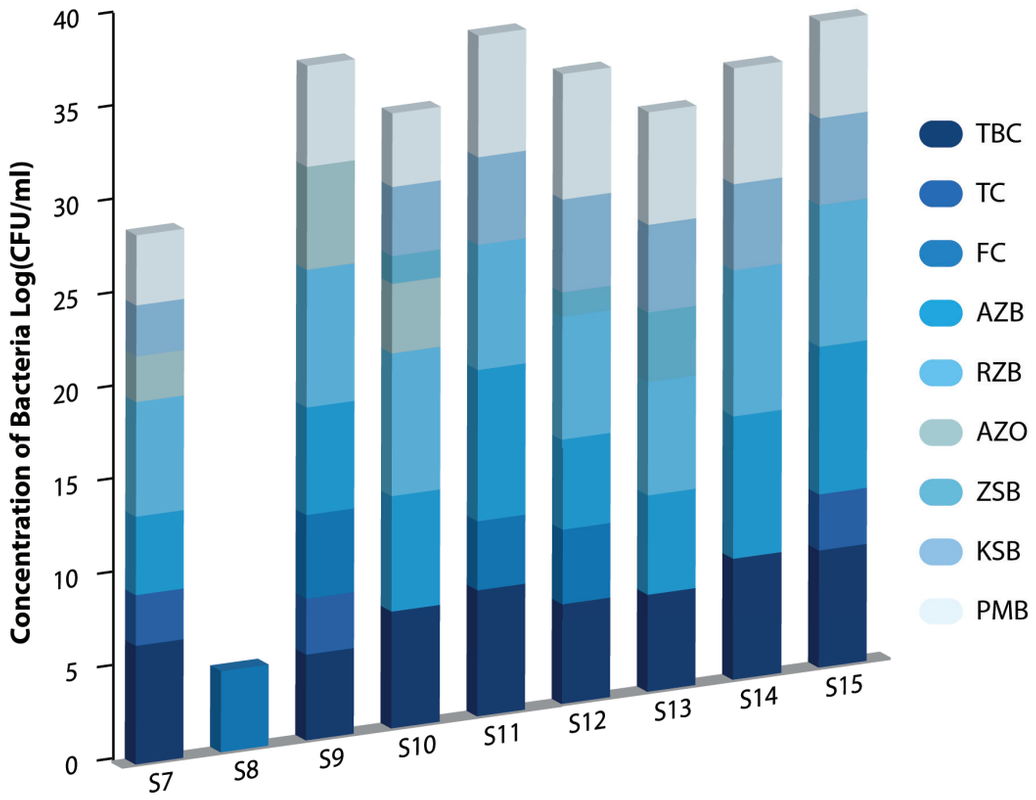


Fig. 8.16 Total and differential bacterial count of *Ficus racemose* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Polygonum plebeium* R.Br.

Site S6 (Bijnor) demonstrates a robust microbial presence with a total bacterial count of (7.80). In contrast, site S9 (Farrukhabad) lacks a recorded total coliform count, while site S6 (Bijnor) indicates a moderate presence with a total coliform count of (3.71), suggesting coliform bacteria activity. Site S6 (Bijnor) records a notable concentration of fecal coliforms in the soil, reflected in the total fecal coliform count of (6.24). The total

Azotobacter bacteria for site S6 (Bijnor) is (6.71), indicating a considerable population of nitrogen-fixing bacteria. Site S9 (Farrukhabad) displays a robust total *Azotobacter* bacteria of (8.57), suggesting a potentially thriving nitrogen-fixing bacterial community. Site S11 (Dalmau) shows favorable conditions for rhizobium bacteria with a total *Rhizobium* bacterium of (7.46), while site S9 (Farrukhabad) lacks a recorded *Rhizobium* bacteria value. Site S6 (Bijnor) exhibits a substantial presence of plant growth-promoting bacteria, as indicated by the *Azospirillum* bacteria of (6.68). Zinc solubilizing bacteria for site S6 (Bijnor) is not recorded, whereas site S9 (Farrukhabad) has a moderate zinc solubilizing bacteria of (3.95), indicative of its role in making zinc more available to plants. Site S6 (Bijnor) shows the presence of nutrient-mobilizing bacteria with a potash mobilizer bacterium of (3.86), while site S9 (Farrukhabad) exhibits a comparable potash-mobilizing bacteria of (3.95). The phosphate-solubilizing bacteria for site S6 (Bijnor) is (4.02), representing a moderate population of phosphate-solubilizing bacteria. Site S9 (Farrukhabad) demonstrates a potentially rich phosphate-solubilizing bacterial community of (6.31) and a given value in log_{10}, as shown in Fig 8.17. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

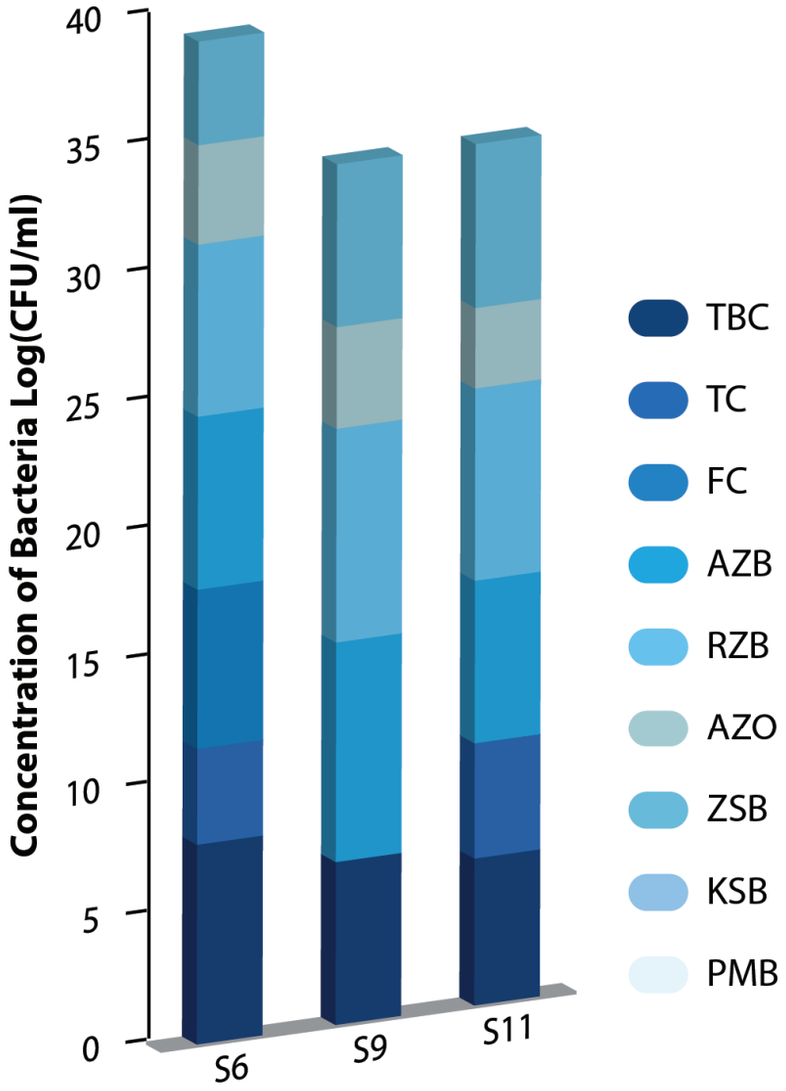


Fig. 8.17 Total and differential bacterial count of *Polygonum plebeium* R.Br.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Ricinus communis* L.

The microbial analysis across different sites reveals notable variations in microbial populations. Site S11 (Dalmau) exhibits the highest total bacterial count at (8.36), indicative of a thriving microbial community. Conversely, Site S8(Badaun) records the lowest total bacterial count at (5.68).

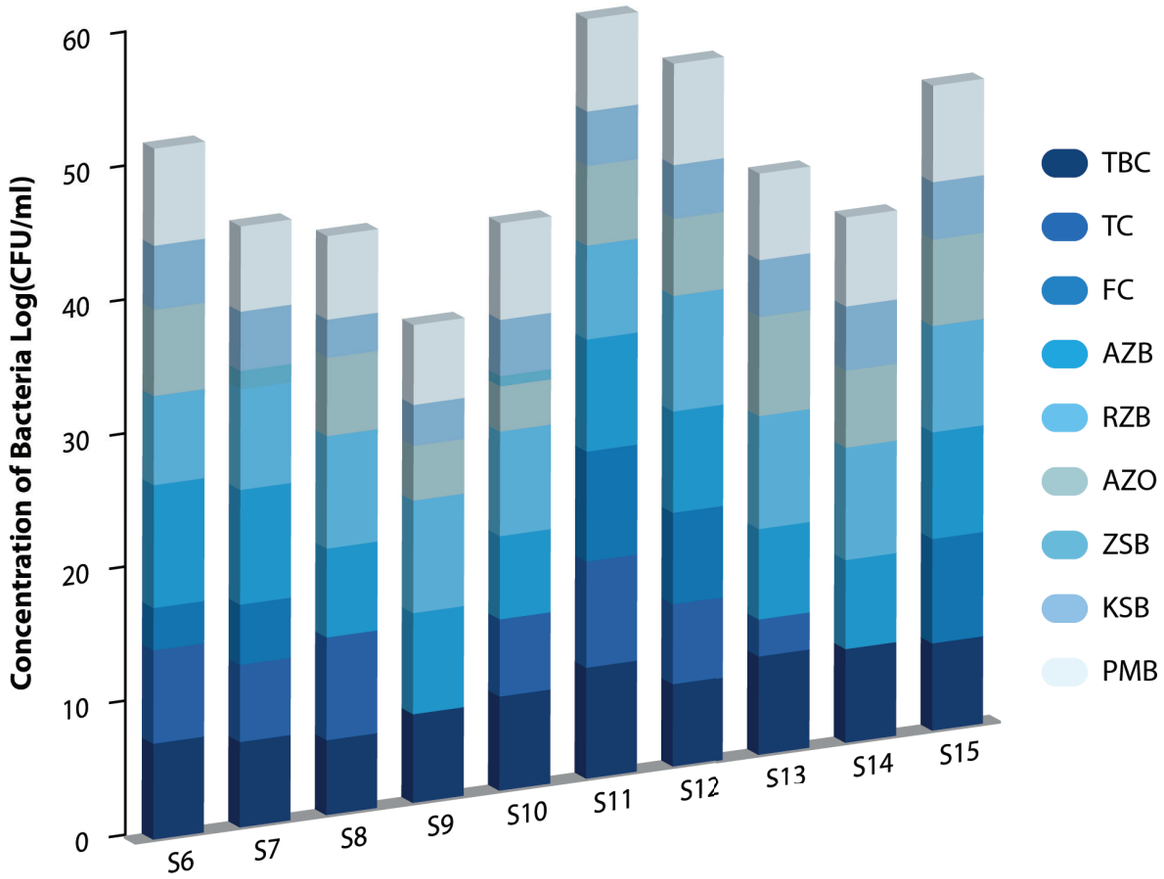


Fig. 8.18 Total and differential bacterial count of *Ricinus communis* L.

Site S11 (Dalmau) also leads in total coliform count at (7.92), highlighting an elevated presence of coliform bacteria, while site S13 (Mirzapur) has the lowest total coliform count. Site S15 (Ballia) shows the highest total fecal coliform count at (7.96), suggesting a potential source of fecal contamination, whereas site S8 (Badaun) records the lowest total fecal count. In terms of specific bacterial populations, site S9 (Farrukhabad) displays the highest *Azotobacter* bacteria count at (8.45), indicating a robust nitrogen-fixing population, while site S7 (Narora) has the lowest count. Site S12 (Prayagraj) showcases the highest total *Rhizobium* bacteria at (8.63), suggesting favorable conditions for *Rhizobium* bacteria, with Site S13 (Mirzapur) recording the lowest count. Site S7 (Narora)

has the highest *Azospirillum* bacteria count at (6.44), indicating a substantial presence of plant growth-promoting bacteria, while site S14 (Varanasi) has the lowest count. Zinc solubilizing bacteria is notably high in site S8 (Badaun) at (2.85) and given value in $\log_{10}$, as shown in Fig 8.18. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn.

The microbial composition across surveyed sites reveals significant variations in bacterial populations and given value in $\log_{10}$. Site S14(Varanasi) exhibits the highest total bacterial count at (7.01), indicating substantial microbial presence, while site S11 (Dalmau) has the lowest at (3.40). For coliform bacteria, site S12 (Prayagraj) has the highest total coliform count at (4.00), indicating a notable presence, with sites S6 (Bijnor) & S15 (Ballia) showing the lowest total coliform count. Site S15 (Ballia) has a notably elevated total fecal coliform count at (7.18), suggesting a potential source of fecal contamination, while sites S6 (Bijnor) & S14 (Varanasi) record the lowest.

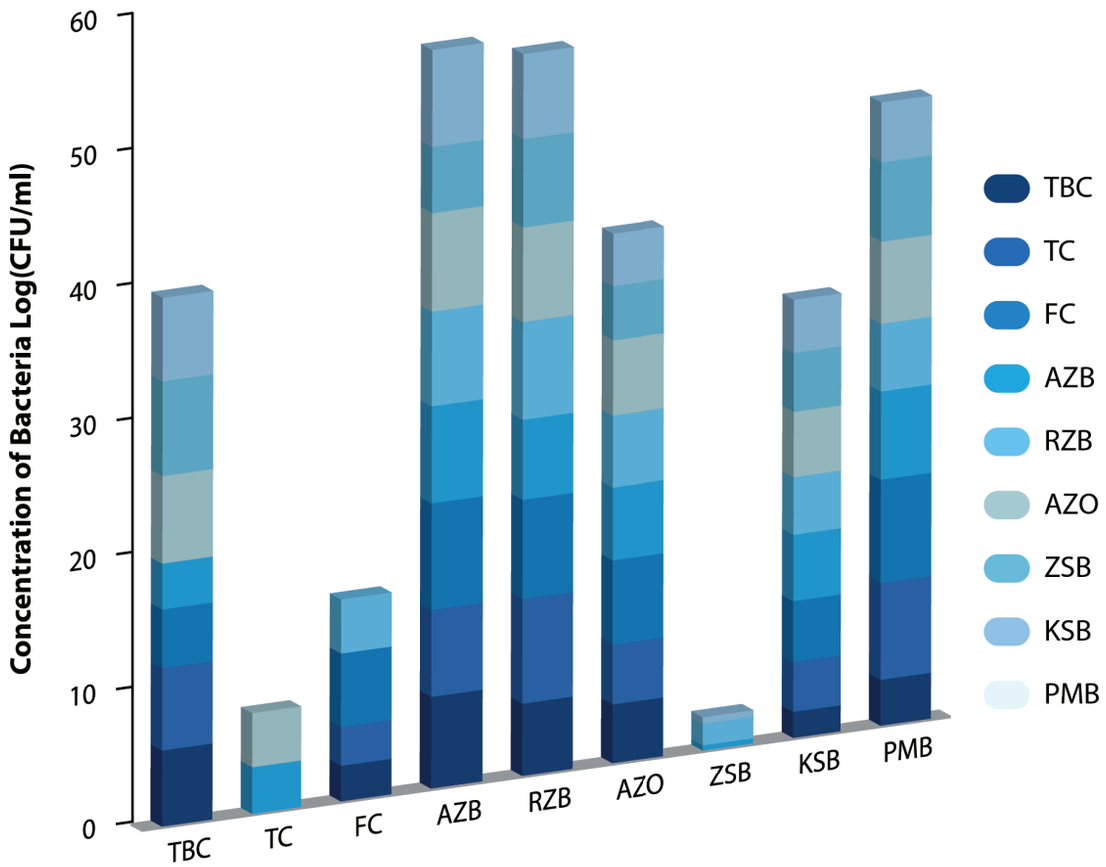


Fig. 8.19 Total and differential bacterial count of *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn

Site S13 (Mirzapur) leads in *Azotobacter* bacteria count at (7.31), indicating a robust nitrogen-fixing population, whereas site S11 (Dalmau) has the lowest count. *Rhizobium* bacteria exhibit variability, with site S7 (Narora) displaying the highest count at (7.76) and site S6 (Bijnor) recording the lowest count. *Azospirillum* bacteria are notably present in Site S14 (Varanasi) at (4.36), indicating a substantial population of plant growth-promoting bacteria, while Site S12 (Prayagraj) records the lowest count. Zinc solubilizing bacteria is highest in site S15 (Ballia) at (3.94), suggesting an active population involved in making zinc more available to plants, while Site S11 (Dalmau) has the lowest zinc solubilizing bacteria. Potash mobilizer bacteria are notably high in site S15(Ballia) at (7.66), playing a crucial role in making potassium more available to plants, while sites S6(Bijnor) & S7 (Narora) exhibit the lowest counts. Phosphate solubilizing bacteria show variability, with site S7 (Narora) displaying the highest count at (8.18), and site S15 (Ballia) recording the lowest count as shown in Fig 8.19. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Tridax procumbens* L.

The total bacterial count exhibits notable variations across the surveyed sites, with site S13 (Mirzapur) recording the highest total bacterial count at (7.10), indicative of a substantial microbial presence. In contrast, site S15 (Ballia) displays the lowest count at (4.36), suggesting a comparatively lower microbial abundance in the soil. Moving on to the total coliform count, site S12 (Prayagraj) stands out with the highest count at (2.89), emphasizing a notable presence of coliform bacteria. However, site S10 (Bithoor) has an undetermined total coliform count, indicating a lack of data for this parameter. For the total fecal coliform count, site S10 (Bithoor) records the highest value at (7.98), suggesting a potential source of fecal contamination. Conversely, site S6 (Bijnor) exhibits the lowest total fecal count at (3.61), indicating a lower concentration of fecal coliforms in the soil. In terms of *Azotobacter* bacteria count, site S13 (Mirzapur) leads with a count of (8.27), indicating a robust population of nitrogen-fixing bacteria, while site S6 (Bijnor) has the lowest count at (5.18). Site S12 (Prayagraj) displays the highest *Rhizobium* bacteria count at (7.97), suggesting favorable conditions for *Rhizobium* bacteria, while Site S11 (Dalmau) records the lowest count at (4.89). In the case of *Azospirillum* bacteria count, site S10 (Bithoor) exhibits the highest count at (6.10), indicative of a substantial population of plant growth-promoting bacteria. Conversely, site S14 (Varanasi) has the lowest count at (3.83). Zinc solubilizing bacteria count is highest in site S10 (Bithoor) at (7.52), suggesting an active population involved in making zinc more available to plants, while site S11 (Dalmau) records the lowest count at (1.44). Potash mobilizer bacteria count is notably high in site S15 (Ballia) at (7.66), emphasizing a crucial role in making potassium more available to plants. In contrast,

site S11 (Dalmau) exhibits the lowest count at (1.72). Finally, for phosphate solubilizing bacteria count, site S10 (Bithoor) leads with a count of (7.52), while site S15 (Ballia) records the lowest count at (4.48) and given value in $\log_{10}$ as shown in Fig 8.20. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

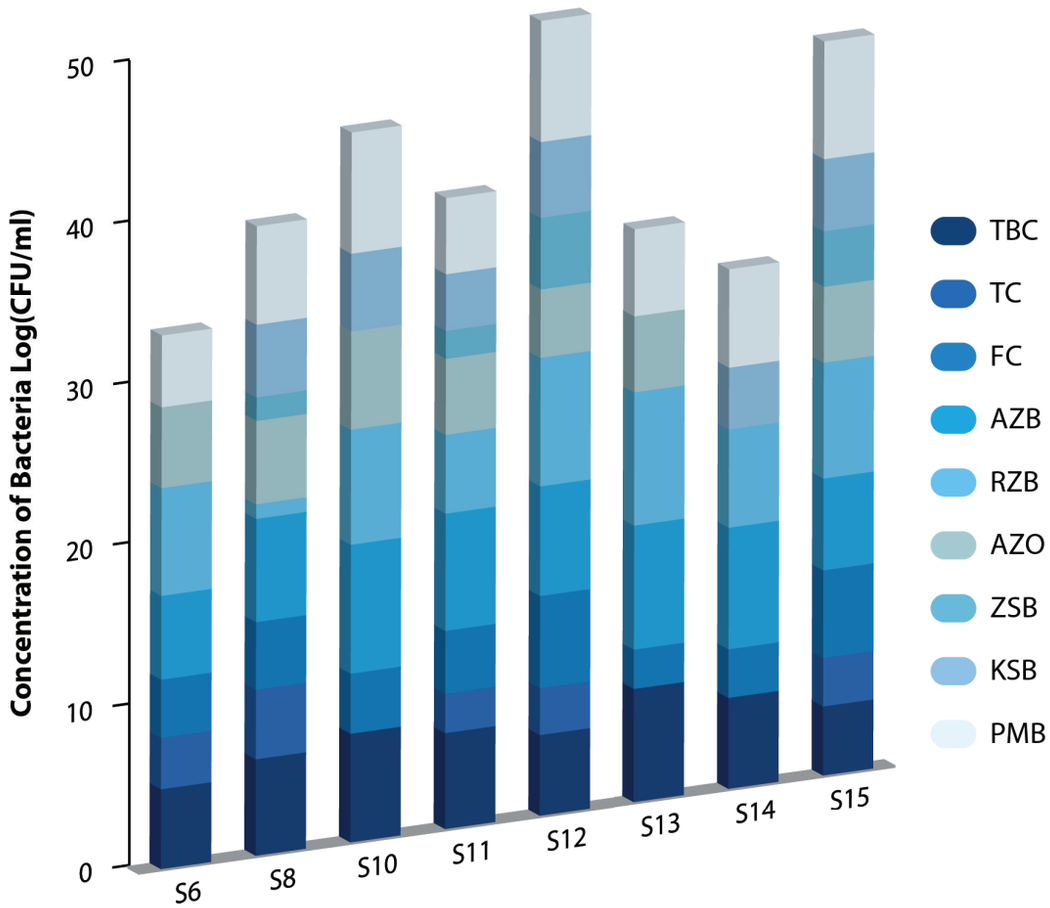


Fig. 8.20 Total and differential bacterial count of *Tridax procumbens* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Boerhavia diffusa* L.

The surveyed sites exhibit significant diversity in bacterial populations. Site S14 (Varanasi) boasts the highest total bacterial count at (7.63), indicating a substantial microbial presence, while site S12 (Prayagraj) has the lowest count at (5.85). Notably, site S8 (Badaun) records the highest total coliform count at (4.03), emphasizing a significant presence of coliform bacteria, whereas site S7 (Narora) lacks a recorded total coliform value. Site S14 (Varanasi) stands out with the highest total fecal coliform count at (8.36), suggesting a potential source of fecal contamination, while sites S6 (Bijnor) & S12

(Prayagraj) display the lowest total fecal values. Site S13 (Mirzapur) leads in *Azotobacter* bacteria count at (8.71), indicating a robust nitrogen-fixing population, while site S6 (Bijnor) has the lowest count. *Rhizobium* bacteria exhibit variability, with site S8 (Badaun) displaying the highest count at (6.60), and site S12 (Prayagraj) recording the lowest count. *Azospirillum* bacteria are notably present in site S14 (Varanasi) at (7.66), indicating a substantial population of plant growth-promoting bacteria, while site S12 (Prayagraj) records the lowest count. Zinc solubilizing bacteria are most abundant in site S8 (Badaun) at (5.73), suggesting an active role in making zinc more available to plants, while site S6 (Bijnor) records the lowest at (1.76). Potash mobilizing bacteria are most prevalent in site S15 (Ballia) at (6.99), contributing significantly to potassium availability, whereas site S8 has the lowest count. For phosphate solubilizing bacteria, site S14 (Varanasi) leads with a count of 7.53, while site S6 (Bijnor) records the lowest count at (6.45) and given value in $\log_{10}$, as shown in Fig 8.21. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

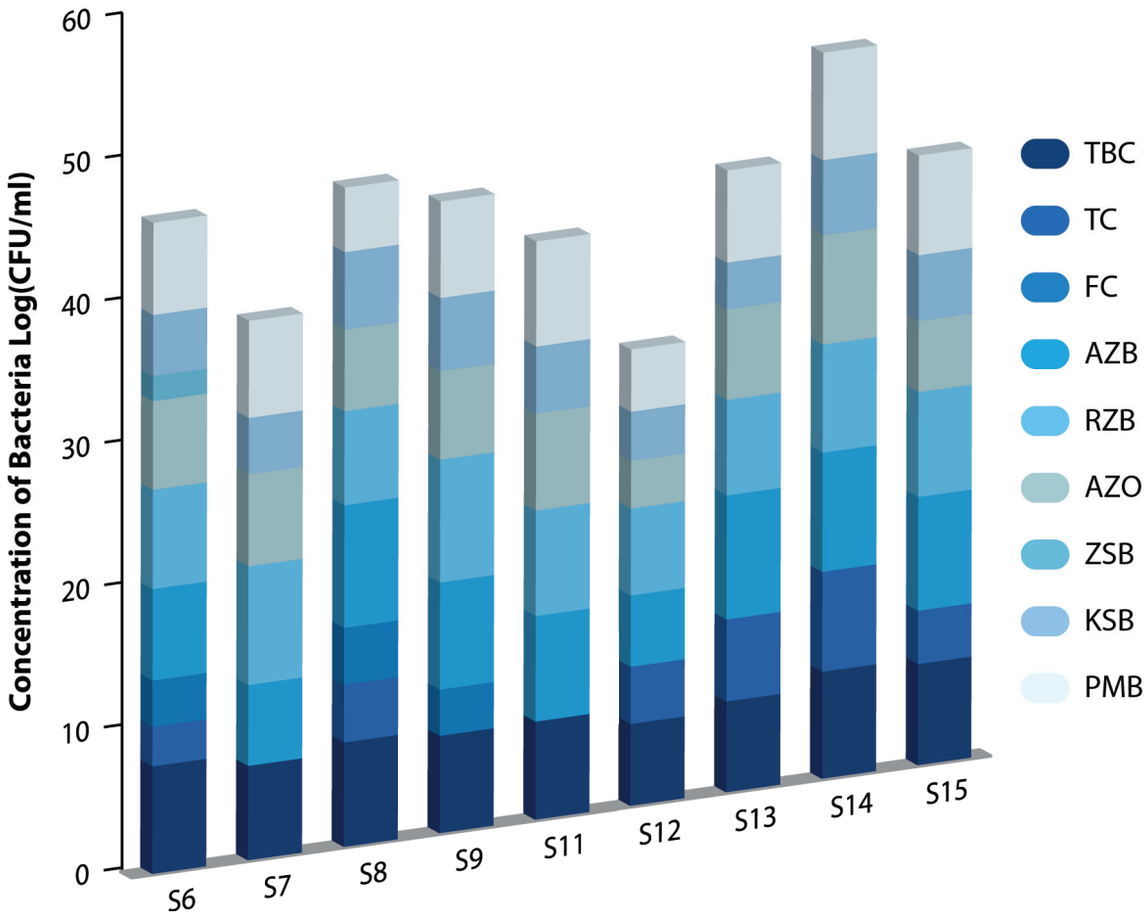


Fig. 8.21 Total and differential bacterial count of *Boerhavia diffusa* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Solanum nigrum* L.

Site S10 (Bithoor) displays the highest total bacterial count at (8.06), indicating a substantial microbial presence, while sites S12 (Prayagraj) and S14 (Varanasi) have total bacterial count values of (6.71) and (6.76), respectively. Site S10 (Bithoor) also records the highest total coliform count at (5.73), suggesting a notable presence of coliform bacteria, whereas sites S11 (Dalmau) and S8 (Badaun) have total bacterial count values of (2.76) each. Site S15 (Ballia) exhibits the highest total fecal coliform count at (8.56), indicating a potential source of fecal contamination, while sites S6 (Bijnor) and S8 (Badaun) record fecal bacteria values of (2.76) and (4.19), respectively.

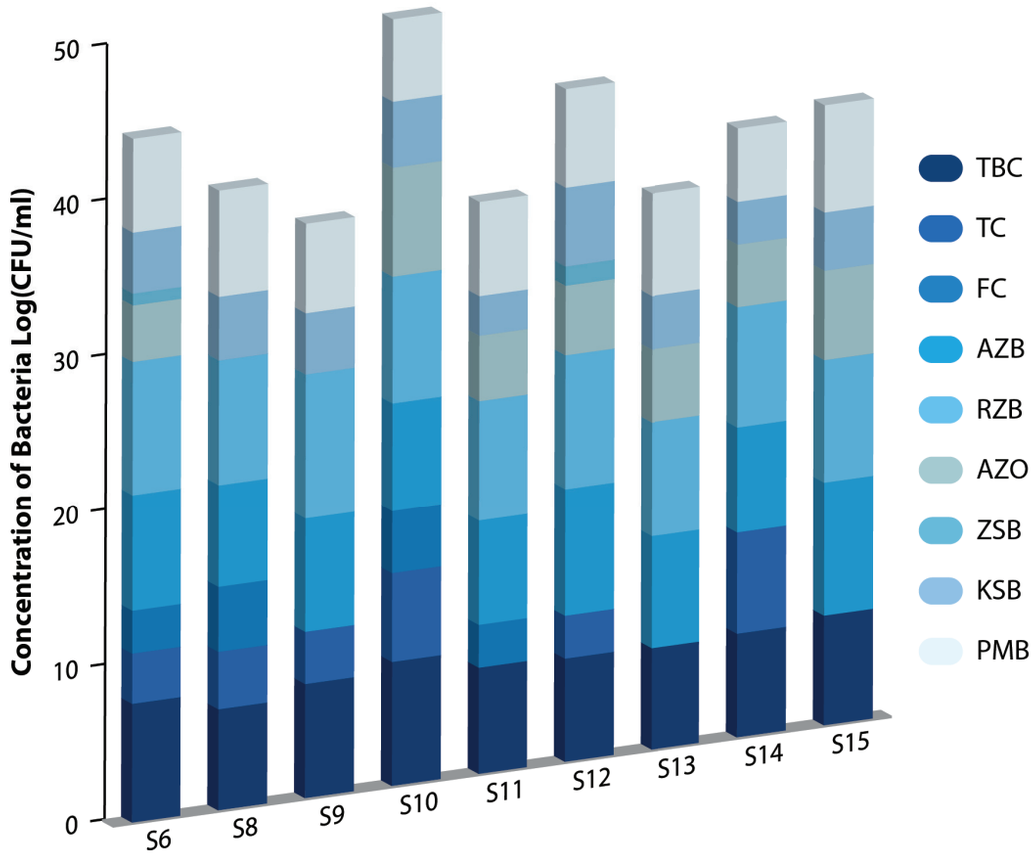


Fig. 8.22 Total and differential bacterial count of *Solanum nigrum* L.

Azotobacter bacteria are most abundant in site S9 (Farrukhabad) with a count of (7.32), while site S6 (Bijnor) has the lowest count at (7.45). Site S10 (Bithoor) also exhibits the highest total rhizobium count at (8.17), signifying favorable conditions for *Rhizobium* bacteria, with Sites S8 (Badaun) and S12 (Prayagraj) having total *Rhizobium* bacteria values of (6.56) and (8.65), respectively. *Azospirillum* bacteria are most abundant in Site S10 (Bithoor) at (7.01), indicating a substantial presence of plant

growth-promoting bacteria, while Site S8 (Badaun) has the lowest count at (4.10). For zinc solubilizing bacteria, site S9 (Farrukhabad) records the highest value at (3.94), suggesting an active population involved in making zinc more available to plants, whereas site S6 (Bijnor) has the lowest zinc solubilizing count at (0.76). Potash mobilizing bacteria for site S6 (Bijnor) is (3.93), while site S14 (Varanasi) has the lowest potash mobilizing bacteria at (2.75). Phosphate-solubilizing bacteria for site S6 (Bijnor) is (6.03), reflecting a moderate population of this solubilizing bacteria, and site S8 (Badaun) has a phosphate-solubilizing bacteria of (6.84), and given value in $\log_{10}$. Indicating a potentially rich kind of solubilizing bacterial community as shown in Fig 8.22. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

Below, in Fig. 8.23, are some representative images of the isolated bacteria from the selected Uttar Pradesh sites.

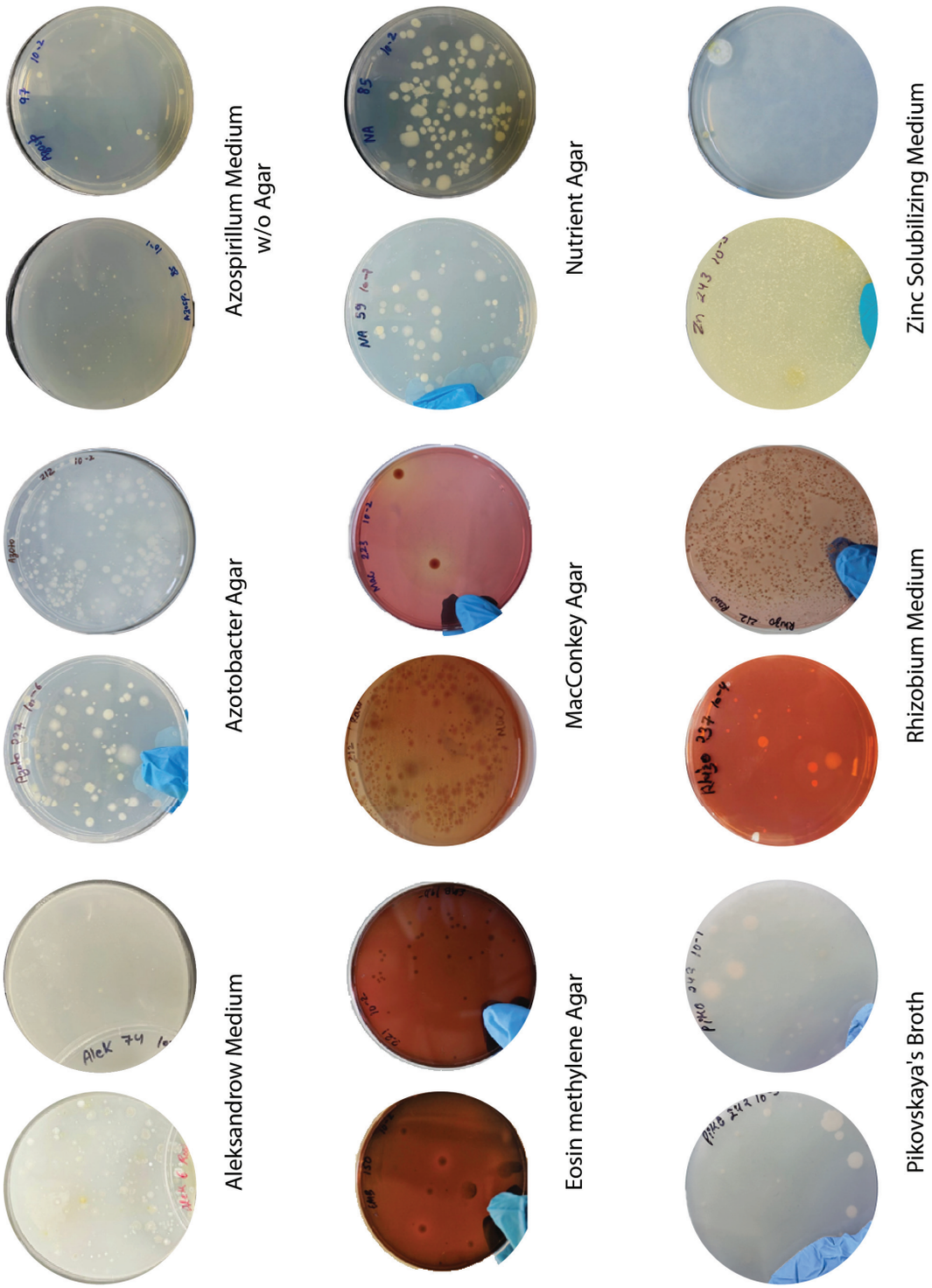


Fig. 8.23 Representative pictures of isolated bacteria of Uttar Pradesh



01

38
Total Rhizosphere Soil Collection

02

6.39CFU/ml
Average Rhizosphere Bacterial Concentration

03

***Achyranthes aspera* L.**
Maximum Bacteria Found

04

4.48CFU/ml
Average Rhizosphere Pathogenic Bacteria Concentration

05

1.4
Benficial Bacteria Ratio Total

BIHAR

BIHAR

Several studies have reported the presence of rhizosphere bacteria in Bihar, India. One study focused on the screening and biocontrol potential of rhizobacteria native to Gangetic Plains and Hilly Regions to induce systemic resistance and promote plant growth in chili against bacterial wilt disease (Kashyap et al., 2021). The study isolated rhizosphere bacteria from chili rhizosphere collected from different agroclimatic zones in Bihar and characterized them based on their colonies' morphology, abundance, and diversity index. Another study aimed to identify plant growth-promoting rhizobacteria (PGPR) in the rhizosphere of lentil-growing soils in eastern India, and isolated sixteen rhizosphere bacteria from two different soil orders. The study obtained that three of the isolated strains, including Bacillus subtilis, showed potential as plant growth-promoting rhizobacteria (Das et al., 2023). These findings demonstrate the diverse range of rhizosphere bacteria obtained in the soils of Bihar, which can contribute to plant growth and overall soil health.

Selected Sites: S16 (Revelganj), S17 (Patna), S18 (Barh), S19 (Bahachoki), S20 (Farka). The sites were selected

Plants Collected: Total 10 plant is collected *Achyranthes aspera* L., *Croton bonplandianus* Baill., *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Solanum nigrum* L., *Terminalia arjuna* R.Br. (Roxb. ex DC.) Wight & Arn, *Tridax procumbens* L., and *Boerhavia diffusa* L.

In the context of Bihar's rich botanical diversity, the presence of various medicinal plants, including *Achyranthes aspera* L., *Croton bonplandianus* Baill., *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Solanum nigrum* L., *Terminalia arjuna* R.Br.(Roxb. ex-DC.) Wight & Arn, *Tridax procumbens* L., and *Boerhavia diffusa* L. were investigated. These plant species are notably distrib wered across different ecological niches within the region. *Achyranthes aspera*, commonly known as Prickly Chaff Flower, is obtained in diverse habitats, from plains to hilly regions (Mengie, T., 2021 and Soorgani, 2023). *Croton bonplandianus*, recognized for its therapeutic properties, is prevalent in lower altitudes. *Cynodon dactylon*., or Bermuda Grass, is ubiquitous in both cultivated and uncultivated areas (Ghosh, T., 2018 Dutta, S., & Chaudhuri, T. K. (2018).) *Ficus racemosa*, *Polygonum plebeium*, *Ricinus communis*, *Solanum nigrum*, *Terminalia arjuna*, *Tridax procumbens*, and *Boerhavia diffusa* exhibit adaptability to varied elevations, showcasing their resilience across Bihar's diverse landscapes. This distribution and adaptability underscore the ecological significance of these plants and form the basis for further exploration of their medicinal properties, ecological roles, and potential applications in traditional and modern healthcare practices (Nagori, B. P., & Solanki, R. (2011) and

Ahmed, F., & Urooj, A. (2010).) The rhizospheric bacteria were isolated and colony morphology was identified. Nine distinct bacteria were identified from a soil sample collected in various locations (ur Rehman, A., et al, 2018). Different bacteria, including total bacterial count, total fecal and coliform bacteria, Zinc-solubilizers, Rhizobium, *Azotobacer*, *Azospirillum*, potash mobilizers, and Phosphate-solubilizers, are isolated using different media. The distinct strains of isolated bacteria have different colony morphologies, such as cream-colored, white colonies with smooth, wavy, and branching margins, green colonies with a metallic sheen, and red colonies with some bacteria-producing zones that show an inhibition zone (Ahsan, et al., 2018).

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Achyranthes aspera* L.

Achyranthes aspera is a highly medicinal plant known for its microbial content and all given values are expressed in Log_{10}. The highest total bacterial count is observed at site (Barh) S18 (8.94), while the lowest count obtained at site (Revelganj) S16 (6.707).

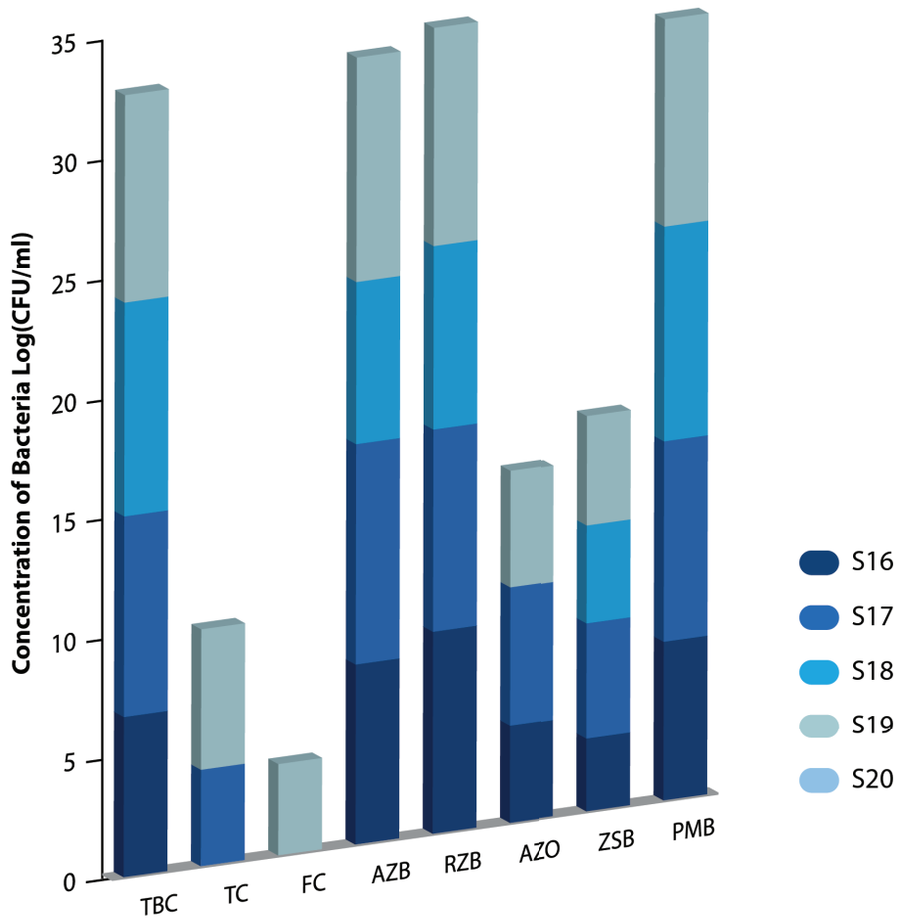


Fig. 8.24 Total and differential bacterial count of *Achyranthes aspera* L.

The highest total coliform count and fecal coliform count are obtained at site (Patna) S17 (8.459 & 9.213, respectively), while the lowest fecal coliform count obtained at site (Bahachoki) S19 (3.849). The highest count of *Azotobacter* bacteria is at site S19 (9.353), while the lowest count is at site S16 (4.087). The highest count of *Rhizobium* bacteria is at site S19 (9.0915), while the lowest count is at site S16 (3.053). The highest count of *Azospirillum* bacteria is observed at site S17 (5.761), while the lowest count is at site S19 (4.849). The highest count of zinc sulfate bacteria is observed at site S16 (3.0536), while the lowest count is at site S19 (4.557). Lastly, the highest count of phosphate solubilizing bacteria is obtained at site S19 (3.60), as shown in Fig 8. 24. The full form of the abbreviations of the culture medium is used in the figure given in the material method section Table 8.4.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Croton bonplandianus* Baill.

The highly therapeutic plant *Croton bonplandianus* Baill. has a high microbial content as shown in Fig. 8.25 and all the values are given in Log_{10}. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

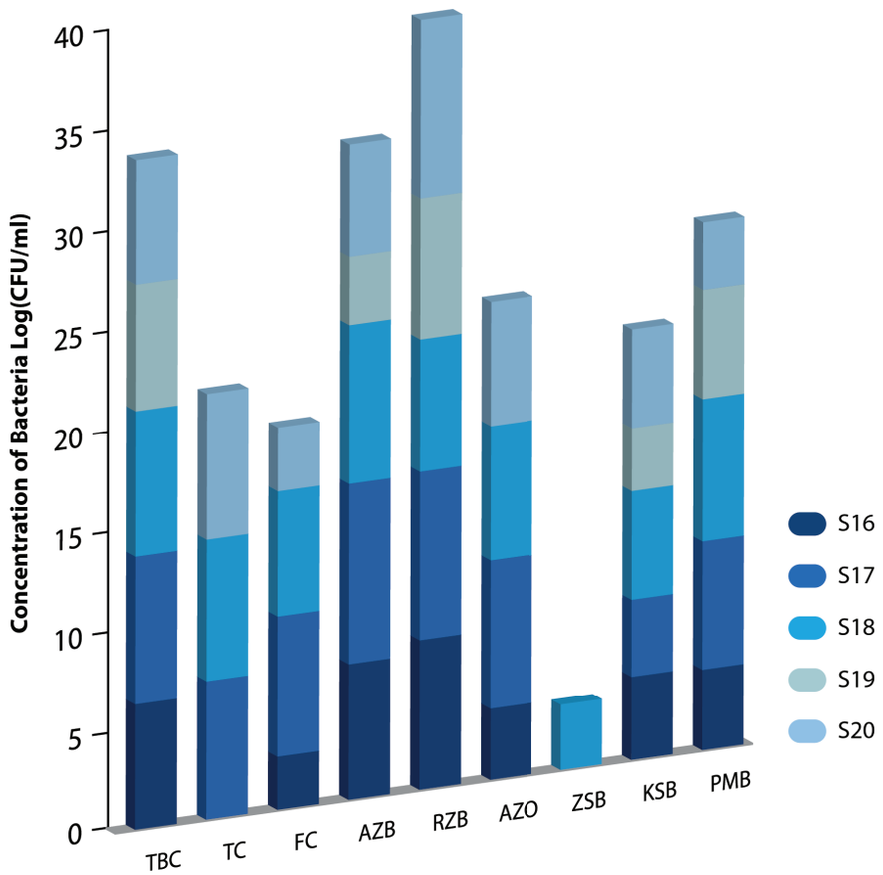


Fig. 8.25 Total and differential bacterial count of *Croton bonplandianus* Baill.

The highest total bacterial count is observed at a site (Patna) S17 (7.332) suggests a possible higher microbial presence, while the lowest total bacterial count value is obtained at the site (Farka) S20 (6.183). The highest total coliform count value is observed the the (Barh) S18 (7.070). The highest fecal coliform count value is observed at site S17 (6.955), and the lowest fecal coliform count value is obtained at site S20 (3.183). The highest count of *Azotobacter* bacteria is at site S17 (7.917), while the lowest count is at site (Revelganj) S16 (6.778). The *Rhizobia* bacteria's lowest count is at site S16 (3.609). The highest count of *Azospirillum* bacteria is observed at site S17 (7.362). The highest count of zinc sulfate bacteria is observed at site S17 (5.419), while the lowest count is at site S18 (3.306). Lastly, the highest count of phosphate-solubilizing bacteria is obtained at site S18 (7.052, while the lowest count is at site S20 (3.357).

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Cynodon dactylon* (L.) Pers.

C. dactylon has medicinal values where all values are expressed in Log_{10}. The highest total bacterial count is observed at site (Bahachoki) S19 (7.18), and the lowest count is at site (Patna) S17 (5.44).

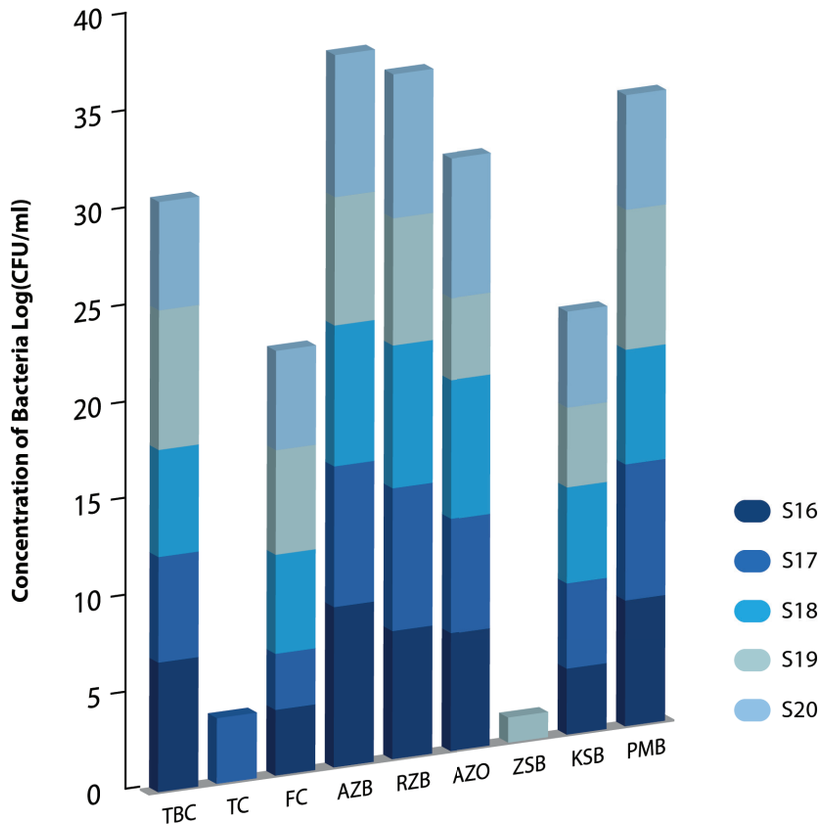


Fig. 8.26 Total and differential bacterial count of *Cynodon dactylon* (L.) Pers.

