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Editorial

Another issue of our esteemed journal *Heritage* is published. As a multidisciplinary journal, like its previous issues, this volume also contains different scholarly articles. All these contributions touched a wide variety of topics ranging from the domain of literature, social science and science. The first article of the journal titled **Unchanged Change and Unrehabilitated Rehabilitation: The Refugee Question in Sankha Ghosh's "Rehabilitation"** jointly authored by Moumita Bhattacharjee and Piyali Gupta opens up a new dimension of the refugee question as reflected in the poems of Sankha Ghosh. This paper tries to locate the severe conditions refugees encounter post-displacement, particularly their struggles with fractured identity, societal marginalization, and the fundamental inadequacies of rehabilitation efforts. Authors have wonderfully dealt with the issues of the trauma inherent in refugee narratives and also recognize their remarkable resilience and persistent hope for genuine belonging in a new home.

The next article by Sukalyan Gain titled **An Institutional Approach Towards Environmental Activism: A Review of the Delhi Science Forum**, throws light on the science movement and environmental awareness in post-independence India.A large segment of human society continues to be influenced by superstition. Promoting scientific awareness involves the verification of beliefs and phenomena through scientific investigation and logical reasoning. In this context, science organizations play a crucial role. This paper delves into the role of Science Club of India along with various science organizations across India during the 1970s and 1980s with special emphasis on the development and role of Delhi Science Forum.

Heritage features five articles in the Science section.

In their review article, **Banana (*Musa* spp.) – A Wonder Crop,** Dwipanwita Sur and Seemanti Ghosh have lucidly described the comprehensive utilization of the banana plant. Their article highlights its use not only for its delicious and nutritious fruit but also for its potential in producing fiber, bio-fertilizers, and various industrial products—ranging from flavoring agents to biofuels. They also note the use of certain plant parts as vegetables.

U.A. Khatun, Paramita Majumder, and Smita Roy authored a research paper titled **A Study on Medicinal Plants: Ecological Distribution and Antimicrobial Effects of Synthesized Nanoparticles.** In this study, they collected medicinal plants from the banks of the Rupnarayan River and investigated their ecological distribution. Furthermore, they synthesized silver, copper, and zinc nano particles from the plant extracts and demonstrated their antibacterial and antifungal properties.

Supriti Paul and Angira Chowdhury, in their review article titled **Qualitative Phytochemical Profiling of Secondary Metabolites in Hydroalcoholic Extracts of Medicinal Plants: A Comparative Study of *Ocimum sanctum*, *Azadirachta indica*, and *Withania somnifera*,** discussed various techniques for isolating secondary metabolites from medicinal plants. They carried out a comparative analysis and metabolic profiling of bioactive compounds in the selected plant species.

In the paper **Star Type Classification Using Hertzsprung–Russell Diagram and Machine Learning Technique,** Saptarshi Mondal classified stars based on their characteristics, using the Hertzsprung–Russell (H-R) diagram in conjunction with machine learning algorithms. His work contributes to a better understanding of stellar evolution.

Finally, Dipanwita Sarkar (Paria) and Nibedita Maji, in their review article **Global Status of Insects as a Food and Feed Source with Indian Aspects: A Review** emphasized the nutritional potential of insects. They reported that approximately 2,200 insect species are consumed worldwide and advocated for the recognition of edible insects as a sustainable alternative source of animal protein—for both human consumption and animal feed.

Continous nurturing by our Officer-in-charge, Dr. Anushila Hazra Bhattacharya only makes this endeavor successful. We are thankful to all reviewers for their sincere contribution during peering. We also convey best wishes to all the contributors. We would also like to thank the journal committee members for their unstinted efforts.

Amrita Bagchi
Nirmalendu Das

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Unchanged Change and Unrehabilitated Rehabilitation : The Refugee Question in Sankha Ghosh's "Rehabilitation"

Moumita Bhattacharjee[1], Piyali Gupta[2]

[1]Student of UG Semester VI, Department of English, Bethune College, Kolkata
[2]Assistant Professor, Department of English, Bethune College, Kolkata.

Abstract:

This study examines the complex narrative of refugee experiences through a critical analysis of Sankha Ghosh's poem "Rehabilitation," which powerfully captures the trauma and displacement resulting from the 1947 partition of India. We conceptualize "refugee" as a relational identity that simultaneously signifies profound loss and an intense yearning for belonging, transforming the refugee's perception of the world into what may be understood as a heterotopia. Ghosh's poetic voice articulates the multidimensional experiences of displaced individuals across diverse backgrounds, demonstrating how memories of homeland function as psychological sanctuaries amid the harsh realities of forced migration. Our analysis reveals the severe conditions refugees encounter post-displacement, particularly their struggles with fractured identity, societal marginalization, and the fundamental inadequacies of rehabilitation efforts. Through close textual examination, we highlight the stark contrasts between what refugees have lost and their often-dehumanizing treatment in host environments. The research challenges the adequacy of the term "rehabilitation" in encompassing the profound nature of refugee loss and their ongoing struggle for dignity. While acknowledging the trauma inherent in refugee narratives, this paper also recognizes their remarkable resilience and persistent hope for genuine belonging in a new home.

Keywords : Refugee, Partition, Home, Trauma, Migration, Sankha Ghosh



Born a refugee or made a refugee ? A three-month-old whose mother was murdred, being spoon fed by relief workers Amritbazar, March 1950

"They are all broken hopeless, inside their hearts is restlessness
They say if we dare speak, won't we be punished by freedom?" (Mehjoor, 1922)

In the history of human compassion that weaves the thread of sanity and hope, the term "refugee" seems like a jarring absurdity, a taint, a flaw in all senses. As Parimal Bhattacharya reminds us, in *Field Notes from a Waterborne Land,* in western Bengal, these migrants were nicknamed "Rifu"—a Bangla word derived from the Arabic 'rafu' meaning darning—signifying those who crisscrossed a land that Partition had torn apart like a fabric, attempting to darn it in inconceivable ways (14). It is a relational noun that announces the possibility of "refuge," but whoever carries this coerced identity finds the entire world to have become a 'heterotopia'[1]. Suddenly, some intangible border lines rendered

[1]The concept of **heterotopia**, as formulated by Michel Foucault in his essay "Of Other Spaces: Utopias and Heterotopias" (1967), offers a revealing framework for understanding the post-Partition refugee experience. Unlike utopias, heterotopias are real spaces that function as "counter-sites" where conventional relationships are

them homeless; unknown faces with unknown intentions decide their fate, and the whole of Pangea and Panthalassa rejects their right to life, liberty, and the pursuit of happiness. A lifetime of memory falls short as an identity proof compared with some easily inflammable documents. With empty stomachs but minds brimming with nostalgia, home for them becomes more of a psychological space than a geographical place. The subject of their longing changes—the intensity does not. A refugee of Bengal misses the cooing of doves, and an Irani seeks the soothing "azaan" amidst the marching of boots. Ugandan refugees braid traditional patterns in their hair so that when they get stripped by raiders, their culture still does not get burgled. Those from Myanmar fantasize about the taste of spices in the gruel of relief slums. "In refugee families all available hands had to be pulled into the process of reconstruction, of rebuilding broken homes" (Butalia, 1988), and the tale of this forced homemaking is written in a bitterly tiring, undesired carpe diem spirit: blood-sucking, bruising.

The poem "Rehabilitation" narrativizes this counter-narrative of the refugee question. In 1947, Sankha Ghosh himself migrated to India from Pabna, Bangladesh (erstwhile East Pakistan). Therefore, his voice resonates with the chronicle of needs and repulsions, ordeals and observations of millions of immigrants.The first stanza articulates the utmost shock and dilemma of an unprepared migration, the displacement of homes and misplacement of identities, and the trauma of physical separation and psychological partition. Ghosh presents broken images in quick succession, conveying the agony of abrupt dislocation, uprooting, and being thrown into a world of strangeness and strangers. As the refugee speaker, he repeatedly uses the word "Whatever" as a refrain, suggesting the little things that encompass and encapsulate the world of the migrants.

The simplicity of "Grass and pebbles" evokes the poet's profound nostalgia for a vanished time and place—what he calls "ভিটেমাটি" (*bhite-mati*) or "homestead" in the original Bengali. This intimate landscape of memory, populated with "broken temples" and "solitary sunset," creates a sacred space in the poet's consciousness, a homeland now accessible only through remembrance. Yet these gentle images of belonging abruptly collided with the bombing news of "Exile"—a punishment traditionally reserved for a country's violators but now imposed upon innocent civilians. Unassumingly, the people of East Pakistan had become enemies of the nation merely because of their religion and language. The poet stood witnessing the "Landslides" of these "homestead[s]" that burned in riots, their foundations butchered by easily erasable cartographical lines that redefined nationhood overnight. The folkloric domain, once a source of cultural continuity and comfort, became terrifyingly real as "Arrows and spears" from these "Folklores" darted out alive. These weapons of myth slaughtered the idyllic peace of Bengal and carved a bloody chapter of massacre, carnage, arson, abuse, abduction, forced conversions, sexual violence, infanticide, dismembering, mutilation, and madness. What begins as a tender recollection of place—the physical touchstones of identity represented by grass, pebbles, and temples—transforms into a horrific chronicle of violence, where the poet's *bhite-mati* becomes not just physically unreachable but existentially violated.

Before the fear could even sink in, in a surge of panic, shivering helplessly, a million tired, tangling feet trudged towards West Bengal: their very own Bengal but in another country now. Each step towards survival was countered by a step back towards their roots. As the boxes of belongings lay broken, left behind due to border security restrictions, the immigrants carried on a heavier yet unseen load of memories, crawling through the crevices of their minds, mirroring the "serpentine crowd."These memories, like the serpentine crowd itself, wound through their consciousness—an ironic parallel between the physical migration and psychological burden. Just as refugees streamed into the new land, memories of home flooded their minds, creating a double displacement. When they finally reached their destination, they discovered true homelessness. As Ashish Nandy observes, "At the heart of that unwritten epic, Partition, there is a great journey to exile too. That exile lasts not for a decade or two; it ensures a lifetime of homelessness" (Nandy, "Invisible Holocaust" 306). This metaphorical exile was manifested through massive physical displacement.Authorities kept a minute audit of the loss of land, revenue, and resources due to partition, but the

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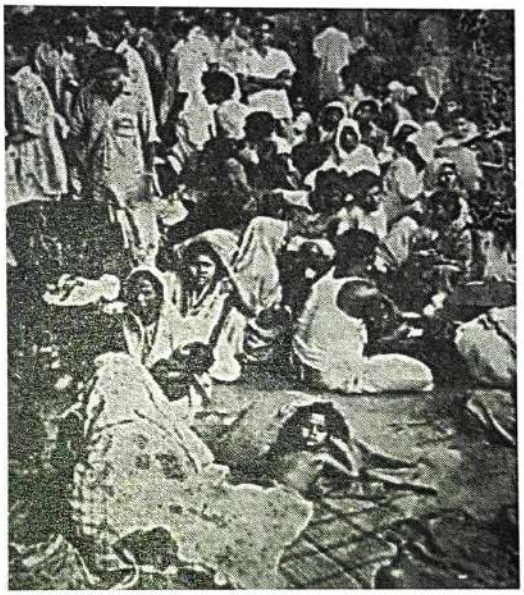
"simultaneously represented, contested, and inverted." The Partition of 1947 transformed the refugee's relationship to space in precisely this manner—creating liminal zones where refugees existed physically in one nation while psychologically inhabiting another. Refugee settlements became heterotopic spaces par excellence: they represented the fragmented homeland left behind while contesting the new national boundaries that had been imposed. For refugees, train stations, camps, and colonies became sites "outside of all places," locations where they were neither fully present in their new surroundings nor able to return to their original homes. The heterotopic quality of refugee existence is evident in how they occupied physical space while remaining culturally and emotionally dislocated—embodying what Foucault characterized as spaces that are "absolutely different from all the sites that they reflect and speak about." This spatial and psychological dislocation is what renders the term "refugee" so profoundly disruptive to conventional understandings of belonging and place.

seriousness of losing one's home was not important enough to theorize upon, let alone spare compassion for voicing the despairing sighs hushed under appalling cries of the refugees, Sankha Ghosh writes in the poem "Birthplace": "Baffled I see, so nearly far broken my homeland lies, absently present." (1987)

The second stanza delves into the condition of the refugees post-migration. Ghosh draws sharp contrasts between what they lost and what they now have to accept—whether they like it or not. Taslima Nasrin writes in her poem "Broken Bengal":

"They shook violently the roots of the land/ And people were flung about who knows where,/None kept account of who perished who survived." (2002).

Sealdah Railway Station in Calcutta emerged as a crucial concentration point for Partition refugees entering India. Its strategic location connected to East Pakistan via Goalundo port made it the first Indian soil for countless unwanted, uninvited migrants seeking urban opportunities. By late 1947, nearly one million refugees crowded the station, transforming it from transit hub to makeshift settlement.Far removed from the rejuvenating shade of trees, the refugees were exposed in the "High noon," endangered by unknown threats. The "blind alleys" and unhygienic "pockmarked walls" of the squatter colonies constricted their movement, much prophesying their future in this country.Despite the bhadraloks' discomfort and government eviction attempts, refugees remained for two decades, redefining Sealdah as a contested heterotopic space where temporary became permanent.



Amidst newborns and corpses , they live. Congestion in Sealdah Station

Refugees were seen as menaces who were causing unemployment, overpopulation, epidemics and cultural contamination. Even the celebrated holiness of the Ganges was reddened by sacrifices of killings and cholera. Hence slogans were raised to evacuate the already evacuated.



The Condition of Calcutta: a man named "Calcutta-resident" is seen on the tree because of twin fear - the tiger in the land named "Housing problem" and a crocodile in the water named "Cholera Germs". Jugantar, May 4, 1950

The city that harboured the Shahid Minar, built in memory of martyrs, paradoxically also harboured the refugees who were themselves martyrs of political conspiracy—yet not an iota of respect was spared for them. Ghosh describes Partition as a force that introduced a new kind of mythopoeia, but a nation with such rich mythological treasure consciously discarded this modern mythology of suffering. Unlike Bhishma from the Mahabharata who, being an active agent in war, brought his end upon himself and earned the privilege to choose his time of death, the refugees were passive sacrifices who were jabbed into "The bed of arrows" with no bounty of euthanasia. These unwilling victims, stripped of agency and dignity, found themselves impaled upon the arrows of displacement without the heroic context that the epic afforded to Bhishma. Their suffering lacked the sanctification of mythology despite being no less profound—their bodies and spirits pierced not by battlefield glory but by the arbitrary violence of political division. The mythological parallel underscores not similarity but stark contrast: while Bhishma's sacrifice was commemorated in epic, the refugees' sacrifice remained unacknowledged, their arrow-beds not a symbol of noble choice but of helpless victimhood.



Diseased but not dead : those who will likely die being thrown out of vehicles to accomodate other migrants. Photo by Maragaret Bourke White, 1951

The darkness around merged with the darkness within. Bodies wounded, identities changed, honour erased—refugees found themselves crippled in a void, their backbones broke under the torment of flickering agitations. The unending drift of time that brings the possibility of change provided them with no solace, as if they knew the eternity of their homelessness will continue indefinitely. Change coupled with changelessness constitutes the anguish of rehabilitation.

The final stanza lays bare the failure of the term "rehabilitation" itself. Amidst death and despair, trauma and turbulence, chaos and crime, the very essence of being alive was lost. Right after the mass exodus of 1947, refugees underwent a systematic dehumanization—first reduced to animals, then to objects, and finally to non-existent nuisance. By 1951, newspapers had deemed rehabilitation rights unworthy of print space.With eyes aghast, the refugees witnessed how their plight, once flowing visibly "like a fountain," became subject to the nation's selective blindness. Every path they chose abandoned its promise of leading to a destination, a refuge, a place to call home. Instead, these paths offered only the "naked" reality as refugees walked on—stripped of comfort, robbed of certainty, and drained of meaning—through an incessant stormy night, holding only a torch of hazy hope.Ghosh reduces their appearances to the fragmented image of "flying hair": dull and lifeless, as if looking like a refugee had become their permanent identity. When this temporal status of "refugee" percolated into their permanent self-identification, reality stagnated into a cycle of the same desperate circumstances, until they found themselves drowning in the quicksand of dejection.

The process of partitioning lacked transparency, yet the macro-history of the nation glorified its importance so extensively that the evident suffering goes unnoticed. While Jawaharlal Nehru proclaimed that the "sound of the dawn" marked India's awakening to "life and freedom," other sounds went unheard: the thumping walk of a thousand tired feet, empty pots rattled by a thousand scrawny hands, the cries of hunger from a thousand gaping mouths.

In the Partition documentary "The Day India Burned," an anonymous relief camp volunteer narrates that female refugees were "systematically raped." He recounts: "I looked at the faces of those who were attending it [the perpetrators] in search of compassion. I found none." This stark contrast continued—while the nation wore the new attire of independence led by men in clean, white clothes, refugees were submerged in filth, sickness, and swarming flies.

The elites of Kolkata complained that refugees brought disease and demise, transforming wherever they stood into cremation grounds. Ila Sen, an elite woman, wrote to the *Times of India* in 1950: "the four and a half million refugees...are now holding the city at ransom. It is impossible to enter from any direction without climbing over their heads." While the immigrants embodied utter powerlessness, ironically, the nation perceived them as threatening—as if they were harbingers of destruction like Lord Shiva, who brings both creation and annihilation.Refugees became living embodiments of perpetual displacement, as rehabilitation proved an unceasing cycle. "Each day" brought the agony of a thousand deaths, and "A thousand days" became a repetition of the same struggle between unhoming and rehoming, suffering and surviving. Birthdays dissolved into daily toil, yet each morning demanded new birth, newer hustle. After endless begging for what was rightfully theirs, refugees sat "in the fading dusk" with nothing but memories in their palms.

In his poem "Home," Ghosh wrote, "No homeland ('bastubhumi') is more existent than memory" (1987). Just as primitive humans transformed stones into tools to create fire, refugees attempted to forge hope from the heavy weight of their memories—comparing what they once had with their current state—to ignite enough determination to face another day of "daily rehabilitation." In a similar vein, Birendra Chattopadhyay in the poem "Exile : Memory : Amnesia", expresses:

A million years of seeing ...
Stone like humans
The face that touches my bosom is nothing more
Than a scrawny breath of wind " (1965)

Ghosh's "Rehabilitation" successfully vocalizes rehabilitation's failure: a term too formal to capture the deeply personal yet universal, evident but inexplicable grief of losing a home. To state apparatus, refugee homes were merely structures of brick, earth, and cement. But the homes refugees actually lost constituted entire worlds of their own—of people, places, touches and feelings, smells and tastes, loves and heartbreaks.Ghosh writes in "Babur's Prayer" :

"Creeping up like creepers
Unbarred memories all green,
In these veins, rafts and rivers
Struggle still." (1987)

From the independence of living in one's own space to begging for existence in another country, from sylvan serenity to the suffocation of the "Jabar-Dakhal" colonies (forcibly occupied settlements), immigrants lost so much of themselves that the optimism to restore their robbed homes remained but an amnesiac fever dream. Unhoming became a past but continuous process, while rehoming became lifelong but perpetually incomplete.

Partition thus becomes a chronicle told by refugees but written, edited, and published by politicians. Their hollow ideology dominates the main text while refugees scream from the margins. For the fathers of the nation, glimmering effigies are built, while the sacrificial lambs are relegated to epitaphs.

My homeland ,
Haven't seen her in so long
Didn't dare asking about her at all
(Chattopadhyay, 1965)

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I would like to express my heartfelt gratitude to my mentor Dr. Piyali Gupta, Assistant Professor in the Department of English at Bethune College, for her invaluable guidance, support, and feedback throughout the course of my study. Her extensive knowledge and experience were instrumental in the completion of this paper.

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My appreciation also goes out to the library staff for their assistance in accessing various resources.

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An Institutional Approach Towards Environmental Activism: A Review of the Delhi Science Forum

Sukalyan Gain
Faculty Member, Department of History
Ph.D. Research Scholar, Department of History, University of Kalyani
e-mail: sukalyangain1@gmail.com Mb: (+ 91)98316 88465

Abstract

The development of science is deeply intertwined with various aspects of human history. Scientific progress has significantly improved human life, yet in many areas, the absence of a scientific approach based on experimental observation remains evident. As a result, a large segment of human society continues to be influenced by superstition. Promoting scientific awareness involves the verification of beliefs and phenomena through scientific investigation and logical reasoning. In this context, science organizations play a crucial role. Their publications—such as journals, magazines, and books—serve as powerful tools in promoting a scientific outlook and combating superstition. In India, several science organizations have actively taken up this responsibility. They emphasize the ideal of *"science for society,"* not only to disseminate scientific knowledge but also to foster a scientific temper among the public. This role has become especially significant in contemporary India.

Alongside efforts to spread science awareness, the **Science Club of India** has contributed notably to environmental protection. During the 1970s and 1980s, various science organizations across Eastern, Southern, and Western India became involved in promoting scientific consciousness within society. This movement gained momentum in North India as well. Amid this backdrop, a prominent science organization was established in New Delhi, the capital of India: the **Delhi Science Forum (DSF).** This research paper will explore the emergence of the Delhi Science Forum and examine its contributions toward protecting the environment.

Key Words : Science Club, Science Movement, Delhi Science Forum, Environment Awareness, Bhopal Gas Tragedy.

The development of science is deeply intertwined with the broader course of human history. Science has shaped, and continues to influence, nearly every aspect of human thought and action. While science has undeniably improved human society, there remains a lack of widespread application of scientific methods in observation, testing, and decision-making. As a result, large sections of society still fall prey to superstition and irrational beliefs.

Recognizing this gap, the **Delhi Science Forum (DSF)**was established in**1978**[i] with the aim of popularizing science and promoting the application of scientific principles for the welfare of society. The organization uses a range of media—such as dramas, slide shows, exhibitions, and workshops—to make science accessible and engaging to the public. DSF believes that science and technology policies have far-reaching social, economic, and political implications. Therefore, public awareness of issues such as nuclear disarmament, energy policy, telecom policy, and others is essential for informed decision-making and societal progress. In many instances, the misuse or misunderstanding of science has caused harm instead of contributing to public welfare subject.[ii]

To counter this, DSF actively organizes campaigns, seminars, workshops, and publishes materials to spread scientific awareness. The organization also collaborates with other groups to further its mission of using science and technology for the betterment of society. In 1980, the Society was registered. The Society will be known as the "**Society for Delhi Science Forum**," or the "**Forum**," as stated in the Memorandum and Articles of Association. The Society's office is located in Saket, New Delhi.[iii]

The aims and objectives of DSF were[iv] :-

1. **To apply the principles of science and technology fairly across social, economic, and political spheres.**
2. **To address and resolve various challenges related to the organization and functioning of scientific and technical institutions.**
3. **To recognize and promote the contribution of scientific and technical professionals to national development.**
4. **To enhance the country's scientific and technological self-reliance.**

5. **To make scientific and technological institutions more inclusive and accessible, encouraging greater creativity among workers and individuals interested in science and technology.**
6. **To inspire public interest and enthusiasm for science.**
7. **To raise awareness about how science and technology policies impact society.**
8. **To conduct research and publish work on issues at the intersection of science and society.**
9. **To undertake any additional activities that support and advance the above objectives.**

The Executive Committee shall consist of ex-officio and members:

1. President
2. Two Vice-Presidents
3. Secretary
4. Two Joint Secretaries
5. Treasurer
6. Fifteen Ordinary Members.

The Executive Committee will be responsible for managing the Forum. This Executive Committee will oversee the Forum's day-to-day management, execution, and operations. It shall also have the authority to take all necessary measures to implement the General Body's decisions and directions, among other things.

This memorandum delineates the responsibilities and authority of the Executive Committee. The Executive Committee shall carry out the following duties, which are subject to the oversight of the Forum's General Body:[v]

- Making new members and life members.
- Sentencing people and cancelling their membership.
- Come up with rules and guidelines for contributions to this Forum so that it can work properly.
- Appointing subcommittees to do different tasks that are considered necessary for the Forum's work.
- To write up, talk about, and settle all issues that affect the members' interests, as long as the General Body gives its final approval.
- Making the Forum's funds last longer and ensuring they have good accounting and auditing.
- To call all General Assembly meetings whenever they think it's helpful.
- To complete all the tasks and actions needed to help the Forum reach its goals and make its activities more regular. The General Assembly will get an annual report on the work of the Forum.
- Setting up forums and seminars run by the Forum where choices can be made about these activities.
- To choose up to four patron members to serve on the Executive Committee. These members will stay in place until the next election.
- To put out a house magazine or bulletin. The submission of properly audited yearly accounts.
- To fill temporary openings in the executive board with people who will serve until the next election.