Likewise, the highest total coliform count is observed at site S19 (5.44), and the lowest count is at Site (Revelganj) S16 (3.44). The highest count is observed at site S16 (8.31), and the lowest count is at site S17 (2.89). The *Azotobacter's* highest count is observed at site S17 (7.25), and the lowest count is at site S16 (6.66). The *Rhizobium* highest count of Rhizobium is observed at Site S17 (7.36), and the lowest count is at Site S19 (4.22). The *Azospirillum* highest count is observed at site S17 (5.89), and the lowest count is at site S19 (1.35). The Zinc sulfate bacteria's highest count is observed at site S19 (6.58), and the lowest count is at site S16 (3.44). The highest count of Potash solubilizing bacteria is observed at site S19 (7.01), and the lowest count is at site S17 (4.44). The highest count of Phosphate-solubilizing bacteria is observed at site S19 (7.20), and the lowest count is at site S17 (4.11) as shown in Fig. 8.26. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Ficus racemose* L.

The provided table shows the values with Log_{10} of different microbial counts at different sites. Site (Revelganj) S16 has the highest total bacterial count of (8.60), while site (Farka) S20 has the lowest total bacterial count of (5.37). Site S20 has the highest total coliform count of (5.00). Site S16 has the highest fecal coliform count of (4.88), while site (Patna) S17 has the lowest fecal count of (2.89). Site S16 has the highest *Azotobacter* bacteria count of (5.72), while site S20 has the lowest count of (4.97). Site S20 has the highest *Rhizobia* bacteria (6.48), while site S16 has the lowest count of (4.02). Site S16 has the highest *Azospirillum* bacteria of (4.023) while site S20 has the lowest count of (3.623). Site S16 has the highest zinc sulfate bacteria count of 2.698). Site S16 has the highest potash solubilizing bacteria count of (4.724), while site S20 has the lowest count of 3.97). Site S16 has the highest phosphate solubilizing bacteria count of (4.312) while site S20 has the lowest count of (3.945). These values provide insights into the microbial presence and soil fertility at different sites as shown in Fig. 8.27. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

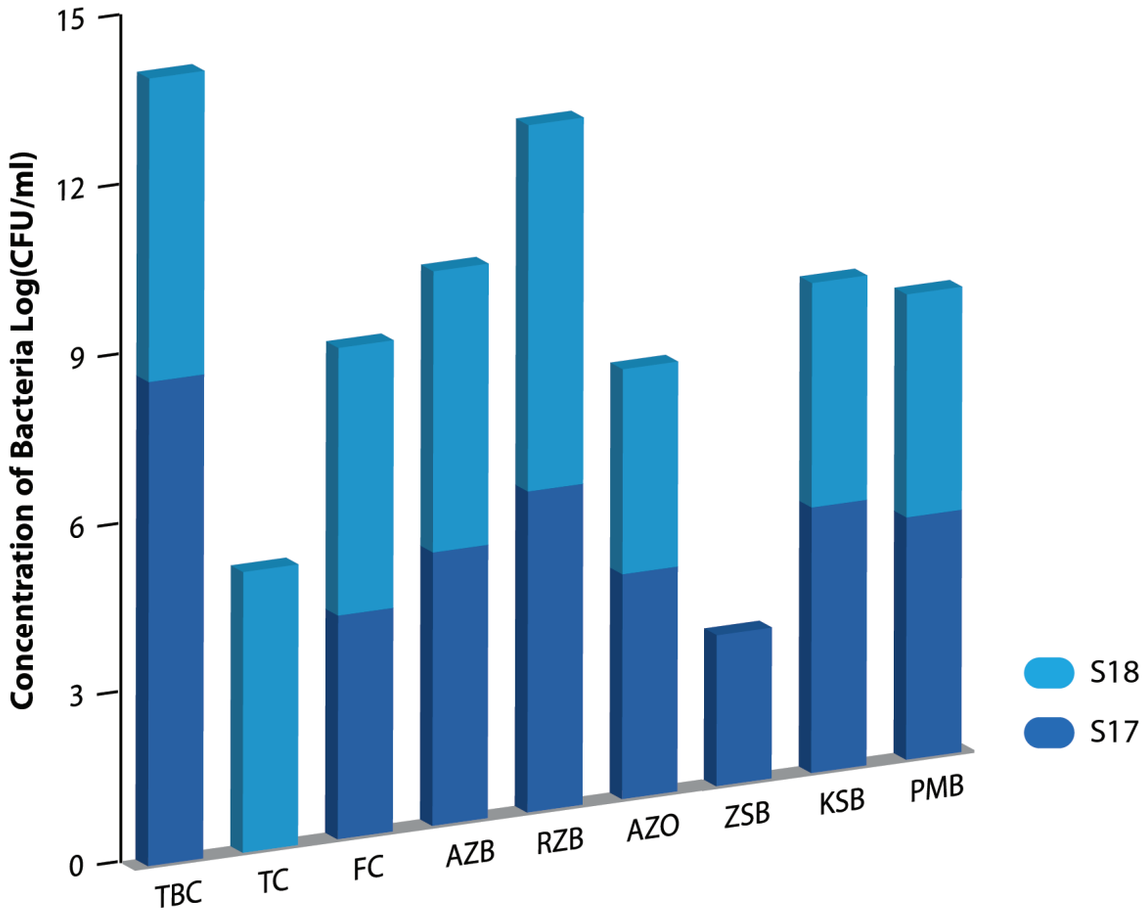


Fig. 8.27 Total and differential bacterial count of *Ficus racemose* L.

Total and Differential Bac0terial Population obtained in the rhizosphere soil of *Polygonum plebeium* R.Br.

The given table provides the Log_{10} values for various microbial counts at different sites. Site (Revelganj) S16 total bacterial count is the highest at (8.60) whereas site (Farka) S20 has the lowest total bacterial count at (5.37). Site (Patna) S17 has the highest fecal coliform count at (7.52), while site (Barh) S18 has the highest *Azotobacter* bacteria at (8.61). Site S20 has the highest *Rhizobia* bacteria at (9.05), and site S16 has the lowest count at (4.02). Site S16 has the highest *Azospirillum* bacteria at (2.70), while site (Bahachoki) S19 has the highest potash solubilizing bacteria count at (7.31). Site S20 has the lowest zinc solubilizing bacteria count at (3.97), and the lowest phosphate solubilizing bacteria at (3.94). These values provide insights into the microbial presence and soil fertility at different sites as shown in Fig 8.28. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

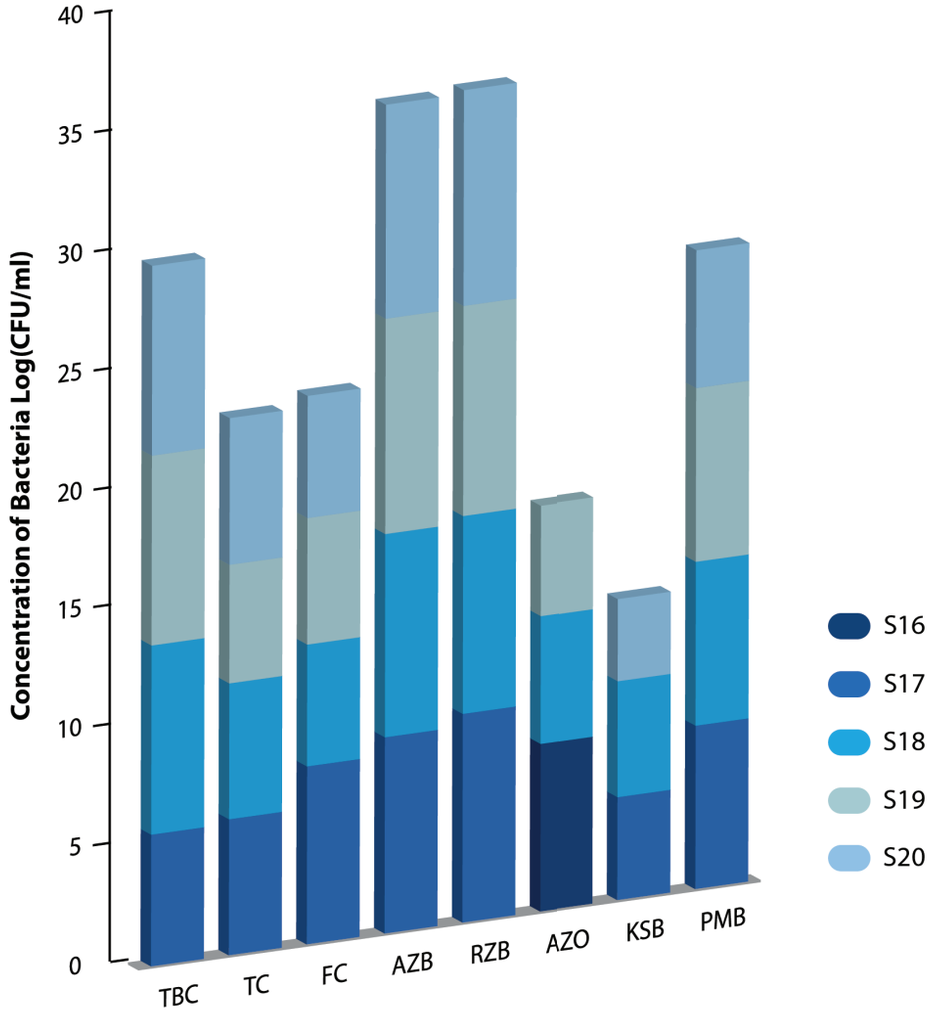


Fig. 8.28 Total and differential bacterial count of *Polygonum plebeium* R.Br.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Ricinus communis* L.

The bacterial count (Log_{10} values) for various sites shows that site (Revelganj) S16 has the highest total bacterial count of (8.263), with (6.141) total coliforms and (4.521) fecal coliforms. In contrast, site (Barh) S18 has a lower total bacterial count of (9.422), with (7.872) total coliforms and 4.738) fecal coliforms. Site (Bahachoki) S19 has an intermediate total bacterial count of (8.779), with 8.410) total coliforms and (8.410) fecal coliforms. Finally, site (Farka) S20 has a total bacterial count of (8.432), with (8.157) total coliforms and (8.157) fecal coliforms. The data also reveals differences in the counts of specific bacterial groups across the sites. For example, site S18 has the highest count of *Azotobacter* bacteria (8.618) compared to S16 (7.921) and S20 (8.157). Similarly, site S16 has the highest count of *Rhizobia* bacteria (8.618)

among the sites, while site S18 has a slightly lower count (8.618) and site S20 has the lowest count (7.872). These differences in bacterial counts can provide insights into the health and productivity of the microbial communities in the sites, as well as their potential impact on the overall environment and ecosystem as shown in Fig 8.29. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

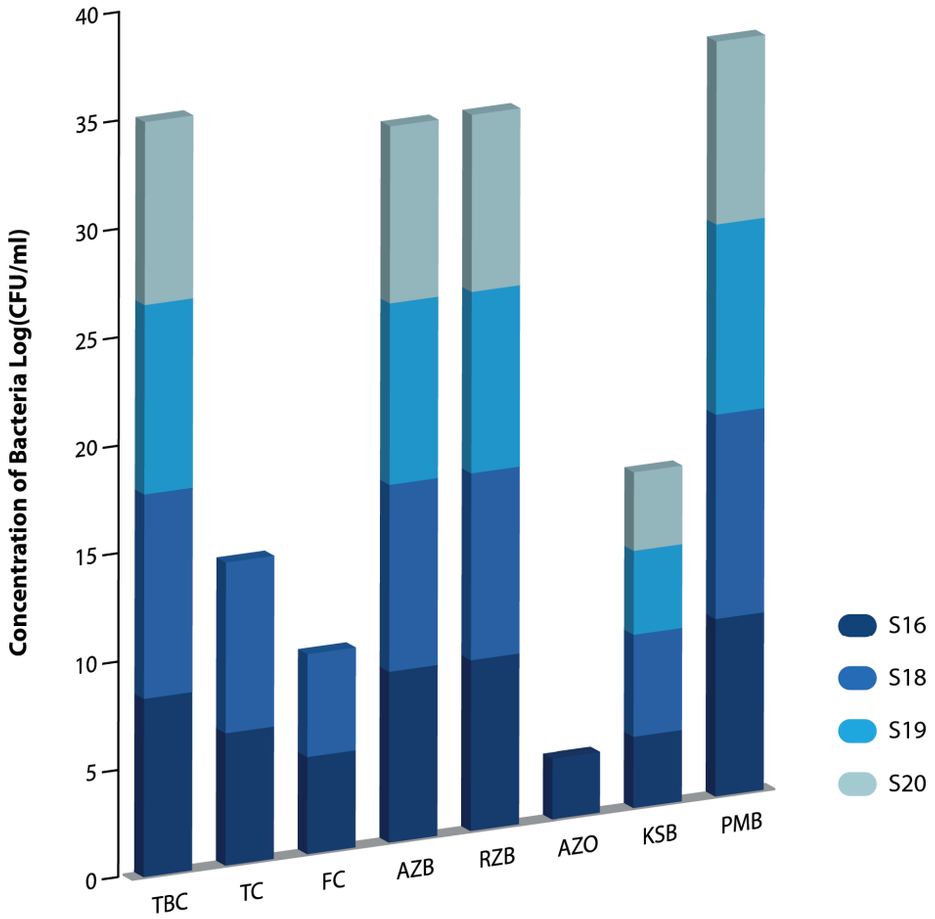


Fig. 8.29 Total and differential bacterial count of *Ricinus communis* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Terminalia arjuna* R.Br.(Roxb. ex-DC.) Wight 4& Arn.

The bacterial count for various sites is given values in Log_{10}. The data shows that site (Barh) S18 has the highest total bacterial count of (9.422), with site (Revelganj) S16 having the lowest total bacterial count of (4.431). Site (Farka) S20 has the highest fecal coliform count (8.157), while site S16 has the lowest (4.255). Site (Bahachoki) S19 has the highest *Azotobacter* bacteria (8.410), while site S16 has the lowest (5.162). Site S20 has the highest *Rhizobia* bacteria (8.064), while site S16 has the lowest (5.033). Site S16

has the highest *Azospirillum* bacteria of (3.602), while site S19 has the lowest *Azospirillum* bacteria of (1.778). Site S18 has the highest potash solubilizing bacteria count of (4.874), while the lowest site S20 (4.029). Finally, site S19 has the highest phosphate solubilizing bacteria count of (8.777), and site S18 has the lowest (2.531) as shown in Fig 8.30. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

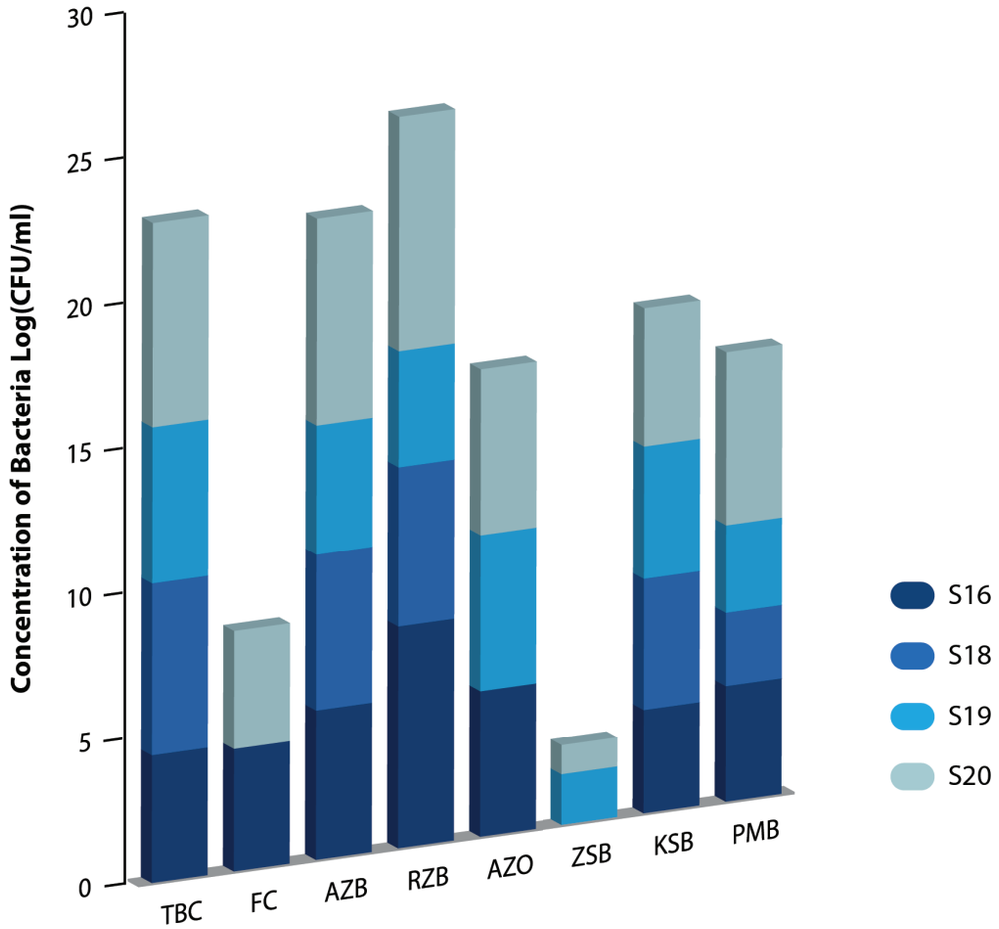


Fig. 8.30 Total and differential bacterial count of *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Tridax procumbens* L.

Site S16 has the lowest total bacterial count and total coliform count, with (3.267) and (3.757). This indicates a lower level of bacterial contamination in this site. Site (Barh) S18 has the highest total bacterial count of (7.268) and fecal coliform count of (6.423). This suggests a higher level of bacterial contamination, particularly in terms of coliform bacteria. Site (Bahachoki) S19 has a similar total bacterial count to S18 but a lower total coliform count, indicating a moderate level of bacterial contamination.

Site (Farka) S20 has a relatively high total bacterial count of (6.960) but a low total coliform count of (3.176), suggesting a lower level of coliform bacteria contamination. In terms of specific bacterial groups, some sites show higher counts for certain bacterium types. For example, site S18 has a high count of *Azotobacter* bacteria (8.618), which are known for their nitrogen-fixing capabilities. This could indicate a potential benefit for plant growth on this site. Similarly, site S20 has a high count of *Azospirillum* bacteria (8.432), which are also known for their nitrogen-fixing abilities, and the values are mentioned in Log_{10} as shown in Fig 8.31. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

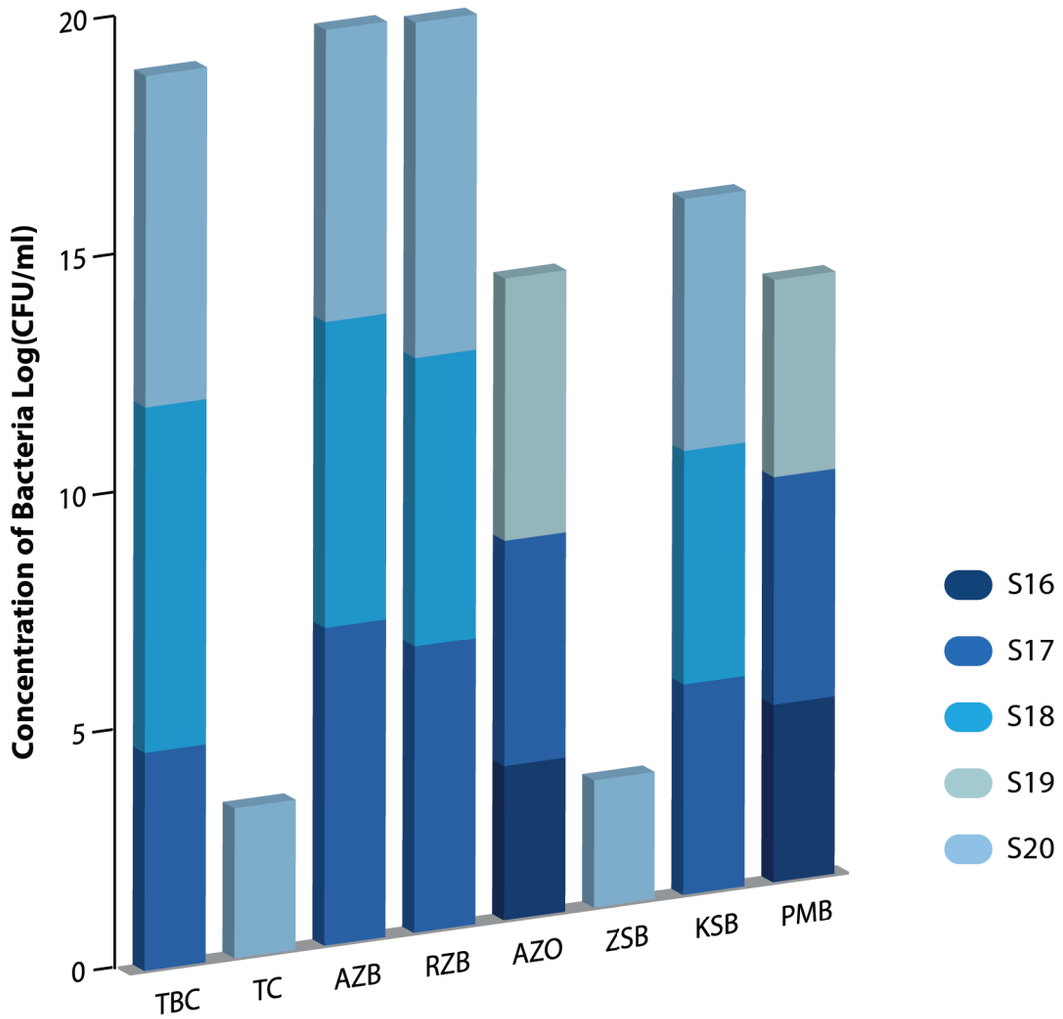


Fig. 8.31 Total and differential bacterial count of *Tridax procumbens* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Boerhavia diffusa* L.

Site (Revelganj) S16 has the lowest total bacterial count (TBC) and total coliform count (TCC) with a total bacterial count of (8.502) and a total coliform count (3.062), indicating a lower level of bacterial contamination in this site. Site (Barh) S18 has the highest total bacterial count of (6.746) and total coliform count of (6.423), suggesting a higher level of bacterial contamination, particularly in terms of coliform bacteria. Site (Bahachoki) S19 has a similar total bacterial count to S18 but a lower total coliform count, indicating a moderate level of bacterial contamination. Site (Farka) S20 has a relatively high TBC of (6.960) but a low TCC (3.176), suggesting a lower level of coliform bacteria contamination. The high count of *Azotobacter* bacteria in site S18 and *Azospirillum* bacteria in site S20 could indicate their potential for nitrogen fixation and plant growth. Site S19 has a high count of Potash solubilizing bacteria, indicating its potential for nutrient management and soil improvement, and the values are mentioned in Log_{10} as shown in Fig 8.32. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

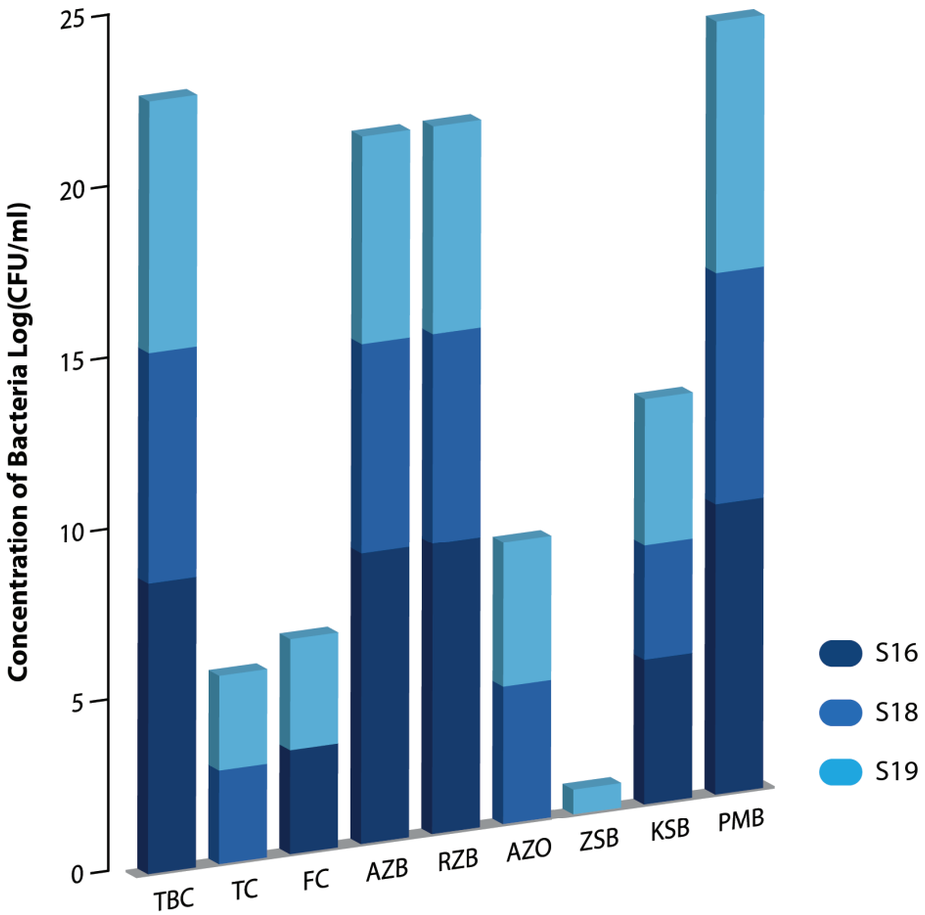


Fig. 8.32 Total and differential bacterial count of *Boerhavia diffusa* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Solanum nigrum* L.

All given values are expressed in Log_{10}. Site (Revelganj) S16 has a total bacterial count (TBC) of (7.988) and a total coliform count (TCC) of (5.948), indicating a moderate level of bacterial contamination. Site (Patna) S17 has a Total Bacterial Count (TBC) of 7.276002308 and a TCC of (2.761), suggesting a lower level of bacterial contamination. Site (Barh) S18 has a TBC (7.355), and Site (Farka) S20 has a TBC of (7.049), both indicating a moderate level of bacterial contamination. The *Azotobacter*, *Rhizobium*, *Azospirillum*, and Zinc sulfate bacteria values also provide insights into the microbial presence at these sites can have implications for soil fertility and plant growth. The TBC and TCC values are key indicators of overall bacterial contamination, which can have implications for environmental and public health as shown in Fig 8.33. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

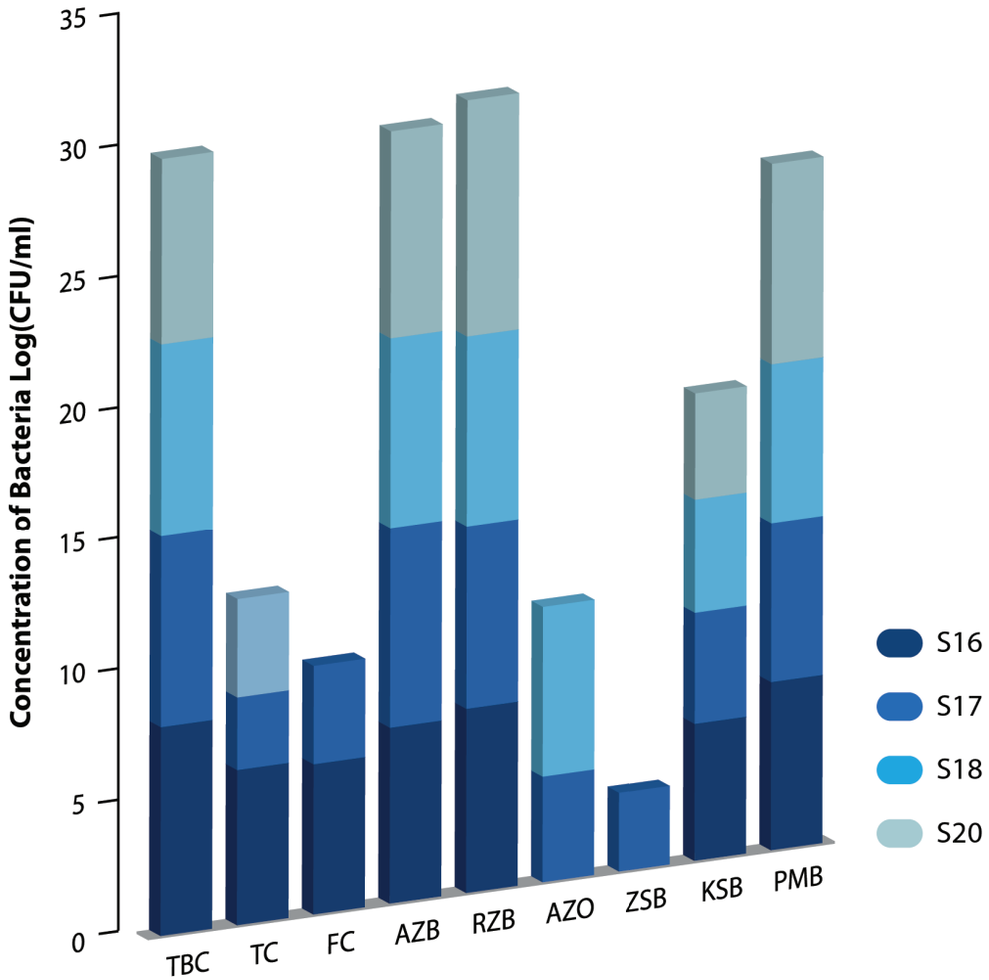


Fig. 8.33 Total and differential bacterial count of *Solanum nigrum* L.

Below, in Fig. 8.34, are some representative images of the isolated bacteria from the selected Bihar sites.

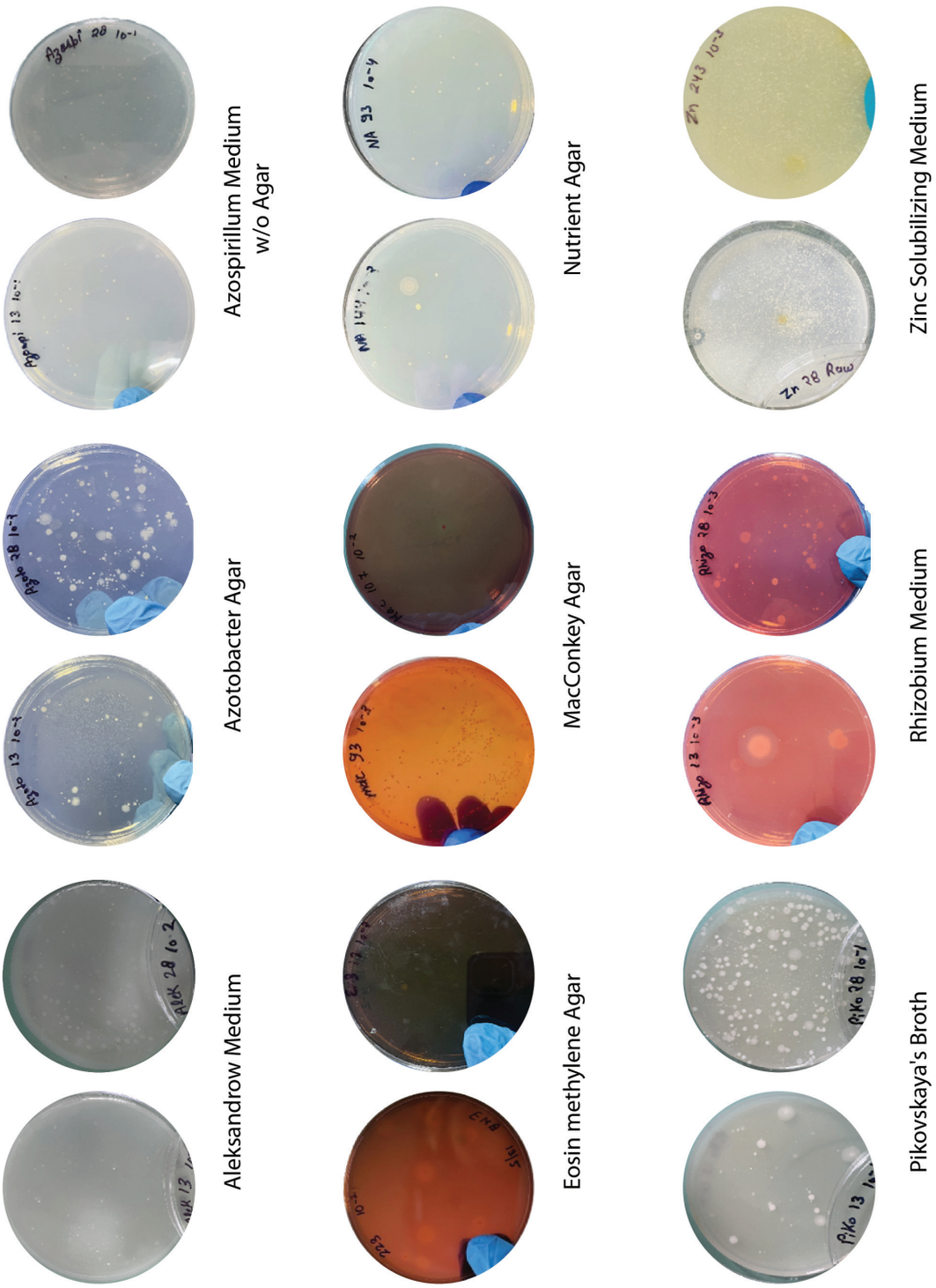


Fig. 8.34 Representative pictures of the isolated bacteria of Bihar



01



9
Total Rhizosphere Soil Collection

02



6.89CFU/ml
Average Rhizosphere Bacterial Concentration

03



***Boerhavia diffusa* L.**
Maximum Bacteria Found

04



5.30CFU/ml
Average Rhizosphere Pathogenic Bacteria Concentration

05



1.3
Benficial Bacteria Ratio Total

JHARKHAND

JHARKHAND

Several studies have reported the presence of rhizosphere bacteria in Jharkhand, India. A study collected maize rhizosphere soils from twelve different locations in Jharkhand and analyzed the microbial populations, including *Pseudomonas* (Kumar et al., 2012). Another study isolated *Bacillus* strains from the rhizosphere of a common bean growing in Uttarakhand Himalaya, which showed potential plant growth-promoting properties (Jyotirmayee et al., 2021). A comparative analysis of rhizospheric bacteria associated with four amla plant soils in Uttarakhand was undertaken. A study characterized bacterial cultures isolated from hot springs in Uttarakhand, including *Bacillus* and *Paenibacillus* species (Bhadrech et al., 2020).

Selected Sites: Sahibganj (S21)

Plants Collected: Total 9 plant is collected *Achyranthes aspera* L., *Croton bonplandianus* Baill., *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L,, *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn, *Tridax procumbens* L., and *Boerhavia diffusa* L.

In the context of Jharkhand, rich botanical diversity, the presence of various medicinal plants, including *Achyranthes aspera* L., *Croton bonplandianus* Baill., *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn, *Tridax procumbens* L., and *Boerhavia diffusa* L.. were investigated. These plant species are notably distributed across different ecological niches within the region. *Achyranthes aspera*, commonly known as Prickly Chaff Flower, is obtained in diverse habitats, from plains to hilly regions (Mengie et al., 2021; Soorgani, N. R., 2023). *Croton bonplandianus*, recognized for its therapeutic properties, is prevalent in lower altitudes. *Cynodon dactylon*., or Bermuda Grass, is ubiquitous in both cultivated and uncultivated areas (Ghosh, T., 2018; Dutta, S., and Chaudhuri, T. K. 2018).) *Ficus racemosa*, *Polygonum plebeium*, *Ricinus communis*, *Solanum nigrum*, *Terminalia arjuna*, *Tridax procumbens*, and *Boerhavia diffusa* exhibit adaptability to varied elevations, showcasing their resilience across Jharkhand diverse landscapes. This distribution and adaptability underscore the ecological significance of these plants and form the basis for further exploration of their medicinal properties, ecological roles, and potential applications in traditional and modern healthcare practices (Nagori, B. P., and Solanki, R. 2011 and Ahmed, F., and Urooj, A. 2010).) The rhizospheric bacteria were Isolated and colony morphology was identified. Nine distinct bacteria were identified from a soil sample collected in various locations (ur Rehman et al, 2018). Different bacteria, including total bacterial count, total fecal and coliform bacteria, Zinc-solubilizers, Rhizobium, *Azotobacer*, *Azospirillum*, potash mobilizers, and Phosphate-solubilizers, are isolated using different media. The distinct strains of isolated

bacteria have different colony morphologies, such as cream-colored, white colonies with smooth, wavy, and branching margins, green colonies with a metallic sheen, and red colonies with some bacteria-producing zones that show an inhibition zone (Ahsan et al., 2018).

Total and Differential Bacterial Populations obtained in the rhizosphere soil of nine different plants.

The comparison of microbial parameters across different plant species reveals distinctive microbial compositions and given values are expressed in Log_{10}.

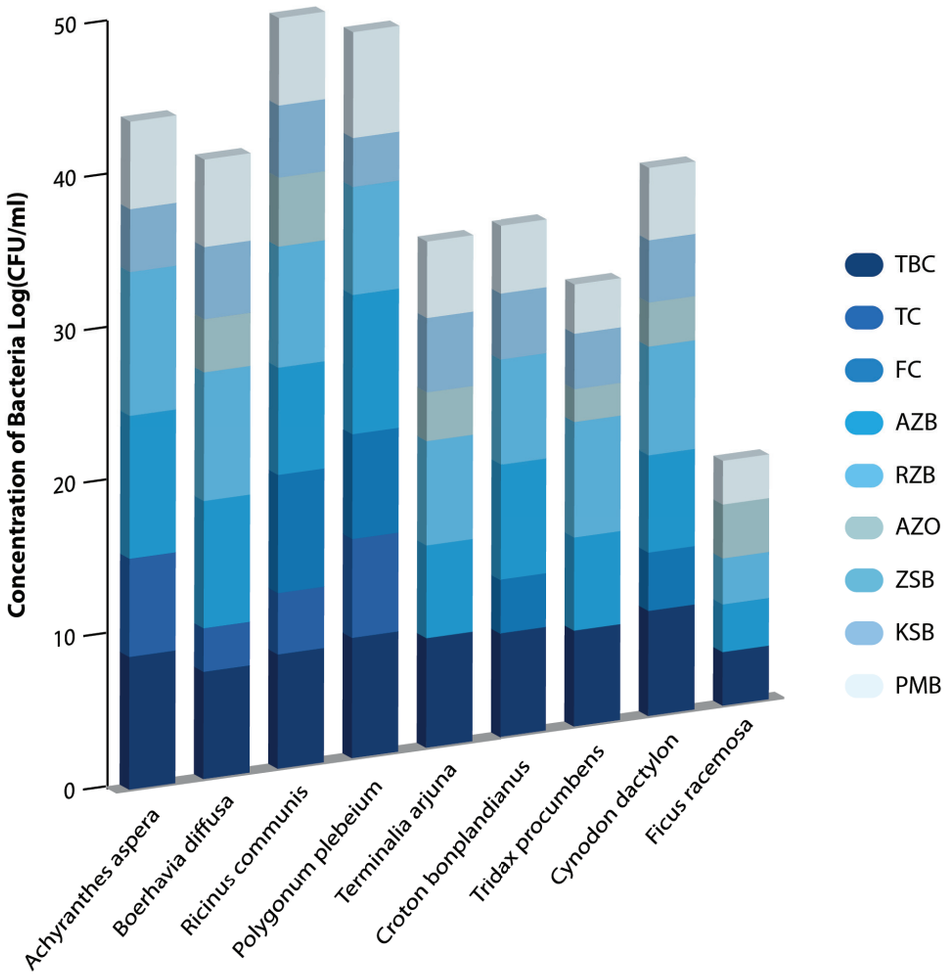


Fig. 8.35 Total and differential bacterial count

Achyranthes aspera demonstrates the highest total bacterial count at (8.72), indicating a robust microbial presence, while *Boerhavia diffusa* and *Ricinus communis* show slightly lower TBC values of (7.06 and 7.54), respectively. In terms of total coliform count, *Achyranthes aspera* again stands out with a value of (6.45), significantly higher

than *Boerhavia diffusa* and *Ricinus communis*. However, *Boerhavia diffusa* exhibits the highest total fecal coliform count at (7.79), emphasizing a potential source of fecal contamination. *Terminalia arjuna*, with the *Azotobacter* bacteria of (6.04), contrasts with *Boerhavia diffusa*, which has the highest *Azotobacter* bacteria at (8.29), indicating variations in nitrogen-fixing bacterial populations. The *Rhizobium* bacteria is highest in *Achyranthes aspera* and *Boerhavia diffusa* at (9.38 and 8.45), respectively. Interestingly, *Boerhavia diffusa* also shows a notable *Azospirillum* bacteria at (3.47), contributing to its potential as a plant growth-promoting bacteria host. Zinc solubilizing bacteria, potash mobilizers, and phosphate solubilizing bacteria exhibit variability across the plant species, indicating diverse microbial dynamics as shown in Fig 8.35. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

Below, in Fig. 8.36, are some representative images of the isolated bacteria from the selected Jharkhand sites.

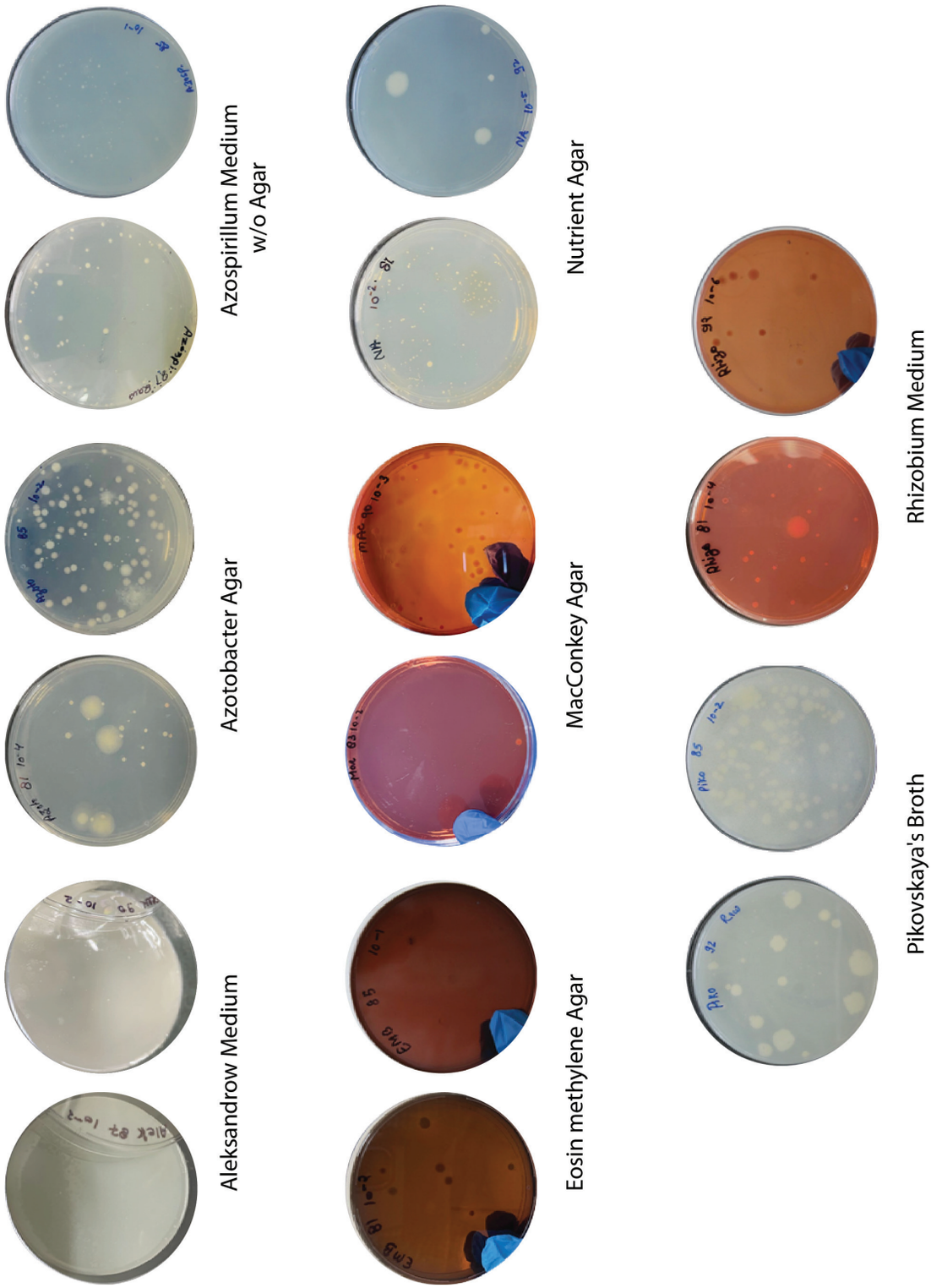


Fig. 8.36 Representative pictures of isolated bacteria of Jharkhand

01



7

Total Rhizosphere Soil Collection

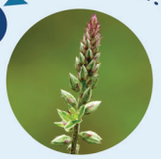
02



7.20CFU/ml

Average Rhizosphere Bacterial Concentration

03



Achyranthes aspera L.

Maximum Bacteria Found

04



4.49CFU/ml

Average Rhizosphere Pathogenic Bacteria Concentration

05



1.4

Benficial Bacteria Ratio Total



WEST BENGAL

WEST BENGAL

Several studies have reported the presence of rhizosphere bacteria in West Bengal, India. One study focused on the rhizosphere bacterial community composition and its effects on cadmium and arsenic contamination in agricultural soils of the Bengal deltaic region of West Bengal (Huang et al., 2021). Another study aimed to identify plant growth-promoting rhizobacteria (PGPR) in the rhizosphere of lentil-growing soils in eastern India, and isolated sixteen rhizosphere bacteria from two different soil orders. The study obtained that three of the isolated strains, including Bacillus subtilis, showed potential as plant growth-promoting rhizobacteria (Das et al., 2023). Additionally, a study reported the isolation of two bacterial strains with plant growth-promoting properties from the rhizosphere of healthy *Solanum lycopersicum* (tomato) plants in West Bengal (Sarbadhikary et al., 2017). These findings demonstrate the diverse range of rhizosphere bacteria and their potential benefits for plant growth and soil health in West Bengal.

Selected Sites: S22 (Farraka), S23 (Hazarduari), S24 (Mayapur), S25 (Hooghly) and S26 (Gangasagar).

Plants Collected: Total 7 plants are collected, *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Solanum nigrum* L., *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn and *Tridax procumbens* L.

In the context of West Bengal's rich botanical diversity, the presence of various medicinal plants, including *Cynodon dactylon* (L.) Pers., *Ficus racemose* L., *Polygonum plebeium* R.Br., *Ricinus communis* L, *Solanum nigrum* L., *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn, and *Tridax procumbens* L., were investigated. These plant species are notably distributed across different ecological niches within the region (Mengie, T., 2021 Soorgani, N. R., 2023). *Cynodon dactylon*., or Bermuda Grass, is ubiquitous in both cultivated and uncultivated areas (Ghosh, T., 2018; Dutta, S., & Chaudhuri, T. K. (2018).) *Ficus racemosa*, *Polygonum plebeium*, *Ricinus communis*, *Solanum nigrum*, *Terminalia arjuna,* and *Tridax procumbens* exhibit adaptability to varied elevations, showcasing their resilience across West Bengal's diverse landscapes. This distribution and adaptability underscore the ecological significance of these plants and form the basis for further exploration of their medicinal properties, ecological roles, and potential applications in traditional and modern healthcare practices (Nagori, B. P., & Solanki, R. (2011) and Ahmed, F., & Urooj, A. (2010).) The rhizospheric bacteria were isolated and colony morphology was identified. Nine distinct bacteria were identified from a soil sample collected in various locations (ur Rehman, A., et al, 2018). Different bacteria, including total bacterial count, total fecal and coliform bacteria, Zinc-solubilizers, Rhizobium, *Azotobacer*, *Azospirillum*, potash mobilizers, and Phosphate-solubilizers, are isolated using different media. The distinct strains of isolated bacteria have different colony morphologies, such as cream-colored, white colonies with

smooth, wavy, and branching margins, green colonies with a metallic sheen, and red colonies with some bacteria-producing zones that show an inhibition zone (Ahsan, et al., 2018)

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Cynodon dactylon* (L.) Pers.