Since its inception, Delhi Science Forum has been committed to saving the environment as it will protect the environment. Similarly, several sessions have also given lessons on environmental protection awareness.

The Delhi Science Forum organized a **"Symposium on India and the International Drinking Water Supply and Sanitation Decade" seminar on May 9, 1981. People from all walks of life expressed enthusiasm and support for the Decade Programme during the symposium. For the first time, all sectors' departments, including technologists, economists, social workers, opinion leaders, equipment manufacturers, consultants, research institutes, universities, State Public Health Engineering Departments, State Water and Sewerage Boards, CPHEEO, and a wide range of non-governmental organizations, met in a single forum. We met and talked about the issues and problems involved. The symposium established itself as the country's forerunner of the decade program.**[vi]

The aims and objectives of the symposium were:

- To raise general awareness in India about the UN initiative.
- To strengthen and broaden the scope of national activities in India.
- To increase interest in activities in India.
- To provide a platform for the engagement of machinery manufacturers and consulting firms in the country.
- To create a forum for volunteer organizations. Furthermore, the various workers in the water supply sector should be involved in the people's work.

The May 9 meeting addressed a variety of water crisis and conservation issues. The articles discussed in this session were compiled into a volume published in December 1981 by the Delhi Science Forum and Water World. The volume's title is Symposium on India and the International Drinking Water Supply and Sanitation Decade Proceedings. There are five sections to the report. The first section provides background information about the symposium. Part II provides a comprehensive conclusion to the seminar. Part III contains the full text of the papers presented and discussed at the conference. The fourth volume focused on the issues, resources, and scope of public participation and institutional arrangements. Part V discusses media coverage and response.

The symposium was attended by over a hundred representatives from various departments associated with this sector, including technologists, economists, social workers, public opinion leaders, equipment manufacturers, consultants, research institutes, universities, state public health engineering departments, and state water and sewerage boards. There were four sessions in the symposium. The inaugural session commenced the seminar and deliberated on the 'aspects of the issue.' The subsequent session focused on the meticulous evaluation of resources. Individuals from multiple organizations were involved in the third session. The fourth session is an evaluation of the entire thing. Vyas Bhiman, PS Rajvanshy, and Ram Lal Parikh presided over the session.[vii]

Mr. K. V. Krishnamurthy, editor of Water World, began by welcoming the participants and briefly explaining the symposium's goals and objectives. He cited several examples of specially designated years and decades organized by the international community. However, they need to generate the sustained enthusiasm expected when introduced. The decade with which this symposium is associated is quite different, as it addresses developing and developed countries. As a result, such a vital, fundamental, and essential human need should elicit the most significant amount of solidarity from all segments of any country's population. He explained the importance of public participation and stated that planning for water supply facilities spans such a large area that it is only possible to imagine how such a program could be completed with everyone's participation. If ever a prospect needed to pique people's interest and enthusiasm, this is it. Thus, the decade should be envisioned to activate government institutions and non-government entities at all levels. He explained that this is one of the fundamental reasons this symposium was organized to engage a segment that has yet to be attracted to the decade's activities.[viii]

Dr. K. L. Rao (former Union Minister of Irrigation and Power) gave the inaugural speech. Unfortunately, he was unable to attend this session. V.V. Prasad read his speech. He emphasized specific water supply and sanitation disparities and urban and rural sanitation, respectively. He advocated for a realignment of priorities so that concrete and tangible results could be achieved in urban and rural India by the decade's end. Dr. Rao discussed another aspect of technology selection. He stated that we must extend our services to all population segments by utilizing low-cost technology, for which research must be conducted with an open mind and innovative spirit. We must find a way to provide facilities appropriate for our economic, political, and social conditions.[ix]

Discussions and deliberations on the presented papers yielded several conclusions. According to the plan, water will be available in urban and rural areas by 1991. Adequate measures for urban and rural sewage/sanitation should be implemented. The Mar del Plata action plan recommended that urban and rural populations receive 100% water supply and sanitation coverage. A 100% water supply coverage will necessitate corresponding wastewater treatment and disposal coverage. Because water supply and sanitation must be developed in tandem, the possibility of complete sanitation coverage in urban and rural areas can be considered. Priorities can be reviewed and realigned to restore a more balanced focus on water supply and sanitation in urban and rural areas. The Sixth Plan focuses on water supply and sanitation, with targets set for the decade 1991 expressed as a percentage of the population. Assume that the targets are defined in physical terms. In that case, the effort in urban water supply over the next decade should be double that of the previous decade. Rural water supply performance should be four times that of the last decade. Adding the problem of augmentation would increase the scale even more.[x]

In 1984, a terrible accident took place in Bhopal, Madhya Pradesh. The Bhopal disaster is universally recognized as a public industrial accident. Thousands of people, primarily poor, lost their lives. Countless others continue to be seriously affected. A large number of people are permanently disabled. The long-term effects and potential genetic damage are enormous.[xi]

As a member of the scientific community, the Delhi Science Forum is deeply distressed by the impact of this massive tragedy. There is great danger here. Science and technology can be considered as the source of the chariot of death and a means of human progress and the pursuit of happiness. This is it. It is, therefore, essential that the public be taken into complete confidence by the authorities. A government team of scientists and technicians has been tasked with investigating the tragedy. It owes itself and the entire scientific community of the country. It is in this spirit that DSF is raising some issues.[xii]

This tragedy brought several issues to the fore. The government needs immediate action to deal with the situation created by the disaster in Bhopal. Disasters like Bhopal also highlight the need to strengthen the mechanisms and legal frameworks to prevent and manage disasters. Delayed effects and monitoring and control. Monitoring and Control of Environmental Pollution and Occupational/Industrial Health Hazards. All these need to be coordinated.

DSF's expert team is investigating the Bhopal tragedy. National laboratory resources and other scientific and technical expertise are available to this team. They will generate a report that is informative, complete, and detailed so that any other member can cross-check data and conclusions independently. DSF's scientific community and others hope such a report will be forthcoming and freely available soon.

A DSF team visited Bhopal from December 9th to 1st, 1984. It met several disaster victims in the Jaiprakash Nagar area. The team also met the operators and engineers of Union Carbide India Limited. The Bhopal plant and many local doctors and scientists each provided valuable information and insights. Other DSF members collected background material. They also consulted with various experts and assisted in drafting and editing the report. DSF is very grateful to all those who have helped formulate and prepare this document.[xiii]

Without prejudice to the ongoing investigation, DSF has covered sufficient evidence to show that Union Carbide Corporation (UCC) has been grossly negligent on both sides in critical areas related to the processing and handling of hazardous MICs. Plant maintenance could have been much better. Worse, many essential safety functions were disabled, some for economic reasons. Such "economy measures" were also responsible for a manning policy that reduced experienced and trained plant personnel, overloaded plant staff, and led to the placement of untrained personnel in critical plant areas. The accident also exposed the complete inadequacy of the safety equipment. The entire plant was designed entirely in terms of a standby system—control and monitoring facilities, security barriers, etc. The Bhopal plant needs to be provided with a computerized monitoring and control system.[xiv]

Regarding water, the DSF team collected a large number of samples. They mainly encountered intensive sampling and testing of two large lakes (the upper and lower lakes of Bhopal), small ponds, and other sources of water, which are often the primary source of poverty for people in many parts of the affected areas.[xv]

The DSF team opined that based on Bhopal's available meteorological and topographic data, detailed gas dispersion modelling and simulation studies of the dispersion pattern of gas emissions into the atmosphere are required. The team found it impossible to get any data on the existing concentration levels of MIC, phosgene, carbon monoxide, and other compounds bound to be present in varying degrees of concentration at different distances and altitudes from the UCIL plant. The expert team undertook no such study, and no air sampling was assigned the task. If such studies have yet to be carried out, the public needs to be informed of the exact nature of the research undertaken. Considering that the highly sophisticated equipment required to carry out such detailed studies is not available in Bhopal, collecting the samples and sending them to places where such equipment is available is necessary. It also came to the team's notice that tissue samples of fish, plants, and animals were still being sent to the ITRC for detailed examination (i.e., on 11th December 1984).

The short and long-term effects of widespread MIC pollution on crops and plants deserve to be closely studied for vegetable pollution and the effects of toxic gases on plant growth and heredity of permanent crops and vegetables within the area. Dr R. H. Riccharia, one-time director of the Central Rice Research Institute, noted that nuclear abnormalities were bound to occur in plants exposed to MIC and suggested the need to identify cultivated fields with standing crops spaced 50 km apart from UCIL's site. According to Dr Richaria, crop samples should be taken from February to March to analyze all standing crops falling within the area.

The Bhopal gas disaster is among the worst industrial disasters in history. The incident happened in the central Indian city of Bhopal on the evening of December 2-3, 1984. A lethal mixture of toxic gases from the Union Carbide pesticide plant that was heavier than air, covering 36 wards out of the 56 municipalities in the city and covering 40 square kilometres surrounding the plant. That evening, over 20,000 people lost their lives, and roughly 550,000 suffered varying degrees of injuries. Today, the path of genetic disorders, death, disfigurement, disability, soil and groundwater contamination, and loss of flora and fauna persists. This is not unique to Bhopal or India. The world is aware of events like the Fukushima and Chornobyl nuclear plant disasters, the Minamata mercury poisoning in Japan, and the core meltdown of the Three Mile Island nuclear power plant in the United States. When taken as a whole, these mishaps significantly altered how the general public views science and technology (S&T). Around the world, a lot of organizations are against this event. DSF made an effort to support the people during the Bhopal gas accident. They are traveling to spend time with people.[xvi]

This increased interaction with the science and technology policy of the Delhi Science Forum (DSF) has sparked some concerns. Several NGOs, civil society groups, and movements are involved; these groups have varying viewpoints, objectives, tactics, operational theatres, domain expertise, and disciplinary backgrounds. S&T's perception as a knowledge system, a component of public policy, an institutional practice, a weapon of state power and corporate influence, and—most importantly—a system of knowing attitudes and actions is a significant concern for PSM. Advances in science and technology have led to better living conditions for people. But sometimes, people's lives have suffered due to science and technology. DSF's mission has always been to advance human welfare via science and technology and persuade the government to employ science and technology for the good of the populace rather than for its gain.