In the examined sites, the value mentioned in Log_{10} where site S24 (Mayapur), stands out with distinctive microbial characteristics. It exhibits the highest total bacterial count at 6.78, indicating a notable microbial presence in the soil. Furthermore, site S24 demonstrates the highest counts for *Azotobacter* bacteria at 6.08, *Rhizobium* bacteria at 6.02, *Azospirillum* bacteria at 5.86, zinc solubilizing bacteria at 5.15, potash mobilizer bacteria at 3.93, and phosphate solubilizing bacteria at 5.15. These elevated values suggest a potentially thriving and diverse microbial community in site S24, reflecting favorable conditions for various bacteria involved in nutrient cycling and soil health. Understanding such variations across sites provides valuable insights into the complex dynamics of microbial populations and their implications for soil ecosystems as shown in Fig 8.37. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

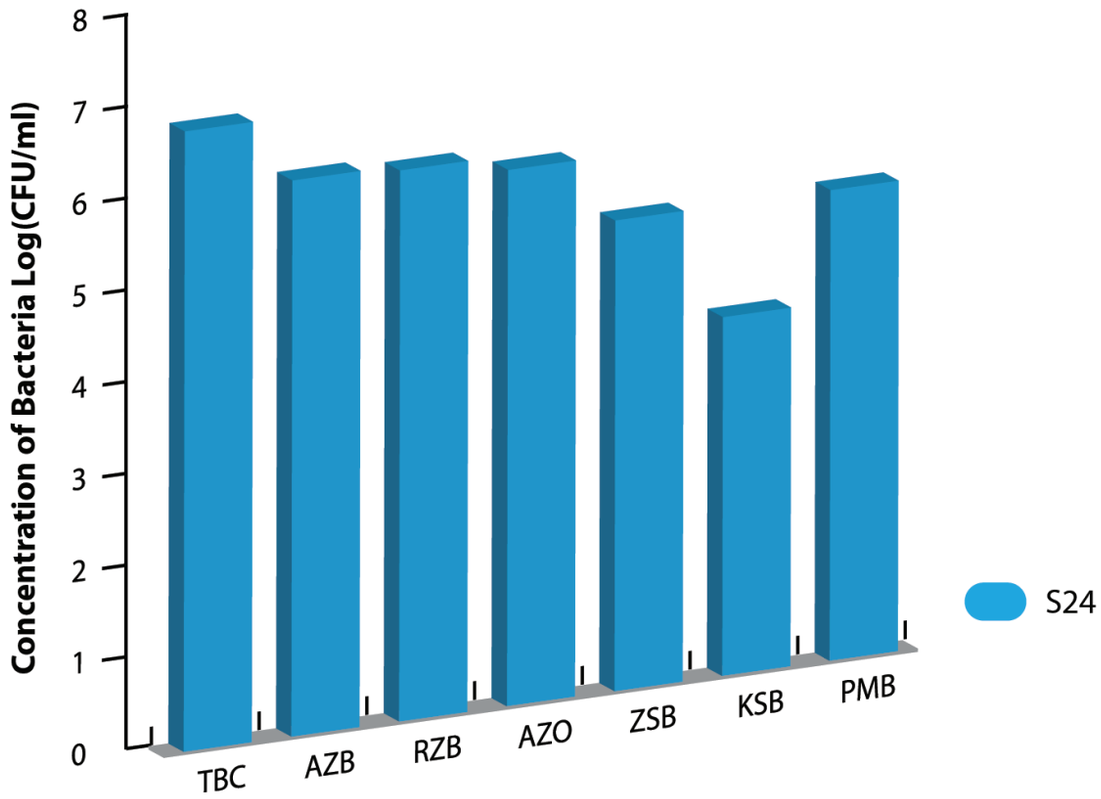


Fig. 8.37 Total and differential bacterial count of *Cynodon dactylon* (L.) Pers.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Ficus racemose* L.

In the surveyed sites, the value mentioned in Log_{10} in which site S26 exhibits distinctive microbial characteristics, with notable variations in the recorded parameters. It displays the highest total bacterial count at 4.95, indicating a substantial microbial presence in the soil. Additionally, site S26 records the highest total fecal coliform count at 5.70, highlighting a potential source of fecal contamination. On the other hand, site S26 shows relatively lower values for the total coliform count at 3.97, Azotobacter bacteria at 4.69, *Rhizobium* bacteria at 5.12, *Azospirillum* bacteria at 4.93, zinc solubilizing bacteria at 3.60, potash mobilizer bacteria at 3.74, and phosphate solubilizing bacteria at 5.10. These findings suggest that while site S26 has a substantial overall microbial presence and potential fecal contamination, it exhibits relatively lower counts for specific bacterial groups as shown in Fig 8.38. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

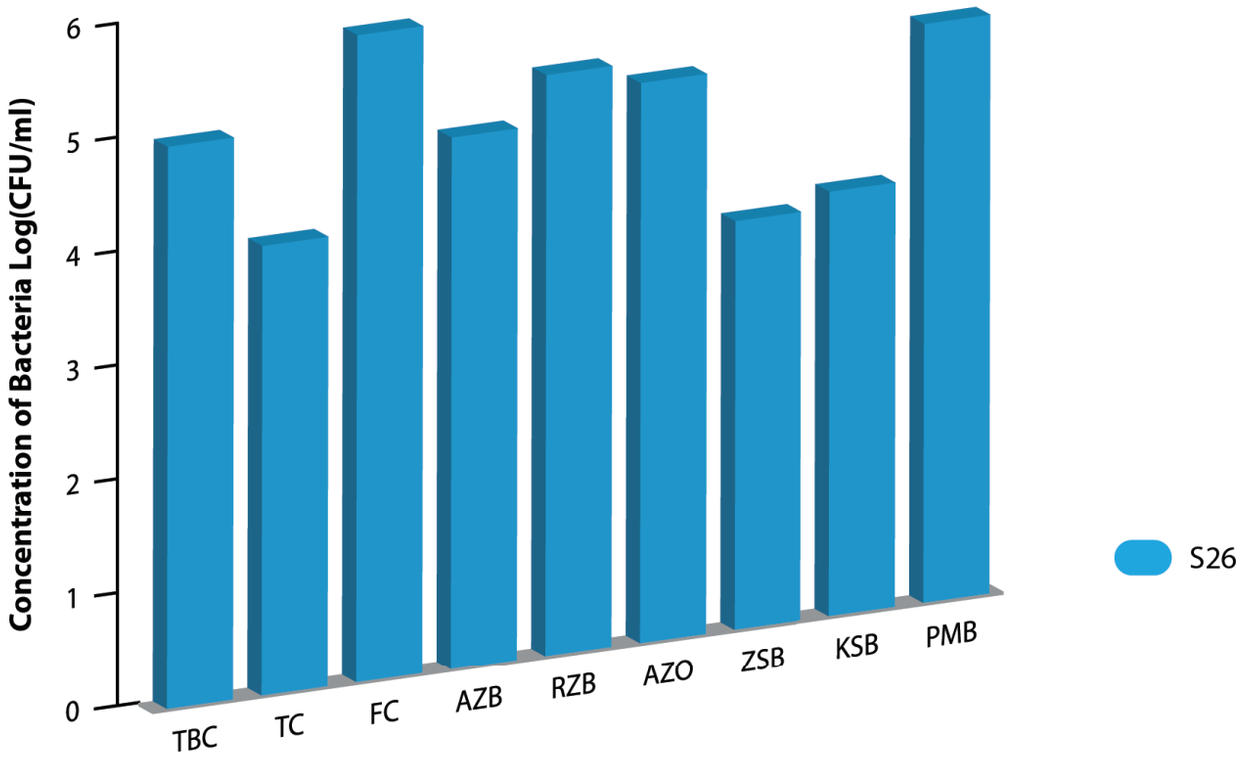


Fig. 8.38 Total and differential bacterial count of *Ficus racemose* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Polygonum plebeium* R.Br.

In the surveyed sites, the values expressed with Log_{10}, and site S25 stand out with distinctive microbial characteristics, displaying the highest total bacterial count at 8.06. This signifies a substantial and thriving microbial presence in the soil. Moreover, site S25 records the highest *Azotobacter* bacteria at 9.20 and the highest *Rhizobium* count at 9.15, indicating a robust population of nitrogen-fixing bacteria. It also exhibits a considerable total coliform count at 4.55 and a moderate total fecal coliform count at 5.12, suggesting the presence of coliform bacteria with potential implications for fecal contamination. Conversely, site S25 shows relatively lower values for *Azospirillum* bacteria at 5.90, potash mobilizer bacteria at 4.78, and phosphate solubilizing bacteria at 5.06. These findings highlight the intricate microbial dynamics across sites, where site S25 excels in overall microbial abundance, nitrogen-fixing bacteria, and coliform counts while displaying comparatively lower counts for specific bacterial groups as shown in Fig. 8.39. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

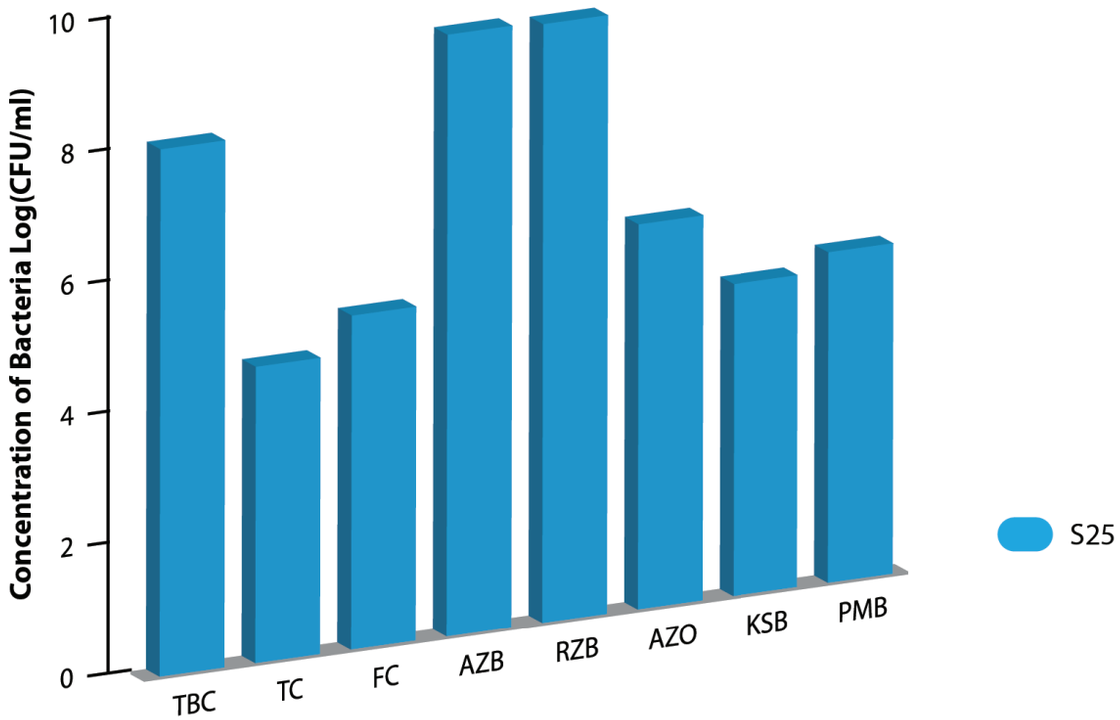


Fig. 8.39 Total and differential bacterial count of *Polygonum plebeium* R.Br.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Ricinus communis* L.

In the examined sites, the values expressed in Log_{10} where site S25 exhibits distinctive microbial characteristics, displaying the highest total bacterial count at 7.25, indicative of a substantial and thriving microbial population in the soil. Moreover, site S25 records the highest *Azotobacter* bacteria at 7.71 and the highest Rhizobium bacteria at 7.85, pointing to a robust presence of nitrogen-fixing bacteria. However, it is noteworthy that Site S25 shows a lower total coliform count at 6.09 and a relatively moderate total fecal coliform count at 3.75, suggesting a comparatively lower abundance of coliform bacteria with reduced potential for fecal contamination. Additionally, site S25 displays lower values for *Azospirillum* bacteria at 3.66, potash mobilizer bacteria at 4.17, and phosphate solubilizing bacteria at 5.85 as shown in Fig. 8.40. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

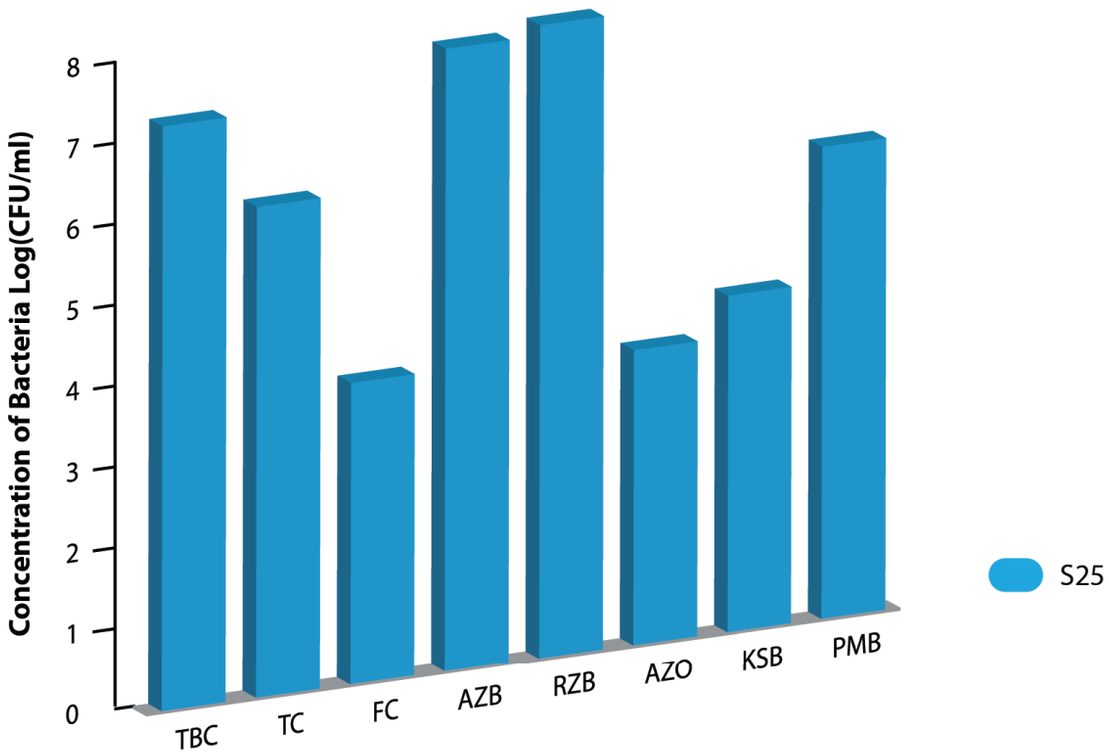


Fig. 8.40 Total and differential bacterial count of *Ricinus communis* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn.

Among the surveyed sites, all the values are expressed with Log_{10}. Site S22 (Farraka) exhibits notable variations in microbial parameters. It displays the highest total bacterial count at [Log_{10}(7.15)], indicating a substantial microbial presence in the soil. However, site S22 has a comparatively lower total coliform count at 4.19 and a moderate total fecal coliform count at 3.90, suggesting a reduced presence of coliform bacteria and potential fecal contamination. In terms of nitrogen-fixing bacteria, site S22 shows concentration of *Azotobacter* bacteria of 5.23 and *Rhizobium* bacteria of 5.36. Notably, site S22 records the lowest zinc solubilizing bacteria at 1.85, indicating a relatively lower population involved in making zinc more available to plants. Additionally, site S22 has moderate values for *Azospirillum* bacteria at 4.93, potash mobilizer bacteria at 4.62, and phosphate solubilizing bacteria at 5.66. These findings highlight the diverse microbial dynamics across sites, with site S22 standing out for its overall microbial abundance while demonstrating lower counts for specific bacterial groups, especially in zinc solubilization as shown in Fig. 8.41. The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

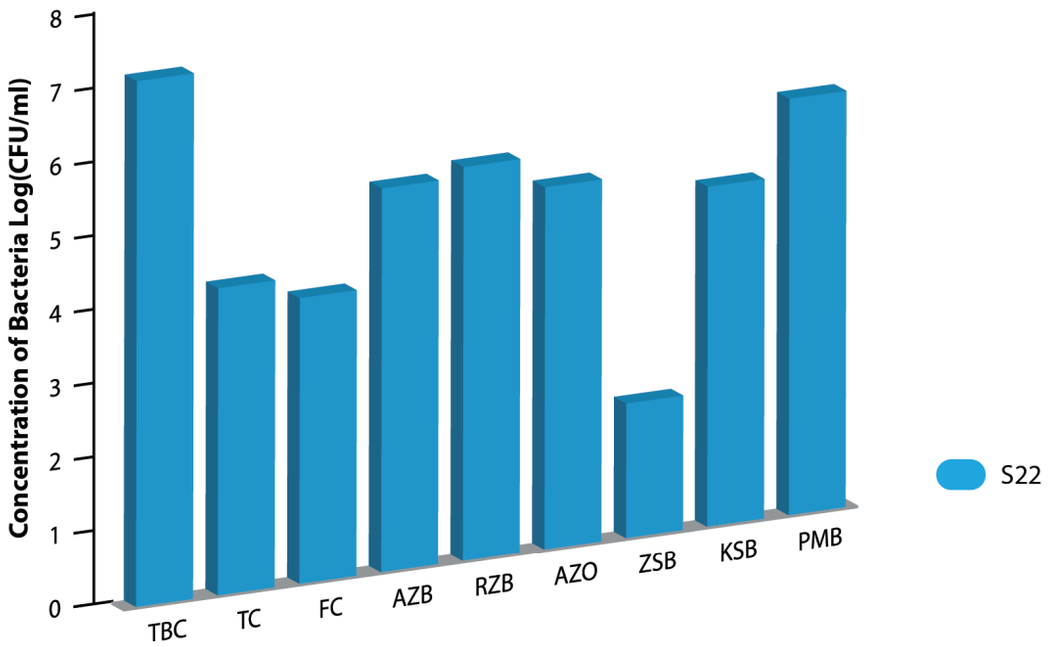


Fig. 8.41 Total and differential bacterial count of *Terminalia arjuna* R.Br.(Roxb. ex DC.) Wight & Arn

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Tridax procumbens* L.

In the comparison of surveyed sites, values mentioned with Log_{10} in which site S25 stands out with distinctive microbial parameters. It boasts the highest total bacterial count at 7.86, indicating a substantial microbial presence in the soil. Site S25 also demonstrates a moderate total coliform count of 4.71 and a total fecal coliform count of 4.29, suggesting a considerable presence of coliform bacteria without a significant fecal contamination risk. In terms of nitrogen-fixing bacteria, Site S25 exhibits an *Azotobacter* bacteria of 5.70 and *Rhizobium* bacteria of 6.66, emphasizing its potential for hosting nitrogen-fixing microbial communities. However, site S25 records the lowest zinc solubilizing bacteria at 2.0, indicating a relatively lower population involved in making zinc more available to plants. Additionally, Site S25 shows moderate values for *Azospirillum* bacteria at 4.04, potash mobilizer bacteria at 5.31, and phosphate solubilizing bacteria at 4.79 as shown in Fig. 8.42 The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

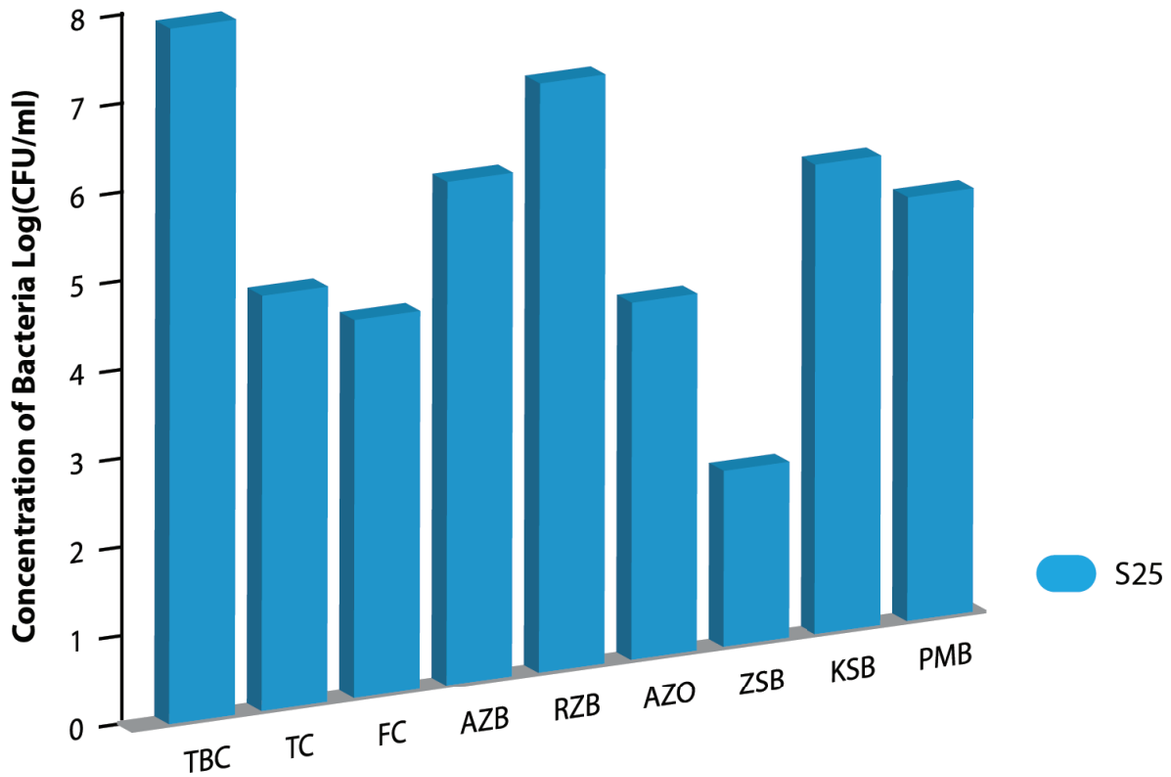


Fig. 8.42 Total and differential bacterial count of *Tridax procumbens* L.

Total and Differential Bacterial Population obtained in the rhizosphere soil of *Solanum nigrum* L.

All the values are given in Log10. Site S25 distinguishes itself in the comparison of surveyed sites with notable microbial parameters. It records the highest total bacterial count at 8.36, signifying a substantial microbial presence in the soil. Despite a relatively lower total coliform count at 3.75 and total fecal coliform count at 3.93, indicating a moderate presence of coliform bacteria and a limited risk of fecal contamination, Site S25 demonstrates potential as a host for nitrogen-fixing microbial communities with Azotobacter bacteria of 5.12 and *Rhizobium* bacteria of 5.41. The site also exhibits a moderate zinc solubilizing bacteria at 2.17, suggesting its role in enhancing zinc availability for plants. Additionally, site S25 displays moderate values for *Azospirillum* bacteria at 3.80, potash mobilizer bacteria at 4.65, and phosphate solubilizing bacteria at 5.52 as shown in Fig. 8.43 The full form of the abbreviations of the culture medium used in the figure given in the material method section Table 8.4.

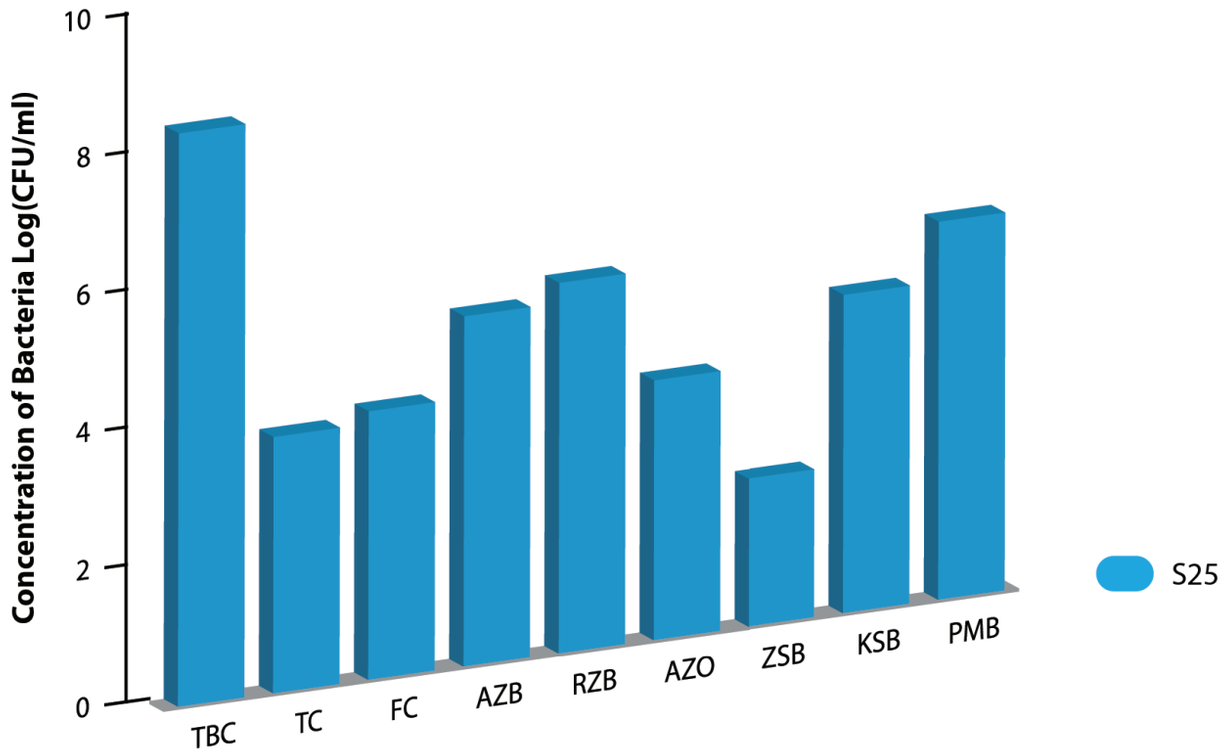


Fig. 8.43 Total and differential bacterial count of *Solanum nigrum* L.

Below, in Fig. 8.44, are some representative images of the isolated bacteria from the selected West Bengal sites.

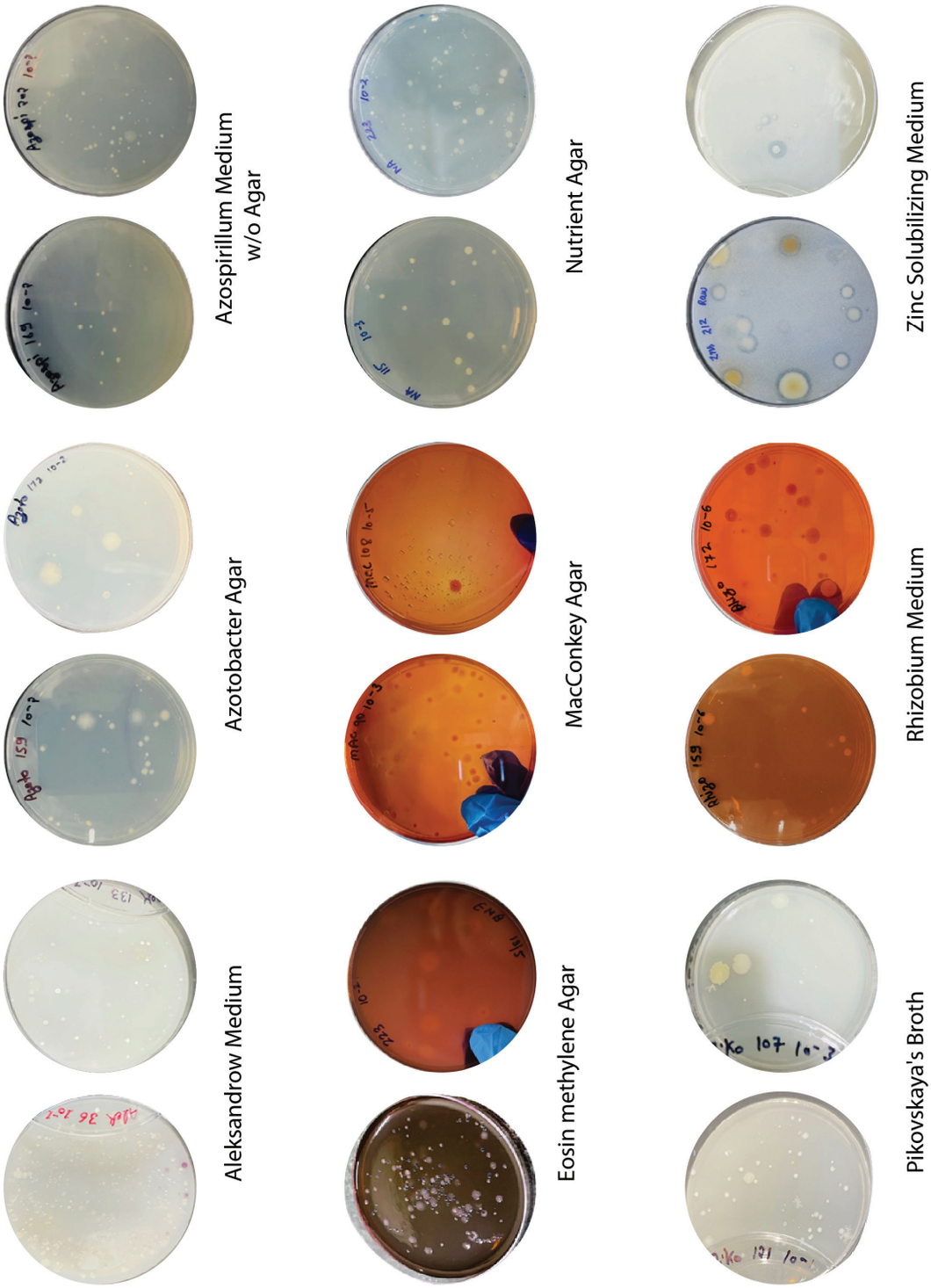


Fig. 8.44 Representative pictures of the isolated bacteria of West Bengal

Comparison of Rhizosphere bacterial population among the medicinal plants

The rhizosphere microbial bacteria across diverse plant species revealed substantial variations in microbial concentrations within their respective environments. The study encompassed an analysis of total bacterial counts, total coliform, and fecal coliform counts, azotobacter, rhizobium, azospirillum, zinc solubilizing, potash mobilizer and phosphate solubilizing bacteria counts across different plant species. A comparison among the selected plants has been shown below in Fig 8.45.

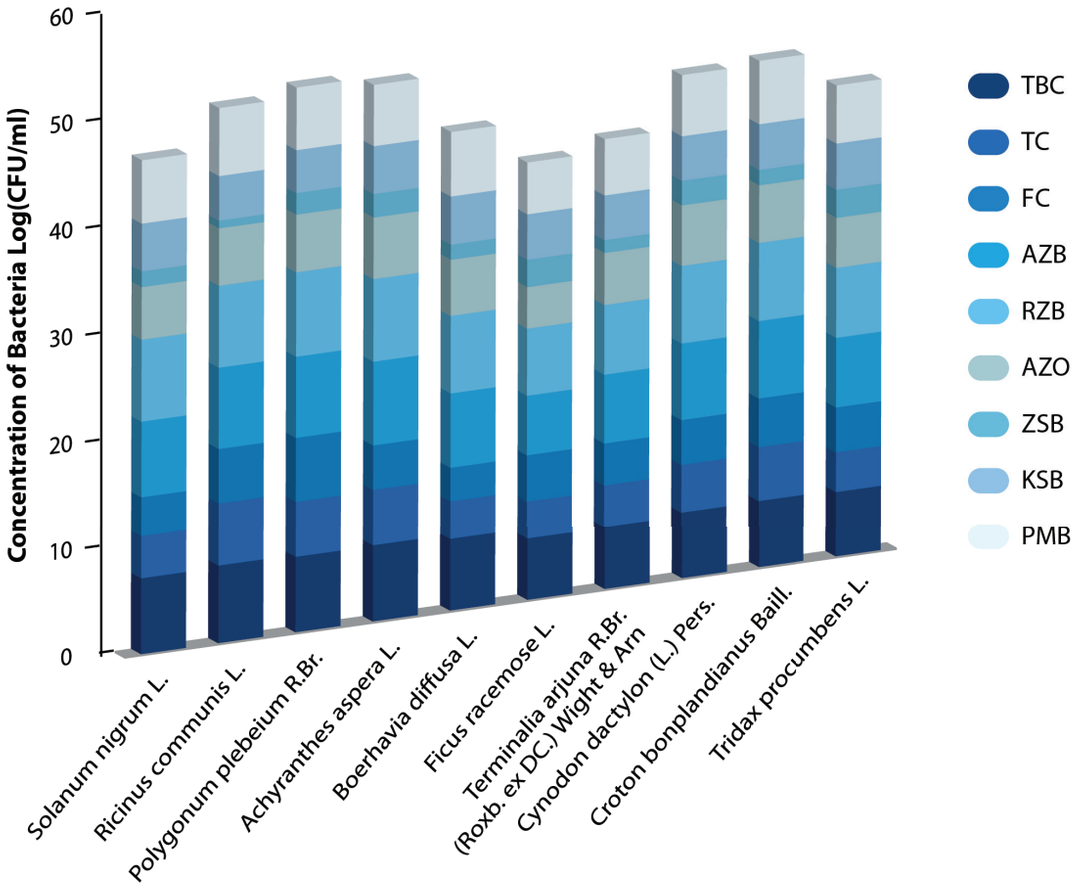


Fig. 8.45 Comparison of rhizosphere bacteria obtained from selected medicinal plants.

Ricinus communis exhibited the highest average total bacterial count at 7.366. *Ficus racemosa* showed a marginally lower average count of 5.847. Other plant species demonstrated intermediate average counts ranging from 3.403 to 8.919. R. communis displayed the highest average total coliform count at 5.883. *F.* racemosa exhibited the

lowest average count at 3.499. Other plant species displayed intermediate average counts ranging from 2.440 to 7.333. *Polygonum plebeium* demonstrated the highest average fecal coliform count at 5.982. *Boerhavia diffusa* displayed the lowest average count at 3.142. Other plant species exhibited intermediate average counts ranging from 2.440 to 8.121. Achyranthes aspera presented the highest average azotobacter count at 7.831. *F. racemosa* recorded the lowest average count at 5.565. Other plant species showed intermediate average counts ranging from 3.403 to 9.025. *Polygonum plebeium* exhibited the highest average rhizobium count at 7.892. *F. racemosa* registered the lowest average count at 6.281. Other plant species displayed intermediate average counts ranging from 0.905 to 9.061. A. aspera recorded the highest average azospirillum count at 5.750. *F. racemosa* displayed the lowest average count at 3.875. Other plant species exhibited intermediate average counts ranging from 2.146 to 7.183. *Tridax procumbens* recorded the highest average zinc sulphate bacteria count at 2.624. R. communis registered the lowest average count at 0.724. Other plant species exhibited intermediate average counts ranging from 0.481 to 5.146. *P. plebeium* showed a consistent average count of 2.021, indicating a stable concentration. *B. diffusa* presented the highest average count at 4.505. *P. plebeium* showed the lowest average count at 4.008. Other plant species exhibited intermediate average counts ranging from 1.633 to 5.581. *P. plebeium* exhibited a constant average count of 4.008, signifying stability. R. communis recorded the highest average phosphate solubilizing bacteria count at 6.353. *F. racemosa* exhibited the lowest average count at 4.835. Other plant species showed intermediate average counts ranging from 2.00 to 7.76. These results underscore the diverse microbial compositions inherent to distinct plant species, highlighting the necessity of considering plant-specific factors in comprehending the ecology of their associated bacterial communities.

Conclusion

In conclusion, extensive microbial analysis conducted across diverse plant species, including *Achyranthes aspera* and others, unveils the intricate relationships between rhizosphere bacteria and soil health. The variations in microbial populations, as highlighted in specific plant species such as *Achyranthes aspera*, *Croton bonplandianus*, *Cynodon dactylon*, and others, underscore the complexity of microbial ecosystems and their potential impact on organic farming. The higher microbial content observed in *Achyranthes aspera*, especially in S5 (Haridwar), suggests a conducive environment for nitrogen fixation and potassium availability, essential elements in organic farming practices. However, the elevated coliform counts raise concerns about potential contamination, emphasizing the need for vigilant attention to water quality issues, a critical aspect in organic farming. Exploring microbial populations in

various medicinal plants provides detailed insights into each plant's rhizosphere, emphasizing the diversity in bacterial counts, particularly in nitrogen-fixing bacteria like *Azotobacter* and *Rhizobium*. These findings have proobtained implications for soil fertility and overall plant growth, crucial considerations in the context of sustainable and organic agriculture. The reported variations in microbial populations between different locations highlight the importance of continued research and monitoring, especially in the context of organic farming. The nuances in the microbial dynamics uncovered in this study contribute to a deeper understanding of plant-microbe interactions, serving as an obtundation for future studies aimed at enhancing agricultural productivity through organic and sustainable practices. Moreover, the incorporation of microbial data across diverse sites for various plant species provides a holistic overview of microbial composition and its potential implications for soil health. The unique characteristics of each plant species and their associated microbial communities, as illustrated in the accompanying figures, offer valuable insights for tailored interventions in organic farming. These findings contribute to the broader understanding of soil ecosystems and serve as a guide for informed decision-making in organic agriculture and environmental stewardship.