Dr. Amit Sengupta worked for DSF with great dedication. A leading figure in the DSF and the larger PSM, he and his colleagues were drawing attention to the problems with people's long-term health and rehabilitation following the Bhopal gas tragedy. He played a significant role in the ongoing effort to shape the conversation about the role of science and technology and related public policy, as well as the campaign for appropriate policy formulation resulting from the Bhopal tragedy and its long-lasting aftermath. The Bhopal gas tragedy catalysed many of these initiatives, but some gained momentum on their own. Institutionalized several of these projects, enlisted the support of other groups that shared similar goals, and frequently worked to establish new networks or organizations at the federal level in different Indian Union states.[xvii]

Following the 9–11 December 1984 disaster, a DSF team led by Prabir Purkayastha and Dinesh Abrol promptly travelled to Bhopal to investigate the industrial accident's underlying factors and potential causes. Both individuals were engineers and played integral roles in establishing the DSF. Possesses expertise in science and technology policy studies, complemented by practical experience in industrial plant design and control systems. Additional DSF members, such as D Raghunandan, remained to assist in gathering supplementary materials, engaging in discussions with experts, and creating the report that would be produced as a result of this investigation. The team visited the area near the Union Carbide plant, which experienced the most severe impact. In addition, they encountered numerous factory workers, engineers, and managers and acquired valuable information through interactions with local doctors, scientists, political leaders, and journalists.[xviii]

Within two weeks of the disaster, the report (Delhi Science Forum, 18 December 1984) was a big step forward. Exploring the reasons and mechanisms behind this disaster laid the groundwork for many subsequent popular movements. It is still the most complete technical analysis of the event, and no other study, including those that came after, has surpassed it or ignored it. The Director General of the Council of Scientific and Industrial Research (CSIR), which comprises more than 40 government research labs working in various fields, wrote the government's analytical report in 1985. The DSF report helped to focus the movement of people after Bhopal and shape their immediate, short, and medium-term needs and goals regarding industrial licensing, industrial siting policies, and rules for the production, storage, and handling of dangerous substances. At Union Carbide Ltd's Bhopal plant, they made the pesticide carbaryl, which they sold under the brand name Sevin. They also made and stored a lot of hazardous chemicals, like methyl isocyanate and fugens.[xix]

The technology was relocated to Bhopal from the West Virginia, United States plant, which was established and managed by the parent company Union Carbide Corporation (UCC). The DSF report indicated that the safety equipment at the Bhopal plant needed to be more robustly designed than the West Virginia plant in the United States. In contrast to the US plant, the Bhopal plant lacked supplementary emergency vent scrubbers to counteract the abrupt discharge of substantial quantities of MIC into the atmosphere, as occurred on that tragic night in Bhopal when it

became contaminated with water and other substances. Contrary to expectations, the Bhopal plant was equipped with a primary scrubber explicitly designed to manage minor and routine emissions of harmful gases. Similarly, the flare tower at Bhopal needed to be increased, and incapable of handling the quantity of MIC and other hazardous gases emitted within a brief timeframe. A notable distinction lies in the fact that the US plant employed an in-line process for utilizing MIC, resulting in the storage of a minimal quantity. Conversely, the Bhopal plant used a less efficient method, necessitating storing a substantial amount of MIC in a large tank. This tank was the catalyst for initiating the MIC contamination incident in Bhopal.[xx]

The DSF report also identified several deficiencies and design flaws in the machinery of the Bhopal plant. The chilling unit was not only designed low, but the tank's contents, which should have kept below 0°C, remained at ambient temperature (around 11° to 26°) because the refrigeration system failed six months ago. There was no "knock down" tank to remove liquid MIC from the storage tank. The safety system was manual rather than automated and computer-controlled, as at the UCC plant in the United States. The storage tank's alarm system, which detects an abnormal rise in temperature or pressure, was faulty and poorly monitored. Unlike the computerized system in the US, Bhopal had no gas detection system other than workers' eyes, which were sensitive to MIC at only two ppm, 100 times the permissible limit.[xxi]

UCIL and its original UCC maintained secrecy from the central and state governments, allegedly due to industrial secrets and intellectual property, details of manufacturing processes, quantities of various input chemicals used, emergency response protocols for fire and accidental gas release, materials, stability, and accidents. The incident involved gas poisoning. The safety precautions and emergency response information provided to staff and UCIL management were either strictly confidential or inadequate. UCIL did not conduct safety drills with plant workers, let alone the general public, in contrast to UCC plants in the United States, where public safety drills are routinely performed, complete with preventive measures and treatment instructions.

Almost a year after the Bhopal gas disaster, on December 4, 1985, oleum gas was released from a factory run by Shriram Foods and Fertilisers (SFF) in Delhi. The same complex also houses a cluster of various industries, including the production of caustic chlorine. The plant was located in an old industrial area of Delhi that was slowly becoming the city's heart. Because the Bhopal disaster was on everyone's minds, the public and the authorities acted quickly. The Supreme Court appointed a three-member committee, including DSF's Prabir Purkayastha, in response to a Public Interest Litigation (PIL) filed against the SFF. The DSF is working on the Bhopal disaster report, which will examine technical aspects and safety precautions and, among other things, recommend whether the plant should be restarted. The case and the subsequent Supreme Court decision established a precedent in environmental law.[xxii]

From DSF's perspective, the petitioner's involvement in the SFF case and PIL had several unfavourable consequences. This case resulted in the wholesale relocation of all industries, including hazardous and polluting ones, from Delhi. This caused significant hardship for the workers, their families, and others whose livelihoods relied on these industries. An essential outcome of the SFF case and its interaction with labor unions and city planners during and after it was that the DSF became deeply involved in Delhi's planning and other urbanization issues, such as the democratization of urban planning and public transportation. In the long run, the potential conflict of interest between workers' rights and environmental protection and sustainability has become an essential aspect of DSF perspectives and agendas, particularly given that the left has historically viewed environmental issues with suspicion and as hostile to workers' interests. Hospitals in Bhopal, particularly those run by the government, responded to the disaster with admirable dedication and urgency despite needing more information. According to the DSF report, Bhopal was the first mass release of MIC gas into the atmosphere without liquefaction. Amit Sengupta spearheaded these efforts and networking with several young doctors from Bhopal, including the late Dr. Ajay Khar, who was instrumental in establishing a new PSM organization known as the Madhya Pradesh Vigyan Sabha.

DSF and MPVS conducted the most extensive survey, polling over 5000 households in Bhopal's worst-hit areas. The survey results were made available to other non-governmental organizations for use as they wished. Raghunandan, who has a background in both engineering and sociology, oversaw the survey's design and analysis. Amit Sengupta, Dr. Ajay Khare, and other Bhopal workers contribute significantly to data collection. DSF's sister organization, the Centre for Technology and Development (CTD), conducts action research programs to develop and implement pro-poor livelihood and housing solutions. They have collaborated on a government-funded project with MPVS to install energy-efficient, smokeless, wood-burning cookstoves in the homes of gas victims. Such stoves, usually improved versions used by poor rural and urban households, use a chimney to vent exhaust gases and smoke outside the home, causing significant indoor air pollution and adversely affecting the load on the lungs. Eklavya,

another PSM organization in Madhya Pradesh specializing in alternative teaching for science and social sciences for middle-school children, established and managed a new trust for rehabilitating gas victims through a manufacturing unit in the affected area for many years. This unit manufactures leather goods with light sewing machines and other equipment that does not require strenuous physical labor from the gas victims who work there. A former UCIL manager who wanted to give back to the community managed the unit, which ran successfully for many years.[xxiii]

A few other non-governmental organizations have undertaken various activities aimed at providing medical assistance, legal assistance, and conducting research in the area. The Bhopal Group for Information and Action (BGIA) conducted a 1996 study on solid and liquid waste dumped around USIL plants over a long period, from 1969-77. 1977-84, which contaminated groundwater, soil, and the surrounding environment with a wide range of toxins, including carcinogenic chemicals. Tonnes of other by-products, such as tarry residues and alpha-naphthol, were stored in the open or in poor conditions within the plant's boundaries, eventually washing away to the ground. Greenpeace International investigated soil and groundwater samples from numerous slums, wells, and residential areas near the factory in 1999 and discovered high levels of mercury, chromium, copper, nickel, lead, and toxic organo-chlorines. Srishti published the findings of a 2002 study on the pathways of chemical pollutants through the food chain based on experiments conducted at the renowned Indian Institute of Technology in Kanpur. The soil, groundwater, and vegetables were contaminated with toxic chemicals and heavy metals. At the same time, breast milk contained carcinogenic organic compounds and benzene hexachloride, which can only be obtained from the Eucalyptus plant. The People's Science Institute (PSI) in Dehradun discovered in 2001 that water from tube wells, hand pumps, solar evaporation ponds inside the Ucil plant, and an open well in the area contained high levels of mercury.[xxiv]

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Banana (*Musa* spp.) - A Wonder Crop

Dwipanwita Sur[1], Seemanti Ghosh[2]

[1]Student Department of Botany, Bethune College, Kolkata

[2]Assistant Professor, Department of Botany, Bethune College, Kolkata

Author for correspondence

Abstract

Banana has been a well-known food crop to mankind since ages. Being in popular demand for its sweet fruit pulp world-wide, its various parts such as, pseudo stem pith and blossoms are also being widely used as vegetables. Apart from these, other parts of this crop, which are often discarded can also be used for excellent purposes such as production of bioethanol, lactic acid etc. from the peels; fibers, packing material from leaves and inflorescence bracts and so on. Moreover, the leaves and bracts can be used in food industries as a source of natural flavoring agent and bio colorant while the discarded peels and root parts could be potentially used in agricultural fields as organic manures after rotting them. The fact that none of the plant part goes to waste makes banana crop a "wander plant". In future aspects, the additional uses of these wastes will not only sustain an eco-friendly way to reuse wastes but will also help to make a profitable economic turnover for banana farmers.

Keywords : Banana, pseudostem, inflorescence, bracts, blossoms, pulp, peels, roots.

1. Introduction

"Banana" is a common term for the herbaceous plants of various species and hybrids under the genus *Musa* belonging to the family Musaceae and also for the fruit which it produces. It is a well-known crop to the mankind with about 5-6 million hectares of land dedicated for its global production. In the history of human agriculture, banana is one of the crops to be cultivated at its earliest. The origin of this plant family has been extending from India to Papua in New Guinea, and also the Southeast Asian regions (De Lange et al., 2009; Arvanitoyannis et al., 2009).

Being one of the gigantic herb groups in the world, banana (Ploetz et al., 2007) and other plants of this family can grow up to 5- 7 m, consisting of a fleshy rhizome (corm), pseudo stem (leaf petioles) and spirally arranged oblong leaves. The plant bears a oval-shaped, long inflorescence which is suspended by a stalk from the tip of pseudostem, enclosing male and female flowers within layers of deep, purple, waxy bracts. The female flowers eventually bear "berry" fruits which gradually becomes horn- shaped up on maturation with white or yellow flesh (Padam et al., 2014).

Generally, the term "banana" refers to the dessert cultivar while the cooking cultivar is referred to as "plantain". Huge mass cultivation and consumption in the recent decades have made banana and plantains the 4th prominent agricultural crop in the world after rice, wheat and maize (Ashokkumar et al., 2018). India contributes of more than 25% of the world's "banana" production and hence remains as the largest banana producing countries in the world **(Table 1)**. However, a large proportion of the banana produced by India are kept aside for its domestic consumption market, and releasing only about 0.04% for export. Reportedly the United States and the European Union are the top banana importers. Uganda is the largest "plantain" producer with an estimated production of around 7.4 million tonnes, followed by Ghana **(Table 1)**. China, Ecuador, Philippines and Nigeria being other leading "banana" and "plantain" producers in the world (Padam et al., 2014).

When compared to other food plants, banana has proved itself as a special crop as each and every part of it can be used some way or the other. Only very few crops possess such a wonderful property, among which banana is the one. We all know that banana fruits being rich in energy and various other nutrient sources are considered to be one of the most important starchy staple foods consumed by the people of tropical humid zone (Onwuka and Onwuka, 2005). Apart from these fruits, other parts of the banana plant are also used in different ways at different places. The banana blossoms and pseudo stem pith are often consumed as vegetable in some parts of India (especially in South India and West Bengal), Sri Lanka and Malaysia (Kennedy, 2009).

Likewise, banana leaves are also used for cooking purposes in many countries and are also used as a plate for serving meals in South India. But what makes this plant a "wonder crop" is that none of the discarded plant part goes

waste- the banana fruit peels, the banana agro-waste and in fact the fibers from the outer shells of the pseudostem can be used effectively for the benefits of mankind. This study thereby focuses to give a clear overview of the conventional and non-conventional uses, benefits and nutritional importance of each and every specific part of the banana plant.

1.1 Banana Leaf

Though not edible itself, the greenish-yellow banana leaf is a magic wand for making every meal sumptuous. Started as a tradition in south-India, thousands of years ago, the trend of serving meals on a large, slender banana leaf has been proved healthy and eco-friendly by scientific experimentations. Various researches have stated that eating on banana leaves enhances the nutritional values of our foods thereby giving us a flavorful, eco-friendly, hygienic and healthy meal.

Banana leaves are packed with polyphenols which are natural antioxidants. While consuming food served on banana leaves, these polyphenols are being absorbed in the food which is imparted to the body further, that in turn fights all the free radicals in the body, thereby preventing grave diseases. Being rich in polyphenol oxidase, banana leaves help to fight Parkinson's disease. Banana leaves also have peculiar anti-bacterial properties that kills any germs present in the food thereby aiding in easy and proper digestion. The waxy coating on the surface of banana leaves gives it a glossy finish thereby adding a subtle flavor to the hot food served on it (http://arunachalabhavan.com/health-benefits-of-eating-on-banana-leaf/).