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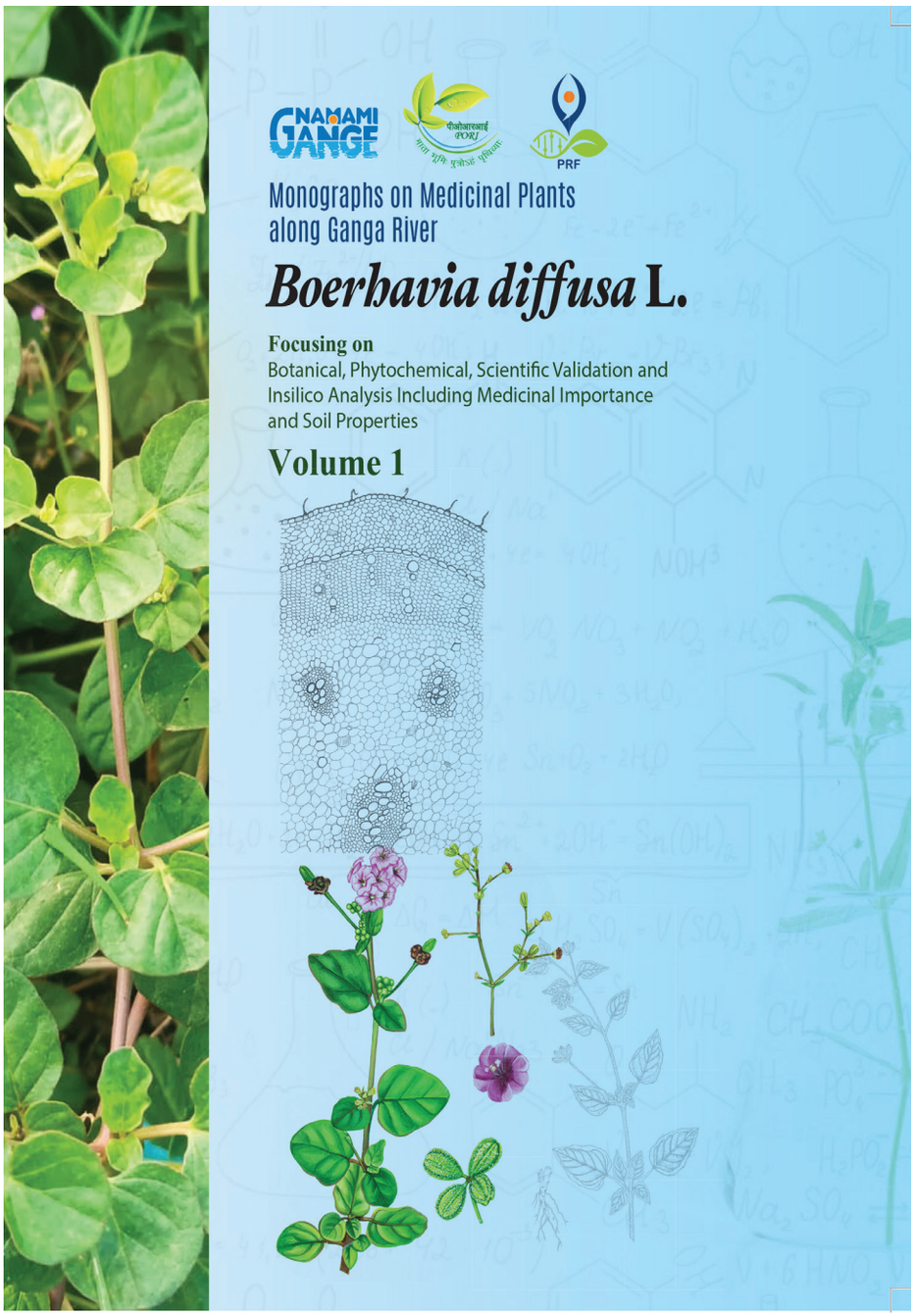
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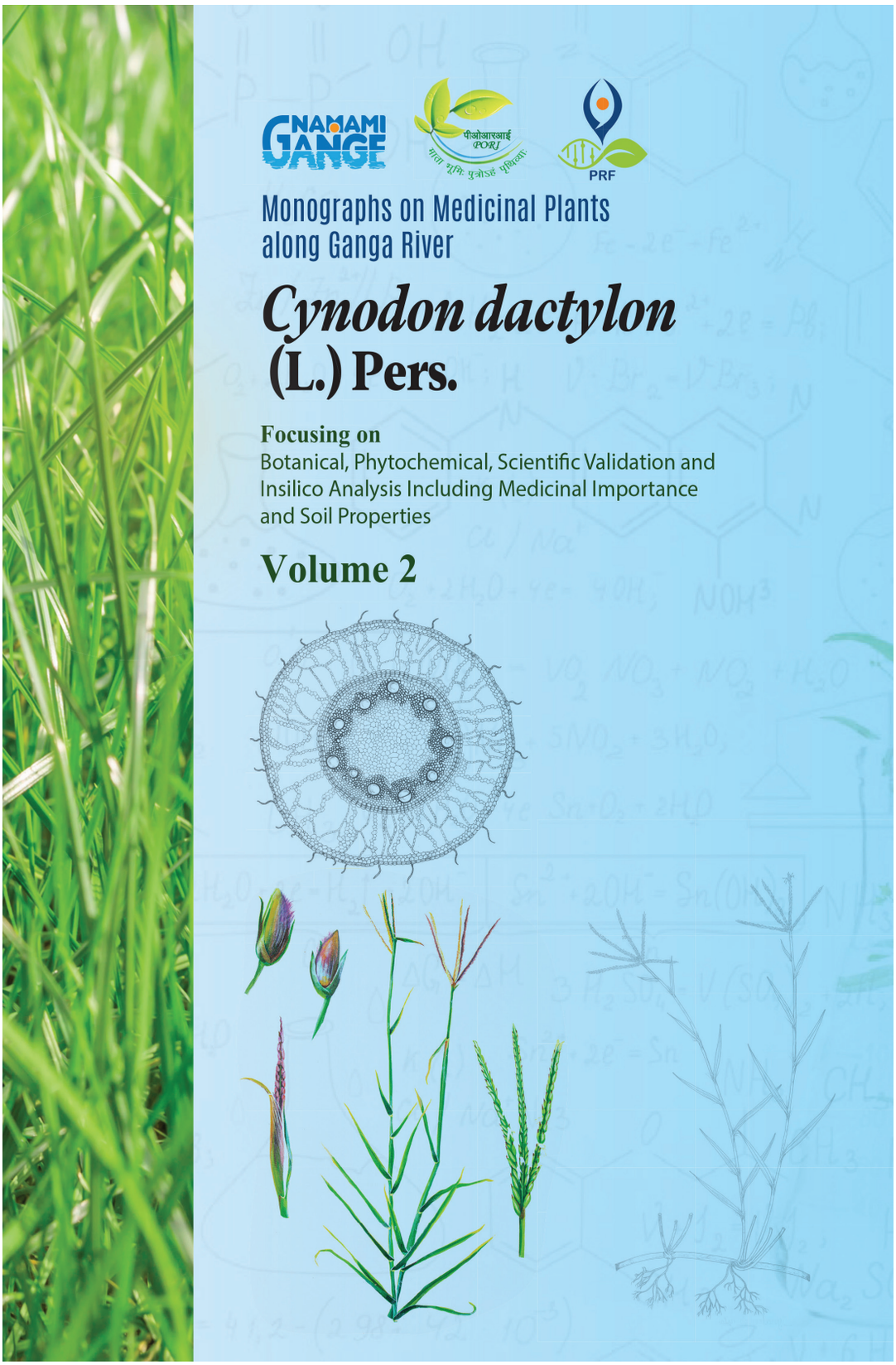
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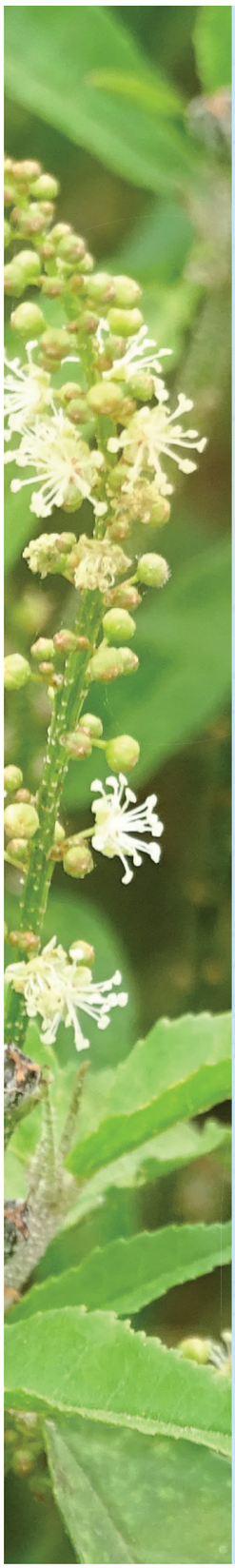
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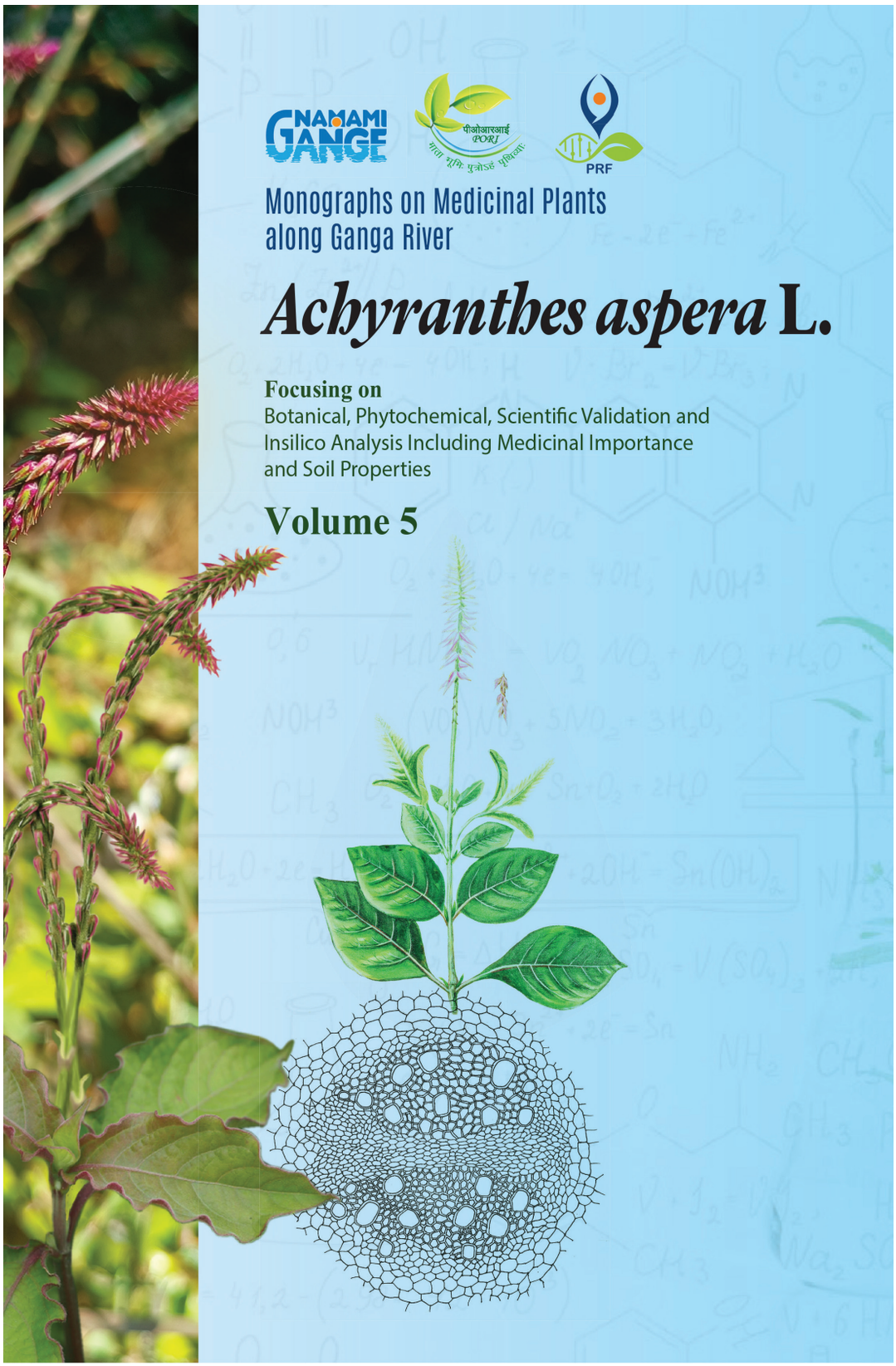
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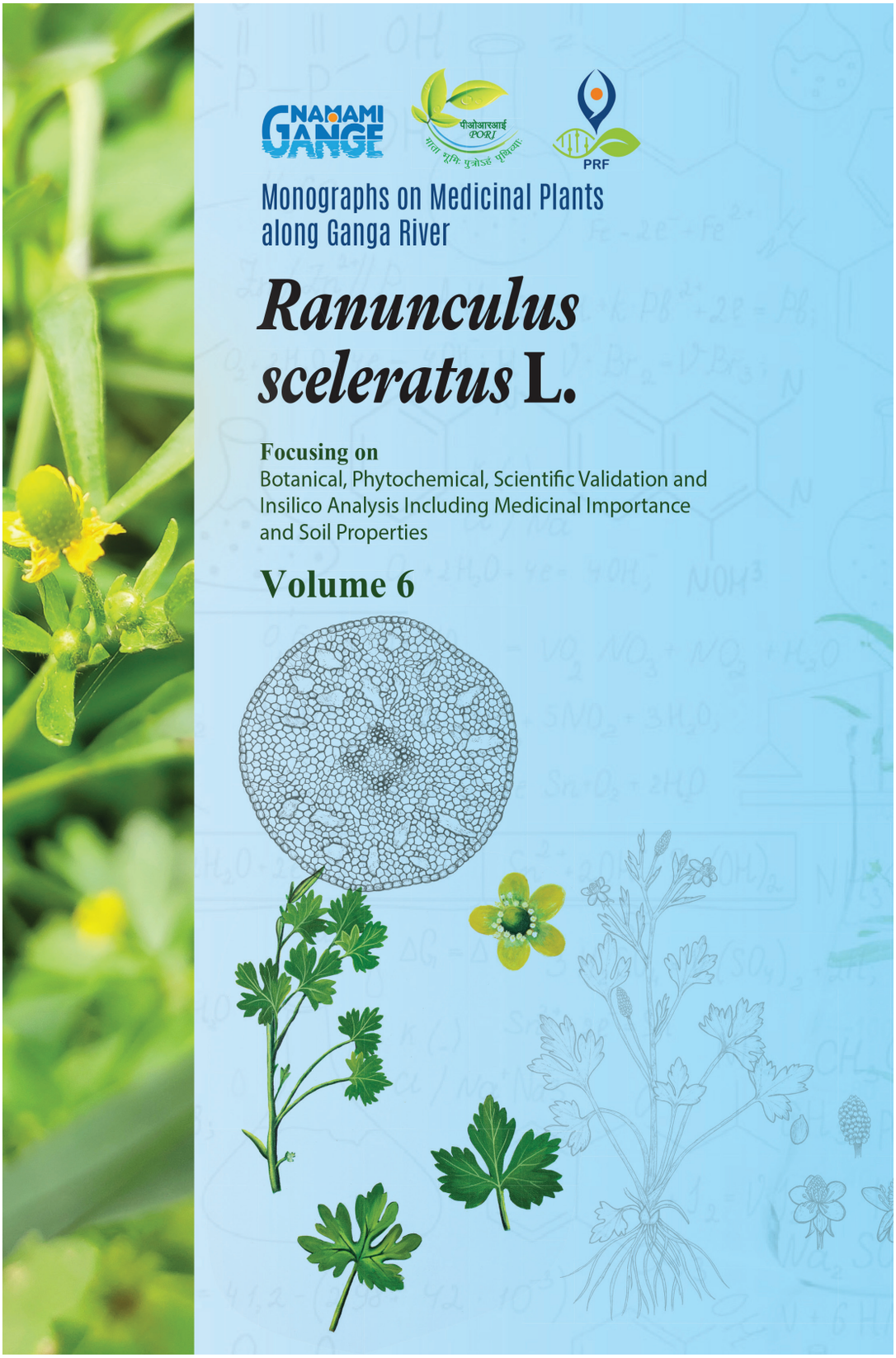
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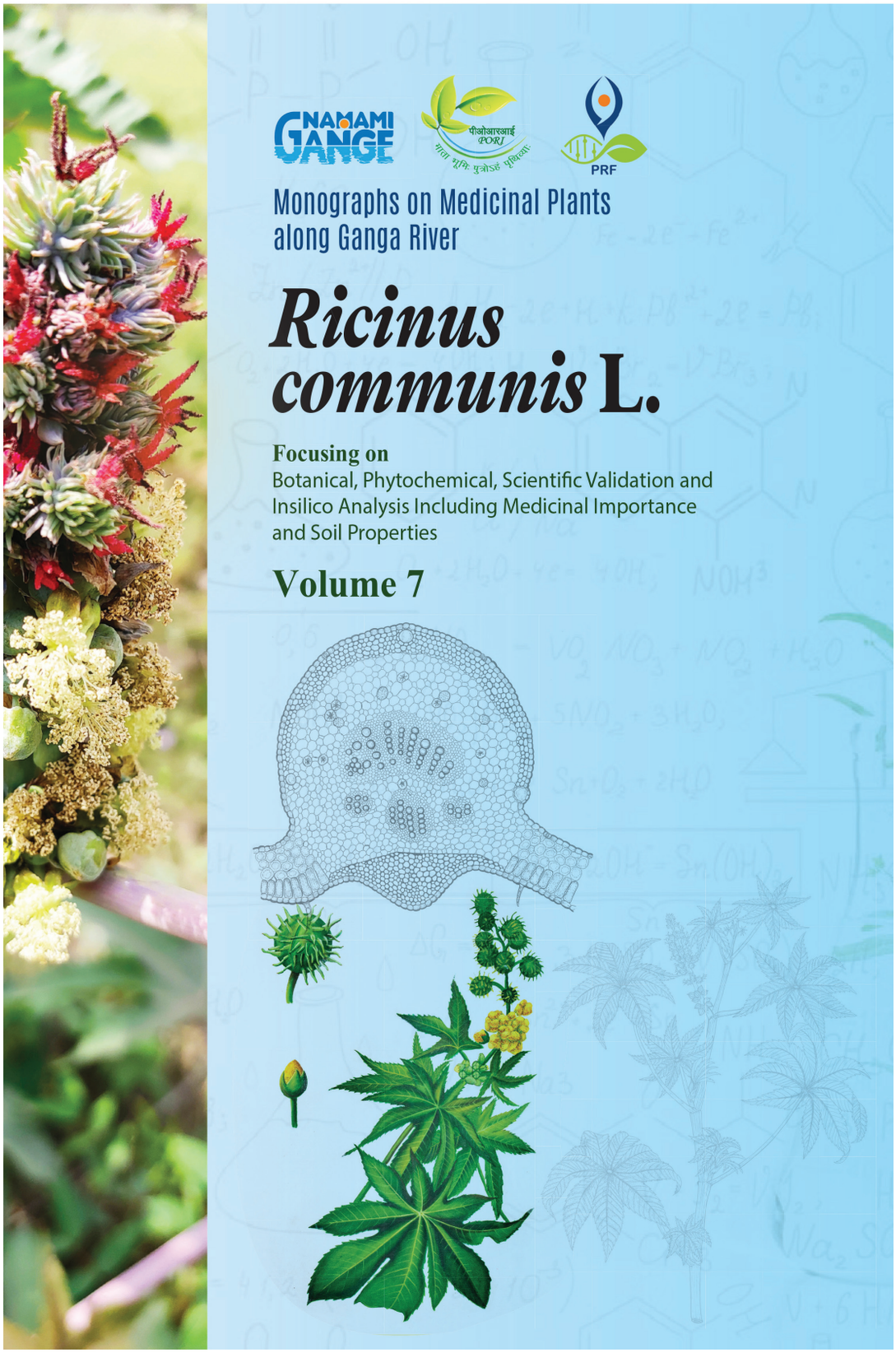
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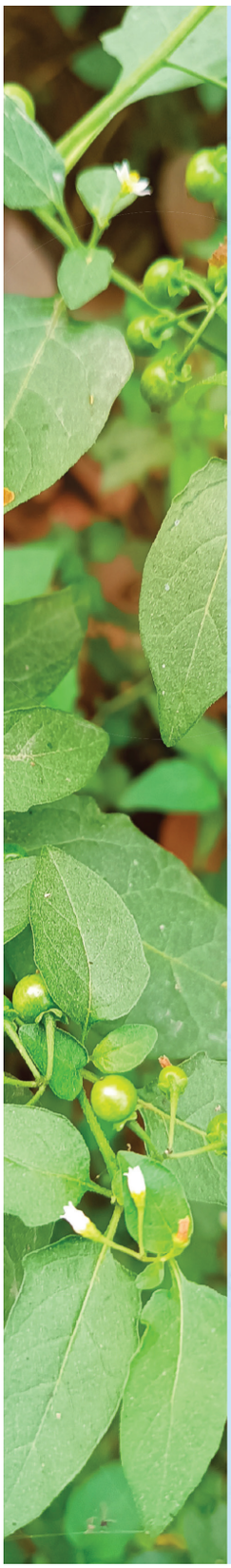
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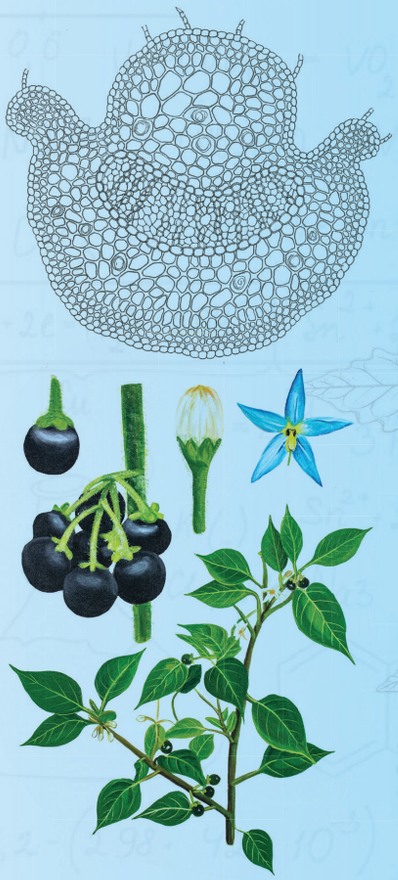


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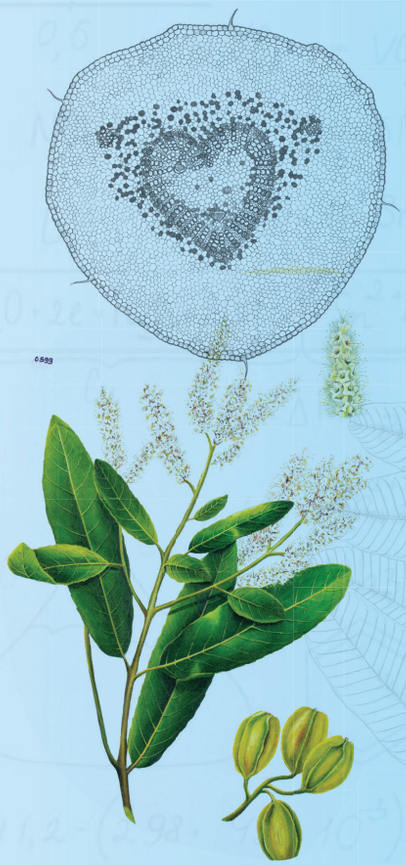
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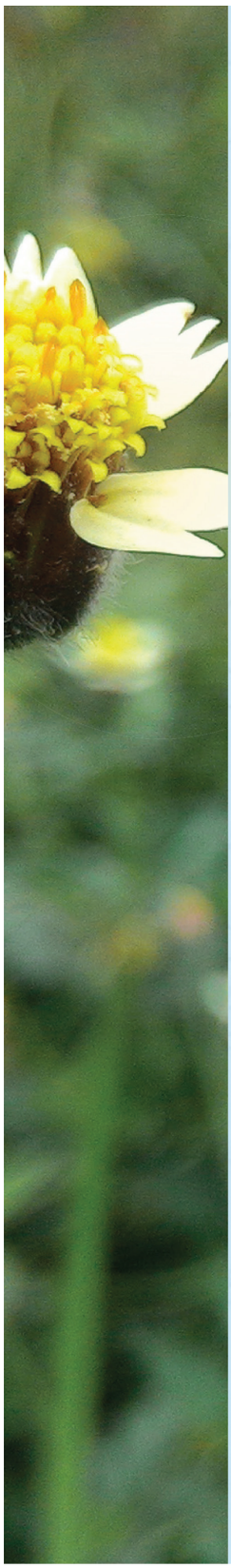
Monographs on Medicinal Plants
along Ganga River

Terminalia arjuna (Roxb. ex DC.) Wight & Arn.

Focusing on
Botanical, Phytochemical, Scientific Validation and
Insilico Analysis Including Medicinal Importance
and Soil Properties

Volume 9



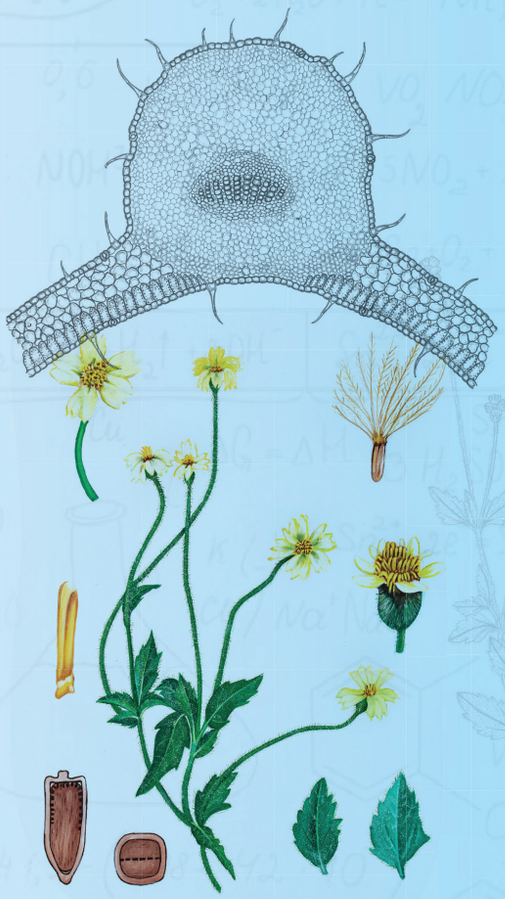


Monographs on Medicinal Plants
along Ganga River

Tridax procumbens L.

Focusing on
Botanical, Phytochemical, Scientific Validation and
Insilico Analysis Including Medicinal Importance
and Soil Properties

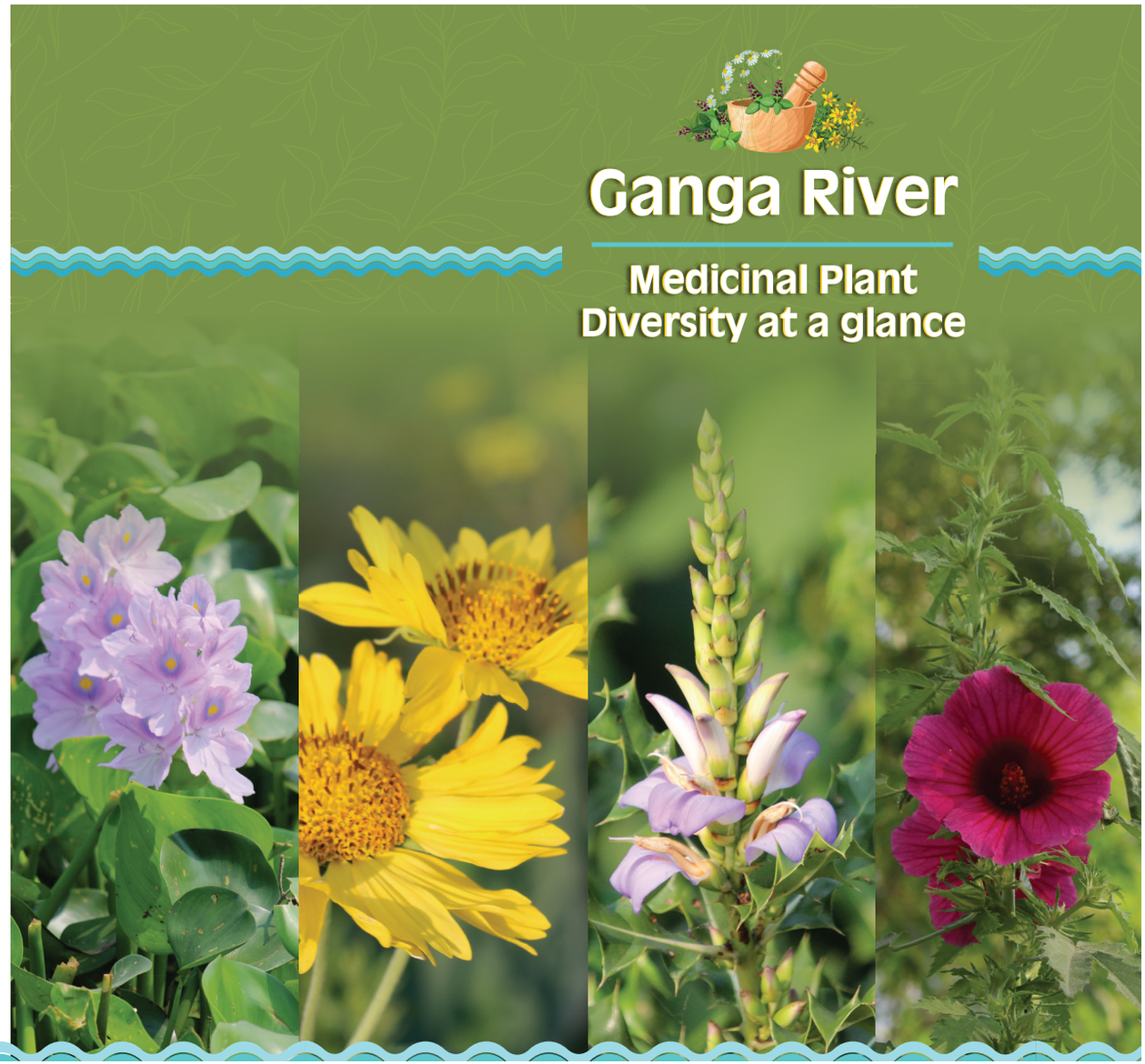
Volume 10



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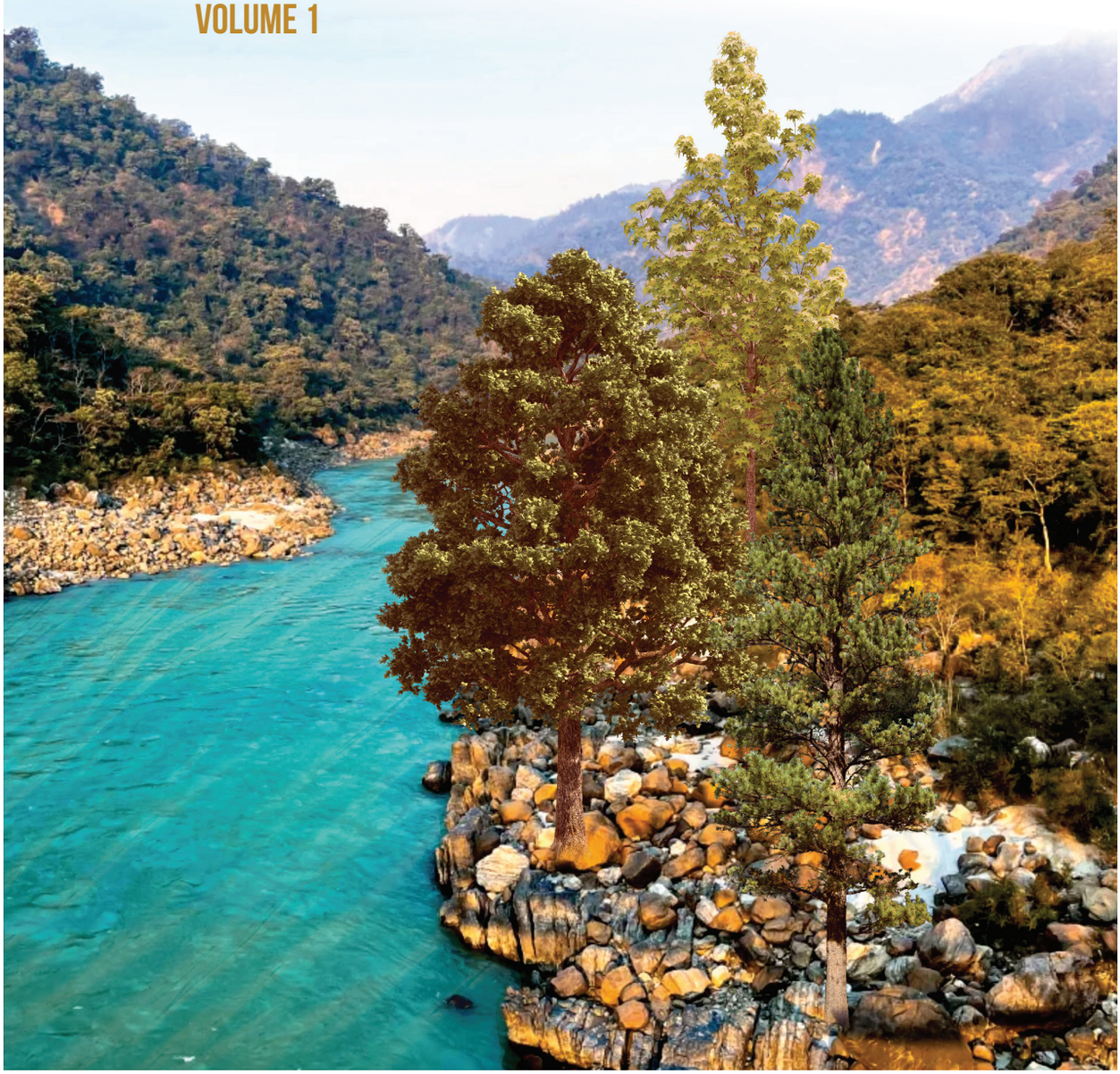
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PLANT WEALTH

ALONG GANGA RIVER, INDIA

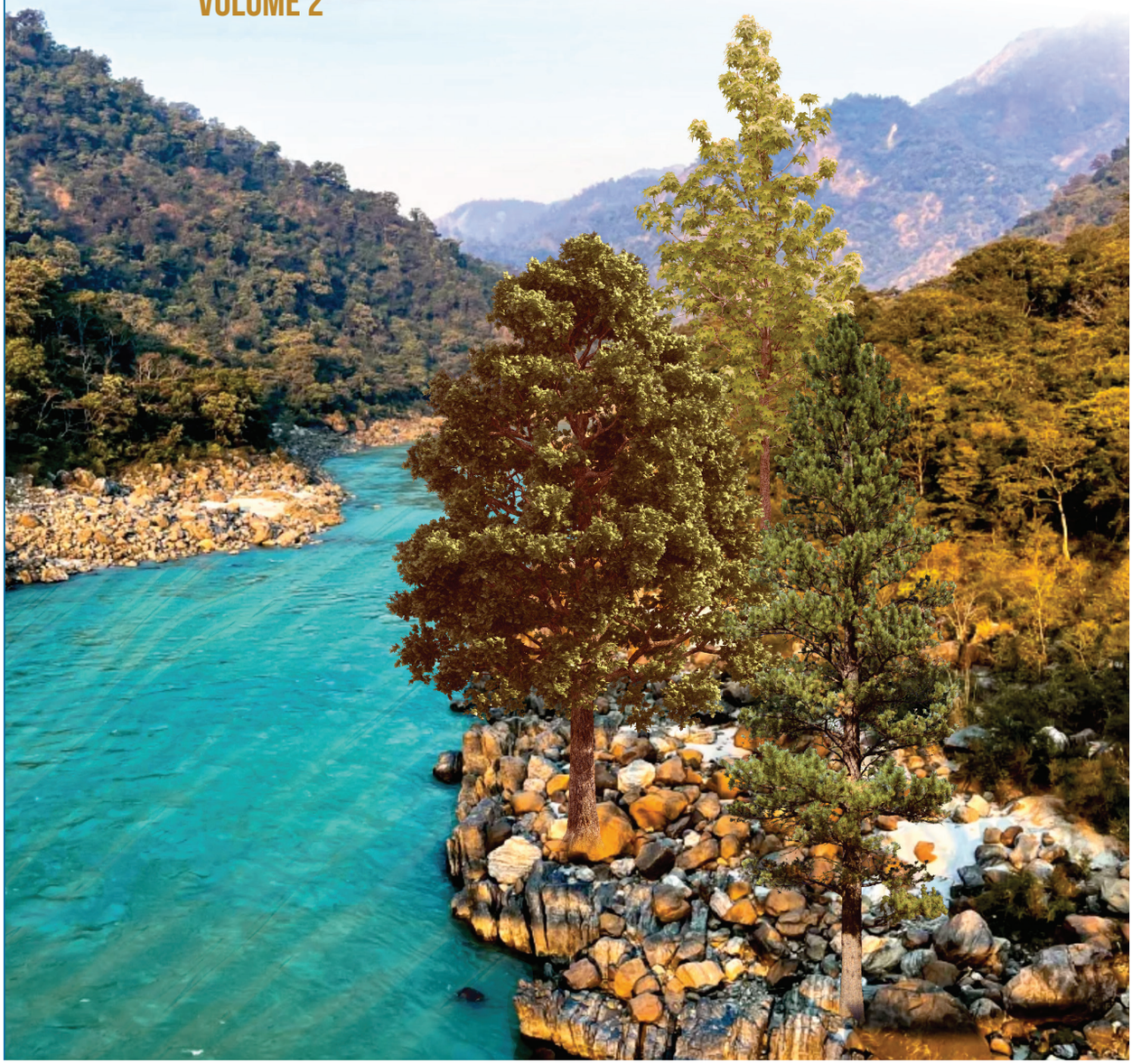
VOLUME 1



PLANT WEALTH

ALONG GANGA RIVER, INDIA

VOLUME 2

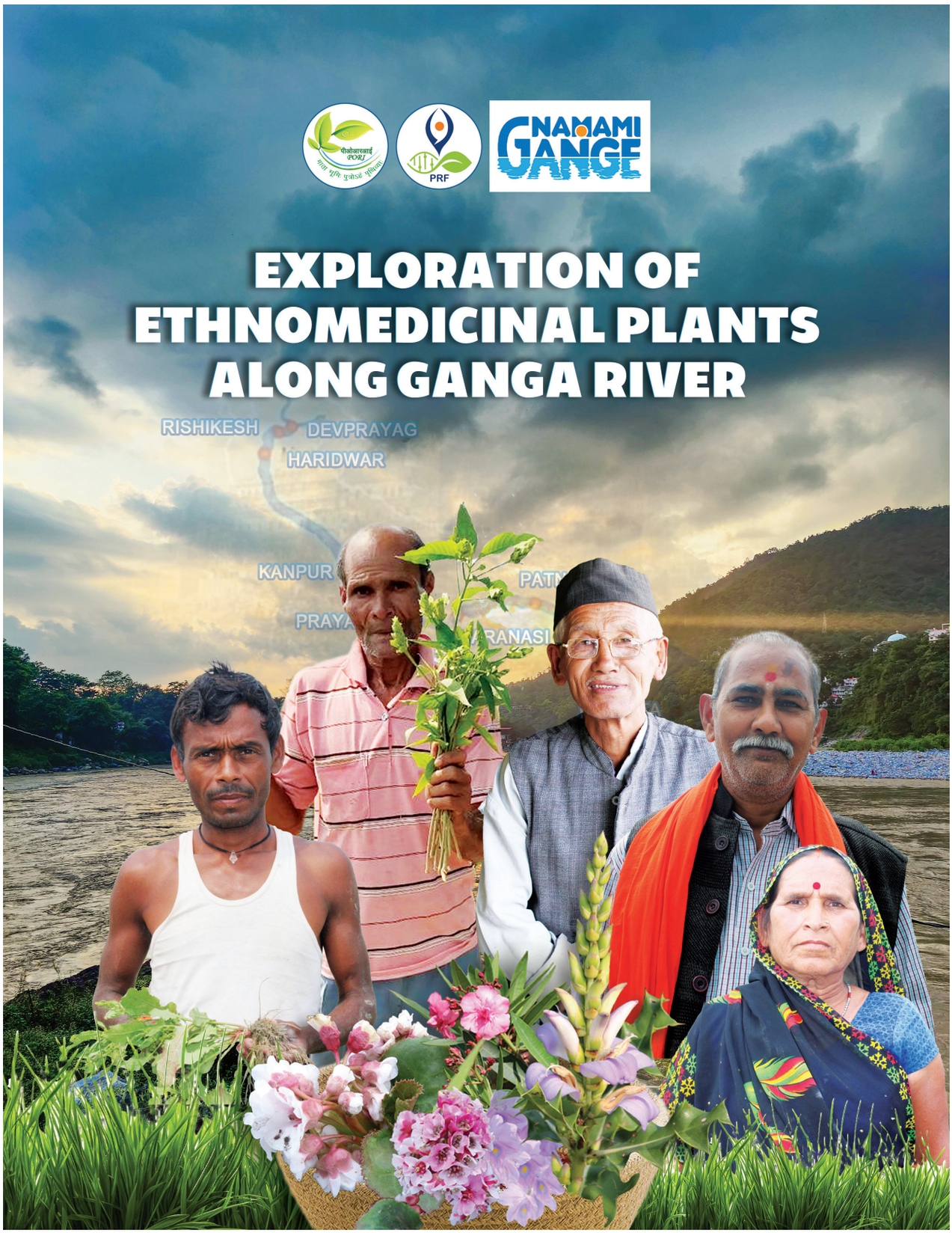


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ALONG GANGA RIVER, INDIA

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RISHIKESH
DEVPRAYAG
HARIDWAR
KANPUR

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1	Mechanistic Insight into Anticancer Prowess of Piper Species and their Bioactive Compounds: A Review	Under Review
2	Sewage Sludge Management Practices: Across the world and an Indian way forward	Under Review
3	Cynodon plectostachyus (Poaceae): A Contribution to the Flora of Jharkhand	Submitted
4	Cyperus longus (Cyperaceae): An Addition to the Flora of West Bengal	Submitted
5	Euploca salicoides (Boraginaceae): A Contribution to the Flora of India	Submitted
6	Ipomoea imperati (Convolvulaceae): New Extended Distributional Plant Record for Mainland India	Submitted
7	Paspalum orbiculare – An addition to the Flora of Bihar.	Published
8	Muntingia calabura (Muntingiaceae): An Addition to the Flora of West Bengal	Submitted
9	Ottelia ulvifolia (Hydrocharitaceae): An Addition to the Flora of India reveals Biogeographical link with Gondwana Super Continent	Submitted
10	Sesbania sesban var. bicolor (Fabaceae): An Addition to the Flora of Uttar Pradesh	Submitted
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12	Some New Plants Addition to the Flora of Bihar	Submitted
13	Some New Plants Record for North India	Submitted
14	Ticanto caesia (Fabaceae): An Addition to the Flora of India from Jharkhand	Submitted
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S. No.	Manuscript Title	Status
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30	Boerhavia Vaill. ex L.: Distributional, Phytochemical, and Ethnopharmacological Aspects with Special Reference to Boerhavia diffusa L.	Accepted
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42	Ethnomedicine, Phytochemistry, and Anti-microbial Proficiency of Tamarindus indica L. and Its Mediated Nanoparticles	Published
43	Hazardous Consequences and Management of Heavy Metals in Sewage Sludge: An Overview	Published

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Assessment of Antibiotic Resistance Profiles in Cultivable Coliform Organisms Isolated from Ganga River Waters Across the Upper, Middle, and Lower Ganga Stretch

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REVIEW

Ethnomedicine, Phytochemistry, and Anti-microbial Proficiency of *Tamarindus indica* L. and Its Mediated Nanoparticles

Acharya Balkrishna[1,2] · Monika Payal[1] · Neelam Rawat Dabhade[1] · Ashwini Singh[1] · Vedpriya Arya[1]

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Abstract
Tamarindus indica is employed in Ayurveda as Agnisandeepano Rasa, Shankhadravaka Rasa, Shankha Vati, Mahashankha Vati, Gudapippali, and Bhruhat Gudapippali for the treatment of various diseases; exhibits therapeutic characteristics *viz.* blood tonic, carminative, digestive, expectorant, laxative etc.; and displays potential antimicrobial properties which can probably be utilized as a groundwork for drug discovery and development. The in-attendance review is designed with the objective to accrue and report the probable antimicrobial potential with Ayurvedic efficiency, therapeutic potential, phytoconstituent's edifice, and other medicinal usages of *T. indica* followed by the identification of its future research opportunities. An informal approach of employing Boolean operators was applied for the primary database searching as a result of which in total, 40 research articles were reviewed using several online scholarly databases. Outcomes of the study deliberated that *T. indica* is being considered to treat more than 30 different types of ailments. Among reported disorders, *T. indica* displayed highest potential in the treatment of asthma, wounds, and inflammatory diseases. Pharmacological studies and analysis affirmed potential antimicrobial activities. Variety of secondary metabolites belonging to different classes of compounds such as anthraquinone, apigenin, coumarin, naringenin, phenols, tannins, and taxifolin were reportedly isolated from *T. indica*. The thorough pharmacological investigations' findings showed that more clinical trials are required for *T. indica* in order to provide trustworthy novel chemicals for the conception of new medicines.

Keywords Antimicrobial · Hemagglutination · Imli · Phytomedicines

1 Introduction

Worldwide for years, in daily life, more than 80,000 medicinal plants have been employed as herbal medicines [1]. Compared to synthetic drugs, medicinal florae have the potential to medicate infectious maladies with low cost and lesser frequency of side effects, which is setting a trend in modern medical science [2]. One such plant is *Tamarindus indica*, having huge medicinal submissions because of its large contents of vitamin B and C, responsible for immune system augmentation in humankind [3, 4].

T. indica L., a native of Madagascar, is introduced into Africa, America, Asia, and Oceania, and it belongs to the family Fabaceae. It is commonly known as Imli, Chincha, and Amlika [3, 5, 6]. According to the World Health Organization (WHO), *Tamarind* is a source of all essential amino acids and organic acids such as acetic acid, citric acid, formic acid, malic acid, succinic acid, and tartaric acid [3, 7]. Almost every part of the plant is employed by different communities as nutraceutical, pharmacological agent and traditional medicine and for ethnobotanical tenacities like, fuelwood, charcoal making, timber source, and fodder [7]. High tannin content (seed powder) imposes the plant species application in food and other industries including textile and brick, glue, jute, leather, and paper etc. [8]. *T. indica* is the furthermost economic and biotechnologically treasured plant, producing a wide range of bioactive secondary metabolites, such as carbohydrates, flavonoids, furocoumarins, glycosides, phenols, resins, saponins, tannins, and triterpenoids [5, 9, 10]. On account of the presence of these phytochemicals, the plant unveils potential pharmacological activities such as analgesic, antiallergic, antibiotic, antidiabetic,

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ORIGINAL PAPER

Molecular Mechanism of *Cynodon dactylon* Phytosterols Targeting MAPK3 and PARP1 to Combat Epithelial Ovarian Cancer: A Multifaceted Computational Approach

Acharya Balkrishna[1,2] · Yoganshi Sharma[1] · Shakshi Dabas[1] · Vedpriya Arya[1,2] · Anurag Dabas[1]

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Abstract
Epithelial Ovarian Cancer (EOC) presents a global health concern, necessitating the development of innovative therapeutic strategies to combat its impact. This study was employed to investigate the unexplored therapeutic efficacy of *Cynodon dactylon* phytochemicals against EOC using a multifaceted computational approach. A total of 19 out of 89 rigorously curated phytochemicals were assessed as potential drug targets via ADMET profiling, while protein-protein interaction analysis scrutinized the top 20 hub genes among 264 disease targets, revealing their involvement in cancer-related pathways and underscoring their significance in EOC pathogenesis. In molecular docking, Stigmasterol acetate showed the highest binding affinity (−10.9 kcal/mol) with Poly [ADP-ribose] polymerase-1 (PDB: 1UK1), while Arundoin and Beta-Sitosterol exhibited strong affinities (−10.4 kcal/mol and −10.1 kcal/mol, respectively); additionally, Beta-Sitosterol interacting with Mitogen-activated protein kinase 3 (PDB: 4QTB) showed a binding affinity of −10.1 kcal/mol, forming 2 hydrogen bonds and a total of 10 bonds with 10 residues. Molecular dynamics simulations exhibited the significant structural stability of the Beta-Sitosterol-4QTB complex with superior binding free energy (−36.61 kcal/mol) among the three complexes. This study identified *C. dactylon* phytosterols, particularly Beta-Sitosterol, as effective in targeting MAPK3 and PARP1 to combat EOC, laying the groundwork for further experimental validation and drug development efforts.

Keywords ADMET · *Cynodon dactylon* · Epithelial Ovarian Cancer · Molecular Docking · MD Simulation · Network Pharmacology

Introduction

Ovarian cancer (OC) poses a significant threat to women's health, ranking the list of cancers that affect the female reproductive system and representing the highest rates of recurrence, morbidity, and mortality. Approximately, 85%–90% of OCs are of epithelial origin. Due to the inadequacy of efficient early screening methods and the absence of distinct symptoms during the initial phases of epithelial ovarian cancer (EOC), patients are diagnosed at the advanced stage (stage III-IV) [1]. EOC constitutes 90% of all ovarian cancer cases. EOC can be categorized into four subtypes based on its origin: serous type, mucinous type (MUC), endometrioid type (END), and clear cell type (CLC). Serous OC is further divided into high-grade serous type (HGS) and low-grade serous type (LGS). The subtypes of EOC exhibit heterogeneity not only in their cellular origins but also in their distribution. High-grade serous EOC may stem from the epithelium of the fallopian tube. Conversely, the origin of low-grade serous EOC is linked to a stepwise progression from benign to borderline tumor, and finally to non-invasive and invasive stages. These subtypes show heterogeneity in their clinical progression, with the high-grade serous subtype exhibiting the most adverse clinical outcomes. Additionally, the four subtypes exhibit distinct molecular alterations and gene expression patterns, suggesting diverse carcinogenic mechanisms proposed across the subtypes, informed by their genetic and molecular backgrounds [2].

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Paspalum orbiculare – An addition to the Flora of Bihar

Acharya Balkrishna[1,2], Bhasker Joshi[1,2], Ved Priya Arya[1,2], Rajesh Kumar Mishra[*3], Anupam Srivastava[1], Amit Kumar[1], Ramesh Kumar[1], Inam Mohammed[1]

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Abstract: *Paspalum orbiculare* G.Forst.- a member of family Poaceae, is reported and described here as a new distributional record to the flora of Bihar. A detailed taxonomic description along with phenology and distribution of species is provided here to aid field identification.

Key Words: Bihar, Poaceae, New Record, River Ganga.

Introduction

Globally, the genus *Paspalum* L. includes 256 species (POWO 2024), of which 16 taxa (including 12 species and 04 varieties) were reported from India (Prasanna & al. 2020). During the field exploration along the bank of Ganga River in Bihar, an interesting grass species was collected. After, a critical study of the specimen and the review of literature (Hooker 1896; Duthie1903-1929; Haines 1910, 1921-1925; Mooney 1950; Sanyal 1957; Srivastava 1955; Bor 1960; Thakur 1963; Srivastava et al.1966; Mishra 1969-1971; Mishra & Jha 1972; Jain et al. 1975; Paul 1966, 1967, 1973; Saxena 1976, 1978; Uniyal & Datta 1984; Mishra 1985; Paria & Chattopadhyay 2000, 2005; Sharma & Sarkar 2002; Singh et al. 2001; Bhattacharya et al. 2011; Prasanna et al. 2020.), it's identity revealed as *Paspalum orbiculare* G.Forst. hitherto unreported from Bihar. Thus, this species has been reported here as new distributional record for the Indian State of Bihar. The updated nomenclature, taxonomic description and digital photographs are provided for its easy identification.

Materials and Methods

The field explorations were conducted between March 2023 to May 2023 (pre-monsoon) and October 2023 to November 2023 (post-monsoon) along Ganga River in Bihar. The voucher specimens were dried, pressed and mounted on herbarium sheets following Jain & Rao (1977) and deposited in Patanjali Research Foundation Herbarium (PRFH), Haridwar, Uttarakhand for future reference and records.

Taxonomic description

Paspalum orbiculare G. Forst., Fl. Ins. Austr.: 7. 1786; Hook.f., Fl. Brit. India 7: 11. 1896, *p.p.*; Bor, Grass. Burma, Ceylon, India &

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Exploring Soil Quality Variations across Upper, Middle, And Lower Ganga Regions: Leveraging GIS & Multivariate Statistical Methods to assess Organic Farming Viability

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Research Article

Keywords: Soil, Pollution, Ganga River, Organic, Fertilizer, Heavy Metal, India

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Hazardous Consequences and Management of Heavy Metals in Sewage Sludge: An Overview

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Abstract: ***Natural substances called heavy metals (HMs) can build up in the environment over time and are dangerous even in small amounts, posing a danger to the ecosystem and human health. Certain metals can infiltrate the wastewater treatment system and eventually accumulate in the sludge produced during the treatment process. Due to its interaction with industrial and household effluents, sludge, a by - product of sewage water treatment, is known to contain significant quantities of toxic metals. Sludge can contain HMs from several sources, such as industrial discharges, domestic wastewater, and agricultural runoff. In this review, the presence of HMs in sludge, and several treatment methods, consisting of physical, chemical, and biological processes have been developed, as have the regulations and guidelines controlling their disposal and usage were discussed. The selection of an appropriate treatment procedure, on the other hand, is dependent on the individual features of the sludge and the target metals. Sludge, if not managed properly, may leach HMs into the environment, damaging water, soil, and food crops. Proper HMs management in sludge is critical for reducing environmental and health concerns and promoting long - term sustainability.***

Keywords: HMs, sludge, toxicity, wastewater treatment, regulatory bodies

1. Introduction

The deposition of suspended solids during sewage treatment operations results in the semisolid residual material known as sewage sludge [1]. Sludge from various industries contains organic chemicals, trace metals, micronutrients, macronutrients, microbes, organic micro - pollutants, and parasitic organism eggs [2]. Although adding nutrients and organic matter to the soil using sewage sludge may be advantageous, the presence of pathogens, HMs, and other pollutants makes this practice risky [1]. Out of which HMs are metallic substances having relative densities equal to or greater than that of water [3]. With the expansion of industry and human activity, HMs have become more common in wastewater. Examples include the plating and electroplating industry, herbicides, power sources, silk industry, mining sector, Bioreactors with fluidized beds, metal rinsing procedures, tanning industry, the industry of metal smelting, textile sector, paper manufacturing, petrochemicals, and electrolysis applications. They are non - biodegradable and may cause cancer [4], [5]. Also, HMs migrate through the water - soil contact and the water - atmosphere interface [6]. Therefore, HMs poisoning of the environment from Sediment with untreated wastewater from numerous sectors is a global environmental hazard [7]. Figure 1 depicts the primary sources of distinct HMs ions.



Figure 1: Numerous sources of HMs in sludge

HMs over permitted limits frequently have negative impacts on people, other creatures, and the environment [8]. Particularly in developing nations, wastewater containing HMs ions such as As (III) /AS (V), Pb (II), Cd (II), Ni (I), Cr (III) /Cr (VI), Zn (II), Cu (II), Hg (I) /Hg (II), and Co (II) is increasingly discharged directly or indirectly into streams, lakes, rivers, or oceans [9]. The two most reliable international organizations, the WHO and United States Environmental Protection Agency (USEPA), have determined somewhat different values for the maximal

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Effect of Coliform Bacteria on Various Environmental Factors: A Review

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ABSTRACT

Sewage sludge is a mud-like residue generated from wastewater treatment that contains pollutants such as heavy metals, fecal coliforms, Escherichia coli, Salmonella, and other harmful bacteria. Coliform bacteria are rod-shaped Gram-negative non-spore forming motile or non-motile bacteria that may ferment lactose with the production of acid and gas when grown at 35-37°C. The presence of coliform bacteria in sludge is a serious problem for both human health ranging from mild gastrointestinal complaints to more severe illnesses and, environmental safety. Controlling coliform bacteria demands proper sludge management, treatment, and disposal. Appropriate treatment processes, such as aerobic digestion and composting, can reduce the number of coliform bacteria in sludge. Several nanoparticles, including silver nanoparticles (AgNPs), titanium dioxide nanoparticles (TiO2NPs), and copper nanoparticles (CuNPs), play a significant role as anti-microbial agents and may be effective in the disinfection of E. coli. The United States Environmental Protection Agency (EPA) has set regulations governing the maximum allowable number of coliform bacteria in sludge. This review provides an overview of the origins of coliform bacteria in sludge, their health concerns, strategies for identification, and various degradation techniques along with their limitations.

Keywords: Coliform, Environment, Regulatory bodies, Degradation, Nanotechnology.

INTRODUCTION

Sludge is a semi-solid substance formed during wastewater treatment [1]. It is made up of organic particles, nutrients, and microbes such as coliform bacteria [2]. Coliform bacteria are frequently regarded as markers of fecal contamination which are frequently identified in association with enteric pathogens [3]. Several coliform bacteria, such as Erwinia and Enterobacter, are often part of the natural flora of many vegetables and usually do not indicate a potential public health problem [4]. Fecal coliforms, a similar subset of the coliforms, are frequently used to detect the presence of E. coli in water. The existence of this organism may indicate fecal contamination and be related to the use of polluted irrigation water, the presence of feces, or poor sanitation and hygiene practices [5]. Vegetables can, however, contain microbes other than E. coli that cause fecal coliform tests to be positive. For instance, only 29% of vegetables that tested positive for fecal coliforms contained recoverable E. coli [6]. False positive results

Outcomes of the Project

Section 1: Survey and Sampling

- The study involved a comprehensive survey of 26 specific sites along the riverbanks, strategically spaced at most 100 km apart to capture ecological variations effectively.
- The sampling process for plants, soil, and water followed established protocols set by government-authorized agencies, ensuring rigorous scientific standards.
- The project was divided into five expert teams, each tasked with surveying specific states in the region, including Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, and West Bengal.
- The teams covered 100% of the sampling sites from 2023-2024, and meticulously documented plant diversity, collecting 4336 plant field numbers and 17344 specimens for analysis.
- Additionally, 26 water and soil samples were gathered for physicochemical and microbial analysis, alongside 234 medicinal plant samples for phytochemical analysis and soil samples from the rhizosphere to explore plant-microbe interactions.

Section 2: Training of farmers and Local Healers

- The proactive engagement with farmers and local healers through comprehensive training sessions in organic farming, soil health management, yoga, and traditional healing practices aimed to empower 549 farmers and 82 local healers with practical insights and techniques over a span of two months.
- The training sessions, totalling 80.25 hours of immersive learning, not only equipped participants with valuable knowledge but also had profound implications for the

communities involved by enhancing agricultural practices, promoting sustainable farming methods, and contributing to food security and economic stability in the region.