Banana leaves are also used for cooking purposes in several countries like India, China and Puerto Rico (Singh, 2017). Primarily the banana leaves are used for wrapping pork, meats and fishes which are further steamed or heated at low flame. This adds more taste and flavor to the food being cooked. This method also preserves the food juices within and prevents it from burning.

According to a report by Kuo et al. (2006), banana leaves produce a membrane-bound enzyme of 9-LOX, which is capable of producing melon-like, fruity cucumber-like and oolong tea-like flavor upon pickling or treating with agents like: linoleic acid, linolenic acid or soybean oil respectively. The kinetic properties of this 9-LOX are comparable to LOX obtained from English pea and Canola seeds. Hence, banana leaves potentially could be a target for generation of natural flavors continuously to be utilized in food industries.

According to a research, the anti-microbial and anti-inflammatory properties of banana leaves are similar to those of petroleum jelly gauze used for dressing wounds. Hence, in many developing countries banana leaves could be a cheap and efficacious alternative for dressing, treating and filling wounds in a shorter period of time (Guenova et al., 2013). Moreover, it will be an excellent, inexpensive and easily available option.

In Tamil Nadu, the banana leaves are often completely dried and used as packing material for carrying food items or even made into cups to accommodate liquids. This in fact, is an eco-friendly option with respect to polythene bags or plastic cups. All the main uses of banana leaves have been summarized in Fig 1.

1.2 Banana Stem (pseudo stem)

The banana stem is termed "pseudo" because it resembles the appearance of a tree trunk. The inner tender part of this pseudo stem is often consumed as vegetable in various parts of India, especially South India and West Bengal. Dishes such as "vazahaithandu kootu", "vazahaithandu porial" are popular in Tamil Nadu and in West Bengal "Thor chapper" is the most common dish being cooked. Consumption of this pseudo stem enriches the body with potassium, calcium, magnesium, phosphorus and iron along with essential vitamins A, C and B6. Apart from high nutrition, it also has certain medicinal values (Singh, 2017): juice of banana pseudo stem

- ✓ is believed to control blood glucose level and hence is beneficial for diabetic patients.
- ✓ cures stomach sores
- ✓ removes urine irritation

Discarded outer shells (leaf sheaths) of the pseudo stem can be utilized effectively for its fibers and can be mend to natural threads. An alternative sustainable fiber source with replacable capability of the conventional usage of wood and pulp from trees for manufacturing timbers, boards, textiles and papers has always been an attractive choice for several fiber industries (Padam et al., 2014). According to Maleque et al. (2005), banana fibers from pseudo stem can be used to reinforce epoxy composites. Moreover, they concluded that the virgin epoxy material has tensile strength that

could be substantially increased by 40% upon using banana stem fibers. Fibers from banana pseudo stem have been in use since decades as textile raw materials required for manufacturing traditional handicrafts and clothes by several communities of people across the globe (Kennedy, 2009).

Also, the pulp obtained from the pseudo stem can be utilized for manufacturing rope, paper, place mats and other goods. Studies have shown that pseudo stem fibers from *Musa acuminata* Colla, *cv.* Cavendish could be of efficient use in pulping and paper processing as its fibers have been found to show interesting potentialities regarding burst index and breaking length either alone or when combined with other common pulps (Cordeiro et al., 2005). More interestingly, papers made from banana have been reported to have a very low water absorptive capacity thereby making the papers more stronger and water resistant than those derived from other wood-pulps (Jacob and Prema, 2008). The uses of banana pseudostem has been summarized in Fig 2.

1.3 Banana Inflorescence

Banana plant bears finger shaped blossoms (unisexual flowers) in the form of an inflorescence subtended by large, fleshy, purple or reddish colored bracts, which are eventually shed off when the fruits mature.

1.4 Blossoms or Flowers:

Due to its enormous nutritional benefits, these blossoms are mostly consumed in the form of vegetables in South East Asian countries- popularly in Indian, Thai and Vietnamese cuisines. Banana flowers also finds an important place in Ayurvedic Cooking. In Indian (mostly in South India and West Bengal) cuisines, these are mostly cooked as curries or soups, may be simply stir fried or eaten as fritters, and even made into pickles and stored for long term usage. Indonesians however mixes it with pork and a hot sambal to be cooked and served on bamboo sections at festivals. Thai cuisines on the other hand prefers banana blossoms to be served raw as sides with pad Thai (http://www.finedininglovers.com/blog/food-drinks/banana-blossom). In Sri Lanka also, it is considered to be an important ingredient for their curries, fritters or may be used as salads.

Singh, 2017 reported that banana blossoms are highly nutritious similar to banana fruits being a rich source of vitamins, certain minerals, fibers, proteins as well as certain phytochemicals which acts as antioxidants. Due to these available nutrients, banana blossoms cater numerous health benefits and as mentioned in Ayurveda, consumption of raw or cooked banana blossoms or even its decoction can help to combat certain health problems such as:

- ✓ Reduction in blood glucose level and raising haemoglobin level, thereby helping diabetic patients.
- ✓ Reducing muscle cramps and excessive bleeding during menstruation in women by regulating normal progesterone levels (http://www.indiatimes.com/health/healthyliving/8- incredible-health-benefits-of-banana-flower-the-health-all- rounder-you-haven-t-heard-of-251391.html).
- ✓ Boosting milk production in lactating mothers.
- ✓ Helpful for people suffering from irritable bowel syndrome (IBS) and diarrhea by providing both soluble and insoluble dietary fibers it (http://www.medindia.net / patients / lifestyle and wellness / health - benefits - of - banana - flower.htm).
- ✓ Helps in management of ulcer irritation by neutralizing gastric juices (http://www.new vision.co.ug / new_vision / news / 1436915 / health - benefits - eating - banana - flower - empumumpu).
- ✓ Helpful in healing wound and burn faster especially in children (http://www.parenting healthy babies.com / health - benefits - of - banana - flower - for - children).

1.5 Bracts:

The discarded bracts of the banana inflorescence contain abundant anthocyanins (a subclass of flavonoids) that are an important pigment group responsible for the red, purple and violet colors of the banana inflorescence (Kitdamrongsont et al., 2008). Anthocyanins are generally good bio-colorants because of its attractive colors and other properties like- water solubility and moderate stability in foods (Ozela et al., 2007; Torslangerpoll and Andersen, 2005) and has also proven to be beneficial for health (Bagchi et al., 2004; Konzack and Zhang, 2004). In the bracts of banana inflorescence *(Musa acuminata* and, *Musa acuminata x balbisiana)*, abundance of anthocyanins has been reported

ranging from 14-32 mg anthocyanin/100 g bracts, consisting mainly of cyanidin-3-rutinoside compound, that could be potentially exploited as a cheap and natural source of food colorant. As a natural bio-colorant, anthocyanins always soar high in demand and hence utility of banana inflorescence bracts as a cheap natural source to anthocyanins has also been increasing (Rymbai et al., 2011).

1.5.1 Other uses:

Recently banana inflorescence has found potential uses in food industry as flour from banana inflorescence is being prepared by cultivars (Vieira Nogueria et al., 2022) and upon investigating its properties, it has been found that fibres from banana bracts of *Musa* ABB is rich in anthocyanin. This can be widely used for bread fortification and additional is has been found to change rheological properties of dough. In a recent study it has been found that providing banana inflorescence fortified biscuits on a daily basis to lactating mothers and infants have reportedly increased milk activity in mothers and it has also shown significant differences in the body mass index (BMI) of infants (Nordin et al, 2020).

Banana inflorescence has also been investigated for utilization of its fibres as fillers for bioplastics which has the potential to replace synthetic plastics for a sustainable alternative (Pongsuwan et al., 2022). Ramirez-Bolanos et al., 2023, also suggested a synergistic relation between aquaculture and banana farming in which the waste banana potential is suggestively having the potential for being the health promoting substance benefitting the growth of fishes.

With the growing popularity of synthesizing nanoparticles of silver, gold, copper, and platinum from plant materials, recent studies have been carried out in this field by using banana inflorescence. Inflorescences of *Musa basjoo* and *Musa acuminata* have been successfully used for synthesizing gold and silver nanoparticles. Significant antibacterial and anticancer effects have been found in these which can be an excellent resource for pharmaceutical productions with antibacterial and anticancer properties (N. Senevirathna et al., 2024) Fig 3. Summarizes all the uses of banana inflorescence.

1.6 Banana Fruit

Banana fruits are one of the most common and important food crops in the world. Cavendish, a type of dessert banana is the most common variety consumed. It is green when unripe and slowly turns to yellow upon maturation (Kothawade, 2019). Apart from this, there are more than 50 species and a dozen of hybrids with different qualities, depending upon size, color and texture with an overall curved and fleshy appearance. Banana fruits are composed of 60% pulp and 40% peel (Acevedo et al., 2021).

1.6.1 Pulp:

Both unripe and ripe banana pulps have been deliberately consumed across the world. Unripe or raw banana pulps are generally consumed as vegetable while the ripe pulps are eaten directly or may be consumed as confectionary. Consumption of banana pulp provides various nutrition to the body. As studies say, raw banana pulps are composed of 75% water, 23% carbohydrates, 1% protein and negligible amount of fat. The ripe banana pulp however is a rich source of essential phytonutrients, such as phenolic compounds, vitamins (B3, B6, B12, C and E), potassium, carotenoids, flavonoids, amine compounds and dietary fibers (Acevedo et al., 2021). The calorie content of banana ranges from 72-135 calories with an average calorie of 105 for a medium- sized fruit. Calorie count for a banana approximately goes as: 93% carbs, 4% proteins and 3% from fats (Kothawade, 2019). The nutritive values for one regular-sized banana pulp (126 gms) goes as:

Major nutrients	% Daily value (DV)
Vitamin C	12
Copper	11
Potassium	10
Magnesium	8
Riboflavin	7
Folate	6
Niacin	5

(https://www.healthline.com/nutrition/11-proven-benefits-of-bananas#TOC_TITLE_HDR_2)

Because of these above nutrients, banana consumption has been believed as an aid to prevent various health diseases. Scientifically, it is believed that:

- ✓ High amount of potassium and magnesium in banana lowers blood pressure, thereby reducing the risk of heart diseases and also helps to maintain healthy kidney function
- ✓ A high fiber content in banana aids in digestion and also helps in weight management
- ✓ Antioxidants like flavonoids and amines help to prevent oxidative damage of the body cells caused by free radicals.

1.6.2 Fruit peel:

Apart from chlorophyll pigments, the discarded fruit peel of banana also contains carbon-rich organic compounds such as:

Organic compounds	*Percentage (%)*
Cellulose	7.6-9.6
Hemicellulose	6.4-9.4
Pectin	10-21
Lignin	6-12

Banana peels are generally used for agricultural purposes as a fertilizer as the peels are rich in organic nutrients which in turn enrich the soil, thereby replacing chemical fertilizers with a natural one. Banana peels can also be used conveniently as a cattle feed. Since banana peels contain a rich amount of nutrients such as: lipid, protein, carbohydrate, fiber, etc. it can be used as a raw material for feed production (Ahnwange 2008).

Apart from agricultural uses, banana peels can also be used effectively for the following purposes:

i. *Bioethanol production:*

Amidst the rising peaks of oil prices and the need for energy security across the world, biofuels are gaining convenient popularity (Rana et al., 2018). According to an experimentation done by Itelima et al. (2013), biomass yielded by banana peels after 7 days of fermentation was 1.60 (OD). During this process, the reducing sugar concentrations for banana peels ranged about 0.20 – 0.82 mg/cm^3. Thereby, the optimal bioethanol yield was reported to be 7.45% v/v for banana peels.

ii. *Lactic acid production:*

Classified as GRAS (generally regarded as safe) for usage as a food additive by the US Food and Drug Administration (FDA), lactic acid can generally be produced either by microbial fermentation or by chemical synthesis. A fermentative Lactic Acid (LA) production was carried out by Umesh M and Preethi K (2014) by utilizing various fruit peel waste (mango, banana, orange and pineapple) as substrates by inoculating *Lactobacillus plantarum* as the starter culture. From this, it was reported that banana peels produced 4.68 g/L of LA.

iii. *As a bio-sorbent for water treatment:*

The available ground water is generally potable and suitable for various usage including drinking, but in some places various types of contaminants may occur making the ground water unfit for use. These contaminants may be geogenic (such as Arsenic, Fluoride and Iron) or may be due to human exploitations (such as nitrates, phosphates, heavy metals, etc.) including agricultural practices, industrial discharges or domestic sewerage. Hence treatment of these contaminated ground water must be done in order to ensure safe usage of them.