Section 3: Plant Diversity Analysis

- The study conducted a detailed analysis of plant diversity along the Ganga River, covering 26 sites across five states: Uttarakhand (5 sites), Uttar Pradesh (10 sites), Bihar (5 sites), Jharkhand (1 site), and West Bengal (5 sites).
- A total of 1117 species were recorded, spanning 660 genera and 152 families. Among these, Angiosperms comprised 1073 species (633 genera and 138 families), Gymnosperms included 12 species (10 genera and 5 families), and Pteridophytes accounted for 32 species (17 genera and 9 families).
- Poaceae has been the largest family with 132 plants. Out of 1117 species, 603 species of herbs, 190 species of trees, 219 species of shrubs, 94 species of climbers, 5 species of epiphyte, and 6 species of lianas.

Section 4: Ethnobotanical Plants

- All 114 medicinal plants identified in the study are classified into 58 plant families. Across all the families, Asteraceae had a leading position with a maximum of 8 plant species.
- A total of 147 respondents from 39 localities of 18 districts from all around the Ganga River have interacted throughout the study. A maximum of 63 (42.86%) respondents were from 5 localities of Bihar who expressed a willingness to share their knowledge.
- In order of shared responses, after Bihar, Uttar Pradesh shared the most with 49 (33.33%) from 23 localities, followed by Uttarakhand with 19 (12.93%) from 5 localities, Jharkhand with 10 (6.80%) from 1 locality, and West Bengal with 6 (4.08%) from 5 localities.
- The habits of all 114 plants were analyzed. Seven different habits have been identified, including herb, shrub, tree, and climber. The maximum 55 (48.25%) medicinal plants were found to be herbaceous, followed by trees (34; 29.82%), shrubs (16; 14.04%), and climbers (9; 7.89%).
- During the study, a total of sixty-two different disease conditions were recognized which were grouped into fifteen use categories (Table 4.1).

Section 5: In Silico Analysis

- 10 plants have been selected for exploration of its unknown therapeutic potential. The results from the Insilico analysis are detailed documented in the monograph of the respective plants.
- The targeted diseases are in the present case are Cancer, Neurodegenerative disorders and Viral diseases.

Section 6: Water Quality Analysis

- The study conducted a comprehensive examination of water quality along the entire stretch of the Ganga River, from Gaumukh to Ganga Sagar, during April to May 2023.
- Coliform contamination observed in 21 samples (80%) across states.
- Majority of samples suitable for drinking (84%) and irrigation (54%), none for industrial use.
- According to CPCB, majority (41%) water samples falls under group E that is used for irrigation, industrial cooling, and controlled disposal.

Section 7: Soil Quality analysis

- The assessment of soil quality parameters within a 10 km radius of the Ganga River highlighted the importance of nitrogen, phosphorus, and potassium in supporting plant growth, with nitrogen playing a significant role in essential plant development processes.
- The notably high concentration of heavy metals pose threat for the soil samples raised concerns. The majority, constituting 76.92%, falls under the "Moderately Effected" category, while "Seriously Effected" and "Strongly Effected" represent 11.54% and 7.69%, respectively. The "Slightly Effected" category makes up 3.85% of the total tested samples.
- Gaumukh in Uttarakhand has the highest Soil Quality Index (SQI) at, indicating robust soil quality. Varanasi in Uttar Pradesh presents a lower SQI of, highlighting potential soil challenges.

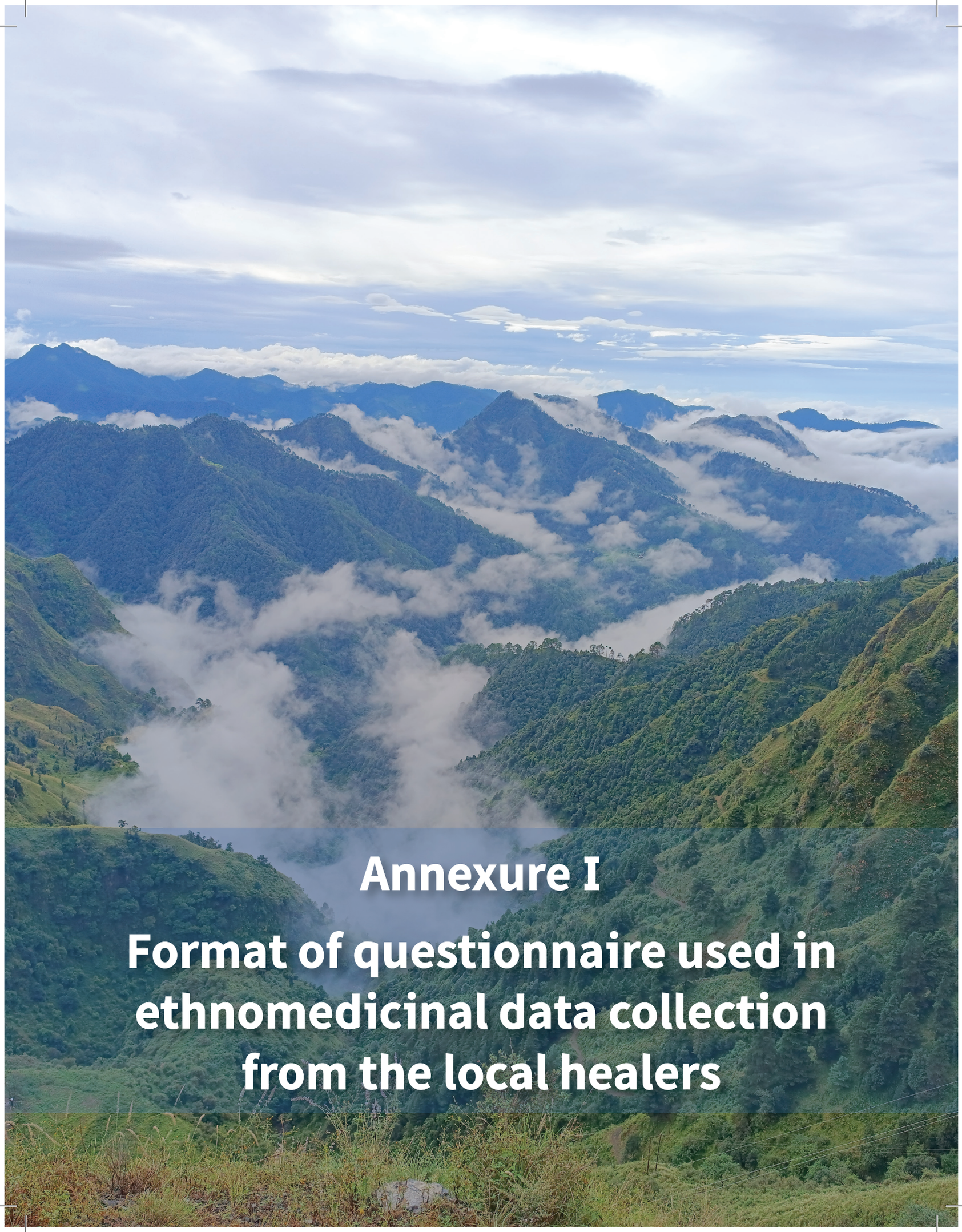
Section 8: Plant-Microbe Interaction

- The rhizosphere soil analysis revealed average beneficial bacteria constituting about 74.30% of total rhizosphere bacteria. This finding has significant implications for agriculture and ecosystem management, as understanding plant-microbe interactions is crucial for optimizing agricultural practices and enhancing crop productivity.
- The study highlights the potential of beneficial microbes in promoting soil health and nutrient cycling, which can contribute to sustainable agricultural systems and reduce the need for chemical inputs.
- The observation of *Achyranthes aspera* L. harbouring the highest bacterial concentrations suggests a potential role of this plant species in shaping the microbial community within its rhizosphere, opening avenues for further research into plant-microbe interactions and their implications for ecosystem functioning and plant health.
- The relatively balanced microbial ecosystem within the rhizosphere of *Achyranthes aspera* L., as indicated by the ratio of beneficial bacteria to total bacteria at 1.34, suggests a favourable environment for plant growth and health.

Annexures



Annexures	Details
Annexure I	Blank format of questionnaire used in ethnomedicinal data collection from the local healers
Annexure II	The permission letters from the approving authorities
Annexure III	SOPs of Plant, Soil and Water collection
Annexure IV	Blank Field Data Format of the Soil and Water survey
Annexure V	Total Plant list for Phytodiversity Study



Annexure I

Format of questionnaire used in ethnomedicinal data collection from the local healers

Scientific Exploration of Floral Diversity near the Ganga River Banks for Ethnobotanical purposes along with their Conservation and Economic Development of the Region Via Skill Development Programs

Respondent No.: ……... Name of the respondent: ……..

Age: …… Sex: …… Education: ……...

State: ……..... District: …….

Locality: ……..... Village: ……....

Altitude: …… Latitude: …….. Longitude: ……

Experience: ……..…… Occupation: ……

ID Proof: …… Phone No: ……...

Guidance, coordination and training of tribal traditional healers:

Approach by the enumerator:

Step- I. Contact with village Head or any other responsible person and collected the information on the respondent's name and house location

Step- II. Taken help from first level informer to reach the actual traditional practitioner

Step- III. Contact and discussion with actual traditional healer

	Name of the disease	Herbs used in the treatment				Methods of preparation	Dose & duration of treatment	No. of patients treated
		Local name	Botanical name	Part	Habit			
1	Cough							
	Asthma							
	Headache							
	Joint pain/ arthritis							
	Mouth ulcer							
	Toothache							
	Stomach ache							
	Diarrhea & Dysentery							
	Fever							
	Malaria/ Dengue							
	Anemia							
	Jaundice							
	Snakebite							
	Urinary diseases							
	Piles							

	Boil							
	Ulcer							
	Blood pressure							
	Sugar							
	Leucorrhoea							
	Eye diseases							
	Nasal sinus							
	Ear & throat diseases							
	Nervous diseases							
	Others							

2	Source of plant material	Naturally occurring (NTFP) [ ]; Domesticated/Cultivated [ ]; Crude drug market [ ]			
3	Availability of the plant material	Abundantly occurring [ ]	Seasonal [ ]	Rare [ ]	
4	Permission from Forest department	Authorized [ ]	Not Authorized [ ]	Not required [ ]	
5	Storage of seasonal plants	Dry form [ ]	Powder form [ ]	Tablet form [ ]	Liquid form [ ]
6	Guidance coordination & training	Whether training is required		Yes [ ]	No [ ]
		Do you feel to give training to others?		Yes [ ]	No [ ]
7	Publication	Do you feel to publish the knowledge?		Yes [ ]	No [ ]

Signature/Thumb impression of the traditional healer with date:

Signature of the enumerator/ PRFT representative with date:

Signature of the Project Head:

Photograph of the respondent



कार्यालय प्रभागीय निदेशक सामाजिक वानिकी प्रभाग फर्रूखाबाद

पत्रांक 1724 / जि0गं0समि0, दिनांक, फर्रूखाबाद मार्च, 03/ 2023

सेवा मे

पतंजलि आर्गेनिक रिसर्च इन्स्टीट्यूट प्रा0लि0
पतंजलि फूड एण्ड हर्बल पार्क
ग्राम–पदार्था लक्सर रोड
हरिद्वार–249404

विषय– मार्च एवं अप्रैल 2023 मे गंगा नदी से सटे हुये ग्रामो मे प्रशिक्षण कार्यक्रम आयोजित करने के सम्बन्ध मे।

संदर्भ– आपका पत्र सं0–PORI/NMCG-FLO/OFF-SETUP/BM-0017 दिनांक 24.02.2023।

महोदय,

अवगत कराना है कि उपरोक्त संदर्भित पत्र के द्वारा गंगा किनारे बसे ग्रामो मे कौशल विकास कार्यक्रमो के माध्यम से क्षेत्र के संरक्षण और आर्थिक विकास के साथ–साथ इथनोबोटैनिक व वानस्पतिक विविधता कार्यक्रम आयोजित करने हेतु अनुमति की आकांक्षा की गई है।

अतः उक्त के आलोक में कार्यक्रम के आयोजन हेतु चिन्हित स्थलो की सूची इस कार्यालय को उपलब्ध कराने का कष्ट करे, ताकि कार्यक्रम को भलीभॉति सम्पन्न कराया जा सके।

भवदीय,

प्रभागीय निदेशक
सामाजिक वानिकी प्रभाग,
फर्रूखाबाद

पत्रांक / समदिनांकित–

प्रतिलिपि–जिलाधिकारी फर्रूखाबाद को सूचनार्थ प्रेषित।

प्रतिलिपि–मुख्य विकास अधिकारी फर्रूखाबाद को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित।

प्रभागीय निदेशक
सामाजिक वानिकी प्रभाग,
फर्रूखाबाद

कार्यालय, अपर प्रमुख वन संरक्षक, वन अनुसंधान, प्रशिक्षण एवं प्रबन्धन, उत्तराखण्ड, हल्द्वानी

टैलीफैक्स 05946–254803
Email :- apccfrtm@gmail.com

पत्रांक :– 760 / 6-31
दिनांक, हल्द्वानी, 18/04/2023

सेवा में,

1 प्रभागीय वनाधिकारी,
उत्तरकाशी वन प्रभाग
उत्तरकाशी ।

2 प्रभागीय वनाधिकारी,
टिहरी वन प्रभाग,
नई टिहरी ।

3 प्रभागीय वनाधिकारी,
हरिद्वार वन प्रभाग,
हरिद्वार।

विषयः– Request for to Permission to conduct vegetation ,water and soil sample survey in the month of March and April 2023 .

संदर्भः– इस कार्यालय की पत्र संख्या 727/6–31 दिनांक 25.03.2023

महोदय,

इस कार्यालय द्वारा Patanjali Organic Research Institute Pvt.Ltd ,Haridwar Uttarakhand से विषयगत सर्वे कार्य से सम्बन्धित सूचना चाही गई, जिसे उनके द्वारा अपनी पत्र संख्या PORI/NMCG-FLO/OFF-SETUP/BM-0041 Date 03.04.2023 से इस कार्यालय को प्रेषित की गई है।

उक्त पत्र की छाया प्रति संलग्न कर इस आशय से प्रेषित की जाती है कि संदर्भित पत्र से चाही गई आख्या उपलब्ध कराने में आपको यह सहायक सिद्ध होगी। कृपया आख्या अविलम्ब प्रेषित करना सुनिश्चित करें।

संलग्न–यथोपरि।

मुख्य प्रशासनिक अधिकारी
कार्यालय अपर प्रमुख वन संरक्षक
अनुसंधान प्रशिक्षण एवं प्रबन्धन
उत्तराखण्ड, हल्द्वानी.

भवदीय

(डॉ० धनंजय मोहन)
प्रमुख वन संरक्षक / महानिदेशक

पत्र संख्या / उक्त दिनांक।

प्रतिलिपिः–

1. प्रमुख वन संरक्षक (Hoff) उत्तराखण्ड, देहरादून को सूचनार्थ प्रेषित।
2. Acharya Balkrishna Patanjali Organic Research Institute Pvt.Ltd Patanjali Food and Herbal Park Village PadarthaLaksar Road, Haridwar Uttarakhand.को उनके उक्त पत्र जो इस कार्यालय में दिनांक 12.04.2023 को प्राप्त हुआ है के क्रम में सूचनार्थ प्रेषित।

(डॉ० धनंजय मोहन)
प्रमुख वन संरक्षक / महानिदेशक

Jharkhand Biodiversity Board
(An autonomous and statutory body of Govt. of Jharkhand)
1st Floor, 138/C, Vidhyalya Marg 'C', Ashok Nagar, Ranchi – 834002

Letter No.: JBB/STUDY DOC-Research-1 /2023- 49 **Ranchi/Date:** 02/03/2023

From,

Member Secretary,
Jharkhand Biodiversity Board, Ranchi

To,

Acharya Balkrishna,
Patanjali Organic Research Institute Pvt. Ltd,
Patanjali Food & Herbal Park, Village – Padartha
Laksar Road, Haridwar - 249404

Sub: Request for permission to conduct vegetation, water, and soil sample survey in the month of March and April 2023

Ref: Patanjali Letter no. PORI/NMCG-FLO/OFF-SETUP/BM-002; Date: 24th Feb, 2023

Sir,

I am directed to inform you that as per chapter –II section – 3, 4 & 5 of the Biological Diversity Act, 2002 permission may be granted for survey of vegetation, soil and water samples in tentative sites adjacent to river Ganges in the district of Sahibganj.

Therefore, you are requested to ensure the compliance of the above sections of the Biological Diversity Act, 2002 before conducting the survey in the said areas.

Yours sincerely,

02/03/2023
Member Secretary
Jharkhand Biodiversity Board

Telefax: +91-651-2972107; E-mail: jbbranchi@gmail.com; Web: https://jbb.jharkhand.gov.in

कार्यालय प्रमुख वन संरक्षक (वन्यजीव)/मुख्य वन्यजीव प्रतिपालक, उत्तराखण्ड, देहरादून।
85 राजपुर रोड, देहरादून, फोन नं० 0135–2742884 फैक्स नं० 0135–2745691 ईमेल–cwlwua@yahoo.co.in

पत्र संख्या 2551 / 5–6 देहरादून, दिनांक 03 मई, 2023

सेवा मे,

Acharya Balkrishna,
Patanjali Food & Herbal Park,
Village Padartha, Laksar Road,
Uttarakhand, Haridwar-249404

विषयः Request for permission to conduct vegetation, water, and soil sample survey.

सन्दर्भः– आपका पत्रांक PORI/NMCG-FLO/OFF-SETUP/BM-0044, दिनांक 15 अप्रैल 2023

महोदय,

उपरोक्त संदर्भित पत्र से आपके द्वारा गंगा नदी के किनारे के पास गंगोत्री नेशनल पार्क एवं राजाजी नेशनल पार्क में चुने गये स्थलों में वनस्पति, पानी और मिट्टी के नमूना सर्वेक्षण के लिये अनुमति चाही गयी है। निदेशक, राजाजी टाइगर रिजर्व, देहरादून के पत्रांक 3408/5–6, दिनांक 03 मई, 2023 से की गयी संस्तुति के आधार पर विषयगत कार्य हेतु अनुमति निम्न शर्तो के तहत प्रदान की जाती हैः–

1. यह अनुमति वनस्पति, पानी और मिट्टी के नमूना सर्वेक्षण के लिये गंगा नदी के किनारे के पास चुने गये स्थलों के लिये ही मान्य होगी।
2. शोध/सर्वेक्षण के दौरान किसी भी प्रकार से वन्य प्राणियों/वनस्पतियों को नुकसान नहीं पहुंचाया जायेगा और कोई पौधा या उसका अंश, प्राणी को नष्ट करने की अनुमति नहीं है।
3. वन्य जीव (संरक्षण) अधिनियम, 1972 यथा संशोधित 2022 का कोई उल्लघंन नहीं किया जायेगा।
4. वन क्षेत्रों में शोध/सर्वेक्षण कार्यक्रम आरम्भ करने से पूर्व आपको सम्बन्धित अधिकारी को सूचित कराना होगा। अपना प्रस्तावित कार्यक्रम प्रभाग कार्यालय को उपलब्ध कराना होगा।
5. शोध/सर्वेक्षण के दौरान नियमानुसार समस्त शुल्कों का वहन करना होगा।
6. शोध/सर्वेक्षण के दौरान किसी भी प्रकार का प्रतिकूल दृश्य/गतिविधि देखे जाने पर उसकी सूचना स्थानीय अधिकारी को देनी होगी।
7. अध्ययन/भ्रमण के दौरान किसी भी प्रकार से टाइगर रिजर्व क्षेत्र में वॉटर हॉलों अथवा बहती हुई नदियों में किसी भी प्रकार से पानी को दूषित नहीं करेंगे।
8. शोध/सर्वेक्षण कार्य हेतु अनुमति इस शर्त के साथ दी जाती है कि उक्त शोध/सर्वेक्षण कार्य के उपरान्त जो भी डाटा एकत्र किया जायेगा, उसकी प्रति/रिपोर्ट निदेशक, राजाजी टाइगर रिजर्व के साथ इस कार्यालय को भी उपलब्ध करायेंगे।
9. शोध/सर्वेक्षण के दौरान आई०डी० प्रुफ, वाहन संख्या आदि का विवरण रेंज कार्यालय में प्रेषित किया जाना आवश्यक है।
10. शोध/सर्वेक्षण के दौरान वन क्षेत्रों के अन्तर्गत आग्नेय अस्त्र साथ नही ले जाया जायेगा।
11. शोध/सर्वेक्षण हेतु सूर्योदय से पूर्व व सूर्यास्त के पश्चात पार्क क्षेत्र में प्रवेश प्रतिवन्धित है।

1/2

12. शोध/सर्वेक्षण के दौरान वन्य जन्तुओं से या किसी अन्य प्रकार से जनधन की हानि के लिये वन विभाग जिम्मेदार नहीं होगा।
13. शोध/सर्वेक्षण के दौरान Disaster management (आपदा प्रबन्धन) के अन्तर्गत भारत सरकार, राज्य सरकार एवं जिला प्रशासन द्वारा समय–समय पर कोविड–19 की रोकथाम हेतु जारी आदेशों का अक्षरशः अनुपालन किया जायेगा।
14. शोध/सर्वेक्षण के दौरान कोविड–19 की रोकथाम हेतु निर्धारित मानको के अनुसार सामाजिक दूरी बनाये रखनी होगी, तथा किसी वन्यजीव का स्पर्श नहीं किया जायेगा।
15. राजाजी टाइगर रिजर्व के क्षेत्रान्तर्गत नमूना सर्वेक्षण कार्य के दौरान एन0टी0सी0ए0, भारत सरकार के दिशा–निर्देशों का अनुपालन करना होगा।
16. उपरोक्त अनुमति पत्र जारी होने की तिथि से दिसम्बर 2023 तक के लिये मान्य होगी।

भवदीय,

(डा0 समीर सिन्हा)
प्रमुख वन संरक्षक (वन्यजीव)/
मुख्य वन्य जीव प्रतिपालक,
उत्तराखण्ड

पत्रांक 2551 / 5-6 उक्तदिनांकित।

प्रतिलिपि– निदेशक, राजाजी टाइगर रिजर्व, देहरादून को उनके पत्रांक 3408/5–6, दिनांक 03 मई, 2023 के क्रम में सूचनार्थ एवं नियमानुसार आवश्यक कार्यवाही हेतु प्रेषित।

प्रतिलिपि– उप निदेशक, गंगोत्री राष्ट्रीय पार्क, कोटबंगला, उत्तरकाशी को सूचनार्थ एवं नियमानुसार आवश्यक कार्यवाही हेतु प्रेषित।

(डा0 समीर सिन्हा)
प्रमुख वन संरक्षक (वन्यजीव)/
मुख्य वन्य जीव प्रतिपालक,
उत्तराखण्ड

कार्यालय, अपर प्रमुख वन संरक्षक, वन अनुसंधान, प्रशिक्षण एवं प्रबन्धन, उत्तराखण्ड, हल्द्वानी

टैलीफैक्स 05946–254803
Email :- apccfrtm@gmail.com

पत्रांक :– 724 / 6-31 दिनांक, हल्द्वानी, 25/03/2023

सेवा में,

Mr. Acharya Balkrishna
Patanjali Organic Research Institute Pvt.Ltd
Patanjali Food and Herbal Park Village Padartha
Laksar Road, Haridwar
Uttarakhand.

विषयः– Request for to permission to conduct vegetation ,water and soil sample survey in the month of March and April 2023 .

संदर्भ :– आपकी पत्र संख्या PORI/NMCG-FLO/OFF-SETUP/BM-0010 दिनांक 24.02.2023

महोदय,

प्रमुख वन संरक्षक (Hoff) उत्तराखण्ड, देहरादून की पत्र संख्या क–1505/6–31 दिनांक 21.03.2023 से आपका संदर्भित पत्र इस कार्यालय में प्राप्त हुआ है, जिसमें आपसे निम्न सूचना/अभिलेख की अपेक्षा की जाती हैः–

1. प्रस्तावित सर्वे के Approved Synopsis की प्रति।
2. प्रस्तावित सर्वे Approval की प्रति।
3. प्रस्तावित सर्वे हेतु निर्धारित स्थल (वन्य जीव क्षेत्र /संरक्षण आरक्षिति के सम्बन्ध में विशिष्ट टिप्पणी)

उक्त अभिलेख/सूचना के अभाव में विषयगत प्रकरण पर कोई निर्णय लिया जाना सम्भव नहीं हो पा रहा है।

भवदीय,

(डॉ० धनंजय मोहन)
प्रमुख वन संरक्षक/ महानिदेशक

पत्र संख्या 724 / **उक्त दिनांक।**

प्रतिलिपिः– प्रमुख वन संरक्षक (Hoff) उत्तराखण्ड, देहरादून को उनके उक्त पत्र के क्रम में सूचनार्थ प्रेषित।

25/03

(डॉ० धनंजय मोहन)
प्रमुख वन संरक्षक/ महानिदेशक

ok

कार्यालय, अपर प्रमुख वन संरक्षक, वन अनुसंधान, प्रशिक्षण एवं प्रबन्धन,
उत्तराखण्ड, हल्द्वानी

टैलीफैक्स 05946–254803
Email :- apccfrtm@gmail.com

पत्रांक :– 760 / 6-31
दिनांक, हल्द्वानी, 18/04/2023

सेवा में,

1 प्रभागीय वनाधिकारी,
उत्तरकाशी वन प्रभाग
उत्तरकाशी ।

2 प्रभागीय वनाधिकारी,
टिहरी वन प्रभाग,
नई टिहरी ।

3 प्रभागीय वनाधिकारी,
हरिद्वार वन प्रभाग,
हरिद्वार।

विषयः– Request for to Permission to conduct vegetation ,water and soil sample survey in the month of March and April 2023 .

संदर्भः– इस कार्यालय की पत्र संख्या 727/6–31 दिनांक 25.03.2023

महोदय,

इस कार्यालय द्वारा Patanjali Organic Research Institute Pvt.Ltd ,Haridwar Uttarakhand से विषयगत सर्वे कार्य से सम्बन्धित सूचना चाही गई, जिसे उनके द्वारा अपनी पत्र संख्या PORI/NMCG-FLO/OFF-SETUP/BM-0041 Date 03.04.2023 से इस कार्यालय को प्रेषित की गई है।

उक्त पत्र की छाया प्रति संलग्न कर इस आशय से प्रेषित की जाती है कि संदर्भित पत्र से चाही गई आख्या उपलब्ध कराने में आपको यह सहायक सिद्ध होगी। कृपया आख्या अविलम्ब प्रेषित करना सुनिश्चित करें।

संलग्न–यथोपरि।

मुख्य प्रशासनिक अधिकारी
कार्यालय अपर प्रमुख वन संरक्षक
अनुसंधान प्रशिक्षण एवं प्रबन्धन
उत्तराखण्ड, हल्द्वानी.

भवदीय

(डॉ० धनंजय मोहन)
प्रमुख वन संरक्षक/ महानिदेशक

पत्र संख्या / उक्त दिनांक।

प्रतिलिपिः–

1. प्रमुख वन संरक्षक (Hoff) उत्तराखण्ड, देहरादून को सूचनार्थ प्रेषित।
2. Acharya Balkrishna Patanjali Organic Research Institute Pvt.Ltd Patanjali Food and Herbal Park Village PadarthaLaksar Road, Haridwar Uttarakhand.को उनके उक्त पत्र जो इस कार्यालय में दिनांक 12.04.2023 को प्राप्त हुआ है के क्रम में सूचनार्थ प्रेषित।

(डॉ० धनंजय मोहन)
प्रमुख वन संरक्षक/ महानिदेशक

"जैव विविधता संरक्षण.....प्रकृति के साथ जीने की कला"

कार्यालय उत्तराखण्ड जैव विविधता बोर्ड, देहरादून।

ई–मेल sbbuttarakhand@gmail.com
वेबसाइट : www.sbb.uk.gov.in
पत्रांक: 747 /30 To Fo - 16-7

423, इन्दिरा नगर कॉलोनी (निकट गलिक चौक),
देहरादून–248006 (टेलीफैक्स - 0135-2769886)
दिनांक: 24, अप्रैल, 2023

सेवा में,

Shri Acharya Balkrishna,
Patanjali Food and Herbal Park,
Plot No. P3, Patanjali Organic Research Institute Pvt. Ltd.,
Laksar Road, Vill- Padartha, Haridwar -249408

विषयः Permission to conduct vegetation, water and Soil sample survey.

संदर्भः आपका पत्र PORI/NMCG-FLO/OFF-SETUP/BM-005 दिनांक 24.02.2023

महोदय,

आपके द्वारा अपने पत्र दिनांक 24.02.2023 में प्रोजेक्ट शीर्षक *"Scientific exploration of floral diversity near the Ganga River Banks for ethnobotanical purposes along with their conservation and economic development of the region via skill development programs"* उत्तराखण्ड राज्य के जनपद उत्तरकाशी, टिहरी गढ़वाल तथा हरिद्वार में चण्डीपुल हरिद्वार, देव प्रयाग संगम, उत्तरकाशी गंगा घाट, गंगोत्री घाट तथा गौमुख क्षेत्र से Vegetation, Water and Soil sample survey हेतु अनुमति चाही गयी है, के संबंध में निम्नानुसार अवगत कराना है कि –

- किसी भारतीय नागरिक अथवा संस्थान को किसी जैव विविधता/जैव सम्पदा पर **अकादमिक शोध कार्य** करने हेतु राज्य जैव विविधता बोर्ड अथवा राष्ट्रीय जैव विविधता प्राधिकरण से पूर्वानुमति लेने की आवश्यकता नही है बशर्ते कि शोध कार्य किसी जैव संसाधन का **वाणिज्यिक उपयोग से संबंधित न हो और ना ही शोध कार्य में किसी विदेशी व्यक्ति अथवा संस्थान की सहभागिता हो।**
- यदि शोध कार्य का वर्तमान उद्देश्य किसी जैव संसाधन का वाणिज्यिक उपयोग करना नही है परन्तु शोध के निष्कर्ष को भविष्य में वाणिज्यिक उपयोग में लाया जा सकता है तो उचित होगा कि शोध कार्य करने से पूर्व राज्य जैव विविधता बोर्ड से पूर्वानुमति ली जाये।

कृपया इस संबंध में और अधिक जानकारी प्राप्त करने के लिये जैव विविधता अधिनियम, 2002 की धारा– 2, 4, 5 व 6 का अध्ययन करने का कष्ट करें।

भवदीय,

24/4/23

(एस.एस.रसाईली)
सदस्य सचिव,
उत्तराखण्ड जैव विविधता बोर्ड,
देहरादून।

बी० प्रभाकर, भा०व०से०
सचिव

उत्तर प्रदेश राज्य जैव विविधता बोर्ड

पर्यावरण, वन एवं जलवायु परिवर्तन विभाग, उत्तर प्रदेश सरकार
(जैव विविधता अधिनियम, 2002, भारत सरकार, के अन्तर्गत गठित स्वायत्त संवैधानिक/नियामक संस्था)

पत्रांक 480/42-2-140 दिनांक 21/03/23

सेवा में,

आचार्य बालकृष्ण,
पतंजलि ऑर्गेनिक रिसर्च इंस्टीट्यूट प्रा0 लि0,
हरिद्वार, उत्तराखंड।

विषयः– Request of Patanjali Organic Reseach Institute Pvt. Ltd. for permission to conduct vegetation, water and soil sample survey in the month of March and April, 2023 के सम्बन्ध में।

महोदय,

उपरोक्त संदर्भित पत्र द्वारा उत्तर प्रदेश के बिजनौर, बुलन्दशहर, बदॉयू, फर्रूखाबाद, कानपुर, रायबरेली, प्रयागराज, मीरजापुर, वाराणसी एवं बलिया जनपदों में भारत सरकार द्वारा स्वीकृत नमामि गंगे–II कार्यक्रम के अन्तर्गत "Scientific exploration of floral divesity near the Ganga River banks for ethnobotanical purposes along with their conservation and economic development of the eregion via skill development programs *(File No. Ad-35013/4/2022-KPMG-NMCG)*" परियोजना के अन्तर्गत वानस्पतिक आवरण, मृदा एवं जल (A Survey of Vegetation, Soil and Water Samples) के नमूनों (Samples) का सर्वेक्षण हेतु अनुमति प्रदान करने का अनुरोध किया गया है।

जैव विविधता अधिनियम, 2002 की धारा 23(b) के प्राविधानों के अन्तर्गत प्रदेश के 11 जनपदों– बिजनौर, बुलन्दशहर, बदॉयू, फर्रूखाबाद, कानपुर, रायबरेली, प्रयागराज, मीरजापुर, वाराणसी एवं बलिया में वानस्पतिक आवरण एवं मृदा जल के नमूनों का जैव सर्वेक्षण (Bio-survey of Vegetation, Soil and Water samples) के प्रस्ताव का अनुमोदन निम्न प्रतिबंधों के साथ किया जाता है:–

- सर्वेक्षण में स्थानीय जैव विविधता को किसी प्रकार की क्षति न पहुँचे।
- क्षेत्र के जैव संसाधन का दोहन/व्यापारिक उपयोग किए जाने की स्थिति में जैव विविधता अधिनियम, 2002 के प्राविधानों के अन्तर्गत उत्तर प्रदेश राज्य जैव विविधता बोर्ड को नियमानुसार पूर्व सूचना दी जानी होगी।
- उक्त जनपदों में वनस्पतियों के नमूने (Samples) एकत्र करते समय वनस्पतियों (Flora) को क्षति नही पहुँचाई जायेगी।
- सर्वेक्षण के दौरान गंगा व अन्य नदियों के जलागम क्षेत्र को क्षति न पहुँचाई जाए तथा नदियों के जल को प्रदूषित न किया जाए।
- कार्य प्रारम्भ करने के पूर्व जनपद के प्रभागीय वनाधिकारी, अन्य सम्बन्धित विभागों एवं सम्बन्धित जैव विविधता प्रबन्ध समितियों (Biodiversity Management Committees) को सूचित करना होगा तथा नियमानुसार यथावश्यक अनुमति प्राप्त करनी होगी।
- सर्वेक्षण के फलस्वरूप एकत्र किए गए नमूनों (Samples) पर किसी भी प्रकार का अनुसंधान कार्य हेतु जैव विविधता अधिनियम, 2002 के सुसंगत प्राविधानों का अनुपालन किया जाएगा।
- Commercial utilization की स्थिति में नियमानुसार Access Benefit Sharing भी किया जाए।
- सर्वेक्षण के आधार पर तैयार की गई रिपोर्ट, पुस्तक व अन्य प्रकाशन का कार्य किए जाने की स्थिति में बोर्ड कार्यालय को उपलब्ध कराया जाए।
- जैव विविधता अधिनियम, 2002, जैव विविधता नियम, 2004, उत्तर प्रदेश राज्य जैव विविधता नियमावली, 2010 के सुसंगत प्राविधानों एवं प्रचलित अन्य अधिनियमों/नियमों का अनुपालन किया जाए।
- सर्वेक्षण समाप्ति की सूचना एवं सारांश से उत्तर प्रदेश राज्य जैव विविधता बोर्ड को अवगत कराया जाए।
- विषयगत प्रस्ताव का अनुमोदन दिनांक 21.03.2023 से 30.04.2023 तक की अवधि हेतु मान्य है।

उक्त प्रतिबंधों के अतिरिक्त राष्ट्रीय जैव विविधता प्राधिकरण द्वारा अन्य कोई प्रतिबन्ध लगाए जाने पर उक्त का अनुपालन आपके द्वारा किया जाएगा।

भवदीय,

(बी0 प्रभाकर) 21.3.2023

पत्रांक /तद्दिनांकित।

प्रतिलिपि निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित।

1. सचिव, राष्ट्रीय जैव विविधता प्राधिकरण, चेन्नई।
2. प्रधान मुख्य वन संरक्षक और विभागाध्यक्ष, उत्तर प्रदेश, लखनऊ।
3. प्रधान मुख्य वन संरक्षक, वन्यजीव, उत्तर प्रदेश।
4. निदेशक, कृषि, उद्यान, मत्स्य एवं पशुपालन, उत्तर प्रदेश।

(बी0 प्रभाकर)

Our Vision: Conservation Beyond Imagination
पूर्वी विंग, तृतीय तल, ए-ब्लाक, पिकप भवन, विभूति खण्ड, गोमतीनगर, लखनऊ-226 010
फोन नं०: 0522-4006746, फैक्स नं० : 0522-4006746
E-mail: upstatebiodiversityboard@gmail.com, Website: http://www.upsbdb.org

WEST BENGAL BIODIVERSITY BOARD

(Department of Environment, Government of West Bengal)

Memo No.: 155 /7M(Bio) – 1/2022 Date: 28 /02/2023

From: Member Secretary
W.B. Biodiversity Board

To: Shri Acharya Balkrishna
Patanjali Organic Research Institute Pvt. Ltd.
Patanjali Food & Herbal Park,
Village Padartha, Laskar Road,
Haridwar – 249404

Sub.: Survey of vegetation, water, and soil sample in the month of March and April 2023 – Reg.

Sir,

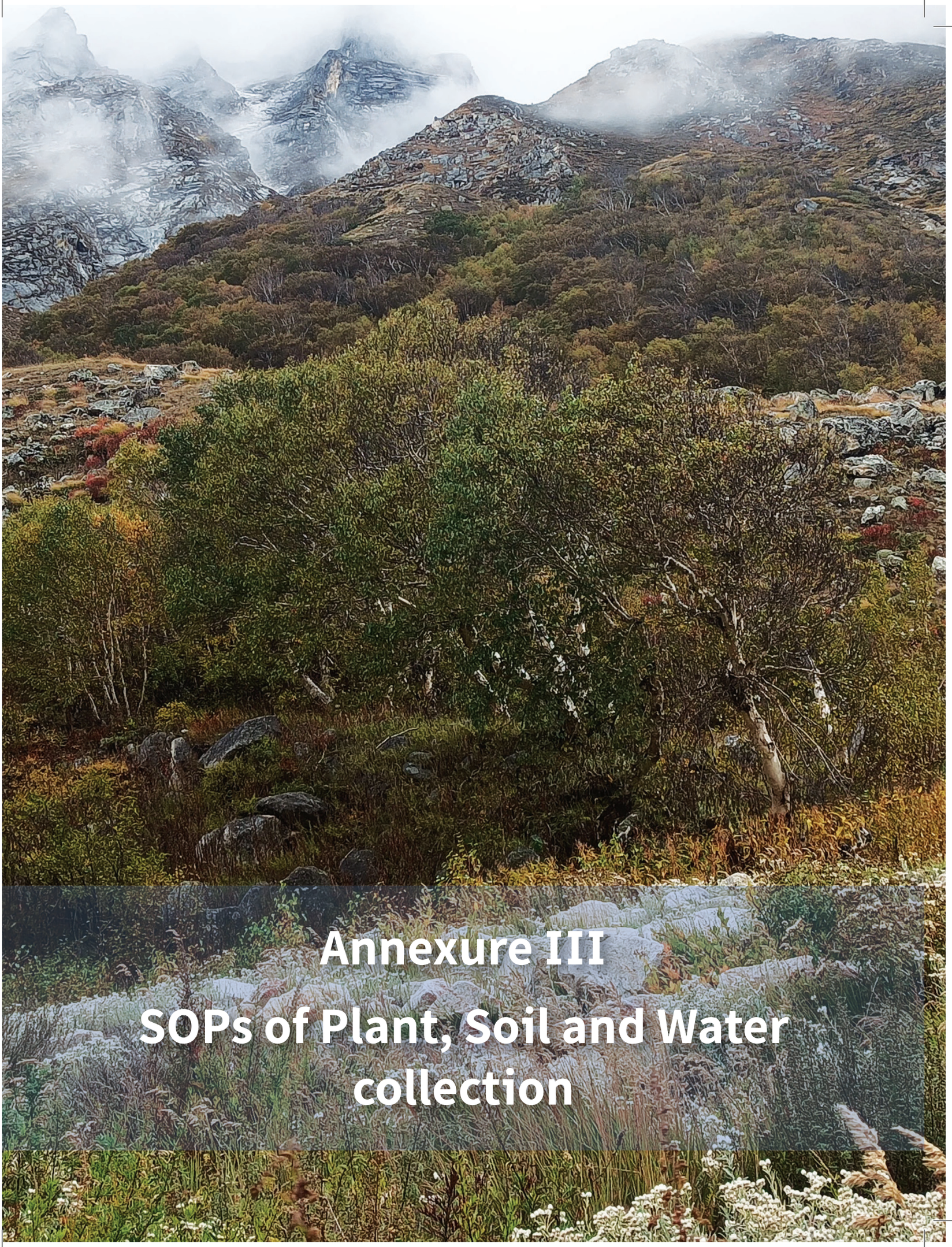
The Board has no objection to grant permission to your organization to 'conduct vegetation, water, and soil sample survey in the month of March and April 2023' in the districts of Murshidabad, Nadia, Hooghly and South 24 Parganas, subject to following terms and conditions:

1. You are required to provide a copy of the **approval/sanction letter** issued to you by the Government of India, under the Namami Gange-II program.
2. You are required to provide the itinerary for field visits that will be conducted during the survey, so that the Biodiversity Management Committees/ local authorities would be intimated.
3. You are required to provide the details regarding the quantity of vegetation, water, and soil samples, if collected.
4. You are required to provide a **declaration** indicating whether the survey is strictly for research purpose only or if any accessed/isolated bioresources or associated traditional knowledge may be used for commercial utilization. In the said declaration, you are also required to declare whether any collection of the resource endangers any component of biological diversity and the risks which may arise from the access.
5. You are required to provide a **plan of action** outlining the steps to be taken to achieve the '*conservation and economic development of the region via skill development programs*', as indicated in the project title, for the survey area.
6. The commercial utilization of the accessed/isolated bioresources or associated traditional knowledge, derived from the survey shall attract **Access and Benefit Sharing** provisions of the Biological Diversity Act, 2002.
7. You are required to submit a copy of the final report of the project.
8. If the concerned area falls under a protected area, **permission must be obtained from the appropriate authority**.

Thanking you,
Yours Sincerely

Member Secretary

Prani Sampad Bhawan (5th Floor), Block: LB-2, Sector: III, Salt Lake City,
Kolkata- 700 106, West Bengal, India
Phone: 033 2335 2731/5954, **Telefax:** 033 2335 2763, **Email:** biodiversity.wbbb@gmail.com, biodiversity.wbbb@nic.in
Website: www.wbbb.wb.gov.in



Annexure III

SOPs of Plant, Soil and Water collection

Standard Operating Procedure for Plant Sample Collection

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Patanjali Organic Research Institute

This document has been prepared by the Expert Committee comprising of:

Name	Designation	Position	Signature
Dr. Vedpriya Arya	Principle Investigator	Scientist E	
Dr. Anupam Shrivastava	Senior Plant Taxonomist	Scientist F	
Dr. Rama Shankar Pathak	Senior Plant Taxonomist	Scientist E	
Dr. Arun Kumar Kushwaha	Plant Taxonomist	Scientist C	
Dr. Bhasker Joshi	Senior Plant Taxonomist	Scientist D	
Dr. Uday Bhan Prajapati	Plant Taxonomist	Scientist C	
Dr. I.P Sharma	Plant Taxonomist	Scientist C	

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The SOPs were developed by a committee of experts and are being distributed to all team members and analysts of the current team for customization and acceptance. These are by no means all-inclusive or mandatory. A concerted attempt has been made to record all dimensions and operational features of typical processes and techniques used in the delivery of various aspects sampling. This document is about the lab. The SOPs that are pertinent to their settings and resources may be modified, adjusted, or adopted by the respective departments. The essential technical guidelines, STGs, and manuals that are stated in the SOPs must also be made available to the stakeholders in addition to providing them with training and familiarization with the SOPs.

DETAILS OF THE DOCUMENT

Document Name:	Standard Operating Procedure for Plant Sample Collection
Document No.:	NMCG Flora/SOP/2023-1
Prepared By:	Name: Dr. Arun Kushwaha Signature:
Approved By:	Name: Dr. Anupam Shrivastava Signature:
Responsibility of Updating:	Name: Dr. Arun Kushwaha Signature:

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1. LABORATORY COLLECTION OF PLANT SAMPLES 7

1.1. **Purpose**: Collection of bulk plant Samples 7

1.2. **Scope**: To prepare herbarium, identification of plant species, phytochemical identification 7

1.3. **Responsibility**: Team Lead with specialized team members 7

1.4. **Procedure**: as under 7

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The Authority over control of this manual is as follow:

Prepared By	**Approved By**	**Issued By**
Name: Dr. Arun Kushwaha Designation: Taxonomist Signature:	Name: Dr. Vedpriya Arya Designation: Principle Investigator Signature:	Name: Dr. Sourav Ghosh Designation: Project Officer Signature:

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1. LABORATORY COLLECTION OF PLANT SAMPLES

1.1. **Purpose**: Collection of bulk plant Samples
1.2. **Scope**: To prepare herbarium, identification of plant species, phytochemical identification
1.3. **Responsibility**: Team Lead with specialized team members
1.4. **Procedure**: as under

Detailed Work	Responsible Person	Supervision
Sampling area selection • The sampling sites have been selected based on three pre-approved criteria. • The sites will be 10 km either side of the Ganga Riverbank • The distance between the sites will be between100-200 km approximately. • The sites will be spanned from Gangotri (Uttarakhand) to Ganga Sagar (West Bengal)	Specialized team members	Team Leader
Field procedures. ➢ When you collect a specimen, look for a plant that is representative of those in the population. ➢ If you are collecting an herb or a grass or other non-woody vascular plant, you should attempt to collect both the above-ground plant parts and the roots. ➢ When possible, choose a specimen that has both flowers and fruits on it. If this is not possible, but the species is both in flower and in fruit in the population, you should make two collections. ➢ Gently dig up the specimen and shake off the excess soil. ➢ Collect enough individuals of the species to generously fill a herbarium sheet (42 x 28 cm). Specimens made from woody plants should be clipped from the shrub, tree, or liana. Try to collect branches that show both flowering and fruiting material. ➢ You may carry the plants in the field by placing them in a plastic bag, into which you have placed a wet paper towel or wet piece of newspaper.	Specialized team members	Team Leader

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➢ Place the plants into the bag, with the roots down, so that specimens will not become too muddy or mixed. ➢ Avoid leaving the collecting bag in the sun, because the specimens may become baked or steamed, and thus ruined. ➢ Field data is very important which will be noted during plant collection in field notebook: • Coloration of foliage and floral parts. • Corolla venation. • Another coloration before and after dehiscence. • Viscidity of parts. • Pollinating agencies. • Texture of foliage and perianth parts. • Colour and nature of fleshy matured fruit. • Habitat. • Exact location (GPS); use proximate object near the site. • Waxed pattern of shoot and root system. • Insecticides and repellents. • Branching pattern of shoot and root system. • Type of soil, moisture content, slope and light conditions.		
Pressing Pressing is the process of placing specimens between the absorbent drying paper under heavy pressure in a plant press. Corrugated cardboard can be inserted between the drying paper to even out the pressure and to facilitate the aeration of the press. Pressing is the most important step in the preparation of specimen and needs careful attention. The specimens should be carefully selected before pressing and the following points may be taken note of: ➢ Underground parts like root, rhizome, etc., must be included in herbs. ➢ Roots and underground parts should be washed thoroughly before pressing to remove soil particles. ➢ Select specimens in flowering or fruiting stage.	Specialized team members	Team Leader

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➢ Ensure that specimens are free from insect feeding, fungal infection and any pathological symptoms. ➢ Fresh specimens should be arranged within the pressing paper. ➢ The maximum surface of pressing paper is covered with the plant specimen to be pressed. ➢ Single specimen should be pressed in a folded pressing paper. ➢ Herbaceous specimens, longer than 40 cm, may be folded in to V-shaped, N-shaped or M-shaped manner and then pressed. ➢ Care should be taken to press the plant parts attached to the plant in their natural position. ➢ A few leaves should be arranged with their lower surfaces facing upward. ➢ A few flowers should be pressed separately of the specimens with gamopetalous corolla. Some of the flowers should be split open and then pressed to expose their essential organs and the nature of the thalamus. ➢ Fleshy and bulky organs should be sliced open to facilitate quick drying. Paper padding or cotton batting around such organs is helpful for drying. ➢ To avoid discoloration and molding, blotters should be changed frequently depending upon the nature of specimen and humidity. ➢ In case of pressing deliquescent corolla or perianth, a layer of absorbent cleaning tissue is put over and beneath the flower before pressing. This tissue is peeled off after the specimen becomes dry.		
Drying: The essential thing is to dry the plant specimen as quickly as possible before the tissues have time to decay. It is therefore necessary to change the drying paper every day at least for the first few days, when the specimens are quite dry they are ready for poisoning.	Specialized team members	Team Leader
Poisoning: The poisoning will be done by dipping the whole plant in a saturated solution of 2% mercuric chloride in ethyl alcohol. Lauryl pentathiophene (LPCP) is used in some herbaria as substitute for mercuric chloride and it	Specialized team members.	Team Leader

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is reported to be very effective and comparatively safer in handling.		
Mounting: When the specimen is pressed, dried and poisoned, it is affixed with label on a mounting sheet (42 x 28 cm). While mounting following precautions should be observed: ➢ Mount only one specimen on one sheet. ➢ The lower part of plant should be at the base of sheet. ➢ Label should be pasted/printed on the right-hand bottom of the sheet. Mounting is done either by gluing the specimen on sheet or by stitching. After identification the specimen should be incorporated (filed) in the herbarium		
Labelling: After mounting the specimen, the herbarium sheet is given a final touch by pasting a label at its lower right hand corner. Size is about 8 × 12 cm. In general, the label will contain the following data such as name of the family, name of the genus and species, locality of collection, date of collection, habitat, collector's name and field number and vernacular name and local uses.	Specialized team members.	Team Leader
Storing: When specimens are ready in all respect, these are stored in wooden or steel almirahs for safe deposit and future record. These almirahs are essentially designed with two to three tiers of pigeonholes. The specimens are arranged in almirahs according to internationally recognized system of plant classification after identification of Bentham & Hooker's Genera Plantarum. Each species is kept in a folded species cover which is lighter in weight and smaller in dimension than the genus cover. The genus cover usually has the name of genus written or printed over it.	Specialized team members	Team Leader

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Voucher Specimen Proforma

Patanjali Research Foundation Herbarium, Haridwar-249404 Namami Gange-II, NMCG, Ministry of Jal Sakti, GOI	
Sampling Site (With Code)	
Collection Number:	
Botanical Name:	
Family:	Habit:
Vernacular Name:	
Locality:	District/State:
Date of Collection:	Flowering and Fruiting:
Ecological Notes:	
Collector:	Identified By:

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2. References

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Standard Operating Procedure for Water Sample Collection

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Patanjali Organic Research Institute

This document has been prepared by the Expert Committee comprising of:

Name	Designation	Position	Signature
Dr. Vedpriya Arya	Principle Investigator	Scientist E	
Dr. Deepika Shrivastava	Microbiologist	Scientist B	
Dr. Divya Joshi	Water Microbiologist	Scientist B	
Dr. Sourav Ghosh	Microbiologist	Scientist C	

The SOPs were developed by a committee of experts and are being distributed to all team members and analysts of the current team for customization and acceptance. These are by no means all-inclusive or mandatory. A concerted attempt has been made to record all dimensions and operational features of typical processes and techniques used in the delivery of various aspects sampling. This document is about the lab. The SOPs that are pertinent to their settings and resources may be modified, adjusted, or adopted by the respective departments. The essential technical guidelines, STGs, and manuals that are stated in the SOPs must also be made available to the stakeholders in addition to providing them with training and familiarization with the SOPs.

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DETAILS OF THE DOCUMENT

Document Name:	Standard Operating Procedure for Water Sample Collection
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Approved By:	Name: Dr. Vedpriya Arya (Principal Investigator) Signature:
Responsibility of Updating:	Name: Dr. Divya Joshi Signature:

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1.2. **Scope**: Physico chemical and microbial analysis of water 7
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Prepared By	**Approved By**	**Issued By**
Name: Dr. Divya Joshi Designation: Water Microbiologist Signature:	Principle Investigator Name: Dr. Vedpriya Arya Signature:	Project Officer Name: Dr. Sourav Ghosh Signature:

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1.1. **Purpose**: Collection of water Samples
1.2. **Scope**: Physico chemical and microbial analysis of water
1.3. **Responsibility**: Team Lead with specialized team members
1.4. **Procedure**: as under

Detailed Work	Responsible Person	Supervision
Sample quantity: According to the analysis attributes, minimum 5liter of water would be needed	Specialized team members	Team Leader
Safety and Precaution and Utility: Sample collection must be done wearing gloves. For the microbiological parameters gloves ensure no contamination. Use parafilm after screw tight the bottle lid.	Specialized team members	Team Leader
Selection of sample containers: Containers are generally made of glass or plastic. Some sample analytes may get absorbed into the walls of plastic containers and/or some contaminants may leach into samples. The containers are selected based on the parameters to be analyzed.	Specialized team members	Team Leader
Sample filling: The containers are either filled to the brim or left with space for air based on the nature of the parameters	Specialized team members.	Team Leader
Sample Labeling: The labeling of the sampling should be done accurately to avoid any confusion. In case of multiple samples form a single source, the sample IDs should be clearly mentioned in the container and Performa provided	Specialized team members.	Team Leader
Performa: Field Data of Water samples A quick brief Performa ensures instant preliminary data logging.	Specialized team members	Team Leader

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Field Data of Water samples

S. No.	Details of the Sample	
1	Name of the Sampling Point (With Code)	
2	Location of the sampling point (Latitude/longitude)	
3	Date (DD/MM/YY) and time (12 Hours Format)	
4	Name of the sample collector	
6	Color (Blue, green, brown, and yellow)	
7	Odor (Aromatic/Plant/Chemical/oil Earthy/musty/Fishy/Foul or rotten/ Not detectable)	
	Foam (Study big foams/medium brown foams/ small cream color foam/ No foam)	
8	Temperature (Record by Thermometer)	
9	pH (Record by pH meter)	
10	TDS (Record by TDS meter)	
11	DO-0 day (Record by DO meter)	
12	DO-5th day (Record by DO meter)	
12	Any other information	

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Standard Operating Procedure for Soil Sample Collection

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Patanjali Organic Research Institute

This document has been prepared by the Expert Committee comprising of:

Name	Designation	Position	Signature
Dr. Vedpriya Arya	Principle Investigator	Scientist E	
Dr. Nidhi Sharma	Mycobiologist	Scientist C	
Dr. Deepika Shrivastava	Microbiologist	Scientist B	
Dr. Srimoyee Banerjee	Soil Microbiologist	Scientist B	
Dr. Sourav Ghosh	Microbiologist	Scientist C	

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Document Name:	Standard Operating Procedure for Soil Sample Collection
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Prepared By:	Name: Dr. Srimoyee Banerjee Signature:
Approved By:	Name: Dr. Vedpriya Arya (PI) Signature:
Responsibility of Updating:	Name: Dr. Srimoyee Banerjee Signature:

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Table of Content

1. LABORATORY COLLECTION OF SOIL SAMPLES 7

1.1. **Purpose**: Collection of soil Samples 7

1.2. **Scope**: Physico chemical and microbial analysis of soil 7

1.3. **Responsibility**: Team Lead with specialized team members 7

1.4. **Procedure**: as under 7

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Prepared By	**Approved By**	**Issued By**
Name: Dr. Srimoyee Banerjee Designation: Soil Microbiologist Signature:	Principal Investigator Name: Dr. Vedpriya Arya Signature:	Project Officer Name: Dr. Sourav Ghosh Signature:

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1.1. **Purpose**: Collection of soil Samples
1.2. **Scope**: Physico chemical and microbial analysis of soil
1.3. **Responsibility**: Team Lead with specialized team members
1.4. **Procedure**: as under

Detailed Work	**Responsible Person**	**Supervision**
Sample quantity: According to the analysis attributes, minimum 2 kg of soil would be needed	Specialized team members	Team Leader
Safety and Precaution and Utility: Sample collection must be done wearing gloves. For the microbiological parameters gloves ensures no contamination	Specialized team members	Team Leader
Selection of sample containers: Containers are generally made of glass or plastic. Some sample analytes may get absorbed into the walls of plastic containers and/or some contaminants may leach into samples. The containers are selected based on the parameters to be analyzed.	Specialized team members	Team Leader
Sampling Procedure for Physicochemical parameters Choose the points for obtaining the samples in a zig-zag manner from one point of sampling. Remove all the grass and litter from the soil surface using a khurpi/Trowel. Dig a 15cm V-shaped pit and from the sides of the pit 1.5 to 2.5cm deep soil should be collected. Note down the temperature of the soil using a soil thermometer. Additionally, note down the coordinates, altitude, environmental temperature, and geotagged picture of the location. In this way, soil from 8-10 points should be collected that represent the area of the soil. All materials like grass, stones, and pebbles should be removed from the collected soil. Collect the soil on a plastic or sac and spread it evenly. Divide it into four parts and remove two opposite sections. Again, repeat step 5 and finally collect approximately 1.5 to 2 Kg of soil.	Specialized team members	Team Leader
Sampling Procedure for Microbiological parameters Gently hold the plant stem and dig out the plant. Wear gloves while collecting plants and soil.	Specialized team members.	Team Leader

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Gently shake the root to collect the soil in a small zip pouch. Around 250-500gm of soil from the rhizosphere/immediate vicinity of the root is required for microbial analysis purposes. If 500gm of soil is not obtained from the rhizosphere by shaking, then use gloves and collect soil from the rhizosphere region. In case of a woody plant, follow the same procedure of digging the soil up to 15cm as given in the protocol for physicochemical parameters. Label the vial correctly and store all samples at a cool and dry place. Try to transfer soil samples (vial and zip pouch) to the laboratory as soon as possible.		
Performa: Field Data of Soil samples A quick brief Performa ensures instant preliminary data logging**.**	Specialized team members	Team Leader

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Field Data of Soil samples

S. No.	Details of the Sample	
1.	Name of the Sampling Point (With Code)	
2.	Location of the sampling point (Latitude/longitude)	
3.	Altitude (Record by GPS meter)	
4.	Date (DD/MM/YY) and time (12 Hours Format)	
5.	Name of the sample collector	
6.	Temperature (Record by Soil meter)	
7.	Moisture (Record by Soil meter)	
8.	pH (Record by Soil meter)	
9.	Sunlight (Record by Soil meter)	
10.	Any other information	

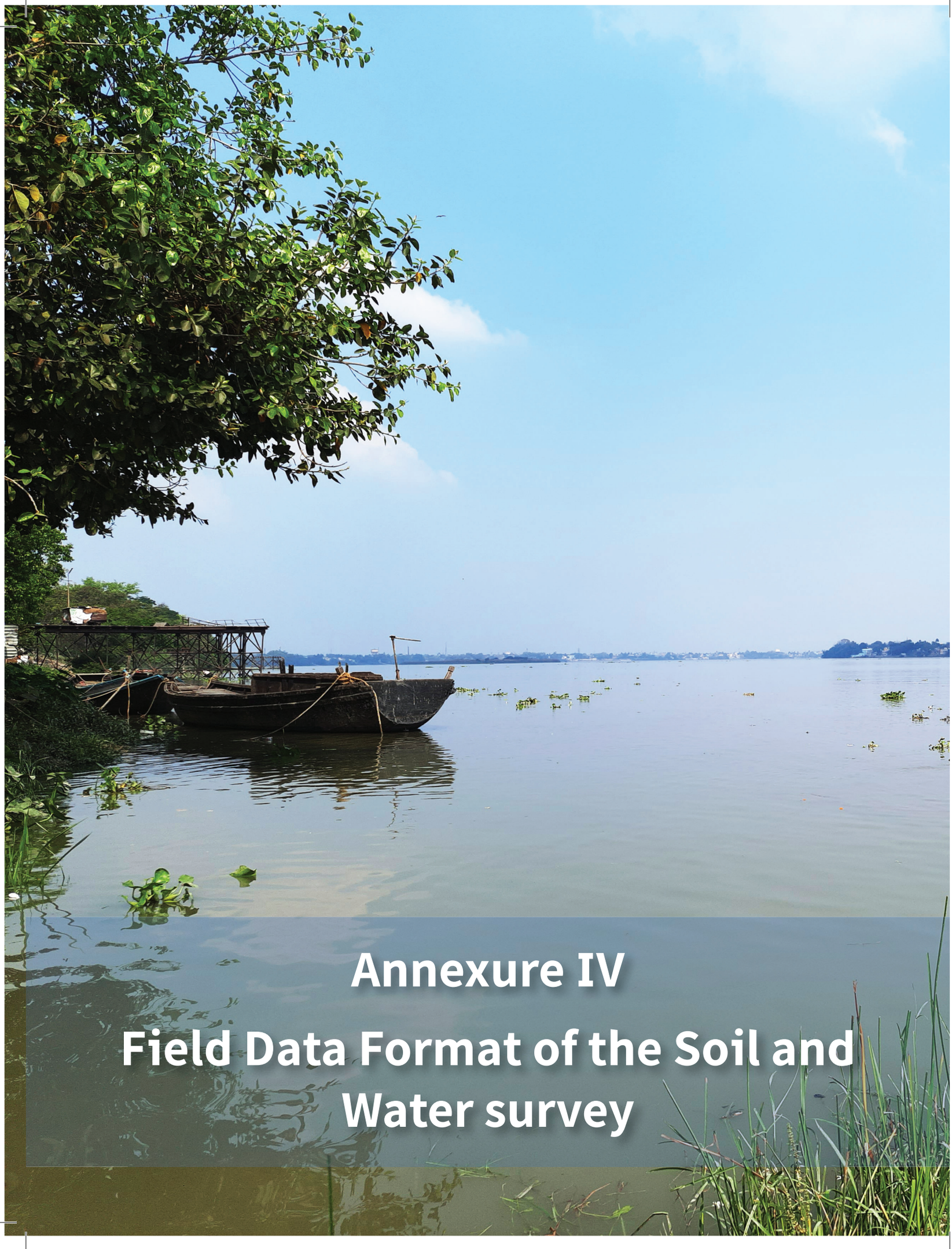
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Annexure IV

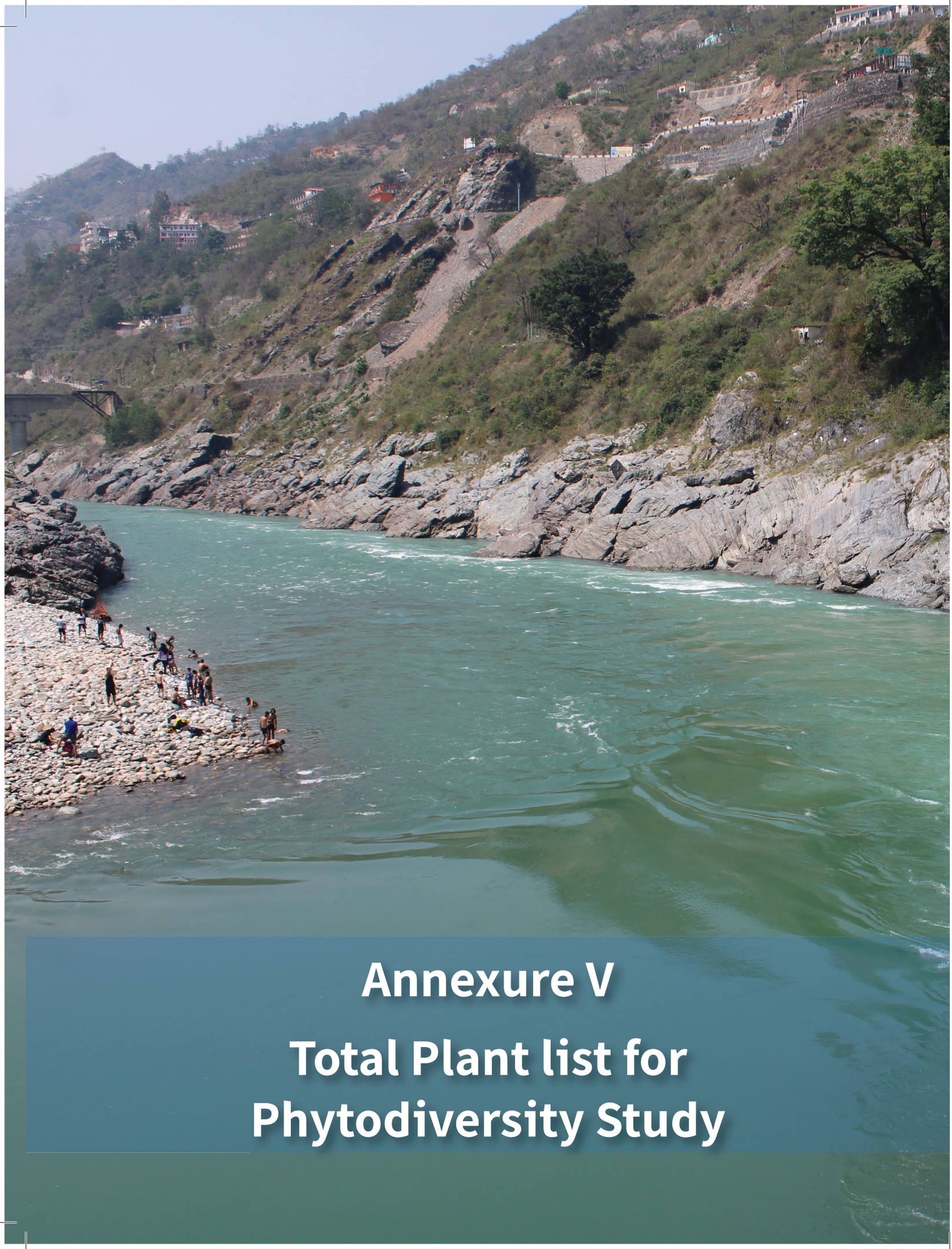
Field Data Format of the Soil and Water survey

Field Data of Soil samples

S. No.	Details of the Sample	
1.	Name of the Sampling Point (With Code)	
2.	Location of the sampling point (Latitude/longitude)	
3.	Altitude (Record by GPS meter)	
4.	Date (DD/MM/YY) and time (12 Hours Format)	
5.	Name of the sample collector	
6.	Temperature (Record by Soil meter)	
7.	Moisture (Record by Soil meter)	
8.	pH (Record by Soil meter)	
9.	Sunlight (Record by Soil meter)	
10.	Any other information	

Field Data of Water samples

S. No.	Details of the Sample	
1	Name of the Sampling Point (With Code)	
2	Location of the sampling point (Latitude/longitude)	
3	Date (DD/MM/YY) and time (12 Hours Format)	
4	Name of the sample collector	
6	Color (Blues, greens, browns, and yellows)	
7	Odor (Aromatic/Plant/Chemical/oil Earthy/musty/Fishy/Foul or rotten/ Not detectable)	
	Foam (Observe big foams/medium brown foams/ small cream color foam/ No foam)	
8	Temperature (Record by Thermometer)	
9	pH (Record by pH meter)	
10	TDS (Record by TDS meter)	
11	DO (Record by DO meter)	
12	Any other information	



Annexure V

Total Plant list for Phytodiversity Study

List of Plants species reported from Gomukh, Uttarakhand to Gangasagar, West Bengal

Sl. No.	Botanical name	Family	Group	Habit	Common name
1	Abelmoschus ficulneus (L.) Wight & Arn.	Malvaceae	Angiosperm	Shrub	Jangli bhindi
2	Abelmoschus manihot (L.) Medik.	Malvaceae	Angiosperm	Shrub	Sweet Hibiscus, Edible Hibiscus, Manihot-mallow, Sunset Hibiscus, Yellow Hibiscus, Jungli bhindi
3	Abelmoschus manihot subsp. tetraphyllus (Roxb. ex Hornem.) Borss.Waalk.	Malvaceae	Angiosperm	Shrub	
4	Abelmoschus moschatus Medik.	Malvaceae	Angiosperm	Shrub	Jangali Bhindi
5	Abies spectabilis (D.Don) Mirb.	Pinaceae	Gymnosperm	Tree	Childrow, Sallur
6	Abrus precatorius L.	Fabaceae	Angiosperm	Climber	Ratti
7	Abutilon indicum (L.) Sweet	Malvaceae	Angiosperm	Shrub	Kanghi
8	Acacia auriculiformis A.Cunn. ex Benth.	Fabaceae	Angiosperm	Tree	Earleaf Acacia
9	Acacia dealbata Link	Fabaceae	Angiosperm	Tree	
10	Acalypha indica L.	Euphorbiaceae	Angiosperm	Herb	Kuppi, kuppikhokhali
11	Acanthus ilicifolius L.	Acanthaceae	Angiosperm	Shrub	Sea Holly, harkata
12	Acer cappadocicum Gled.	Sapindaceae	Angiosperm	Tree	Caucasian Maple
13	Achyranthes aspera L.	Amaranthaceae	Angiosperm	Herb	Putkanda, Apamarga
14	Achyranthes aspera var. sicula L.	Amaranthaceae	Angiosperm	Herb	Kanphuli
15	Acilepis divergens (DC.) H.Rob. & Skvarla	Asteraceae	Angiosperm	Shrub	
16	Acmella calva (DC.) R.K.Jansen	Asteraceae	Angiosperm	Herb	Toothache plant

Sl. No.	Botanical name	Family	Group	Habit	Common name
17	Acmella paniculata (Wall. ex DC.) R.K.Jansen	Asteraceae	Angiosperm	Herb	Akarkar
18	Acmella uliginosa (Sw.) Cass.	Asteraceae	Angiosperm	Herb	Marsh Para Cress
19	Acorus calamus L.	Acoraceae	Angiosperm	Herb	Bach
20	Acrachne racemosa (B. Heyne ex Roth) Ohwi	Poaceae	Angiosperm	Herb	
21	Adenostemma lavenia (L.) Kuntze	Asteraceae	Angiosperm	Herb	Sticky Daisy
22	Adiantum capillus-veneris L.	Pteridaceae	Pteridophyte	Herb	
23	Adiantum caudatum L.	Pteridaceae	Pteridophyte	Herb	
24	Adiantum incisum Forssk.	Pteridaceae	Pteridophyte	Herb	
25	Adiantum philippense L.	Pteridaceae	Pteridophyte	Herb	
26	Adina cordifolia (Roxb.) Brandis	Rubiaceae	Angiosperm	Tree	Haldu
27	Aegle marmelos (L.) Correa	Rutaceae	Angiosperm	Tree	Bel
28	Aeschynomene indica L.	Fabaceae	Angiosperm	Herb	Kath shola, Didhen, Phulan
29	Agave americana L.	Asparagaceae	Angiosperm	Shrub	Ram-bans
30	Agave vivipara L.	Asparagaceae	Angiosperm	Shrub	Dwarf aloe
31	Ageratina adenophora (Spreng.) R.M.King & H.Rob.	Asteraceae	Angiosperm	Herb	Catweed, Crofton weed
32	Ageratum conyzoides L.	Asteraceae	Angiosperm	Herb	Jangli pudina, Visadodi
33	Ageratum houstonianum Mill.	Asteraceae	Angiosperm	Herb	Blue Billygoat Weed
34	Agropogon lutosus (Poir.) P.Fourn.	Poaceae	Angiosperm	Herb	
35	Ailanthus excelsa Roxb.	Simaroubaceae	Angiosperm	Tree	Marukh, Aralu
36	Ajuga brachystemon Maxim.	Lamiaceae	Angiosperm	Herb	Neelkanthi, Rathpathi, Neekanthi
37	Ajuga integrifolia Buch.-Ham. ex D.Don	Lamiaceae	Angiosperm	Herb	Bracted Bugleweed, Neelkanthi

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38	Ajuga parviflora Benth.	Lamiaceae	Angiosperm	Herb	Small-Flowered Bugleweed
39	Alangium salviifolium (L.f.) Wangerin	Cornaceae	Angiosperm	Tree	Ankol
40	Albizia chinensis (Osbeck) Merr.	Fabaceae	Angiosperm	Tree	Kala-siris
41	Albizia julibrissin Durazz.	Fabaceae	Angiosperm	Tree	Sirsa
42	Albizia lebbeck (L.) Benth.	Fabaceae	Angiosperm	Tree	Saras, Siris
43	Albizia odoratissima (L.f.) Benth.	Fabaceae	Angiosperm	Tree	Siris
44	Albizia procera (Roxb.) Benth.	Fabaceae	Angiosperm	Tree	White Siris, Safed Siris
45	Alhagi maurorum Medik.	Fabaceae	Angiosperm	Shrub	Javasa
46	Allamanda cathartica L.	Apocynaceae	Angiosperm	Shrub	Golden Trumpet Vine, Allamanda Vine
47	Alliaria petiolata (M.Bieb.) Cavara & Grande	Brassicaceae	Angiosperm	Herb	Garlic Mustard, hedge garlic, jack-by-the-hedge
48	Allium cepa L.	Amaryllidaceae	Angiosperm	Herb	Piyaz
49	Allium sativum L.	Amaryllidaceae	Angiosperm	Herb	Lahasun
50	Allophylus serratus (Roxb.) Kurz	Sapindaceae	Angiosperm	Shrub	Toothed-Leaf Allophylus, Tippani
51	Alnus nepalensis D.Don	Betulaceae	Angiosperm	Tree	Utees
52	Alocasia indica (Lour.) Spach	Araceae	Angiosperm	Herb	Mankanda, Giant Taro
53	Aloe vera (L.) Burm.f.	Asphodelaceae	Angiosperm	Shrub	Ghrit kumari
54	Alstonia scholaris (L.) R.Br.	Apocynaceae	Angiosperm	Tree	Satparni
55	Alternanthera ficoidea (L.) P.Beauv.	Amaranthaceae	Angiosperm	Herb	Sanguinarea
56	Alternanthera paronychioides A.St.-Hil.	Amaranthaceae	Angiosperm	Herb	Smooth Chaff Flower
57	Alternanthera philoxeroides (Mart.) Griseb.	Amaranthaceae	Angiosperm	Herb	Alligator weed

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58	Alternanthera pungens Kunth	Amaranthaceae	Angiosperm	Herb	Khaki weed
59	Alternanthera sessilis (L.) R.Br. ex DC.	Amaranthaceae	Angiosperm	Herb	Ghardughia
60	Alysicarpus ovalifolius (Schumach.) J.Léonard	Fabaceae	Angiosperm	Herb	Oval-Leaf Alyce Clover
61	Alysicarpus vaginalis (L.) DC.	Fabaceae	Angiosperm	Herb	Chauli
62	Amaranthus blitum L.	Amaranthaceae	Angiosperm	Herb	Mediterranean Amaranth
63	Amaranthus caudatus L.	Amaranthaceae	Angiosperm	Herb	Chaulai
64	Amaranthus hybridus L.	Amaranthaceae	Angiosperm	Herb	Choulai
65	Amaranthus spinosus L.	Amaranthaceae	Angiosperm	Herb	Prickly Amaranth, Kanta chaulai
66	Amaranthus viridis L.	Amaranthaceae	Angiosperm	Herb	Jangli-Chauiai
67	Ammannia baccifera L.	Lythraceae	Angiosperm	Herb	Blistering ammania
68	Ammannia multiflora Roxb.	Lythraceae	Angiosperm	Herb	
69	Amorphophallus paeoniifolius (Dennst.) Nicolson	Araceae	Angiosperm	Herb	Elephant Foot Yam, Oal, Gandira
70	Andrographis paniculata (Burm.f.) Wall. ex Nees	Acanthaceae	Angiosperm	Herb	Kalmegh
71	Androsace lanuginosa Wall.	Primulaceae	Angiosperm	Herb	
72	Anethum graveolens L.	Apiaceae	Angiosperm	Herb	Soya
73	Anisomeles indica (L.) Kuntze	Lamiaceae	Angiosperm	Shrub	Kala bhangra, Indian Catmint
74	Annona reticulata L.	Annonaceae	Angiosperm	Tree	Ram-phal
75	Annona squamosa L.	Annonaceae	Angiosperm	Tree	Sitha-phal
76	Antigonon leptopus Hook. & Arn.	Polygonaceae	Angiosperm	Climber	Coral vine, Honolulu creeper
77	Apluda mutica L.	Poaceae	Angiosperm	Herb	Mauritian Grass,Tachula, Tachhila
78	Arachis hypogaea L.	Fabaceae	Angiosperm	Herb	Peanut, Moongphali
79	Araucaria heterophylla (Salisb.) Franco	Araucariaceae	Gymnosperm	Tree	Norfolk Pine

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80	Arenaria serpyllifolia L.	Caryophyllaceae	Angiosperm	Herb	Thyme-Leaved Sandwort,
81	Argemone mexicana L.	Papaveraceae	Angiosperm	Herb	Satyanashi, Rhus
82	Argemone ochroleuca Sweet	Papaveraceae	Angiosperm	Herb	Yellow Poppy
83	Argyreia nervosa (Burm.f.) Bojer	Convolvulaceae	Angiosperm	Climber	Elephant Creeper, Vidhara
84	Aristida adscensionis L.	Poaceae	Angiosperm	Herb	
85	Arnebia hispidissima (Sieber ex Lehm.) A.DC.	Boraginaceae	Angiosperm	Herb	Ram Bui
86	Artabotrys hexapetalus (L.f.) Bhandari	Annonaceae	Angiosperm	Shrub	Hara champa
87	Artemisia capillaris Thunb.	Asteraceae	Angiosperm	Herb	Manva, Jhirun
88	Artemisia gmelinii Weber ex Stechm.	Asteraceae	Angiosperm	Herb	Ganga Tulsi
89	Artemisia nilagirica (C.B.Clarke) Pamp.	Asteraceae	Angiosperm	Shrub	Dona, Pati
90	Artemisia vulgaris L.	Asteraceae	Angiosperm	Shrub	Nagadouna
91	Arthraxon lanceolatus (Roxb.) Hochst.	Poaceae	Angiosperm	Herb	
92	Arthraxon lancifolius (Trin.) Hochst.	Poaceae	Angiosperm	Herb	Lanceleaf Carpetgrass
93	Artocarpus heterophyllus Lam.	Moraceae	Angiosperm	Tree	Jackfruit, Katahal
94	Artocarpus lacucha Buch.-Ham.	Moraceae	Angiosperm	Tree	Lakucha, Badhal
95	Arundinella nepalensis Trin.	Poaceae	Angiosperm	Herb	
96	Arundo donax L.	Poaceae	Angiosperm	Herb	Tinta, Baranai
97	Asclepias curassavica L.	Apocynaceae	Angiosperm	Shrub	Kakatundi, Blood Flower
98	Asparagus adscendens Roxb.	Asparagaceae	Angiosperm	Climber	Dholi moosli
99	Asparagus curillus Buch.-Ham. ex Roxb.	Asparagaceae	Angiosperm	Shrub	Jangli Satavar
100	Asparagus filicinus Buch.-Ham. ex D.Don	Asparagaceae	Angiosperm	Shrub	Sharanoi, Kaunia

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101	Asperugo procumbens L.	Boraginaceae	Angiosperm	Herb	Madwort
102	Asplenium dalhousieae Hook.	Aspleniaceae	Pteridophyte	Herb	
103	Asplenium nidus L.	Aspleniaceae	Pteridophyte	Epiphyte	
104	Asplenium trichomanes L.	Aspleniaceae	Pteridophyte	Herb	
105	Astragalus candolleanus Royle ex Benth.	Fabaceae	Angiosperm	Herb	Vajradanti
106	Astragalus himalayanus Klotzsch	Fabaceae	Angiosperm	Shrub	Rudravanti
107	Avena fatua L.	Poaceae	Angiosperm	Herb	
108	Avena sativa L.	Poaceae	Angiosperm	Herb	Common Oat
109	Azadirachta indica A.Juss.	Meliaceae	Angiosperm	Tree	Neem
110	Azanza lampas (Cav.) Alef.	Malvaceae	Angiosperm	Shrub	Jangli bhindi
111	Azima tetracantha Lam.	Salvadoraceae	Angiosperm	Shrub	Kanta-gur-kamai
112	Bacopa monnieri (L.) Wettst.	Plantaginaceae	Angiosperm	Herb	Brahmi, brahmi
113	Baliospermum solanifolium (Burm.) Suresh	Euphorbiaceae	Angiosperm	Shrub	Danti
114	Bambusa bambos (L.) Voss	Poaceae	Angiosperm	Shrub	Bans
115	Bambusa tulda Roxb.	Poaceae	Angiosperm	Shrub	Bans
116	Barleria cristata L.	Acanthaceae	Angiosperm	Shrub	Sairiyak
117	Barleria lupulina Lindl.	Acanthaceae	Angiosperm	Shrub	Hophead
118	Basella alba L.	Basellaceae	Angiosperm	Climber	Poi
119	Bauhinia acuminata L.	Fabaceae	Angiosperm	Tree	Safed Kachnar, Shwetkanchan
120	Bauhinia purpurea L.	Fabaceae	Angiosperm	Tree	Khairwal, Guiral
121	Bauhinia racemosa Lam.	Fabaceae	Angiosperm	Tree	Jhinjheri, Kachnal
122	Bauhinia variegata L.	Fabaceae	Angiosperm	Tree	Kachnar
123	Berberis chitria Buch.-Ham. ex Lindl.	Berberidaceae	Angiosperm	Shrub	Kilmora
124	Berberis lycium Royle	Berberidaceae	Angiosperm	Shrub	Indian Barberry, Daruhaldi
125	Berberis pseudumbellata R. Parker	Berberidaceae	Angiosperm	Shrub	

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126	Bergenia ciliata (Haw.) Sternb.	Saxifragaceae	Angiosperm	Herb	Patthar Chatta
127	Bergia ammannioides Roxb.	Elatinaceae	Angiosperm	Herb	Ammannia Waterwort
128	Betula alnoides Buch.-Ham. ex D.Don	Betulaceae	Angiosperm	Tree	Kath-bhuj
129	Betula utilis D.Don	Betulaceae	Angiosperm	Tree	Bhojpatra
130	Bidens pilosa L.	Asteraceae	Angiosperm	Herb	Kumra, Kumur, Kurei
131	Biophytum sensitivum (L.) DC.	Oxalidaceae	Angiosperm	Herb	Lajalu
132	Bixa orellana L.	Bixaceae	Angiosperm	Tree	Kumkum
133	Blitum virgatum L.	Amaranthaceae	Angiosperm	Herb	Strawberry Sticks
134	Blumea axillaris (Lam.) DC.	Asteraceae	Angiosperm	Herb	Soft Blumea
135	Blumea lacera (Burm.f.) DC.	Asteraceae	Angiosperm	Herb	Kakranda
136	Blumea obliqua (L.) Druce	Asteraceae	Angiosperm	Herb	
137	Blumea sinuata (Lour.) Merr.	Asteraceae	Angiosperm	Herb	Sow-Thistle Blumea
138	Boehmeria virgata subsp. macrophylla (Hornem.) Friis & Wilmot-Dear	Urticaceae	Angiosperm	Shrub	Bara-Siauru
139	Boehmeria virgata var. macrostachya (Wight) Friis & Wilmot-Dear	Urticaceae	Angiosperm	Shrub	False Nettle, Khagsa
140	Boerhavia diffusa L.	Nyctaginaceae	Angiosperm	Herb	Punarnava
141	Boerhavia erecta L.	Nyctaginaceae	Angiosperm	Herb	Punarnava
142	Bolboschoenus glaucus (Lam.) S.G.Sm.	Cyperaceae	Angiosperm	Herb	
143	Bolboschoenus maritimus (L.) Palla	Cyperaceae	Angiosperm	Herb	Sea Club-Rush
144	Bombax ceiba L.	Malvaceae	Angiosperm	Tree	Semal
145	Bonnaya ciliata (Colsm.) Spreng.	Linderniaceae	Angiosperm	Herb	Fringed Lindernia

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146	Borassus flabellifer L.	Arecaceae	Angiosperm	Tree	Tar
147	Bothriochloa bladhii (Retz.) S.T.Blake	Poaceae	Angiosperm	Herb	Caucasian Bluestem Grass, Australian bluestem, Forest bluegrass, Plains bluestem, Purple plume grass
148	Bothriochloa pertusa (L.) A.Camus	Poaceae	Angiosperm	Herb	
149	Bougainvillea glabra Choisy	Nyctaginaceae	Angiosperm	Shrub	Bougainvillea
150	Bougainvillea spectabilis Willd.	Nyctaginaceae	Angiosperm	Shrub	Bougainvillea
151	Brachiaria mutica (Forssk.) Stapf	Poaceae	Angiosperm	Herb	
152	Brassica campestris var. sarson Prain	Brassicaceae	Angiosperm	Herb	Sarson
153	Brassica juncea (L.) Czern.	Brassicaceae	Angiosperm	Herb	Kali Rai
154	Breynia retusa (Dennst.) Alston	Phyllanthaceae	Angiosperm	Shrub	Kambhi
155	Bromelia pinguin L.	Bromeliaceae	Angiosperm	Shrub	
156	Bromus catharticus Vahl	Poaceae	Angiosperm	Herb	Annual prairie grass, Brome grass
157	Bromus tectorum L.	Poaceae	Angiosperm	Herb	Cheatgrass, downy brome
158	Brugmansia suaveolens (Humb. & Bonpl. ex Willd.) Sweet	Solanaceae	Angiosperm	Shrub	Tree Dhatura, Dhatura
159	Buddleja asiatica Lour.	Scrophulariaceae	Angiosperm	Shrub	White Butterfly Bush
160	Buddleja crispa Benth.	Scrophulariaceae	Angiosperm	Shrub	Himalayan Butterfly Bush
161	Bulbostylis barbata (Rottb.) C.B.Clarke	Cyperaceae	Angiosperm	Herb	Bearded Watergrass
162	Bupleurum hamiltonii N.P.Balakr.	Apiaceae	Angiosperm	Herb	Jangli-Jeera

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163	Butea monosperma (Lam.) Kuntze	Fabaceae	Angiosperm	Tree	Dhak, Tesu
164	Caesalpinia decapetala (Roth) Alston	Fabaceae	Angiosperm	Shrub	Kingari, Kunju, Karanj
165	Caesalpinia pulcherrima (L.) Sw.	Fabaceae	Angiosperm	Shrub	Peacock Flower, Pride of Barbados, Dwarf poinciana, Guletura
166	Caesulia axillaris Roxb.	Asteraceae	Angiosperm	Herb	Pink Node Flower
167	Cajanus cajan (L.) Huth	Fabaceae	Angiosperm	Shrub	Arhar
168	Cajanus scarabaeoides (L.) Thouars	Fabaceae	Angiosperm	Herb	Bandal
169	Calamus tenuis Roxb.	Arecaceae	Angiosperm	Shrub	Beit, Vetashah
170	Calliandra haematocephala Hassk.	Fabaceae	Angiosperm	Tree	Red Powder Puff
171	Callicarpa arborea Roxb.	Lamiaceae	Angiosperm	Tree	Ghiwala
172	Callicarpa macrophylla Vahl	Lamiaceae	Angiosperm	Shrub	Kumhar, Ghiwala
173	Calophyllum inophyllum L.	Calophyllaceae	Angiosperm	Tree	পুন্নাগ Punnaga, Beauty Leaf, Sultan Champa
174	Calotropis gigantea (L.) W.T.Aiton	Apocynaceae	Angiosperm	Shrub	Safed Aak
175	Calotropis procera (Aiton) W.T.Aiton	Apocynaceae	Angiosperm	Shrub	Aak, Madar
176	Calystegia hederacea Wall.	Convolvulaceae	Angiosperm	Climber	
177	Campanula pallida Wall.	Campanulaceae	Angiosperm	Herb	Purple Bellflower
178	Campylotropis macrostyla (D.Don) Lindl. ex Miq.	Fabaceae	Angiosperm	Shrub	
179	Canavalia gladiata (Jacq.) DC.	Fabaceae	Angiosperm	Climber	Khadsampal, Badi sem
180	Canna indica L.	Cannaceae	Angiosperm	Herb	Keli
181	Cannabis sativa L.	Cannabaceae	Angiosperm	Herb	Bhang
182	Capillipedium assimile (Steud.) A.Camus	Poaceae	Angiosperm	Herb	

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183	Capparis decidua (Forssk.) Edgew.	Capparaceae	Angiosperm	Shrub	Karira
184	Capparis sepiaria L.	Capparaceae	Angiosperm	Shrub	Kcmthari
185	Capparis zeylanica L.	Capparaceae	Angiosperm	Climber	Hinsra, Aradanda
186	Capsella bursa-pastoris (L.) Medik.	Brassicaceae	Angiosperm	Herb	Shepherds purse
187	Capsicum annuum L.	Solanaceae	Angiosperm	Herb	Chilli, Mirch
188	Cardamine scutata Thunb.	Brassicaceae	Angiosperm	Herb	
189	Cardiospermum halicacabum L.	Sapindaceae	Angiosperm	Climber	Balloon Vine
190	Carica papaya L.	Caricaceae	Angiosperm	Tree	Papeeta
191	Carissa carandas L.	Apocynaceae	Angiosperm	Shrub	Karonda
192	Carissa spinarum L.	Apocynaceae	Angiosperm	Shrub	Jungli Karonda
193	Carthamus tinctorius L.	Asteraceae	Angiosperm	Shrub	Kusumphal
194	Carum carvi L.	Apiaceae	Angiosperm	Herb	Siya-Jeera, Jangli-Dhania, Sahi Jeera Krishna-jeerak
195	Caryota urens L.	Arecaceae	Angiosperm	Tree	Fishtail Palm
196	Cascabela thevetia (L.) Lippold	Apocynaceae	Angiosperm	Shrub	Yellow Oleander, Peeli Kaner
197	Casearia graveolens Dalzell	Salicaceae	Angiosperm	Tree	Chilla
198	Casearia tomentosa Roxb.	Salicaceae	Angiosperm	Tree	Chilla
199	Cassia fistula L.	Fabaceae	Angiosperm	Tree	Amaltas
200	Cassytha filiformis L.	Lauraceae	Angiosperm	Climber	Amarbeli
201	Casuarina equisetifolia L.	Casuarinaceae	Angiosperm	Tree	Whistling Pine, Junglisaru
202	Catharanthus roseus (L.) G.Don	Apocynaceae	Angiosperm	Herb	Sadhabahar
203	Catunaregam spinosa (Thunb.) Tirveng.	Rubiaceae	Angiosperm	Tree	Maindal, Mainfal
204	Cayratia trifolia (L.) Domin	Vitaceae	Angiosperm	Climber	Amarlati
205	Cedrus deodara (Roxb. ex D.Don) G.Don	Pinaceae	Gymnosperm	Tree	Deodar

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206	Ceiba pentandra (L.) Gaertn.	Malvaceae	Angiosperm	Tree	Vilayatisemal
207	Ceiba speciosa (A.St.-Hil., A.Juss. & Cambess.) Ravenna	Malvaceae	Angiosperm	Tree	Silk floss tree, Kapok, Floss silk tree, Resham rui
208	Celastrus paniculatus Willd.	Celastraceae	Angiosperm	Climber	Malkangani
209	Celosia argentea L.	Amaranthaceae	Angiosperm	Herb	Murgkesh
210	Cenchrus americanus (L.) Morrone	Poaceae	Angiosperm	Herb	Bajra
211	Cenchrus ciliaris L.	Poaceae	Angiosperm	Herb	
212	Cenchrus orientalis (Rich.) Morrone	Poaceae	Angiosperm	Herb	
213	Cenchrus pennisetiformis Steud.	Poaceae	Angiosperm	Herb	
214	Cenchrus setiger Vahl	Poaceae	Angiosperm	Herb	
215	Cenchrus setosus Sw.	Poaceae	Angiosperm	Herb	
216	Centella asiatica (L.) Urb.	Apiaceae	Angiosperm	Herb	Brahmi-buti
217	Cerastium cerastoides (L.) Britton	Caryophyllaceae	Angiosperm	Herb	Mountain Chickweed
218	Cereus hexagonus (L.) Mill.	Cactaceae	Angiosperm	Shrub	
219	Cestrum nocturnum L.	Solanaceae	Angiosperm	Shrub	Raat Ki Rani
220	Chenopodiastrum murale (L.) S.Fuentes, Uotila & Borsch	Amaranthaceae	Angiosperm	Herb	Nettle-Leaved Goosefoot
221	Chenopodium adpressifolium Pandeya & A.Pandeya	Amaranthaceae	Angiosperm	Shrub	Jangali Bathua
222	Chenopodium album L.	Amaranthaceae	Angiosperm	Herb	Bathua
223	Chenopodium opulifolium Schrad. ex W.D.J.Koch & Ziz	Amaranthaceae	Angiosperm	Herb	
224	Chloris barbata Sw.	Poaceae	Angiosperm	Herb	Swollen Finger Grass
225	Chloris virgata Sw.	Poaceae	Angiosperm	Herb	
226	Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	Angiosperm	Herb	Siam Weed, Tivra gandha, Bagh dhoka

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227	Chrozophora rottleri (Geiseler) Spreng.	Euphorbiaceae	Angiosperm	Herb	Suryavarti
228	Chrozophora tinctoria (L.) A.Juss.	Euphorbiaceae	Angiosperm	Herb	
229	Chrysanthemum indicum L.	Asteraceae	Angiosperm	Herb	
230	Chrysojasminum humile (L.) Banfi	Oleaceae	Angiosperm	Shrub	Yellow Jasmine, Peeli chameli
231	Chrysopogon aciculatus (Retz.) Trin.	Poaceae	Angiosperm	Herb	Golden Beardgrass
232	Chrysopogon fulvus (Spreng.) Chiov.	Poaceae	Angiosperm	Herb	Tiger Grass
233	Chrysopogon zizanioides (L.) Roberty	Poaceae	Angiosperm	Herb	Khas
234	Cicer arietinum L.	Fabaceae	Angiosperm	Herb	Chana
235	Cichorium intybus L.	Asteraceae	Angiosperm	Herb	Kasni
236	Cirsium arvense (L.) Scop.	Asteraceae	Angiosperm	Herb	Creeping Thistle, Field Thistle
237	Cirsium wallichii DC.	Asteraceae	Angiosperm	Herb	Kendeiya, Kandra, Bungsee
238	Cissampelos pareira L.	Menispermaceae	Angiosperm	Climber	Akaudi, Patha
239	Cissus quadrangularis L.	Vitaceae	Angiosperm	Climber	
240	Citrullus lanatus (Thunb.) Matsum. & Nakai	Cucurbitaceae	Angiosperm	Climber	Watermelon, Tarbooz
241	Citrus × limon (L.) Osbeck	Rutaceae	Angiosperm	Tree	Baranimbu
242	Clematis buchananiana DC.	Ranunculaceae	Angiosperm	Climber	Lemon Clematis
243	Clematis gouriana Roxb. ex DC.	Ranunculaceae	Angiosperm	Climber	Indian Clematis, Churanhar
244	Clematis montana Buch.-Ham. ex DC.	Ranunculaceae	Angiosperm	Climber	Kujju, Kajju, Kaunia, Kaunia-bali
245	Cleome gynandra L.	Cleomaceae	Angiosperm	Herb	Gandhuli
246	Cleome rutidosperma DC.	Cleomaceae	Angiosperm	Herb	Fringed Spider Flower

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247	Cleome viscosa L.	Cleomaceae	Angiosperm	Herb	Asian spider flower, Bagra
248	Clerodendrum infortunatum L.	Lamiaceae	Angiosperm	Shrub	Bhant, Karu
249	Clerodendrum phlomidis L.f.	Lamiaceae	Angiosperm	Shrub	Inni
250	Clinopodium umbrosum (M.Bieb.) K.Koch	Lamiaceae	Angiosperm	Herb	Shady Calamint, Birchee
251	Clitoria ternatea L.	Fabaceae	Angiosperm	Climber	Aparajita
252	Coccinia grandis (L.) Voigt	Cucurbitaceae	Angiosperm	Climber	Kundaru
253	Cocculus hirsutus (L.) W.Theob.	Menispermaceae	Angiosperm	Climber	Jaljamani
254	Coix aquatica Roxb.	Poaceae	Angiosperm	Herb	Aquatic Job's Tears
255	Coix lacryma-jobi L.	Poaceae	Angiosperm	Herb	Job's Tears
256	Colebrookea oppositifolia Sm.	Lamiaceae	Angiosperm	Shrub	Lulr, Bambher
257	Colocasia esculenta (L.) Schott	Araceae	Angiosperm	Herb	Pindalu
258	Colocasia fallax Schott	Araceae	Angiosperm	Herb	Deceptive Taro
259	Combretum indicum (L.) DeFilipps	Combretaceae	Angiosperm	Liana	Rangoon Creeper, Madhu Malati
260	Commelina attenuata Vahl	Commelinaceae	Angiosperm	Herb	
261	Commelina benghalensis L.	Commelinaceae	Angiosperm	Herb	Kanchara
262	Commelina erecta L.	Commelinaceae	Angiosperm	Herb	White-Mouth Dayflower
263	Commelina undulata R.Br.	Commelinaceae	Angiosperm	Herb	Wavy-Leaf Dayflower
264	Commicarpus chinensis (L.) Heimerl	Nyctaginaceae	Angiosperm	Herb	Diffuse Hogweed
265	Convolvulus arvensis L.	Convolvulaceae	Angiosperm	Herb	Hirankhuri
266	Convolvulus prostratus Forssk.	Convolvulaceae	Angiosperm	Herb	Prostrate Bindweed, Shankhpushpi
267	Corchorus aestuans L.	Malvaceae	Angiosperm	Shrub	Chonch
268	Corchorus capsularis L.	Malvaceae	Angiosperm	Shrub	Jute, White Jute
269	Corchorus fascicularis Lam.	Malvaceae	Angiosperm	Shrub	Bankosta, Chunchi