As reported by Reddy et al. (2015), banana peels could be feasibly used as a Biosorbent for removal of nitrate from drinking water. When 0.05 g of banana peel powder of 106 µm size fraction, was added to 100 ml of contaminated water sample having 200 mg/l of nitrate concentration for a contact time of 0.5 h, the treatment's efficiency was nearly 80%.

iv. *In food industry:*

In recent studies by Saifullah et al., it has been studied that banana peel flour can be an excellent component fo noodles. This can also be an excellent source of dietary fibres and can also be treated as a gluten-free product. The use of banana fruit has been highlighted in Fig 4.

1.7 Banana Root

The banana root system begins as a single rhizome putting out adventitious roots (suckers) eventually, gradually forming new plants which later on can replace the matured dying main plant after fruiting. Though not edible otherwise, consumption of the banana rhizoid's decoction has surprising health benefits according to ayurveda (https://www.my-island-jamaica.com/surprising- health-benefits-of-banana-roots.html).

- ✓ Helps to relief toothache
- ✓ Keeps eyes healthy due to presence of high Vitamin A content
- ✓ Controls blood pressure
- ✓ Relieves asthma as well as stomach and brain inflammation
- ✓ Helps relieving mouth ulcer burns

Apart from these, the roots are believed to replenish the exhausted soil with required nutrients, thereby making the soil fertile. For this advantage, banana plantations are often done during "crop rotation" practices in order to make the soil ready for next growing season. Fig 5. Summarizes all the uses of banana roots.

Table 1: Top ten major banana and plantain producers in the world by country (FAO, 2020):

Rank	Banana		Plantain	
	Country	*Production**	*Country*	*Production**
1.	India	31504000	Uganda	7401579
2.	China	11872600	Ghana	4667999
3.	Indonesia	8182756	Cameroon	4526069
4.	Brazil	6637308	Philippines	3100839
5.	Ecuador	6023390	Nigeria	3077159
6.	Philippines	5955311	Colombia	2475611
7.	Guatemala	4476680	Cote d' Ivoire	1882779
8.	United republic of Tanzania	3419436	Rwanda	913231
9.	Mexico	2464171	Ecuador	722298
10.	Colombia	2434900	United republic of Tanzania	579589

**Values expressed in metric tonnes*

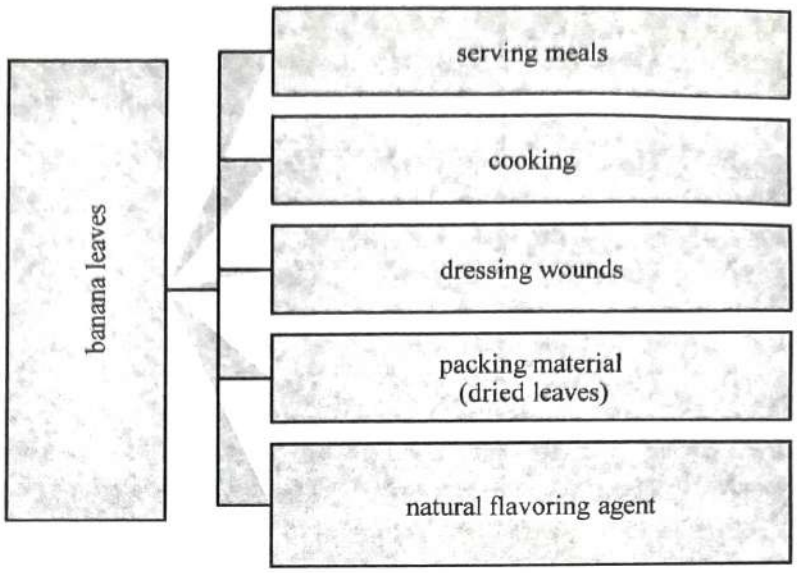


Figure 1. Schematic representation for the various uses of banana leaves.

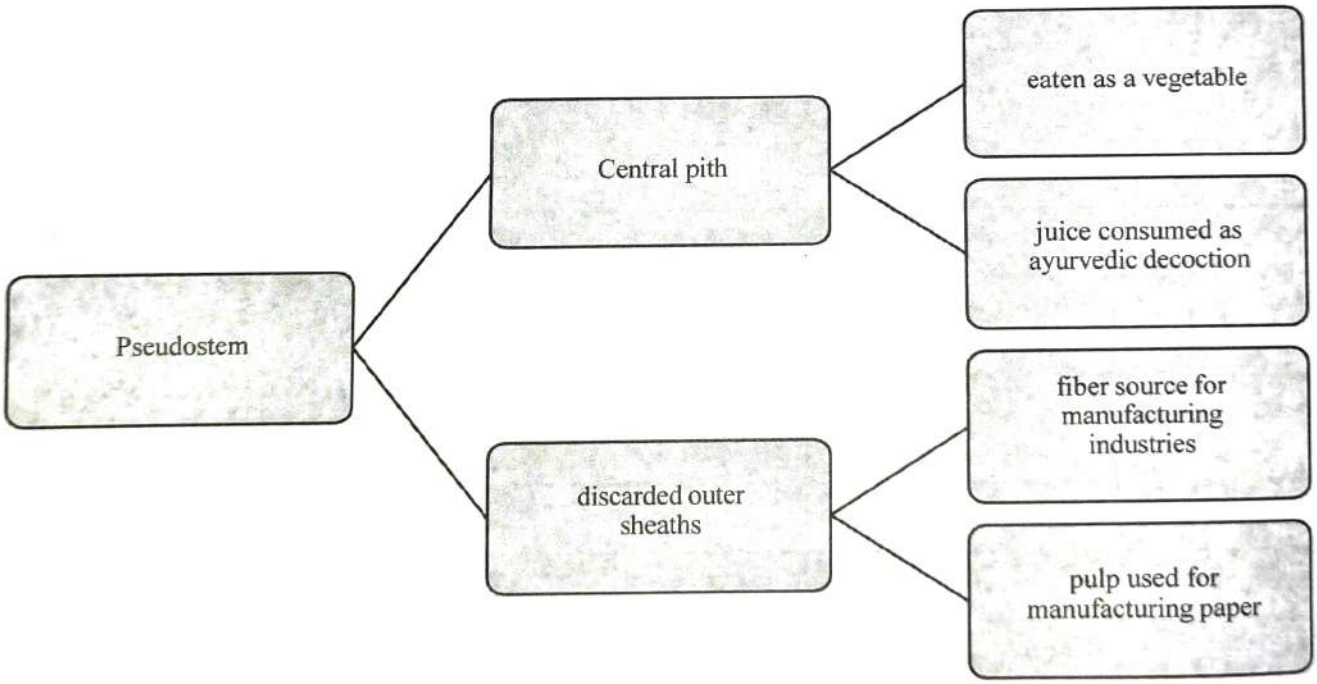


Figure 2. Schematic diagram showing probable uses of the pseudo stem.

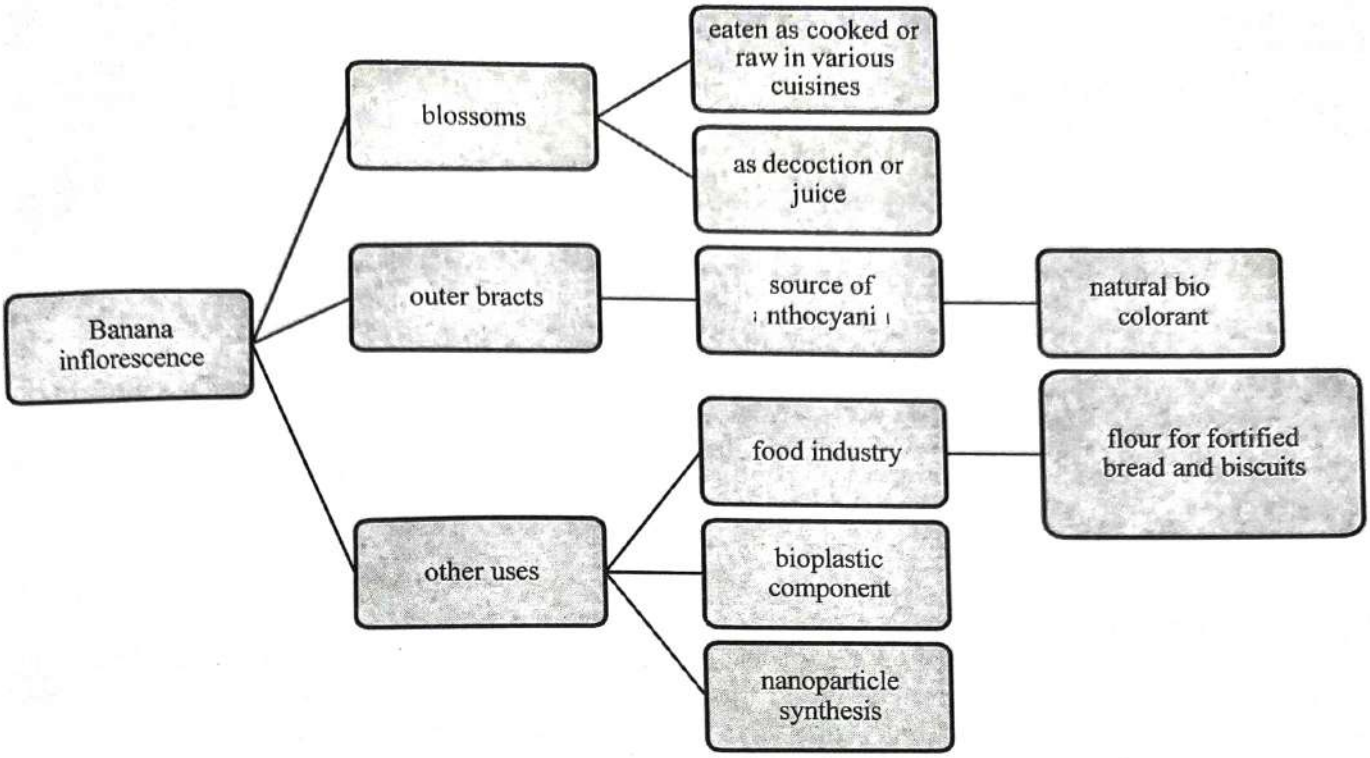


Figure 3. Schematic diagram showing potential uses of banana inflorescence.