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270	Corchorus olitorius L.	Malvaceae	Angiosperm	Shrub	Nalta Jute
271	Corchorus trilocularis L.	Malvaceae	Angiosperm	Shrub	Wild Jute, Kadukosta, Kadvapat, Hardikaket
272	Cordia dichotoma G.Forst.	Boraginaceae	Angiosperm	Tree	Lasura
273	Cordia myxa L.	Boraginaceae	Angiosperm	Tree	Lasura
274	Coriandrum sativum L.	Apiaceae	Angiosperm	Herb	Dhaniya
275	Coriaria napalensis Wall.	Coriariaceae	Angiosperm	Shrub	Masura
276	Cornus macrophylla Wall.	Cornaceae	Angiosperm	Tree	Khagsi, Kandar, Kachur, Himalayan Dog Wood
277	Cotinus coggygria Scop.	Anacardiaceae	Angiosperm	Shrub	Gad-tungla, Kalmina, Tungoi
278	Cotoneaster lindleyi Steud.	Rosaceae	Angiosperm	Shrub	
279	Cotoneaster microphyllus Wall. ex Lindl.	Rosaceae	Angiosperm	Shrub	Bugarchilla
280	Crateva adansonii subsp. odora (Buch.-Ham.) Jacobs	Capparaceae	Angiosperm	Tree	
281	Crateva magna (Lour.) DC.	Capparaceae	Angiosperm	Tree	Large Garlic Pear, Bama
282	Crateva religiosa G.Forst.	Capparaceae	Angiosperm	Tree	Varun
283	Crepidium acuminatum (D.Don) Szlach.	Orchidaceae	Angiosperm	Herb	Jivak
284	Crinum asiaticum L.	Amaryllidaceae	Angiosperm	Herb	Sudarshan
285	Crinum lorifolium Roxb.	Amaryllidaceae	Angiosperm	Herb	
286	Crotalaria albida B.Heyne ex Roth	Fabaceae	Angiosperm	Herb	Mountain Rattlepod, Chunchuni
287	Crotalaria juncea L.	Fabaceae	Angiosperm	Shrub	Sunn
288	Crotalaria medicaginea Lam.	Fabaceae	Angiosperm	Herb	Medick Rattlepod
289	Crotalaria pallida Aiton	Fabaceae	Angiosperm	Shrub	Smooth Rattlepod, salts rattlebox

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290	Crotalaria pusilla Roxb. ex Roth	Fabaceae	Angiosperm	Shrub	Small Rattlepod
291	Crotalaria spectabilis Roth	Fabaceae	Angiosperm	Shrub	Showy Rattlepod, Sanni, Ghungri, Dhundhuni, Jhunjhunia
292	Croton bonplandianus Baill.	Euphorbiaceae	Angiosperm	Herb	Ban tulsi, Kala Bhangra
293	Croton persimilis Müll.Arg.	Euphorbiaceae	Angiosperm	Tree	Chucka
294	Cryptolepis buchananii R.Br. ex Roem. & Schult.	Apocynaceae	Angiosperm	Climber	Dudhi-bel, Karanta
295	Cucumis maderaspatanus L.	Cucurbitaceae	Angiosperm	Climber	Madras Pea Pumpkin, Kachari
296	Cucumis melo L.	Cucurbitaceae	Angiosperm	Climber	Melon
297	Cucumis melo var. agrestis Naudin	Cucurbitaceae	Angiosperm	Climber	
298	Cucumis sativus L.	Cucurbitaceae	Angiosperm	Climber	Kheera
299	Cucumis sativus subsp. hardwickii (Royle) Banfi & Galasso	Cucurbitaceae	Angiosperm	Climber	Cucumber
300	Cucurbita pepo L.	Cucurbitaceae	Angiosperm	Climber	Pumpkin
301	Cupressus torulosa D.Don ex Lamb.	Cupressaceae	Gymnosperm	Tree	Surai, Raisul
302	Cuscuta campestris Yunck.	Convolvulaceae	Angiosperm	Climber	Golden Dodder, common dodder
303	Cuscuta capitata Roxb.	Convolvulaceae	Angiosperm	Climber	Amarbel
304	Cuscuta hyalina Roth	Convolvulaceae	Angiosperm	Climber	Amarbel
305	Cuscuta reflexa Roxb.	Convolvulaceae	Angiosperm	Climber	Amarbel
306	Cyanotis axillaris (L.) D.Don ex Sweet	Commelinaceae	Angiosperm	Herb	Creeping Cradle Plant, Kana
307	Cyanotis cristata (L.) D.Don	Commelinaceae	Angiosperm	Herb	Crested Dew-Grass
308	Cyanthillium cinereum (L.) H.Rob.	Asteraceae	Angiosperm	Herb	Sehdevi

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309	Cyathocline purpurea (Buch.-Ham. ex D.Don) Kuntze	Asteraceae	Angiosperm	Herb	Bandhaniya
310	Cyathula tomentosa (Schult.) Moq.	Amaranthaceae	Angiosperm	Shrub	Lichkura, Silla
311	Cycas revoluta Thunb.	Cycadaceae	Gymnosperm	Tree	King Sago Palm, Sago Cycad
312	Cyclea peltata (Burm.f.) Hook.f. & Thomson	Menispermaceae	Angiosperm	Climber	Indian Moon-Seed, raj patha
313	Cymbopogon jwarancusa (Jones) Schult.	Poaceae	Angiosperm	Herb	
314	Cymbopogon martini (Roxb.) W.Watson	Poaceae	Angiosperm	Herb	Creeping Signal Grass, Gandhabel
315	Cynodon dactylon (L.) Pers.	Poaceae	Angiosperm	Herb	Doorwa, Doob Ghas
316	Cyperus alopecuroides Rottb.	Cyperaceae	Angiosperm	Herb	
317	Cyperus alternifolius L.	Cyperaceae	Angiosperm	Herb	
318	Cyperus brevifolius (Rottb.) Hassk.	Cyperaceae	Angiosperm	Herb	Green Water Sedge, Globe Cyperus
319	Cyperus compressus L.	Cyperaceae	Angiosperm	Herb	
320	Cyperus cuspidatus Kunth	Cyperaceae	Angiosperm	Herb	
321	Cyperus difformis L.	Cyperaceae	Angiosperm	Herb	Variable Flatsedge
322	Cyperus digitatus Roxb.	Cyperaceae	Angiosperm	Herb	
323	Cyperus exaltatus Retz.	Cyperaceae	Angiosperm	Herb	
324	Cyperus flavidus Retz.	Cyperaceae	Angiosperm	Herb	
325	Cyperus haspan L.	Cyperaceae	Angiosperm	Herb	
326	Cyperus iria L.	Cyperaceae	Angiosperm	Herb	Rice Flat Sedge, Iria flatsedge, Moth
327	Cyperus metzii (Hochst. ex Steud.) Mattf. & Kük.	Cyperaceae	Angiosperm	Herb	
328	Cyperus michelianus (L.) Delile	Cyperaceae	Angiosperm	Herb	
329	Cyperus mindorensis (Steud.) Huygh	Cyperaceae	Angiosperm	Herb	White Water Sedge

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330	Cyperus nutans Vahl	Cyperaceae	Angiosperm	Herb	
331	Cyperus pilosus Vahl	Cyperaceae	Angiosperm	Herb	
332	Cyperus rotundus L.	Cyperaceae	Angiosperm	Herb	Motha
333	Cyrtococcum accrescens (Trin.) Stapf	Poaceae	Angiosperm	Herb	
334	Dactyloctenium aegyptium (L.) Willd.	Poaceae	Angiosperm	Herb	Crowfoot Grass
335	Dalbergia lanceolaria L.f.	Fabaceae	Angiosperm	Tree	Takoli
336	Dalbergia sissoo Roxb. ex DC.	Fabaceae	Angiosperm	Tree	Sisham
337	Datura innoxia Mill.	Solanaceae	Angiosperm	Shrub	Safed Datura
338	Datura metel L.	Solanaceae	Angiosperm	Shrub	Dhattura
339	Datura stramonium L.	Solanaceae	Angiosperm	Shrub	Dhatura
340	Daucus carota subsp. sativus (Hoffm.) Schübl. & G.Martens	Apiaceae	Angiosperm	Herb	Gajar
341	Debregeasia saeneb (Forssk.) Hepper & J.R.I.Wood	Urticaceae	Angiosperm	Shrub	Puruni
342	Deeringia amaranthoides (Lam.) Merr.	Amaranthaceae	Angiosperm	Shrub	Kalalori
343	Delonix regia (Bojer ex Hook.) Raf.	Fabaceae	Angiosperm	Tree	Flame Tree, Gulmohar
344	Delphinium denudatum Wall. ex Hook.f. & Thomson	Ranunculaceae	Angiosperm	Herb	Nirvisi
345	Dendrocalamus strictus (Roxb.) Nees	Poaceae	Angiosperm	Shrub	বাঁশ bamsa, Karali
346	Dendrophthoe falcata (L.f.) Ettingsh.	Loranthaceae	Angiosperm	Epiphyte	Banda
347	Desmodium scorpiurus (Sw.) Poir.	Fabaceae	Angiosperm	Herb	Scorpion Tick Trefoil
348	Desmodium velutinum (Willd.) DC.	Fabaceae	Angiosperm	Shrub	Velvet-Leaf Desmodium
349	Desmostachya bipinnata (L.) Stapf	Poaceae	Angiosperm	Herb	কুশ Kush

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350	Deutzia staminea R.Br. ex Wall.	Hydrangeaceae	Angiosperm	Shrub	Ghugtai, Bhatkukri
351	Dichanthium annulatum (Forssk.) Stapf	Poaceae	Angiosperm	Herb	Sheda Grass
352	Dichanthium caricosum (L.) A.Camus	Poaceae	Angiosperm	Herb	
353	Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae	Angiosperm	Tree	Kairi
354	Dicliptera bupleuroides Nees	Acanthaceae	Angiosperm	Herb	Thorowax Foldwing
355	Dicliptera chinensis (L.) Juss.	Acanthaceae	Angiosperm	Herb	
356	Dicliptera paniculata (Forssk.) I.Darbysh.	Acanthaceae	Angiosperm	Herb	Kakajangha
357	Digera muricata (L.) Mart.	Amaranthaceae	Angiosperm	Herb	False Amaranth, chanchali
358	Digitalis purpurea L.	Plantaginaceae	Angiosperm	Herb	Common Foxglove
359	Digitaria ciliaris (Retz.) Koeler	Poaceae	Angiosperm	Herb	Wild Crabgrass, bamboo grass, crabgrass
360	Digitaria cruciata (Nees ex Steud.) E.G.Camus & A.Camus	Poaceae	Angiosperm	Herb	
361	Digitaria longiflora (Retz.) Pers.	Poaceae	Angiosperm	Herb	
362	Digitaria radicosa (J.Presl) Miq.	Poaceae	Angiosperm	Herb	
363	Digitaria violascens Link	Poaceae	Angiosperm	Herb	
364	Dioscorea alata L.	Dioscoreaceae	Angiosperm	Climber	Kamalu
365	Dioscorea bulbifera L.	Dioscoreaceae	Angiosperm	Climber	Bana alu
366	Dioscorea deltoidea Wall. ex Griseb.	Dioscoreaceae	Angiosperm	Climber	Tarur, Harvish, Keerish
367	Dioscorea pentaphylla L.	Dioscoreaceae	Angiosperm	Climber	Kanta alu
368	Diospyros melanoxylon Roxb.	Ebenaceae	Angiosperm	Tree	Tendu
369	Diospyros montana Roxb.	Ebenaceae	Angiosperm	Tree	Bishtendu

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370	Diplazium esculentum (Retz.) Sw.	Aspleniaceae	Pteridophyte	Herb	Lingura
371	Diplocyclos palmatus (L.) C.Jeffrey	Cucurbitaceae	Angiosperm	Climber	Shivalingi
372	Dodonaea viscosa Jacq.	Sapindaceae	Angiosperm	Shrub	Vilayti-mehdi
373	Dracaena trifasciata (Prain) Mabb.	Asparagaceae	Angiosperm	Herb	Snake Plant
374	Drimia indica (Roxb.) Jessop	Asparagaceae	Angiosperm	Herb	Indian Squill
375	Drynaria quercifolia (L.) J.Sm.	Polypodiaceae	Pteridophyte	Epiphyte	
376	Dryopteris caroli-hopei Fraser-Jenk.	Polypodiaceae	Pteridophyte	Herb	
377	Dryopteris cochleata (D.Don) C.Chr.	Dryopteridaceae	Pteridophyte	Herb	
378	Dryopteris filix-mas (L.) Schott	Polypodiaceae	Pteridophyte	Herb	
379	Duhaldea rubricaulis (Wall. ex DC.) Anderb.	Asteraceae	Angiosperm	Shrub	
380	Duranta erecta L.	Verbenaceae	Angiosperm	Shrub	Nilkanta
381	Dysphania ambrosioides (L.) Mosyakin & Clemants	Amaranthaceae	Angiosperm	Herb	Mexican Tea
382	Ecbolium ligustrinum (Vahl) Vollesen	Acanthaceae	Angiosperm	Shrub	Udajati
383	Echinochloa colonum (L.) Link	Poaceae	Angiosperm	Herb	Jungle Rice, Jangli jhangora, Jharwa, Jirio, Shama
384	Echinochloa colonum subsp. edulis (Honda) Banfi & Galasso	Poaceae	Angiosperm	Herb	
385	Echinochloa crus-galli (L.) P.Beauv.	Poaceae	Angiosperm	Herb	Barnyard Grass, Sanwak, Samak
386	Echinochloa crus-pavonis (Kunth) Schult.	Poaceae	Angiosperm	Herb	
387	Echinochloa picta (J.Koenig) P.W.Michael	Poaceae	Angiosperm	Herb	

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388	Echinochloa stagnina (Retz.) P.Beauv.	Poaceae	Angiosperm	Herb	
389	Echinops echinatus Roxb.	Asteraceae	Angiosperm	Herb	Utkataria
390	Eclipta prostrata (L.) L.	Asteraceae	Angiosperm	Herb	Bhringaraj
391	Ehretia laevis Roxb.	Boraginaceae	Angiosperm	Tree	Chamror, Datranga, Tamorriya
392	Eleocharis atropurpurea (Retz.) J.Presl & C.Presl	Cyperaceae	Angiosperm	Herb	Purple Spike-Rush
393	Eleocharis geniculata (L.) Roem. & Schult.	Cyperaceae	Angiosperm	Herb	
394	Eleusine coracana (L.) Gaertn.	Poaceae	Angiosperm	Herb	Finger Millet, Mandua, Mandwa, Marua, Maruwa, Ragi
395	Eleusine indica (L.) Gaertn.	Poaceae	Angiosperm	Herb	Indian Crowfoot Grass, Malankuri, Balraja, Mandla
396	Engelhardia spicata var. integra (Kurz) W.E.Manning ex Steenis	Juglandaceae	Angiosperm	Tree	Gadh mauha
397	Enteropogon dolichostachyus (Lag.) Keng	Poaceae	Angiosperm	Herb	
398	Enydra fluctuans Lour.	Asteraceae	Angiosperm	Herb	Buffalo Spinach
399	Ephedra gerardiana Wall. ex Klotzsch & Garcke	Ephedraceae	Gymnosperm	Shrub	Chesna, Somlata
400	Epipremnum aureum (Linden & André) G.S.Bunting	Araceae	Angiosperm	Climber	Money Plant
401	Equisetum arvense L.	Equisetaceae	Pteridophyte	Herb	
402	Equisetum diffusum D.Don	Equisetaceae	Pteridophyte	Herb	
403	Equisetum ramosissimum Desf.	Equisetaceae	Pteridophyte	Herb	
404	Equisetum ramosissimum var. huegelii (Milde) Christenh. & Husby	Equisetaceae	Pteridophyte	Herb	

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405	Eragrostis atrovirens (Desf.) Trin. ex Steud.	Poaceae	Angiosperm	Herb	
406	Eragrostis ciliaris (L.) R.Br.	Poaceae	Angiosperm	Herb	
407	Eragrostis coarctata Stapf	Poaceae	Angiosperm	Herb	
408	Eragrostis japonica (Thunb.) Trin.	Poaceae	Angiosperm	Herb	Pond Lovegrass
409	Eragrostis minor Host	Poaceae	Angiosperm	Herb	Little Lovegrass, Lesser Love Grass
410	Eragrostis multiflora Trin.	Poaceae	Angiosperm	Herb	
411	Eragrostis nutans (Retz.) Nees ex Steud.	Poaceae	Angiosperm	Herb	
412	Eragrostis tef (Zuccagni) Trotter	Poaceae	Angiosperm	Herb	
413	Eragrostis tenella (L.) P.Beauv. ex Roem. & Schult.	Poaceae	Angiosperm	Herb	Shada fulka
414	Erigeron bonariensis L.	Asteraceae	Angiosperm	Herb	
415	Erigeron canadensis L.	Asteraceae	Angiosperm	Herb	
416	Erigeron karvinskianus DC.	Asteraceae	Angiosperm	Herb	
417	Erigeron sublyratus Roxb. ex DC.	Asteraceae	Angiosperm	Herb	
418	Eriochloa procera (Retz.) C.E.Hubb.	Poaceae	Angiosperm	Herb	Tropical Cupgrass
419	Erioscirpus comosus (Wall.) Palla	Cyperaceae	Angiosperm	Herb	
420	Erysimum hieraciifolium L.	Brassicaceae	Angiosperm	Herb	European Wallflower, Siberian wallflower, Tall wormseed mustard
421	Erythrina stricta Roxb.	Fabaceae	Angiosperm	Tree	Dhol dhak
422	Eucalyptus camaldulensis Dehnh.	Myrtaceae	Angiosperm	Tree	Liptus
423	Eucalyptus tereticornis Sm.	Myrtaceae	Angiosperm	Tree	Safeda

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424	Eulaliopsis binata (Retz.) C.E.Hubb.	Poaceae	Angiosperm	Herb	
425	Euphorbia chamaesyce L.	Euphorbiaceae	Angiosperm	Herb	Dudhi
426	Euphorbia helioscopia L.	Euphorbiaceae	Angiosperm	Herb	Dudhi
427	Euphorbia heterophylla L.	Euphorbiaceae	Angiosperm	Herb	Dudhi
428	Euphorbia heyneana Spreng.	Euphorbiaceae	Angiosperm	Herb	Dudhi
429	Euphorbia hirta L.	Euphorbiaceae	Angiosperm	Herb	Dudhi
430	Euphorbia hypericifolia L.	Euphorbiaceae	Angiosperm	Herb	
431	Euphorbia neriifolia L.	Euphorbiaceae	Angiosperm	Shrub	Sehund
432	Euphorbia prostrata Aiton	Euphorbiaceae	Angiosperm	Herb	Prostrate Sandmat, red euphorbia
433	Euphorbia thymifolia L.	Euphorbiaceae	Angiosperm	Herb	Choti-dudhi
434	Euphorbia tithymaloides L.	Euphorbiaceae	Angiosperm	Shrub	Nagdon
435	Euploca strigosa (Willd.) Diane & Hilger	Boraginaceae	Angiosperm	Herb	Chitiphul
436	Evolvulus alsinoides (L.) L.	Convolvulaceae	Angiosperm	Herb	Visnukrantha
437	Evolvulus nummularius (L.) L.	Convolvulaceae	Angiosperm	Herb	Safed-shankhpushpi
438	Falconeria insignis Royle	Euphorbiaceae	Angiosperm	Tree	Khinna
439	Fernandoa adenophylla (Wall. ex G.Don) Steenis	Bignoniaceae	Angiosperm	Tree	Katsagon
440	Ferula jaeschkeana Vatke	Apiaceae	Angiosperm	Herb	Hingu, Hingupatri
441	Ficus auriculata Lour.	Moraceae	Angiosperm	Tree	Tiamla
442	Ficus benghalensis L.	Moraceae	Angiosperm	Tree	Barh, Banyan tree
443	Ficus exasperata Vahl	Moraceae	Angiosperm	Tree	Brahma's Banyan
444	Ficus heterophylla L.f.	Moraceae	Angiosperm	Shrub	Creeping Fig
445	Ficus hispida L.f.	Moraceae	Angiosperm	Tree	Totmila, Gobla
446	Ficus lacor Buch.-Ham.	Moraceae	Angiosperm	Tree	Pakhar
447	Ficus mollis Vahl	Moraceae	Angiosperm	Tree	
448	Ficus palmata subsp. palmata	Moraceae	Angiosperm	Tree	Bedu
449	Ficus palmata subsp. virgata Browicz	Moraceae	Angiosperm	Tree	Bedu
450	Ficus racemosa L.	Moraceae	Angiosperm	Tree	Gular

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451	Ficus religiosa L.	Moraceae	Angiosperm	Tree	Peepal
452	Ficus sarmentosa Buch.-Ham. ex Sm.	Moraceae	Angiosperm	Climber	Beduli
453	Ficus semicordata Buch.-Ham. ex Sm.	Moraceae	Angiosperm	Tree	Drooping Fig, Khaina
454	Ficus subincisa Buch.-Ham. ex Sm.	Moraceae	Angiosperm	Tree	Chanchri
455	Ficus virens Aiton	Moraceae	Angiosperm	Tree	Pakhar
456	Filago hurdwarica (Wall. ex DC.) Wagenitz	Asteraceae	Angiosperm	Herb	
457	Fimbristylis aestivalis (Retz.) Vahl	Cyperaceae	Angiosperm	Herb	Tella juvvi
458	Fimbristylis bisumbellata (Forssk.) Bubani	Cyperaceae	Angiosperm	Herb	
459	Fimbristylis complanata (Retz.) Link	Cyperaceae	Angiosperm	Herb	
460	Fimbristylis cymosa R.Br.	Cyperaceae	Angiosperm	Herb	
461	Fimbristylis dichotoma (L.) Vahl	Cyperaceae	Angiosperm	Herb	Forked Fimbry, Eight day grass
462	Fimbristylis ovata (Burm.f.) J.Kern	Cyperaceae	Angiosperm	Herb	
463	Fimbristylis polytrichoides (Retz.) R.Br.	Cyperaceae	Angiosperm	Herb	
464	Fimbristylis quinquangularis (Vahl) Kunth	Cyperaceae	Angiosperm	Herb	Grasslike Fimbry, Globe finger rush
465	Flacourtia indica (Burm.f.) Merr.	Salicaceae	Angiosperm	Tree	Kandai
466	Flueggea virosa (Roxb. ex Willd.) Royle	Phyllanthaceae	Angiosperm	Shrub	White-Berry Bush, Safed chainari, Dalme, Patala
467	Foeniculum vulgare Mill.	Apiaceae	Angiosperm	Herb	Saunf
468	Fragaria nubicola (Lindl. ex Hook.f.) Lacaita	Rosaceae	Angiosperm	Herb	Himalayan Strawberry

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469	Fraxinus micrantha Lingelsh.	Oleaceae	Angiosperm	Tree	Angu, Angar, Himalayan Ask
470	Fumaria indica (Hausskn.) Pugsley	Papaveraceae	Angiosperm	Herb	Indian Fumitory, Pit Papra
471	Galinsoga parviflora Cav.	Asteraceae	Angiosperm	Herb	Marchya
472	Galium aparine L.	Rubiaceae	Angiosperm	Herb	Khuskusa, Kuri
473	Galium asperuloides Edgew.	Rubiaceae	Angiosperm	Herb	Leswakuri
474	Gamochaeta pensylvanica (Willd.) Cabrera	Asteraceae	Angiosperm	Herb	
475	Gardenia jasminoides J.Ellis	Rubiaceae	Angiosperm	Shrub	Gardenia, Cape jasmine, গংধৰাজ Gandhraj
476	Gentiana argentea (Royle ex D.Don) Royle ex D.Don	Gentianaceae	Angiosperm	Herb	Silvery Gentian
477	Geranium nepalense Sweet	Geraniaceae	Angiosperm	Herb	Bhanda
478	Geranium wallichianum D.Don ex Sweet	Geraniaceae	Angiosperm	Herb	Kaphlya, Laljari
479	Girardinia diversifolia (Link) Friis	Urticaceae	Angiosperm	Shrub	Bhainsya-Kandali, Jhir-Kandali
480	Glinus lotoides L.	Molluginaceae	Angiosperm	Herb	Gandibudi
481	Glinus oppositifolius (L.) Aug. DC.	Molluginaceae	Angiosperm	Herb	Jima, Grishma-sundaraka
482	Glycosmis pentaphylla (Retz.) DC.	Rutaceae	Angiosperm	Shrub	Van nimbu, Pilu
483	Gmelina arborea Roxb. ex Sm.	Lamiaceae	Angiosperm	Tree	Gambhari
484	Gomphrena celosioides Mart.	Amaranthaceae	Angiosperm	Herb	Cockscomb Gomphrena
485	Gonostegia pentandra (Roxb.) Miq.	Urticaceae	Angiosperm	Herb	Piparisari
486	Gossypium herbaceum L.	Malvaceae	Angiosperm	Shrub	Kapas
487	Grangea maderaspatana (L.) Poir.	Asteraceae	Angiosperm	Herb	Madras Carpet

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488	Grevillea robusta A.Cunn. ex R.Br.	Proteaceae	Angiosperm	Tree	Silver Oak
489	Grewia optiva J.R.Drumm. ex Burret	Malvaceae	Angiosperm	Tree	Bhimal
490	Grewia serrulata DC.	Malvaceae	Angiosperm	Tree	Serrulate-Leaf Grewia, bhansuli, Kakki, Kaori, Kathbhemal, Phirsan
491	Grewia subinaequalis DC.	Malvaceae	Angiosperm	Tree	Phalsa, Falsa
492	Grona triflora (L.) H.Ohashi & K.Ohashi	Fabaceae	Angiosperm	Herb	Creeping Tick Trefoil, Kudaliya
493	Guilandina bonduc L.	Fabaceae	Angiosperm	Shrub	Kantkaranj
494	Gymnema sylvestre (Retz.) R.Br. ex Sm.	Apocynaceae	Angiosperm	Climber	Gurmar, মেষশৃঙ্গ Meshashrunga
495	Hackelochloa granularis (L.) Kuntze	Poaceae	Angiosperm	Herb	Pitscale Grass
496	Hedera nepalensis K.Koch	Araliaceae	Angiosperm	Climber	Laguti, Mithiari
497	Helianthus debilis Nutt.	Asteraceae	Angiosperm	Herb	
498	Helichrysum luteoalbum (L.) Rchb.	Asteraceae	Angiosperm	Herb	Weedy Cudweed, Jersey Cudweed
499	Helicteres isora L.	Malvaceae	Angiosperm	Shrub	Marorphali
500	Helinus lanceolatus Brandis	Rhamnaceae	Angiosperm	Climber	
501	Heliotropium indicum L.	Boraginaceae	Angiosperm	Herb	Indian Heliotrope
502	Hellenia speciosa (J.Koenig) S.R.Dutta	Costaceae	Angiosperm	Herb	Keu
503	Hemarthria compressa (L.f.) R.Br.	Poaceae	Angiosperm	Herb	Whip Grass
504	Hemidesmus indicus (L.) R.Br.	Apocynaceae	Angiosperm	Climber	Dudhibel
505	Hemigraphis hirta (Vahl) T.Anderson	Acanthaceae	Angiosperm	Herb	Hairy Coneflower
506	Hemigraphis latebrosa (B.Heyne ex Roth) Nees	Acanthaceae	Angiosperm	Herb	Shade Loving Coneflower

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507	Hemionitis albomarginata (C.B.Clarke) Christenh.	Pteridaceae	Pteridophyte	Herb	Silver Fern
508	Hemionitis anceps (Blanf.) Christenh.	Pteridaceae	Angiosperm	Herb	
509	Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	Poaceae	Angiosperm	Herb	
510	Hibiscus cannabinus L.	Malvaceae	Angiosperm	Shrub	Kenaf, Deccan Hemp, Brown Indian Hemp, Patsan, San
511	Hibiscus lobatus (Murray) Kuntze	Malvaceae	Angiosperm	Shrub	Lobed Leaf Mallow
512	Hibiscus panduriformis Burm.f.	Malvaceae	Angiosperm	Shrub	
513	Hibiscus rosa-sinensis L.	Malvaceae	Angiosperm	Shrub	Gurhal
514	Hibiscus sabdariffa L.	Malvaceae	Angiosperm	Shrub	Lakra, Patsan
515	Hibiscus vitifolius L.	Malvaceae	Angiosperm	Shrub	বনকাপাস banakapasa, Grape Leaved Mallow
516	Himalrandia tetrasperma (Wall. ex Roxb.) T.Yamaz.	Rubiaceae	Angiosperm	Shrub	Madan Phal
517	Hiptage benghalensis (L.) Kurz	Malpighiaceae	Angiosperm	Liana	Madhavi Lata
518	Holarrhena pubescens Wall. ex G.Don	Apocynaceae	Angiosperm	Tree	Kutaja
519	Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	Angiosperm	Tree	Kanju, Papari
520	Homonoia riparia Lour.	Euphorbiaceae	Angiosperm	Shrub	Jalbent
521	Hordeum vulgare L.	Poaceae	Angiosperm	Herb	Jau
522	Hydrilla verticillata (L.f.) Royle	Hydrocharitaceae	Angiosperm	Herb	Hydrilla
523	Hydrocotyle sibthorpioides Lam.	Araliaceae	Angiosperm	Herb	Garh-brahmi
524	Hydrolea zeylanica (L.) Vahl	Hydroleaceae	Angiosperm	Herb	Koliary

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525	Hygrophila auriculata (Schumach.) Heine	Acanthaceae	Angiosperm	Herb	Marsh Barbel, tal makhana
526	Hygrophila difformis (L.f.) Blume	Acanthaceae	Angiosperm	Herb	
527	Hygrophila erecta (Burm.f.) Hochr.	Acanthaceae	Angiosperm	Herb	
528	Hygrophila polysperma (Roxb.) T.Anderson	Acanthaceae	Angiosperm	Herb	
529	Hypericum oblongifolium Choisy	Hypericaceae	Angiosperm	Shrub	Pendant Hypericum
530	Hypericum perforatum L.	Hypericaceae	Angiosperm	Herb	Choli-phulya, Basant
531	Hypodematium crenatum (Forssk.) Kuhn	Polypodiaceae	Pteridophyte	Herb	
532	Ichnocarpus frutescens (L.) W.T.Aiton	Apocynaceae	Angiosperm	Climber	Kamu
533	Imperata cylindrica (L.) P.Beauv.	Poaceae	Angiosperm	Herb	ঊলূ Ooloo
534	Indigofera atropurpurea Buch.-Ham. ex Hornem.	Fabaceae	Angiosperm	Shrub	Kala-Sakina
535	Indigofera heterantha Wall. ex Brandis	Fabaceae	Angiosperm	Shrub	Sakina, Kathi, Kathoj, Shakina
536	Indigofera linifolia (L.f.) Retz.	Fabaceae	Angiosperm	Herb	Torki
537	Indigofera tinctoria L.	Fabaceae	Angiosperm	Shrub	True Indigo, Neel
538	Indigofera linnaei Ali	Fabaceae	Angiosperm	Herb	Birdsville Indigo, Vasuka
539	Ipomoea aitonii Lindl.	Convolvulaceae	Angiosperm	Climber	
540	Ipomoea aquatica Forssk.	Convolvulaceae	Angiosperm	Herb	Water Morning Glory, Kalmisak
541	Ipomoea cairica (L.) Sweet	Convolvulaceae	Angiosperm	Climber	Railway Creeper, Neeli-bel
542	Ipomoea carnea subsp. fistulosa (Mart. ex Choisy) D.F.Austin	Convolvulaceae	Angiosperm	Shrub	Besharam

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543	Ipomoea hederifolia L.	Convolvulaceae	Angiosperm	Climber	Scarlet Morning Glory, Scarlet creeper
544	Ipomoea muricata (L.) Jacq.	Convolvulaceae	Angiosperm	Climber	Purple Moonflower, Clove Bean, Lavender Moonvine, Lavender Moonflower
545	Ipomoea nil (L.) Roth	Convolvulaceae	Angiosperm	Climber	Mirchai
546	Ipomoea obscura (L.) Ker Gawl.	Convolvulaceae	Angiosperm	Climber	Obscure Morning Glory
547	Ipomoea pes-tigridis L.	Convolvulaceae	Angiosperm	Climber	Tiger Foot Morning Glory, Panchpatia
548	Ipomoea sagittifolia Burm.f.	Convolvulaceae	Angiosperm	Climber	বনকলমি bankalami, বন পেঁয়াজ bawn peyanj, Purple Heart Glory
549	Ipomoea sindica Stapf	Convolvulaceae	Angiosperm	Climber	Sind Morning Glory
550	Ipomoea triloba L.	Convolvulaceae	Angiosperm	Climber	Little Bell Morning Glory
551	Iris versicolor L.	Iridaceae	Angiosperm	Herb	Iris
552	Ischaemum rugosum Salisb.	Poaceae	Angiosperm	Herb	Saramolla Grass, Maronda, Murchi
553	Iseilema hackelii U. B. Shrestha & Gandhi	Poaceae	Angiosperm	Herb	
554	Ixora coccinea L.	Rubiaceae	Angiosperm	Shrub	Ixora, Jungle geranium, Rugmini, Rangan
555	Ixora parviflora Lam.	Rubiaceae	Angiosperm	Shrub	
556	Jacaranda mimosifolia D.Don	Bignoniaceae	Angiosperm	Tree	Coin-fruit plant, Nupur, Neeli gulmohur

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557	Jacobaea nudicaulis (Buch.-Ham. ex D.Don) B.Nord.	Asteraceae	Angiosperm	Herb	Bare-Stem Ragwort, Kakrata
558	Jasminum multiflorum (Burm.f.) Andrews	Oleaceae	Angiosperm	Climber	Chameli
559	Jasminum sambac (L.) Aiton	Oleaceae	Angiosperm	Shrub	Mogra, Bela
560	Jatropha curcas L.	Euphorbiaceae	Angiosperm	Shrub	Pahari-arand, Jangli-Arandi
561	Jatropha gossypiifolia L.	Euphorbiaceae	Angiosperm	Shrub	Ratanjoti
562	Juglans regia L.	Juglandaceae	Angiosperm	Tree	Akhrot
563	Juncus bufonius L.	Juncaceae	Angiosperm	Herb	Toad Rush
564	Juncus prismatocarpus R.Br.	Juncaceae	Angiosperm	Herb	
565	Juniperus chinensis L.	Cupressaceae	Gymnosperm	Tree	Chinese Juniper
566	Juniperus semiglobosa Regel	Cupressaceae	Gymnosperm	Shrub	Thelu
567	Jurinea heteromalla (D.Don) N.Garcia, Herrando & Susanna	Asteraceae	Angiosperm	Herb	Murang
568	Justicia adhatoda L.	Acanthaceae	Angiosperm	Shrub	Arusa
569	Justicia gendarussa Burm.f.	Acanthaceae	Angiosperm	Shrub	Daun Rusa
570	Kalanchoe integra (Medik.) Kuntze	Crassulaceae	Angiosperm	Herb	Bish-Kaphra, Zakhmihayat
571	Kalanchoe pinnata (Lam.) Pers.	Crassulaceae	Angiosperm	Shrub	Patthar Chatta
572	Kigelia africana (Lam.) Benth.	Bignoniaceae	Angiosperm	Tree	Balam khira
573	Kydia calycina Roxb.	Malvaceae	Angiosperm	Tree	Pateh
574	Lablab purpureus (L.) Sweet	Fabaceae	Angiosperm	Climber	Sem
575	Lactuca dissecta D.Don	Asteraceae	Angiosperm	Herb	Split-Leaf Lettuce
576	Lagascea mollis Cav.	Asteraceae	Angiosperm	Herb	Silk Leaf
577	Lagenaria siceraria (Molina) Standl.	Cucurbitaceae	Angiosperm	Climber	Lauki
578	Lagerstroemia indica L.	Lythraceae	Angiosperm	Tree	Common Crape Myrtle, Saona, জারুল Jarul
579	Lagerstroemia speciosa (L.) Pers.	Lythraceae	Angiosperm	Tree	Pride of India, Jarul

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580	Lamium album L.	Lamiaceae	Angiosperm	Herb	White Dead Nettle, blind nettle, dumb nettle, deaf nettle
581	Lamium amplexicaule L.	Lamiaceae	Angiosperm	Herb	Henbit
582	Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	Angiosperm	Tree	Jhingan
583	Lantana camara L.	Verbenaceae	Angiosperm	Shrub	Kuri-ghas, Laltenya
584	Lantana indica Roxb.	Verbenaceae	Angiosperm	Shrub	Panjphulli
585	Lathyrus aphaca L.	Fabaceae	Angiosperm	Herb	Jangli-matar
586	Lathyrus oleraceus Lam.	Fabaceae	Angiosperm	Herb	Matar
587	Lathyrus sativus L.	Fabaceae	Angiosperm	Herb	Grass Pea, Khesari, Latari
588	Launaea acaulis (Roxb.) Babc. ex Kerr	Asteraceae	Angiosperm	Herb	
589	Launaea aspleniifolia Hook.f.	Asteraceae	Angiosperm	Herb	
590	Launaea nudicaulis (L.) Hook.f.	Asteraceae	Angiosperm	Herb	
591	Launaea procumbens (Roxb.) Ramayya & Rajagopal	Asteraceae	Angiosperm	Herb	
592	Lawsonia inermis L.	Lythraceae	Angiosperm	Shrub	Mehendi, Henna
593	Leea indica (Burm.f.) Merr.	Vitaceae	Angiosperm	Shrub	Bandicoot Berry, Kukur jihwa
594	Leersia hexandra Sw.	Poaceae	Angiosperm	Herb	Rice Grass, Southern Cutgrass
595	Lemna minor L.	Araceae	Angiosperm	Herb	Lesser Duckweed
596	Leonotis nepetifolia (L.) R.Br.	Lamiaceae	Angiosperm	Herb	Bara-guma
597	Leonurus japonicus Houtt.	Lamiaceae	Angiosperm	Herb	Guma
598	Lepidagathis cristata Willd.	Acanthaceae	Angiosperm	Herb	Crested Lepidagathis
599	Lepidagathis trinervis Nees	Acanthaceae	Angiosperm	Herb	Frilly Lepidagathis
600	Lepidium didymum L.	Brassicaceae	Angiosperm	Herb	Bitter Cress, Lesser Swinecress, Wart cress
601	Lepidium pinnatifidum Ledeb.	Brassicaceae	Angiosperm	Herb	

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602	Lepidium virginicum L.	Brassicaceae	Angiosperm	Herb	Virginia Pepperweed, least pepperwort, peppergrass, poor-man's-pepper
603	Leptochilus pteropus (Blume) Fraser-Jenk.	Polypodiaceae	Pteridophyte	Herb	
604	Leptochloa chinensis (L.) Nees	Poaceae	Angiosperm	Herb	
605	Leptochloa panicea (Retz.) Owhi	Poaceae	Angiosperm	Herb	Thread Sprangletop
606	Leptopus cordifolius Decne.	Euphorbiaceae	Angiosperm	Shrub	Heart-Leaf Maiden-Bush, Bharti
607	Lespedeza juncea (L.f.) Pers.	Fabaceae	Angiosperm	Herb	Rush Bush-Clover
608	Leucaena leucocephala (Lam.) de Wit	Fabaceae	Angiosperm	Tree	Subabul
609	Leucas aspera (Willd.) Link	Lamiaceae	Angiosperm	Herb	Chota halkkusha
610	Leucas cephalotes (Roth) Spreng.	Lamiaceae	Angiosperm	Herb	Gumba
611	Leucas decemdentata (Willd.) Sm.	Lamiaceae	Angiosperm	Herb	Flaccid Leucas
612	Leucas lanata Benth.	Lamiaceae	Angiosperm	Herb	Gumma, Bis-kapra
613	Leucas lavandulifolia Sm.	Lamiaceae	Angiosperm	Herb	Thumbe
614	Leucomeris spectabilis D.Don	Asteraceae	Angiosperm	Tree	Pandwa, Phusiari
615	Limnophila indica (L.) Druce	Plantaginaceae	Angiosperm	Herb	Indian Marshweed
616	Limonia acidissima L.	Rutaceae	Angiosperm	Tree	Bilashin
617	Lindenbergia indica (L.) Vatke	Orobanchaceae	Angiosperm	Herb	Indian Lindenbergia, Pili-buti
618	Lindenbergia macrostachya (Benth.) Benth.	Orobanchaceae	Angiosperm	Herb	West-Himalayan Lindenbergia
619	Lindernia parviflora (Roxb.) Haines	Linderniaceae	Angiosperm	Herb	
620	Linum usitatissimum L.	Linaceae	Angiosperm	Herb	Alsi

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621	Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson	Verbenaceae	Angiosperm	Shrub	Bushy Lippia
622	Litchi chinensis Sonn.	Sapindaceae	Angiosperm	Tree	Leechee
623	Litsea glutinosa (Lour.) C.B.Rob.	Lauraceae	Angiosperm	Tree	Maida-lakri
624	Lonicera quinquelocularis Hardw.	Caprifoliaceae	Angiosperm	Shrub	Taknoi
625	Lotus corniculatus L.	Fabaceae	Angiosperm	Herb	
626	Ludwigia adscendens (L.) H.Hara	Onagraceae	Angiosperm	Herb	Water Primrose, Water Dragon
627	Ludwigia hyssopifolia (G.Don) Exell	Onagraceae	Angiosperm	Herb	Hyssop-Leaved Water Primrose, Seedbox
628	Ludwigia octovalvis (Jacq.) P.H.Raven	Onagraceae	Angiosperm	Herb	Bhu-lavang
629	Ludwigia perennis L.	Onagraceae	Angiosperm	Herb	Perennial Water Primrose, paddy clove
630	Luffa cylindrica (L.) M.Roem.	Cucurbitaceae	Angiosperm	Climber	Ghia Turai
631	Luffa echinata Roxb.	Cucurbitaceae	Angiosperm	Climber	Bindaal
632	Lygodium flexuosum (L.) Sw.	Schizaeaceae	Pteridophyte	Climber	
633	Lyonia ovalifolia (Wall.) Drude	Ericaceae	Angiosperm	Tree	Anyar
634	Lysimachia arvensis (L.) U.Manns & Anderb.	Primulaceae	Angiosperm	Herb	Jonkmari
635	Madhuca longifolia var. latifolia (Roxb.) A.Chev.	Sapotaceae	Angiosperm	Tree	Koinadori
636	Magnolia figo (Lour.) DC.	Magnoliaceae	Angiosperm	Tree	Banana Shrub
637	Malachra capitata (L.) L.	Malvaceae	Angiosperm	Herb	Brazil Jute, Van bhindi
638	Mallotus nudiflorus (L.) Kulju & Welzen	Euphorbiaceae	Angiosperm	Tree	Pindalu, Gutel
639	Mallotus philippensis (Lam.) Müll.Arg.	Euphorbiaceae	Angiosperm	Tree	Kaamala Tree, Rohini

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640	Malva neglecta Wallr.	Malvaceae	Angiosperm	Herb	Common Mallow, Sonchala
641	Malva parviflora L.	Malvaceae	Angiosperm	Herb	
642	Malva verticillata L.	Malvaceae	Angiosperm	Herb	
643	Malvastrum coromandelianum (L.) Garcke	Malvaceae	Angiosperm	Shrub	False Mallow
644	Malvaviscus arboreus Dill. ex Cav.	Malvaceae	Angiosperm	Shrub	Sleeping Hibiscus
645	Mangifera indica L.	Anacardiaceae	Angiosperm	Tree	Aam
646	Marrubium vulgare L.	Lamiaceae	Angiosperm	Herb	White Horehound, Pahari gandana
647	Marsilea minuta L.	Marsileaceae	Pteridophyte	Herb	
648	Martynia annua L.	Martyniaceae	Angiosperm	Shrub	Devils Claws, Baghnakh
649	Mazus pumilus (Burm.f.) Steenis	Mazaceae	Angiosperm	Herb	Asian Mazus, Mastyar
650	Mazus surculosus D.Don	Mazaceae	Angiosperm	Herb	
651	Mecardonia procumbens (Mill.) Small	Plantaginaceae	Angiosperm	Herb	Makardana
652	Medicago edgeworthii Širj.	Fabaceae	Angiosperm	Herb	
653	Medicago lupulina L.	Fabaceae	Angiosperm	Herb	Black Medic, Hop-clover
654	Medicago polymorpha L.	Fabaceae	Angiosperm	Herb	Janglighas
655	Megathyrsus maximus (Jacq.) B.K.Simon & S.W.L.Jacobs	Poaceae	Angiosperm	Herb	
656	Melaleuca citrina (Curtis) Dum.Cours.	Myrtaceae	Angiosperm	Tree	Bottle-brush
657	Melaleuca viminalis (Sol. ex Gaertn.) Byrnes	Myrtaceae	Angiosperm	Tree	Bottle-brush
658	Melia azedarach L.	Meliaceae	Angiosperm	Tree	Dakrain, Bakain
659	Melia dubia Cav.	Meliaceae	Angiosperm	Tree	Bakain, Bitar
660	Melilotus albus Medik.	Fabaceae	Angiosperm	Herb	Safed-Murela
661	Melilotus indicus (L.) All.	Fabaceae	Angiosperm	Herb	Ban-Meithi
662	Melochia corchorifolia L.	Malvaceae	Angiosperm	Shrub	Bilpat

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663	Mentha spicata L.	Lamiaceae	Angiosperm	Herb	Mentha
664	Merremia aegyptia (L.) Urb.	Convolvulaceae	Angiosperm	Climber	Egyptian Woodrose
665	Merremia dissecta (Jacq.) Hallier f.	Convolvulaceae	Angiosperm	Climber	Alamo Vine
666	Merremia emarginata (Burm.f.) Hallier f.	Convolvulaceae	Angiosperm	Herb	Musakani
667	Merremia hederacea (Burm.f.) Hallier f.	Convolvulaceae	Angiosperm	Climber	Ivy Woodrose
668	Mesosphaerum suaveolens (L.) Kuntze	Lamiaceae	Angiosperm	Shrub	Vilayati-Tulsi
669	Micromeria biflora (Buch.-Ham. ex D.Don) Benth.	Lamiaceae	Angiosperm	Herb	Lemon Savory, Ban ajwain, Gorakhopan
670	Mikania micrantha Kunth	Asteraceae	Angiosperm	Climber	Climbing Hempweed
671	Mimosa pudica L.	Fabaceae	Angiosperm	Shrub	Lajvanti
672	Mimosa rubicaulis Lam.	Fabaceae	Angiosperm	Shrub	South-Indian Mimosa
673	Mimosa rubicaulis subsp. himalayana (Gamble) H.Ohashi	Fabaceae	Angiosperm	Shrub	Himalayan Mimosa
674	Mirabilis jalapa L.	Nyctaginaceae	Angiosperm	Herb	Gul abbas
675	Mitragyna parvifolia (Roxb.) Korth.	Rubiaceae	Angiosperm	Tree	Phaldu, Kaim
676	Momordica charantia L.	Cucurbitaceae	Angiosperm	Climber	Karela
677	Momordica dioica Roxb. ex Willd.	Cucurbitaceae	Angiosperm	Climber	Spiny Gourd, Ban karela
678	Monoon longifolium (Sonn.) B.Xue & R.M.K.Saunders	Annonaceae	Angiosperm	Tree	False Ashok, Ashok
679	Morinda citrifolia L.	Rubiaceae	Angiosperm	Tree	Bartundi
680	Moringa oleifera Lam.	Moringaceae	Angiosperm	Tree	Sojna
681	Morus alba L.	Moraceae	Angiosperm	Tree	Sahtoot
682	Morus nigra L.	Moraceae	Angiosperm	Tree	Shahtoot