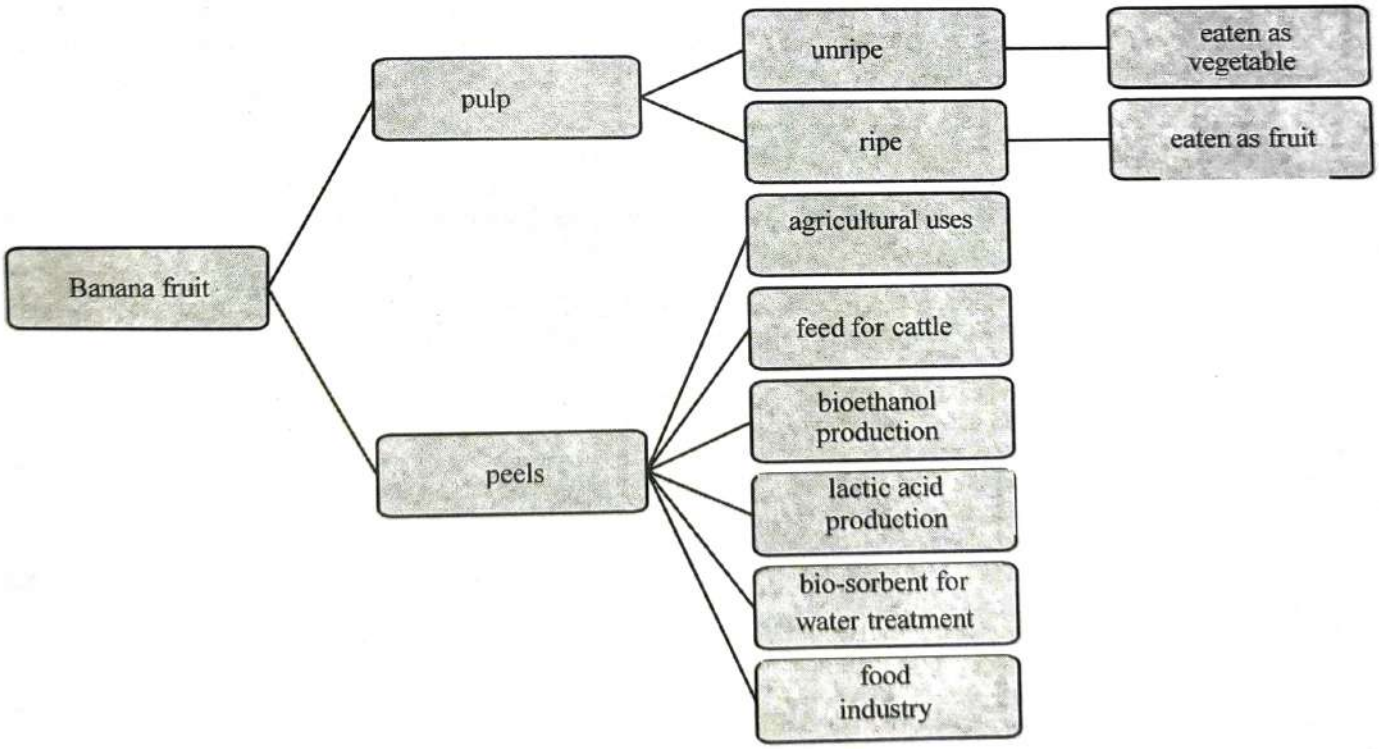


Figure 4. Schematic representation for different uses of the banana fruit.

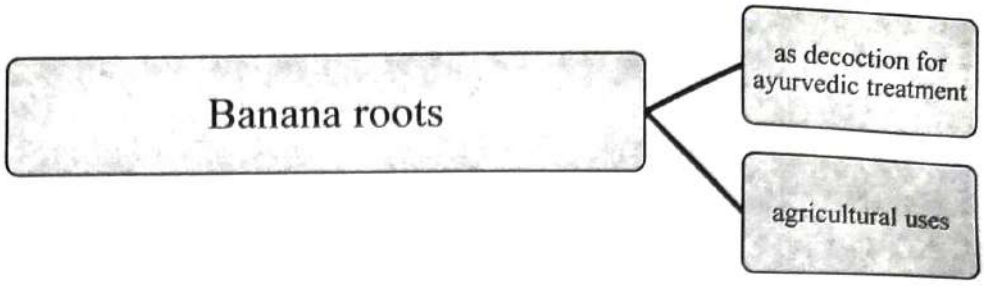


Figure 5. Schematic representation for various uses of banana roots

2. Conclusions

The banana plant as a whole is quite important for various purposes like: food, feed, packaging, pharmaceuticals as well as industrial uses. The banana agricultural farms produce tonnes of waste-losses that can be effectively used for various recovery processes, such as wastewater treatment, production of biofuels, production of fibers, fertilizers, etc. by which a circular economy could be implemented. As mentioned, usage of banana peels for effective production of biofuels can be increased on an industrial scale due to its high content of organic compounds, being rich in carbon such as polysaccharides. Similarly, usage of banana leaves and pseudo stem sheaths can be implemented on a global scale for production of biodegradable packaging, fibers for textiles, organic fertilizers for farming, etc. In food industries, the inflorescence bracts can be implemented as natural bio colorant while the leaves can be utilized as a natural flavoring agent.

However this is an ongoing issue demanding continuous attention and improvements by the innovative minds for creating high value and quality products with large-scale economic impacts. An increasing trend towards utilization of eco-friendly products and an exponential increase in world population has created a much-needed steady platform for continuation of innovative researches on development of products from banana wastes, so that in near future it could be a sustainable way of commodity production and income.

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A study on medicinal plants: ecological distribution and antimicrobial effects of synthesized nanoparticles

Sk Ummey Sabiya Khatun[1], Paramita Majumder[2], Smita Ray[3]

[1]PG Semester IV, Department of Botany, Bethune College,
[2]Assistant Professor, Department of Chemistry, Bethune College,
[3]Assistant Professor, Department of Botany, Bethune College

Abstract

Riverbanks provide complex biophysical habitat and support diversities of flora and fauna. The composition and species distribution in an ecosystem is greatly determined by various biotic and abiotic factors. The first part of our study was related to understanding the distribution of plants on Rupnarayn (Benapur and Panitras) and Hooghly(Panchpara) river bank area with emphasis on medicinal plants. Plants respond to heavy metal stress by metal complexation process like production of phytochelations or by other metal chelating peptides. In this paper we report the synthesis of silver, copper and zinc nanoparticles utilizing eight different medicinal plant extracts namely *Acacia nilotica, Ocimum sanctum, Azadirachta indica, Justiciaadhatoda, Mikaniamicrantha, Phyla nodiflora, Eclipta alba* and *Senna occidentalis*. The antimicrobial test conducted on *Bacillus cereus*, *Klebsiella sp*, *Aspergillus niger* and *Rhizopus stolonifer* showed good zone of inhibitions showing potentiality of the different nanoparticles as a remedy for infectious diseases caused by tested pathogens. Bacterial pathogens were better inhibited than fungal pathogens in our present study. As per our observation highest inhibition was obtained with silver nanoparticles from Acacia *nilotica* followed by zinc nanoparticles from the same species on *Bacillus cereus*

Keywords : Medicinal plants, Ecology, Nanoparticles, anti-microbial effect

1. Introduction

A vital constituent of the biosphere systems are river banks that bear diverse vegetation. The composition and species distribution in an ecosystem is greatly determined by various habitat factors such as elevation, slope, soil moisture and soil chemistry and anthropogenic factors (Dad 2022). The present study was carried out at Rupnarayan and Hooghly River Bank Area. The aim was to elucidate the floristic composition, and species distribution pattern, and to assess current distribution of important medicinal plant tax a in this area, and relate it to various environmental factors. Medicinal plants are vulnerable to overexploitation and loss of habitat. One of the variables generally considered when explaining the traditional use of plants is their ecological availability.If a species is more abundant in one area, it will most probably be used to treat a common problem in that community. This requires biotechnological interventions. Nanotechnology is a recent development of applied science and technology involving devices and dosage ranging from 1 to 100 nm in size (Ansari et al 2012) and has shown promising results in the field of medicine. Phytochemicals have attracted the modern-day therapeutic industry owing to their efficacy, minimal side effects and ease in production and are functional as immunomodulatory, antiviral, antitumor, anticarcinogenic, antimicrobial, and antioxidative drugs (Ezzat et al 2019, Naithani et al 2010). Nanoparticles (NPs), diameter of 0.1 μm, synthesized from phytochemicals provides numerous advantages including the efficient delivery of active medicinal constituents. There are various report that show its application in various type of human ailments (Chandra et al 2022). The metallic nanoparticles are multifunctional in nature, and they have been extensively used in a variety of sectors of industries and medicine including drug delivery, cancer treatment, wastewater treatment, and DNA analysis, as antibacterial agent and biosensors and in solar power generation and catalysis. The green synthesis of metallic nanoparticles has been proposed as a cost-effective and environmentally friendly alternative to chemical and physical methods. In recent years copper nanoparticles (Cu NPs) have attracted much attention of researchers due to its applications in industries and medicine. However, other nanoparticles, such as platinum, gold, iron oxide, silicon oxides, and nickel, have not shown bactericidal effects in studies with *Escherichia coli* (Mittal et al 2013). Our work aimed at synthesizing copper, silver and zinc nanoparticles from the medicinal plants *Acacia nilotica, Ocimum sanctum, Azadirachtaindica, Justiciaadhatoda, Mikaniamicrantha, Phyla nodiflora, Eclipta alba* and *Senna occidentalis* and testing the antimicrobial efficacy*in vitro*.

2. Materials and Methods

Ecological studies and determination of Shanon Weiner index: Plant samples were collected from two sites at the bank of Rupnarayan and one site on the bank of Hooghly riverof West Bengal (Fig 1, 2) during the period December 2022 to April 2023.Line transects Method was applied during the sampling process.Speciesdiversity of Riverbank was determined by Shanon-Weiner Index andsimilarity of three plant community were done by Sorenson`s Coefficient(Dey and Panigrahi 2021).Shanon-Wiener index(H):Shannon index has been a popular diversity index in the ecological literature, it is also known as Shannon diversity index, Shannon wiener index. (Spellerberg et al 2003) commonly used to characterize species diversity in a community. Based on the information theory it measures the species diversity of a community. Shannon's diversity index accounts for both species Evenness and richness. As the Shanon index increases,both species richness and Evenness of the community increases. It is calculated by summing the proportions of each species in the community multiplied by the natural logarithm of their respective proportions.

$H' = - \sum (p\square * \ln(p\square))$

Where:

- H': is the Shannon-Wiener Index
- p□ :is the proportion of individuals belonging to species i in the total population (n/N)
- n = Total number of individuals of a particular species in the sample.
- N = Total number of individuals of all species present in the sample.
- ln: is the natural logarithm
- ∑: represents the sum of all species in the community

Sorenson's Coefficient (CC): It is a statistic used to gauge the similarity of two samples. Given by the following formula –

CC = 2C/ (S1+S2). Here, 2C = number of species common to both communities; S1= Number of species in community 1; S2 = Number of species in community 2.

Nanoparticle synthesis: Preparation of plant extract: 10 gm of plant sample (leaves) of each plant was collected and washed thoroughly with runningtap water, the leaves were cut into pieces and boiled in 100 ml of water to prepare 10% of plant extract. The suspended mass was then filtered. The obtained liquid contains the bioactive components leached from the leaves which was used further for the synthesis of nanoparticles.

Synthesis of Copper, Zinc Oxide and silver Nanoparticles (from medicinal plant extracts): 5mM aqueous solution each of $CuSO_4$. $5H_2O$, $ZnSO_4$. $7H_2O$, and $AgNO_3$ solution were prepared and stored in a brown bottle.50 ml of each solution was taken in conical flask, and to this 10 ml of plant extract of each sample was added drop wise with continuous shaking with the help of magnetic stirrer. This same protocol applied for all the eight herbal extracts. the colour change was checked periodically (1hr,2hr,3hr,24hr,72hr). The synthesized phytonanoparticles were characterized by UV-Visible Spectroscopy as per Thakur et al 2018, in the wavelength range 400-600 nm.

Antimirobial assay: Antimicrobial activity was assayed by using standard Disc Diffusion Method (DDM) against two human pathogenic bacteria *Bacillus cereus* (gram positive),and*Klebsiella* sp (gram-negative),and the fungi *Aspergillus niger,*and *Rhizopus stolonifer*. Bacterial strains weregrown on nutrient broth, for this 15ml of broth was taken in a conical flask and with the help of aseptic inoculating loop, few bacterial colonies were inoculated into this broth and incubated at 37°C, 130 rpm for 24hours. For the fungal strains 20ml of distilled water was taken in a conical flask and to this with the help of aseptic inoculating loop some fungal mycelia were transferred followed by incubating this mixture in BOD shaker cum incubator (130rpm) at 28°C for 24 hours. Nutrient agar media for bacteria and PDA(Potato Dextrose Agar) media for fungi were used to perform this antimicrobial assay.Fresh overnight prepared grown cultures of the bacteria and fungi were spread on sterile petri plates containing nutrient agar, and PDA with the help of spreader. In these plates 50 µl nanoparticles containing discs (5mm in diameter) were placed on the surface of microbes containing media.The discs were prepared withWhatman No 1 Filter paper. The bacterial strains containing plates were incubated at 37°C, and fungal strains containing plates were incubated at 28°C for 24 hours, and the diameter of zone of inhibition was measured with the help of mm scale.