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683	Mosla dianthera (Buch.-Ham. ex Roxb.) Maxim.	Lamiaceae	Angiosperm	Herb	
684	Mucuna pruriens (L.) DC.	Fabaceae	Angiosperm	Climber	Velvet Bean, Kiwach
685	Muntingia calabura L.	Muntingiaceae	Angiosperm	Tree	
686	Murdannia nudiflora (L.) Brenan	Commelinaceae	Angiosperm	Herb	Doveweed, Kansura
687	Murraya koenigii (L.) Spreng.	Rutaceae	Angiosperm	Shrub	Gandhela, Curry-Leaf Tree
688	Murraya paniculata (L.) Jack	Rutaceae	Angiosperm	Shrub	Orange Jasmine, Kamini
689	Musa × paradisiaca L.	Musaceae	Angiosperm	Herb	Kela
690	Myrica esculenta Buch.-Ham. ex D.Don	Myricaceae	Angiosperm	Tree	Kafal
691	Nanorrhinum ramosissimum (Wall.) Betsche	Plantaginaceae	Angiosperm	Herb	Indian Toadflax, Khunger booti
692	Naringi crenulata (Roxb.) Nicolson	Rutaceae	Angiosperm	Tree	Kathbel, Beli
693	Nasturtium officinale W.T. Aiton	Brassicaceae	Angiosperm	Herb	Water-cress
694	Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	Angiosperm	Tree	Kadam, Kadamb
695	Nepeta cataria L.	Lamiaceae	Angiosperm	Herb	
696	Nepeta graciliflora Benth.	Lamiaceae	Angiosperm	Herb	Slender Catmint
697	Nepeta hindostana (B.Heyne ex Roth) Haines	Lamiaceae	Angiosperm	Herb	
698	Nephrolepis cordifolia (L.) C.Presl	Polypodiaceae	Pteridophyte	Herb	
699	Nerium oleander L.	Apocynaceae	Angiosperm	Shrub	Kaner
700	Neyraudia arundinacea (L.) Henrard	Poaceae	Angiosperm	Herb	
701	Nicandra physalodes (L.) Gaertn.	Solanaceae	Angiosperm	Herb	Tambukya, Endu

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702	Nicotiana plumbaginifolia Viv.	Solanaceae	Angiosperm	Herb	Ban-Tambakhu, Tambaku
703	Nicotiana rustica L.	Solanaceae	Angiosperm	Herb	Tambakhu
704	Nicotiana tabacum L.	Solanaceae	Angiosperm	Herb	Tambaku
705	Nigella sativa L.	Ranunculaceae	Angiosperm	Herb	Kala-jeera
706	Nyctanthes arbor-tristis L.	Oleaceae	Angiosperm	Tree	Parijat, Harsingar
707	Nymphaea alba L.	Nymphaeaceae	Angiosperm	Herb	White water lily
708	Nymphaea nouchali Burm.f.	Nymphaeaceae	Angiosperm	Herb	Neelkamal
709	Nymphaea pubescens Willd.	Nymphaeaceae	Angiosperm	Herb	White Water Lily, Kumud
710	Nymphoides hydrophylla (Lour.) Kuntze	Menyanthaceae	Angiosperm	Herb	
711	Nymphoides indica (L.) Kuntze	Menyanthaceae	Angiosperm	Herb	Barachuli
712	Ocimum americanum L.	Lamiaceae	Angiosperm	Herb	Vantulsi
713	Ocimum basilicum L.	Lamiaceae	Angiosperm	Herb	Kali Tulsi, Ram Tulsi
714	Ocimum kilimandscharicum Gürke	Lamiaceae	Angiosperm	Herb	Camphor Basil, Kilimanjaro Basil, Kapur Tulsi
715	Ocimum tenuiflorum L.	Lamiaceae	Angiosperm	Herb	Tulsi
716	Oenanthe benghalensis (DC.) Miq.	Apiaceae	Angiosperm	Herb	
717	Oenanthe javanica (Blume) DC.	Apiaceae	Angiosperm	Herb	
718	Oenothera laciniata Hill	Onagraceae	Angiosperm	Herb	Cutleaf Evening Primrose
719	Oenothera rosea L'Hér. ex Aiton	Onagraceae	Angiosperm	Herb	Pink Evening Primrosa
720	Oldenlandia affinis (Roem. & Schult.) DC.	Rubiaceae	Angiosperm	Herb	Blue Diamond Flower
721	Oldenlandia corymbosa L.	Rubiaceae	Angiosperm	Herb	Daman-papar
722	Operculina turpethum (L.) Silva Manso	Convolvulaceae	Angiosperm	Climber	Nishoth, Pipal pant

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723	Oplismenus burmanni (Retz.) P.Beauv.	Poaceae	Angiosperm	Herb	Wavy-Leaf Basketgrass
724	Oplismenus compositus (L.) P.Beauv.	Poaceae	Angiosperm	Herb	Running Mountain Grass
725	Opuntia dejecta Salm-Dyck	Cactaceae	Angiosperm	Shrub	Prickly Pear
726	Opuntia elatior Mill.	Cactaceae	Angiosperm	Shrub	Prickly Pear
727	Opuntia vulgaris Mill.	Cactaceae	Angiosperm	Shrub	Nagphani
728	Oreoseris gossypina (Royle) X.D.Xu & V.A.Funk	Asteraceae	Angiosperm	Herb	Kupheru, Jhula
729	Oroxylum indicum (L.) Kurz	Bignoniaceae	Angiosperm	Tree	Pharkat, Arula
730	Oryza rufipogon Griff.	Poaceae	Angiosperm	Herb	Red Rice
731	Oryza sativa L.	Poaceae	Angiosperm	Herb	Rice, paddy, Chaval, ধান Dhan
732	Ouret lanata (L.) Kuntze	Amaranthaceae	Angiosperm	Herb	Mountain Knot Grass, Gorakhaganja
733	Ouret sanguinolenta (L.) Kuntze	Amaranthaceae	Angiosperm	Herb	Sufed Phulia, Kali jad
734	Oxalis corniculata L.	Oxalidaceae	Angiosperm	Herb	Khattibuti, Amrul
735	Oxalis debilis Kunth	Oxalidaceae	Angiosperm	Herb	Bhilmori
736	Oxystelma esculentum (L.f.) Sm.	Apocynaceae	Angiosperm	Climber	Dudhialata
737	Paeonia emodi Royle	Paeoniaceae	Angiosperm	Herb	Chandra
738	Panicum antidotale Retz.	Poaceae	Angiosperm	Herb	Blue Panicgrass, Gobra ghas
739	Panicum curviflorum Hornem.	Poaceae	Angiosperm	Herb	
740	Panicum repens L.	Poaceae	Angiosperm	Herb	
741	Parkia timoriana (DC.) Merr.	Fabaceae	Angiosperm	Tree	
742	Parkinsonia aculeata L.	Fabaceae	Angiosperm	Tree	Vilayati-cheonkar
743	Parthenium hysterophorus L.	Asteraceae	Angiosperm	Herb	Carrot Grass, Congress grass, Gajar ghas

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744	Paspalidium distans (Trin.) Hughes	Poaceae	Angiosperm	Herb	
745	Paspalum distichum L.	Poaceae	Angiosperm	Herb	
746	Paspalum scrobiculatum L.	Poaceae	Angiosperm	Herb	
747	Paspalum vaginatum Sw.	Poaceae	Angiosperm	Herb	
748	Paspalum virgatum L.	Poaceae	Angiosperm	Herb	
749	Passiflora foetida L.	Passifloraceae	Angiosperm	Climber	Stinking Passion Flower, Rakhipushpa
750	Passiflora suberosa L.	Passifloraceae	Angiosperm	Climber	Corky Passion Flower
751	Pennisetum purpureum Schumach.	Poaceae	Angiosperm	Herb	Purple Fountain Grass
752	Pentanema britannica (L.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & M.M.Mart. Ort.	Asteraceae	Angiosperm	Herb	
753	Pentanema divaricatum Cass.	Asteraceae	Angiosperm	Herb	
754	Pentapetes phoenicea L.	Malvaceae	Angiosperm	Shrub	Dupahariya
755	Peperomia pellucida (L.) Kunth	Piperaceae	Angiosperm	Herb	Shiny Bush
756	Pergularia daemia (Forssk.) Chiov.	Apocynaceae	Angiosperm	Climber	Trellis Vine
757	Perilla frutescens (L.) Britton	Lamiaceae	Angiosperm	Herb	Bhangjeera, Bhangiri
758	Perotis indica (L.) Kuntze	Poaceae	Angiosperm	Herb	
759	Persicaria barbata (L.) H.Hara	Polygonaceae	Angiosperm	Herb	
760	Persicaria capitata (Buch.-Ham. ex D.Don) H.Gross	Polygonaceae	Angiosperm	Herb	Kaflya
761	Persicaria glabra (Willd.) M.Gómez	Polygonaceae	Angiosperm	Herb	Ameta
762	Persicaria hydropiper (L.) Delarbre	Polygonaceae	Angiosperm	Herb	Ameta

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763	Persicaria lapathifolia (L.) Delarbre	Polygonaceae	Angiosperm	Herb	
764	Persicaria pubescens (Blume) H.Hara	Polygonaceae	Angiosperm	Herb	Drooping Knotweed
765	Petalidium barlerioides (B.Heyne ex Roth) Nees	Acanthaceae	Angiosperm	Shrub	Drakalpa
766	Phalaris minor Retz.	Poaceae	Angiosperm	Herb	Phulla
767	Phanera vahlii (Wight & Arn.) Benth.	Fabaceae	Angiosperm	Liana	Maljan
768	Phleum himalaicum Mez	Poaceae	Angiosperm	Herb	
769	Phoenix acaulis Roxb.	Arecaceae	Angiosperm	Tree	Khajuri
770	Phoenix sylvestris (L.) Roxb.	Arecaceae	Angiosperm	Tree	khajur
771	Phragmites australis (Cav.) Trin. ex Steud.	Poaceae	Angiosperm	Herb	
772	Phragmites karka (Retz.) Trin. ex Steud.	Poaceae	Angiosperm	Herb	
773	Phyla nodiflora (L.) Greene	Verbenaceae	Angiosperm	Herb	Frog Fruit, Bhu okra
774	Phyllanthus amarus Schumach. & Thonn.	Phyllanthaceae	Angiosperm	Herb	Jarmala
775	Phyllanthus emblica L.	Phyllanthaceae	Angiosperm	Tree	Amla
776	Phyllanthus maderaspatensis L.	Phyllanthaceae	Angiosperm	Herb	Madras Leaf-Flower, Hajarmani
777	Phyllanthus parvifolius Buch.-Ham. ex D.Don	Phyllanthaceae	Angiosperm	Shrub	
778	Phyllanthus reticulatus Poir.	Phyllanthaceae	Angiosperm	Shrub	Black-Honey Shrub
779	Phyllanthus urinaria L.	Phyllanthaceae	Angiosperm	Herb	Bhumi Amla
780	Phyllanthus virgatus G.Forst.	Phyllanthaceae	Angiosperm	Herb	Bhuiamla
781	Physalis angulata L.	Solanaceae	Angiosperm	Herb	Makoy, Papotan
782	Physalis halicacabum Crantz	Solanaceae	Angiosperm	Herb	Damphu
783	Physalis peruviana L.	Solanaceae	Angiosperm	Herb	Cape Gooseberry, Rasbhari
784	Picea smithiana (Wall.) Boiss.	Pinaceae	Gymnosperm	Tree	Rai, Ragha, Khutrau, Morinda

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785	Picrorhiza kurroa Royle ex Benth.	Plantaginaceae	Angiosperm	Herb	Kutki
786	Pilea microphylla (L.) Liebm.	Urticaceae	Angiosperm	Herb	Gunpowder Plant, Artillery plant, Rockweed
787	Pinus roxburghii Sarg.	Pinaceae	Gymnosperm	Tree	Chir-Pine
788	Pinus wallichiana A.B.Jacks.	Pinaceae	Angiosperm	Tree	Chir
789	Piper betle L.	Piperaceae	Angiosperm	Climber	Paan
790	Piptatherum munroi (Stapf ex Hook.f.) Mez	Poaceae	Angiosperm	Herb	
791	Pistacia chinensis subsp. integerrima (J.L.Stewart) Rech.f.	Anacardiaceae	Angiosperm	Tree	Kakkar, Kakra-singi
792	Pistia stratiotes L.	Araceae	Angiosperm	Herb	Jalakumbhi
793	Pithecellobium dulce (Roxb.) Benth.	Fabaceae	Angiosperm	Tree	Jangal jalebi
794	Plantago asiatica subsp. erosa (Wall.) Z.Yu Li	Plantaginaceae	Angiosperm	Herb	Luhurya, Lahyrya
795	Platycladus orientalis (L.) Franco	Cupressaceae	Gymnosperm	Shrub	Morpankhi
796	Pleurolobus gangeticus (L.) J.St.-Hil. ex H.Ohashi & K.Ohashi	Fabaceae	Angiosperm	Shrub	Salpani, Shalparni
797	Pluchea indica (L.) Less.	Asteraceae	Angiosperm	Shrub	Indian Camphor-Weed
798	Pluchea lanceolata (DC.) C.B.Clarke	Asteraceae	Angiosperm	Shrub	Rasna, Phaar
799	Plumbago zeylanica L.	Plumbaginaceae	Angiosperm	Shrub	Chitrak
800	Plumeria alba L.	Apocynaceae	Angiosperm	Tree	Champa
801	Poa annua L.	Poaceae	Angiosperm	Herb	Annual Bluegrass, Annual Meadow Grass
802	Poa nemoralis L.	Poaceae	Angiosperm	Herb	
803	Poa pratensis L.	Poaceae	Angiosperm	Herb	

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804	Poa stellaris Veldkamp	Poaceae	Angiosperm	Herb	
805	Poa trivialis L.	Poaceae	Angiosperm	Herb	
806	Podophyllum hexandrum Royle	Berberidaceae	Angiosperm	Herb	Himalayan May Apple, Indian may apple, Ban kakri
807	Pogostemon benghalensis (Burm.f.) Kuntze	Lamiaceae	Angiosperm	Shrub	Bengal pogostemon, Lujrya
808	Polyalthia suberosa (Roxb.) Thwaites	Annonaceae	Angiosperm	Tree	Cham-khinni
809	Polygonatum verticillatum (L.) All.	Asparagaceae	Angiosperm	Herb	Kantula, Meda, Mahameda
810	Polygonum plebeium R.Br.	Polygonaceae	Angiosperm	Herb	Small Knotweed
811	Polypogon fugax Nees ex Steud.	Poaceae	Angiosperm	Herb	
812	Polypogon monspeliensis (L.) Desf.	Poaceae	Angiosperm	Herb	Annual Beard Grass
813	Polystichum aculeatum (L.) Roth	Polypodiaceae	Pteridophyte	Herb	
814	Polystichum mehrae Fraser-Jenk. & Khullar	Polypodiaceae	Pteridophyte	Herb	
815	Pongamia pinnata (L.) Pierre	Fabaceae	Angiosperm	Tree	Kanja, Kanji
816	Pontederia crassipes Mart.	Pontederiaceae	Angiosperm	Herb	Jal-Kumbhi
817	Pontederia hastata L.	Pontederiaceae	Angiosperm	Herb	Arrow Leaf Pondweed
818	Pontederia vaginalis Burm.f.	Pontederiaceae	Angiosperm	Herb	Pickerel Weed
819	Populus ciliata Wall. ex Royle	Salicaceae	Angiosperm	Tree	Syan, Gar Peepal
820	Populus deltoides W.Bartram ex Marshall	Salicaceae	Angiosperm	Tree	Poplar
821	Portulaca oleracea L.	Portulacaceae	Angiosperm	Herb	Kulfa
822	Portulaca pilosa L.	Portulacaceae	Angiosperm	Herb	Hairy pigweed
823	Potamogeton crispus L.	Potamogetonaceae	Angiosperm	Herb	Curled Pondweed
824	Potamogeton natans L.	Potamogetonaceae	Angiosperm	Herb	

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825	Potentilla argyrophylla Wall. ex Lehm.	Rosaceae	Angiosperm	Herb	Silver-Leaved Cinquefoil
826	Potentilla atrosanguinea G. Lodd.	Rosaceae	Angiosperm	Herb	Ruby cinquefoil, Himalayan cinquefoil
827	Potentilla gerardiana Lindl. ex Lehm.	Rosaceae	Angiosperm	Herb	Bajradanti
828	Potentilla indica (Andrews) Th.Wolf	Rosaceae	Angiosperm	Herb	Indian Strawberry, Mock strawberry, Kiphaliya
829	Potentilla supina L.	Rosaceae	Angiosperm	Herb	Spreading Cinquefoil
830	Pouzolzia rugulosa (Wedd.) Acharya & Kravtsova	Urticaceae	Angiosperm	Tree	Genthi
831	Pouzolzia zeylanica (L.) Benn.	Urticaceae	Angiosperm	Herb	Graceful Pouzolz's Bush
832	Premna mollissima Roth	Lamiaceae	Angiosperm	Tree	Akond
833	Primula denticulata Sm.	Primulaceae	Angiosperm	Herb	Jayan
834	Prinsepia utilis Royle	Rosaceae	Angiosperm	Shrub	Bhenkuli
835	Prosopis juliflora (Sw.) DC.	Fabaceae	Angiosperm	Tree	Junglee kikar
836	Prunus armeniaca L.	Rosaceae	Angiosperm	Tree	Khubani, Chulu, Chilu
837	Prunus cerasoides Buch.-Ham. ex D.Don	Rosaceae	Angiosperm	Tree	Padam
838	Prunus cornuta (Wall. ex Royle) Steud.	Rosaceae	Angiosperm	Tree	Jamna, Jamoni, Himalayan Bird Cherry.
839	Prunus persica (L.) Batsch	Rosaceae	Angiosperm	Tree	Aadu
840	Pseudocaryopteris bicolor (Roxb. ex Hardw.) P.D.Cantino	Lamiaceae	Angiosperm	Shrub	Karui
841	Pseudognaphalium affine (D.Don) Anderb.	Asteraceae	Angiosperm	Herb	
842	Pseudosorghum fasciculare (Roxb.) A.Camus	Poaceae	Angiosperm	Herb	Ganga Beardgrass

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843	Psidium guajava L.	Myrtaceae	Angiosperm	Tree	Amrud
844	Pteridium aquilinum (L.) Kuhn	Dennstaedtiaceae	Pteridophyte	Herb	
845	Pteris cretica L.	Pteridaceae	Pteridophyte	Herb	
846	Pteris vittata L.	Pteridaceae	Pteridophyte	Herb	
847	Pterospermum acerifolium (L.) Willd.	Malvaceae	Angiosperm	Tree	Kanak Champa, Muchkund
848	Pulicaria undulata (L.) C.A.Mey.	Asteraceae	Angiosperm	Herb	Desert Golden Daisy, Dhola lizru
849	Punica granatum L.	Lythraceae	Angiosperm	Tree	Dadim
850	Pupalia lappacea (L.) Juss.	Amaranthaceae	Angiosperm	Herb	Forest Burr
851	Putranjiva roxburghii Wall.	Putranjivaceae	Angiosperm	Tree	Putranjiva
852	Pycreus polystachyos (Rottb.) P.Beauv.	Cyperaceae	Angiosperm	Herb	
853	Pyracantha crenulata (D.Don) M.Roem.	Rosaceae	Angiosperm	Shrub	Ghingharu
854	Pyrus communis L.	Rosaceae	Angiosperm	Tree	Nashpati
855	Pyrus pashia Buch.-Ham. ex D.Don	Rosaceae	Angiosperm	Tree	Mehal
856	Quercus floribunda Lindl. ex A.Camus	Fagaceae	Angiosperm	Tree	Tilonj, Moru
857	Quercus leucotrichophora A. Camus	Fagaceae	Angiosperm	Tree	Banj, White Oak
858	Ranunculus distans D.Don	Ranunculaceae	Angiosperm	Herb	Cheerful Buttercup
859	Ranunculus sceleratus L.	Ranunculaceae	Angiosperm	Herb	Celery-leaf Buttercup
860	Rauvolfia serpentina (L.) Benth. ex Kurz	Apocynaceae	Angiosperm	Shrub	Sarpagandha
861	Rauvolfia tetraphylla L.	Apocynaceae	Angiosperm	Shrub	বড চন্দ্রিকা bar chandrika, গন্ধনকুলী gandhanakuli, Wild Snake Root

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862	Rheum webbianum Royle	Polygonaceae	Angiosperm	Herb	Indian Rhubarb, Dolu, Gilgiti rhubarb, Small Himalayan rhubarb
863	Rhodiola heterodonta (Hook.f. & Thomson) Boriss.	Crassulaceae	Angiosperm	Herb	
864	Rhododendron arboreum Sm.	Ericaceae	Angiosperm	Tree	Burans
865	Rhynchosia capitata (B.Heyne ex Roth) DC.	Fabaceae	Angiosperm	Climber	Clustered-Flower Snoutbean
866	Rhynchosia minima (L.) DC.	Fabaceae	Angiosperm	Climber	Burn-Mouth Vine
867	Rhynchosia rothii Benth. ex Aitch.	Fabaceae	Angiosperm	Climber	Silky Snoutbean
868	Ribes alpestre Wall. ex Decne.	Grossulariaceae	Angiosperm	Shrub	
869	Ricinus communis L.	Euphorbiaceae	Angiosperm	Tree	Caster bean, Arandi
870	Rivina humilis L.	Petiveriaceae	Angiosperm	Herb	Baby Pepper, rouge plant
871	Rorippa dubia (Pers.) H.Hara	Brassicaceae	Angiosperm	Herb	Diverse-Leaf Yellow Cress,
872	Rorippa indica (L.) Hiern	Brassicaceae	Angiosperm	Herb	Indian Field-Cress, Chamsuru
873	Rosa brunonii Lindl.	Rosaceae	Angiosperm	Shrub	Himalayan Rose
874	Rosa indica L.	Rosaceae	Angiosperm	Shrub	Desi Gulab
875	Rosa macrophylla Lindl.	Rosaceae	Angiosperm	Shrub	Himalayan Rose
876	Rosa moschata Herrm.	Rosaceae	Angiosperm	Shrub	Jangali Gulab
877	Rosa sericea var. glandulosa Osmaston	Rosaceae	Angiosperm	Shrub	Dur Kunja
878	Rosmarinus officinalis L.	Lamiaceae	Angiosperm	Shrub	Rosemary, Sagargandha
879	Rostellularia diffusa (Willd.) Nees	Acanthaceae	Angiosperm	Herb	Spreading Rostellularia
880	Rostraria cristata (L.) Tzvelev	Poaceae	Angiosperm	Herb	

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881	Rosularia rosulata (Edgew.) H.Ohba	Crassulaceae	Angiosperm	Herb	Rosette-Leaf Sedum
882	Rottboellia cochinchinensis (Lour.) Clayton	Poaceae	Angiosperm	Herb	
883	Roylea cinerea (D.Don) Baill.	Lamiaceae	Angiosperm	Shrub	Kadu
884	Rubia manjith Roxb.	Rubiaceae	Angiosperm	Climber	Manjisth
885	Rubus ellipticus Sm.	Rosaceae	Angiosperm	Shrub	Hisalu
886	Rubus niveus Thunb.	Rosaceae	Angiosperm	Climber	Kala Katrana
887	Rubus paniculatus Sm.	Rosaceae	Angiosperm	Climber	Kala Hisalu
888	Ruellia prostrata Poir.	Acanthaceae	Angiosperm	Herb	Bell weed, Black weed
889	Ruellia tuberosa L.	Acanthaceae	Angiosperm	Herb	Waterkanon, Feverroot
890	Rumex acetosa L.	Polygonaceae	Angiosperm	Herb	
891	Rumex crispus L.	Polygonaceae	Angiosperm	Herb	
892	Rumex dentatus L.	Polygonaceae	Angiosperm	Herb	Jangli-palak
893	Rumex hastatus D.Don	Polygonaceae	Angiosperm	Herb	Almoru, Kilmori
894	Rumex nepalensis Spreng.	Polygonaceae	Angiosperm	Herb	
895	Rungia pectinata (L.) Nees	Acanthaceae	Angiosperm	Herb	Comb Rungia
896	Rungia repens (L.) Nees	Acanthaceae	Angiosperm	Herb	
897	Sabulina kashmirica (Edgew.) Dillenb. & Kadereit	Caryophyllaceae	Angiosperm	Herb	Kashmir Sandwort
898	Saccharum arundinaceum Retz.	Poaceae	Angiosperm	Herb	
899	Saccharum filifolium Steud.	Poaceae	Angiosperm	Herb	
900	Saccharum officinarum L.	Poaceae	Angiosperm	Shrub	Ganna
901	Saccharum spontaneum L.	Poaceae	Angiosperm	Herb	Kans grass, Kaans, Kansh
902	Sacciolepis interrupta (Willd.) Stapf	Poaceae	Angiosperm	Herb	Interrupted Cupscale Grass
903	Sagittaria guayanensis Kunth	Alismataceae	Angiosperm	Herb	Burr Arrowhead
904	Sagittaria montevidensis Cham. & Schltdl.	Alismataceae	Angiosperm	Herb	Aztec Arrowhead, Giant Arrowhead

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905	Sagittaria sagittifolia L.	Alismataceae	Angiosperm	Herb	Chinese Arrowhead
906	Salix oxycarpa Andersso	Salicaceae	Angiosperm	Tree	
907	Salvia cana Wall. ex Benth.	Lamiaceae	Angiosperm	Herb	
908	Salvia coccinea Buc'hoz ex Etl.	Lamiaceae	Angiosperm	Herb	Texas Sage, scarlet sage, tropical sage, blood sage
909	Salvia plebeia R.Br.	Lamiaceae	Angiosperm	Herb	Kakrondha
910	Saraca asoca (Roxb.) W.J.de Wilde	Fabaceae	Angiosperm	Tree	Sita Asoka
911	Sarcococca saligna (D.Don) Müll.Arg.	Buxaceae	Angiosperm	Shrub	Piruli, Geru, Tiliara
912	Sauromatum diversifolium (Wall. ex Schott) Cusimano & Hett.	Araceae	Angiosperm	Herb	Himalayan Sauromatum
913	Schefflera venulosa (Wight & Arn.) Harms	Araliaceae	Angiosperm	Shrub	Schefflera Vine, Kursemli, Suinl, Karbut Semul
914	Schoenoplectiella articulata (L.) Lye	Cyperaceae	Angiosperm	Herb	Jointed Sedge
915	Schoenoplectiella mucronata (L.) J.Jung & H.K.Choi	Cyperaceae	Angiosperm	Herb	
916	Schoenoplectiella roylei (Nees) Lye	Cyperaceae	Angiosperm	Herb	
917	Schoenoplectiella supina (L.) Lye	Cyperaceae	Angiosperm	Herb	Reclining Club-Rush
918	Scoparia dulcis L.	Scrophulariaceae	Angiosperm	Herb	Mithi patti, Ghoda tulsi
919	Scutellaria repens Buch.-Ham. ex D.Don	Lamiaceae	Angiosperm	Herb	Kasha, Karwi-ghas
920	Scutellaria scandens D.Don	Lamiaceae	Angiosperm	Herb	
921	Searsia parviflora (Roxb.) F.A.Barkley	Anacardiaceae	Angiosperm	Tree	Tungla
922	Selaginella bryopteris (L.) Baker	Selaginellaceae	Pteridophyte	Herb	

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923	Senegalia catechu (L.f.) P.J.H.Hurter & Mabb.	Fabaceae	Angiosperm	Tree	Katha
924	Senna alata (L.) Roxb.	Fabaceae	Angiosperm	Shrub	Candle Bush, Dadmurdan
925	Senna occidentalis (L.) Link	Fabaceae	Angiosperm	Shrub	Coffee Senna
926	Senna siamea (Lam.) H.S.Irwin & Barneby	Fabaceae	Angiosperm	Tree	Kassod
927	Senna sophera (L.) Roxb.	Fabaceae	Angiosperm	Shrub	Chakunda
928	Senna sulfurea (DC. ex Collad.) H.S.Irwin & Barneby	Fabaceae	Angiosperm	Tree	Sulphur Cassia,
929	Senna tora (L.) Roxb.	Fabaceae	Angiosperm	Shrub	Stinking Cassia, Panwar, Chakunda, Chakvat
930	Sesamum indicum L.	Pedaliaceae	Angiosperm	Herb	Til
931	Sesbania sesban (L.) Merr.	Fabaceae	Angiosperm	Shrub	Jainti
932	Setaria flavida (Retz.) Veldkamp	Poaceae	Angiosperm	Herb	
933	Setaria gracillima Hook.f.	Poaceae	Angiosperm	Herb	
934	Setaria homonyma (Steud.) Chiov.	Poaceae	Angiosperm	Herb	
935	Setaria plicata (Lam.) T.Cooke	Poaceae	Angiosperm	Herb	
936	Setaria pumila (Poir.) Roem. & Schult.	Poaceae	Angiosperm	Herb	
937	Setaria punctata (Burm.f.) Veldkamp	Poaceae	Angiosperm	Herb	
938	Setaria verticillata (L.) P.Beauv.	Poaceae	Angiosperm	Herb	Bristly Foxtail
939	Shorea robusta C.F.Gaertn.	Dipterocarpaceae	Angiosperm	Tree	Sal
940	Sibbaldia cuneata Edgew.	Rosaceae	Angiosperm	Herb	
941	Sida acuta Burm.f.	Malvaceae	Angiosperm	Shrub	Baraira
942	Sida cordata (Burm.f.) Borss. Waalk.	Malvaceae	Angiosperm	Herb	Fardbuti
943	Sida cordifolia L.	Malvaceae	Angiosperm	Shrub	Bala

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944	Sida mysorensis Wight & Arn.	Malvaceae	Angiosperm	Shrub	Mysore Fanpetals
945	Sida rhombifolia L.	Malvaceae	Angiosperm	Shrub	Mahabala
946	Sida spinosa L.	Malvaceae	Angiosperm	Shrub	Prickly Fan-Petals, Prickly Sida
947	Skimmia laureola (DC.) Siebold & Zucc. ex Walp.	Rutaceae	Angiosperm	Shrub	Nairpatti, Patrang
948	Smilax aspera L.	Smilacaceae	Angiosperm	Climber	
949	Smilax elegans Wall. ex Kunth	Smilacaceae	Angiosperm	Climber	Kukurdara, Sarya
950	Smilax ovalifolia Roxb. ex D.Don	Smilacaceae	Angiosperm	Climber	Kumarika
951	Sohmaea laxiflora (DC.) H.Ohashi & K.Ohashi	Fabaceae	Angiosperm	Shrub	Loose Flowered Desmodium,
952	Solanum anguivi Lam.	Solanaceae	Angiosperm	Shrub	African Eggplant, Barhanta
953	Solanum erianthum D.Don	Solanaceae	Angiosperm	Tree	Akra
954	Solanum giganteum Jacq.	Solanaceae	Angiosperm	Shrub	Red Bitter Berry, healing-leaf tree
955	Solanum incanum L.	Solanaceae	Angiosperm	Shrub	Banbhatuja
956	Solanum lycopersicum L.	Solanaceae	Angiosperm	Herb	Tomato, Tamatar
957	Solanum melongena L.	Solanaceae	Angiosperm	Shrub	Baingan
958	Solanum nigrum L.	Solanaceae	Angiosperm	Herb	Makoy, American Black Nightshade
959	Solanum sisymbriifolium Lam.	Solanaceae	Angiosperm	Shrub	Bitter apple
960	Solanum torvum Sw.	Solanaceae	Angiosperm	Shrub	Bhurat, Bhankatiya
961	Solanum tuberosum L.	Solanaceae	Angiosperm	Herb	Potato
962	Solanum viarum Dunal	Solanaceae	Angiosperm	Shrub	Kachriya bhanta
963	Solanum villosum Mill.	Solanaceae	Angiosperm	Herb	Yellow Nightshade
964	Solanum violaceum Ortega	Solanaceae	Angiosperm	Shrub	Indian Nightshade
965	Solanum virginianum L.	Solanaceae	Angiosperm	Shrub	Kanteli
966	Soliva anthemifolia (Juss.) Sweet	Asteraceae	Angiosperm	Herb	Button Burrweed
967	Sonchus arvensis L.	Asteraceae	Angiosperm	Herb	
968	Sonchus asper (L.) Hill	Asteraceae	Angiosperm	Herb	Dudhi

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969	Sonchus brachyotus DC.	Asteraceae	Angiosperm	Herb	
970	Sonchus oleraceus L.	Asteraceae	Angiosperm	Herb	Dudiya, Dudhkani
971	Sonneratia alba Sm.	Lythraceae	Angiosperm	Tree	Sweet-Scented Apple Mangrove
972	Sorbaria tomentosa (Lindl.) Rehder	Rosaceae	Angiosperm	Shrub	Bhiloka, Kathi, Kyans
973	Sorghum bicolor (L.) Moench	Poaceae	Angiosperm	Herb	Jwar
974	Sorghum halepense (L.) Pers.	Poaceae	Angiosperm	Herb	
975	Spermacoce articularis L.f.	Rubiaceae	Angiosperm	Herb	Shaggy buttonweed
976	Spermacoce brachystema R.Br. ex Benth.	Rubiaceae	Angiosperm	Herb	
977	Sphagneticola trilobata (L.) Pruski	Asteraceae	Angiosperm	Herb	Yellow Dots, Creeping daisy, Wedelia
978	Sphenoclea zeylanica Gaertn.	Sphenocleaceae	Angiosperm	Herb	Chickenspike
979	Spiraea vacciniifolia D.Don	Rosaceae	Angiosperm	Shrub	Phulanga
980	Spondias pinnata (L.f.) Kurz	Anacardiaceae	Angiosperm	Tree	Wild Mango, Ambara, Ambari, Amra
981	Sporobolus diandrus (Retz.) P.Beauv.	Poaceae	Angiosperm	Herb	
982	Sporobolus virginicus (L.) Kunth	Poaceae	Angiosperm	Herb	
983	Stellaria media (L.) Vill.	Caryophyllaceae	Angiosperm	Herb	Buch-bucha, Chickweed
984	Stephania elegans Hook.f. & Thomson	Menispermaceae	Angiosperm	Climber	Gindaru
985	Stephania japonica (Thunb.) Miers	Menispermaceae	Angiosperm	Climber	Akanadi, Kanadi, Chhotopard, Tape Vine
986	Sterculia villosa Roxb. ex Sm.	Malvaceae	Angiosperm	Tree	Udar
987	Streblus asper Lour.	Moraceae	Angiosperm	Tree	Dahia
988	Stuckenia pectinata (L.) Börner	Potamogetonaceae	Angiosperm	Herb	Fennel Pondweed

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989	Suregada multiflora (A.Juss.) Baill.	Euphorbiaceae	Angiosperm	Tree	False Lime, Ban Naranga
990	Swietenia macrophylla King	Meliaceae	Angiosperm	Tree	Big-Leaf Mahogany
991	Symplocos paniculata (Thunb.) Miq.	Symplocaceae	Angiosperm	Tree	Lodh, Lodhra
992	Synedrella nodiflora (L.) Gaertn.	Asteraceae	Angiosperm	Herb	Cinderella Weed, Pig grass
993	Syzygium cumini (L.) Skeels	Myrtaceae	Angiosperm	Tree	Jamun
994	Syzygium salicifolium J.Graham	Myrtaceae	Angiosperm	Tree	Kath Jamun, Paniya Jamun
995	Tabernaemontana divaricata (L.) R.Br. ex Roem. & Schult.	Apocynaceae	Angiosperm	Shrub	Chandani
996	Tagetes erecta L.	Asteraceae	Angiosperm	Herb	Marigold, Genda
997	Tagetes minuta L.	Asteraceae	Angiosperm	Herb	Wild Merigold
998	Tamarindus indica L.	Fabaceae	Angiosperm	Tree	Imli
999	Tamarix dioica Roxb. ex Roth	Tamaricaceae	Angiosperm	Shrub	Jhau
1000	Tamarix ericoides Rottler & Willd.	Tamaricaceae	Angiosperm	Shrub	Jhau
1001	Tamarix indica Willd.	Tamaricaceae	Angiosperm	Shrub	ঝাউ jhau
1002	Taraxacum officinale F.H.Wigg.	Asteraceae	Angiosperm	Herb	Dandelion
1003	Tecoma castanifolia (D.Don) Melch.	Bignoniaceae	Angiosperm	Shrub	Chestnutleaf Trumpetbush
1004	Tecoma stans (L.) Juss. ex Kunth	Bignoniaceae	Angiosperm	Shrub	Chandaprabha, Piliya, Yellow trumpet
1005	Tectona grandis L.f.	Lamiaceae	Angiosperm	Tree	Sagwan
1006	Telosma pallida (Roxb.) Craib	Apocynaceae	Angiosperm	Liana	Surkilla
1007	Tephrosia purpurea (L.) Pers.	Fabaceae	Angiosperm	Shrub	Sar-punkha
1008	Teramnus labialis (L.f.) Spreng.	Fabaceae	Angiosperm	Climber	Mashparni
1009	Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Combretaceae	Angiosperm	Tree	Arjun

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1010	Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	Angiosperm	Tree	Bahera
1011	Terminalia catappa L.	Combretaceae	Angiosperm	Tree	Deshi-badam
1012	Terminalia chebula Retz.	Combretaceae	Angiosperm	Tree	Harra, Harad
1013	Tetrataenium canescens (Lindl.) Manden.	Apiaceae	Angiosperm	Herb	
1014	Thalictrum foetidum L.	Ranunculaceae	Angiosperm	Herb	
1015	Thalictrum foliolosum DC.	Ranunculaceae	Angiosperm	Shrub	Pili Jarhi
1016	Thelypteris dentata (Forssk.) E.P.St.John	Aspleniaceae	Pteridophyte	Herb	
1017	Thelypteris palustris subsp. pubescens (G.Lawson) Fraser-Jenk.	Aspleniaceae	Pteridophyte	Herb	
1018	Thelypteris prolifera (Retz.) C.F.Reed	Aspleniaceae	Pteridophyte	Herb	
1019	Thelypteris subpubescens (Blume) K.Iwats.	Aspleniaceae	Pteridophyte	Herb	
1020	Thunbergia grandiflora Roxb.	Acanthaceae	Angiosperm	Climber	Neel lata
1021	Thymus linearis Benth.	Lamiaceae	Angiosperm	Herb	Ban Ajwain
1022	Thysanolaena latifolia (Roxb. ex Hornem.) Honda	Poaceae	Angiosperm	Herb	Broom Grass
1023	Tiliacora acuminata (Lam.) Miers	Menispermaceae	Angiosperm	Liana	
1024	Tinospora cordifolia (Willd.) Hook.f. & Thomson	Menispermaceae	Angiosperm	Climber	Giloy, Guduchi
1025	Toona hexandra (Wall.) M.Roem.	Meliaceae	Angiosperm	Tree	Toon
1026	Torenia crustacea (L.) Cham. & Schltdl.	Linderniaceae	Angiosperm	Herb	Brittle False Pimpernel
1027	Tradescantia pallida (Rose) D.R.Hunt	Commelinaceae	Angiosperm	Herb	
1028	Tragia involucrata L.	Euphorbiaceae	Angiosperm	Herb	Barhanta
1029	Trapa natans L.	Lythraceae	Angiosperm	Herb	Water Chestnut

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1030	Trema orientale (L.) Blume	Cannabaceae	Angiosperm	Shrub	Chikan, Jiban, Gio, Pigeon wood
1031	Trema politoria (Planch.) Blume	Cannabaceae	Angiosperm	Shrub	Gio, Jivan, Oriental nettle
1032	Trianthema portulacastrum L.	Aizoaceae	Angiosperm	Herb	Santhi, Swet-Punarva
1033	Tribulus terrestris L.	Zygophyllaceae	Angiosperm	Herb	Gokhura
1034	Trichodesma indicum (L.) Sm.	Boraginaceae	Angiosperm	Herb	Adhapuspi
1035	Trichosanthes cucumerina L.	Cucurbitaceae	Angiosperm	Climber	Jangli Chichinda, Wild Snake Gourd
1036	Trichosanthes dioica Roxb.	Cucurbitaceae	Angiosperm	Climber	Parval
1037	Trichosanthes pilosa Lour.	Cucurbitaceae	Angiosperm	Climber	
1038	Trichosanthes tricuspidata Lour.	Cucurbitaceae	Angiosperm	Climber	Mahakal
1039	Tridax procumbens L.	Asteraceae	Angiosperm	Herb	Kanphuli
1040	Trifolium alexandrinum L.	Fabaceae	Angiosperm	Herb	Egyptian Clover
1041	Trifolium repens L.	Fabaceae	Angiosperm	Herb	White clover
1042	Trifolium resupinatum L.	Fabaceae	Angiosperm	Herb	Shaftal
1043	Trifolium tomentosum L.	Fabaceae	Angiosperm	Herb	
1044	Trigastrotheca pentaphylla (L.) Thulin	Molluginaceae	Angiosperm	Herb	
1045	Trigonella balansae Boiss. & Reut.	Fabaceae	Angiosperm	Herb	Kasuri methi
1046	Trigonella emodi Benth.	Fabaceae	Angiosperm	Herb	Ban-Methi
1047	Trigonella foenum-graecum L.	Fabaceae	Angiosperm	Herb	Methi, Greek-clover
1048	Tripidium bengalense (Retz.) H.Scholz	Poaceae	Angiosperm	Herb	Munj, Sarkanda
1049	Tripidium ravennae (L.) H.Scholz	Poaceae	Angiosperm	Herb	Ravenna Grass, Dholu
1050	Triticum aestivum L.	Poaceae	Angiosperm	Herb	Gehun
1051	Triumfetta annua L.	Malvaceae	Angiosperm	Shrub	Orange Burr-Bush
1052	Triumfetta rhomboidea Jacq.	Malvaceae	Angiosperm	Shrub	Burr Bush, Chikti

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1053	Triumfetta rotundifolia Lam.	Malvaceae	Angiosperm	Shrub	Roundleaf Burr-Bush, Mendurli
1054	Tropaeolum majus L.	Tropaeolaceae	Angiosperm	Herb	
1055	Turnera ulmifolia L.	Passifloraceae	Angiosperm	Shrub	Yellow Alder, Yellow Buttercups
1056	Typha domingensis Pers.	Typhaceae	Angiosperm	Herb	Patera, Pater
1057	Typha latifolia L.	Typhaceae	Angiosperm	Herb	
1058	Ulmus wallichiana Planch.	Ulmaceae	Angiosperm	Tree	Chamarmora, Mairu
1059	Uraria rufescens (DC.) Schindl.	Fabaceae	Angiosperm	Shrub	
1060	Urena lobata L.	Malvaceae	Angiosperm	Shrub	Caesar Weed
1061	Urena lobata subsp. sinuata (L.) Borss.Waalk.	Malvaceae	Angiosperm	Shrub	Kunjuya
1062	Urochloa distachyos (L.) T.Q.Nguyen	Poaceae	Angiosperm	Herb	
1063	Urochloa polystachya (Kunth) Mabb.	Poaceae	Angiosperm	Herb	
1064	Urochloa ramosa (L.) T.Q.Nguyen	Poaceae	Angiosperm	Herb	Browntop Millet, Makra, Murat
1065	Urochloa reptans (L.) Stapf	Poaceae	Angiosperm	Herb	
1066	Urtica ardens Link	Urticaceae	Angiosperm	Shrub	Bichu buti
1067	Urtica dioica L.	Urticaceae	Angiosperm	Herb	Kandali, Kali H. Bicchu-ghas
1068	Urtica urens L.	Urticaceae	Angiosperm	Shrub	Bicchu Buti
1069	Utricularia stellaris L.f.	Lentibulariaceae	Angiosperm	Herb	Star Bladderwort
1070	Vachellia farnesiana (L.) Wight & Arn.	Fabaceae	Angiosperm	Shrub	
1071	Vachellia leucophloea (Roxb.) Maslin, Seigler & Ebinger	Fabaceae	Angiosperm	Tree	Karir
1072	Vachellia nilotica subsp. indica (Benth.) Kyal. & Boatwr.	Fabaceae	Angiosperm	Tree	Babul
1073	Valeriana jatamansi Jones ex Roxb.	Caprifoliaceae	Angiosperm	Herb	Jatamansi, Balchhari

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1074	Vallaris solanacea (Roth ex Roem. & Schult.) Kuntze	Apocynaceae	Angiosperm	Climber	Bread Flower, Dudhi Ki Bel
1075	Vallisneria spiralis L.	Hydrocharitaceae	Angiosperm	Herb	Sawala
1076	Vanda tessellata (Roxb.) Hook. ex G.Don	Orchidaceae	Angiosperm	Epiphyte	Checkered Vanda, Vanda
1077	Vandellia micrantha (D.Don) Eb.Fisch., Schäferh. & Kai Müll.	Linderniaceae	Angiosperm	Herb	
1078	Ventilago denticulata Willd.	Rhamnaceae	Angiosperm	Liana	Karia bouri
1079	Verbascum coromandelianum (Vahl) Hub.-Mor.	Scrophulariaceae	Angiosperm	Herb	Chinese-Mullein
1080	Verbascum thapsus L.	Scrophulariaceae	Angiosperm	Herb	Gidar tambakhu
1081	Verbena officinalis L.	Verbenaceae	Angiosperm	Herb	Vervain
1082	Verbesina encelioides (Cav.) Benth. & Hook.f. ex A.Gray	Asteraceae	Angiosperm	Herb	Golden Crownbeard, Cowpen Daisy
1083	Veronica anagallis-aquatica L.	Plantaginaceae	Angiosperm	Herb	Water Speedwell, Sada
1084	Veronica peregrina L.	Plantaginaceae	Angiosperm	Herb	
1085	Veronica persica Poir.	Plantaginaceae	Angiosperm	Herb	Persian Speedwell, Birdeye Speedwell, Common Field Speedwell
1086	Viburnum cotinifolium D.Don	Viburnaceae	Angiosperm	Shrub	Bhatnoi, Guya, Matyanu, Tumnlya
1087	Viburnum erubescens Wall. ex DC.	Viburnaceae	Angiosperm	Shrub	Ganai
1088	Vicia faba L.	Fabaceae	Angiosperm	Herb	Bakla
1089	Vicia lens (L.) Coss. & Germ.	Fabaceae	Angiosperm	Herb	Masoor, Masur
1090	Vicia sativa L.	Fabaceae	Angiosperm	Herb	Kurphali
1091	Vicia tenera Benth.	Fabaceae	Angiosperm	Herb	Kura
1092	Vicoa indica (L.) DC.	Asteraceae	Angiosperm	Herb	Bichhloo
1093	Vigna trilobata (L.) Verdc.	Fabaceae	Angiosperm	Herb	Mungam
1094	Viola betonicifolia subsp. jaunsariensis (W.Becker) H.Hara	Violaceae	Angiosperm	Herb	Banafsa

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1095	Viola pilosa Blume	Violaceae	Angiosperm	Herb	Smooth-Leaf White Violet, Banafsha
1096	Viscum articulatum Burm.f.	Santalaceae	Angiosperm	Epiphyte	Leafless Mistletoe
1097	Vitex negundo L.	Lamiaceae	Angiosperm	Shrub	Nirgundi
1098	Wahlenbergia marginata (Thunb.) A.DC.	Campanulaceae	Angiosperm	Herb	Asiatic Bellflower, Southern rockbell
1099	Waltheria indica L.	Malvaceae	Angiosperm	Herb	Sleepy Morning
1100	Wendlandia heynei (Schult.) Santapau & Merchant	Rubiaceae	Angiosperm	Tree	Tilak
1101	Wigandia urens (Ruiz & Pav.) Kunth	Boraginaceae	Angiosperm	Tree	Stinging Wigandia, Fiberglass Plant
1102	Withania somnifera (L.) Dunal	Solanaceae	Angiosperm	Shrub	Aswagandha
1103	Woodfordia fruticosa (L.) Kurz	Lythraceae	Angiosperm	Shrub	Fire Flame Bush, Dhaula
1104	Wrightia arborea (Dennst.) Mabb.	Apocynaceae	Angiosperm	Tree	Indrajau
1105	Wrightia tinctoria subsp. rothii (G.Don) Ngan	Apocynaceae	Angiosperm	Tree	Indrajau
1106	Xanthium strumarium L.	Asteraceae	Angiosperm	Shrub	Chota dhatura
1107	Youngia japonica (L.) DC.	Asteraceae	Angiosperm	Herb	
1108	Zanthoxylum acanthopodium DC.	Rutaceae	Angiosperm	Shrub	Timur
1109	Zea mays L.	Poaceae	Angiosperm	Herb	Makka
1110	Zingiber roseum (Roxb.) Roscoe	Zingiberaceae	Angiosperm	Herb	Rosy Ginger
1111	Zingiber rubens Roxb.	Zingiberaceae	Angiosperm	Herb	
1112	Zinnia peruviana (L.) L.	Asteraceae	Angiosperm	Herb	Peruvian Zinnia
1113	Ziziphus jujuba Mill.	Rhamnaceae	Angiosperm	Tree	Ber
1114	Ziziphus mauritiana Lam.	Rhamnaceae	Angiosperm	Tree	Ber
1115	Ziziphus nummularia (Burm.f.) Wight & Arn.	Rhamnaceae	Angiosperm	Shrub	Jharberi, Beri
1116	Ziziphus oenopolia (L.) Mill.	Rhamnaceae	Angiosperm	Climber	Makoh
1117	Ziziphus xylopyrus (Retz.) Willd.	Rhamnaceae	Angiosperm	Tree	Banber