3. Results and Discussions

Ecological study: After conducting the detailed survey, the data obtained from the three different sites at the river banks has been presented in Table 1(a-d). Vegetation encompassed herbs, shrubs and trees ranging over a wide range of genera and families. Crustose Lichens are also spotted in this area. This type of lichens forms a crust which strongly adheres to the substrate (Soil,Rock,tree bark etc). The general structure of a lichen is composed of layers of fungus and alga. Shanon-Wiener index was used to calculate the diversity of plant species in different sampling area, alongside Sorrensen's coefficient was used to represent the similarity indices amongst herbs, shrubs, and trees of the sampling areas studied as represented in Table 2 (a-c), 3 (a-c) and 4 (a-c). Results obtained for Shanon Weiner indices for data taken at Benapur, Panitras and Kadamtala are represented in Table 2-4respectively followed by Sorensen's similarity coefficient among the herb, shrub and tree species from the above-mentioned areasOur studies were an extension of the report presented by Dey et al 2021at the sampling site of Rupnarayan river bank. High diversity of flora was not observed since Shanon wiener Diversity ranged from 0.767 for trees of Panitras area to 2.564 for herbs of the same area, though interestingly we noted the presence of mangrove in the area. Abiotic factors such as erosion and anthropogenic activities might be the causes for lack of species diversity in spite of good edaphic conditions normally observed in river banks. Plantation programs as well as people's awareness are the two effective tools to increase plant diversity.

Synthesis of nanoparticles from medicinal plants and their antimicrobial activities:After mixing the solution of coppersulphate, zincoxide and silver nitrate with aqueous leaf extracts (Table 5);copper sulphateand zinc oxide reaction mixturechange incolourswas observed between 24-48 hours. In case of silver nitrate,reaction mixture turnedbrown in colour in between 4-6 hours. The change incolourof the reaction mixture indicated the formation of nanoparticle (Fig 3) due to the excitation of surfaceplasmon vibrations. After the reduction of the ion absorption at 500-600 nm range wavelength confirms that the ions of copper sulphate and Zinc Sulphate are reduced to CuNPs and ZnONPs respectively, and absorption at 400-500nm range wavelength confirms that the ions of silver nitrate are reduced to AgNPs (Silver Nano particles).

Herbal plants *Acacia nilotica, Azadirachta indica, Mikania micrantha, Phyla nodiflora, Justicia adhatoda, Eclipta alba, Senna occidentalis* and *Ocimum sanctum* leaf extracts chelated to silver, zinc and copper nanoparticle were subjected to antibacterial activity against two bacterial strains:one gram-positive bacteria *Bacillus cereus (Bc)s, and* onegram-negative bacteria *Klebsiella sp* (K. sp), as well asfungi:*Aspergillus niger (An,)* and *Rhizopus stolonifer(Rs)*.The tests generated good zone of inhibitions showing potentiality of the nanoparticles against infectious diseases caused, Bacterial pathogens were better inhibited than fungal pathogens in our experiments. Highest inhibition was obtained with silver nano particles from Acacia *nilotica* followed by zinc nano particles from the same species on *Bacillus cereus.* All the microbes are more or less sensitive to the leaf extracts containing nano particles (Fig 4, 5).In this study, zone of inhibition was recorded, results were tabulated along with figures and graph.

From the study it is evident that nanoparticles synthesized from medicinal plant extracts show higher efficacy in pathogen inhibition *in vitro* compared to plant extracts. Our results are in accordance to Chinnaswamy et al2021 who have reported that the antibacterial activity of *Azadirachta indica*-AgNPs (1,000 µg/mL) confirmed by disc diffusion assay with zone of inhibition against *Bacillus cereus*, *Escherichia coli*, *Pseudomonas aeruginosa,* and *Staphylococcus aureus*in descending order of inhibition by nanoparticles bearing herbal extracts Minimum inhibitory concentration and minimum bactericidal concentration values ranged between 390 and 780 µg/mL. In our case, highest efficacy was noted for *Eclipta prostrata*-CuNPs against *Kleisiella* sp; *Acacia nilotica*-ZnNPs against *B. cerueus*; *Mikania macrantha*-ZnNPs against *A. niger* and *O. sanctum*-Ag NPs against *A. niger*. Markedincrease in inhibition zone was seen in case of nanoparticles synthesized using herbal extracts in compared to use of herbal extracts only (Table 6).Herbal plantsextract of leaf are capable of producing nanoparticles extracellular which are quite stable in solution. Biosynthesis of copper, zinc and silver nanoparticles using a rapid time scale and low-cost procedures using environmentally benign natural resources as an alternative to chemical synthesis protocols.

.Sampling site	Latitude	Longitude	pH of Soil	pH of water
Benapur (bank of Rupnarayan river)	22.40334°N	87.949573°E	8.07	7.65
Panitras (bank of Rupnarayan river)	22.47567°N	87.905333°E	8.29	7.9
Panchpara; Kadamtala (bank of Hoogly river)	22.564303°N	88.256403°E	8.13	8.16

Table 1-a Ecological details of sampling sites

Name of Plants	Family	Order	Local Name
Herbs			
Xanthium strumarium	Asteraceae	Asterales	Okra
Phyla nodiflora	Verbenaceae	Lamiales	Bhui Okra
Mikania micrantha	Asteraceae	Asterales	Rabon lata
Bacopa monnieri	Plantaginaceae	Lamiales	Brahmmi
Cyanodon dactylon	Poaceae	Poales	Durva
Ipomea carnea	Convolvulaceae	Solanales	Dhol Kolmi
Typha elephantina	Typhaceae	Poales	Hoghla bon
Wedelia trilobata	Asteraceae	Asterales	Bhringaraj
Colocasia esculenta	Araceae	Alismatales	Buno kochu
Deris scandens	Fabaceae	Fabales	Noalata
Shrub			
Datura innoxia Mill.	Solanaceae	Solanales	Dhutro
Senna occidentalis	Fabaceae	Fabales	Kolkesunda
Acanthus ilicifolius	Acanthaceae	Lamiales	Nil tengrakata
Jatropha gossypifolia	Euphorbiaceae	Malpighiales	Lal bherenda
Justicia adhatoda	Acanthaceae	Lamiales	Basak
Ocimum sanctum	Lamiaceae	Lamiales	Tulsi
Tree			
Acacia nilotica	Fabaceae	Fabales	Babla
Trewia nudiflora	Euphorbiaceae	Malpighiales	Bhola
Azadirachta indica	Meliaceae	Sapindales	Neem

Table 1-bSampling station 1(Benapur)

Name of plant	Family	Order	Local Name
Herb			
Eclipta prostrate	Asteraceae	Asterales	Bhringraj
Mikania micrantha	Asteraceae	Asterales	Bikas lata
Ocimum sanctum	Lamiaceae	Lamiales	Tulsi
Justicia adhatoda	Acanthaceae	Lamiales	Basak
Partheniumhysterophorus	Asteraceae	Asterales	Gajar ghas
Rumex dentatus	Polygonaceae	Caryophyllales	Pahari palang
Cardiospermum helicabum	Sapindaceae	Sapindales	Sibjol ful
Blumea lacera	Asteraceae	Asterales	Tamrachura
Musa paradisiaca	Musaceae	Zingiberales	Kola gach
Shrub			
Senna occidentalis	Fabaceae	Fabales	Kalkesunda
Acanthus ilicifolius	Acanthaceae	Lamiales	Nil Tengrakata
Lippia alba	Verbenaceae	Lamiales	Motmoti
Tree			
Trewia nudiflora	Euphorbiaceae	Malpighiales	Bhola
Acacia nilotica	Fabaceae	Fabales	Babla
Phoenix dactylifera	Arecaceae	Arecales	Khejur gach
Borassus flabellifer	Arecaceae	Arecales	Tal gach
Azadirachta indica	Meliaceae	Sapindales	Neem

Table 1-c - Sampling Station 2(Panitras)

Table – 1d: Sampling station 3 (Panchpara Kadamtala)

Name of Plant	Family	Order	Local Name
Herb:			
Phyla nodiflora	Verbenaceae	Lamiales	Bhui Okhra
Xanthium strumarium	Asteraceae	Asterales	Okra
Colocasia esculenta	Araceae	Alismatales	Buno kochu
Cyanodon dactylon	Poaceae	Poales	Durva
Eclipta prostrate	Asteraceae	Asterales	Bhringraj
Mikania micrantha	Asteraceae	Asterales	Bikas lata
Ipomea carnea	Convolvulaceae	Solanales	Dhol Kalmi
Alternenthera philoxeroides	Amaranthaceae	Caryophyllales	Shalinche
Cleome viscosa	Cleomaceae	Brassicales	Holud hurhuri
Polygonum hydropiper	Polygonaceae	Caryophyllales	Bishkatali
Elusine indica	Poaceae	Poales	Chapra ghas
Commelina diffusa	Commelinaceae	Commelinales	Dholpata
Shrub:			
Lippia alba	Verbenaceae	Lamiales	Motmoti
Solanum torvum	Solanaceae	Solanales	Bon tomato
Ricinus communis	Euphorbiaceae	Malpighiales	Redi
Senna occidentalis	Fabaceae	Fabales	Kalkasunda
Ocimum sanctum L.	Lamiaceae	Lamiales	Tulsi
Justicia adhatoda	Acanthaceae	Lamiales	Basak
Tree:			
Azadirachta indica	Meliaceae	Sapindales	Neem
Mangifera indica	Anacardiaceae	Sapindales	Aam
Trewia nudiflora	Euphorbiaceae	Malpighiales	Bhola
Neolamarckia cadamba	Rubiaceae	Genitales	Kadam gach
Sonneratia caseolaris	Sonneratiaceae	Myrtales	Kewra

Table 2a: Shanon Weiner index for Benapur (Herb)

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Xanthium strumarium	13	13/423	0.0307	0.000942	-3. 483	-0. 107
Phyla nodiflora	120	120/423	0.283	0.08008	-1. 262	-0. 357
Mikania micrantha	10	10/423	0.0236	0.00556	-3. 746	-0. 088
Bacopa monnieri	85	85/423	0.20094	0.40376	-1.609	-0. 321
Cyanodon dactylon	120	120/423	0.2836	0.0804	-1.262	-0. 357
Ipomea carnea	6	6/423	0.0142	0.020164	-4. 254	-0. 0604
Typha elephantina	3	30/423	0.0709	0.00502	-2. 646	-0. 188
Wedelia trilobata	4	4/423	0.00945	0.0000893	-4. 662	-0. 044
Colocasia esculenta	30	30/423	0.0709	0.00502	-2.6	-0.188
Deris scandens	5	5/423	0.01182	0.0009	-4.439	-0.052

Total number of species(S) = 10
Total number of individual = 423

$H = -\{(-0.107)+(-0.357)+(-0.088)+(-0.321)+(-0.357)+(-0.0604)+(-0.188)+(-0.044)+(-0.188)+(-0.052)\}$
$= 1.7624$

Hmax = ln (S) = ln(10) = 2.3025
E= 1.7624/2.3025 = 0.765
Shanon-Wiener diversity index – 1.7624
Evenness = 0.765

Table 2b: Shanon Weiner index for Benapur (Shrub)

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Datura innoxia Mill.	7	7/82	0.085	0.007	-2.465	-0.209
Senna occidentalis	9	9/82	0.121	0.014	-2.111	-0.255
Acanthus ilicifolius	59	59/82	0.731	0.534	-0.313	-0.228
Jatropha gossypifolia	5	5/82	0.060	0.003	-2.813	-0.168
Justicia adhatoda	1	1/82	0.0121	0.00014	-8.8738	-0.1073
Ocimum sanctum	1	1/82	0.0121	0.00014	-8.8738	-0.1073

Total Number of Species= 6
Total number of individual = 82

$$H = -\{(-0.209)+(-0.255)+(-0.228)+(-0.168)+(-0.107)+(-0.1073)\}$$
$$= 1.0443$$

Hmax = ln(S) = ln (6) = 1.791
E = 1.0443/1.791 = 0.5830
Shanon – wiener index = 1.0443
Evenness = 0.5830

Table 2c: Shanon Weiner index for Benapur (Tree)

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Acacia nilotica	8	8/12	0.666	0.443	-0.406	-0.270
Trewia nudiflora	2	2/12	0.166	0.027	-1.795	-0.297
Azadirachta indica	2	2/12	0.166	0.027	-1.795	-0.297

Total number of species = 3
Total numberof Individual = 12

$$H = -\{(-0.270)+(-0.297)+(-0.297)\}$$
$$= 0.864$$

Hmax = ln(S) = ln (3) = 1.0986
E = 0.864/1.0986 = 0.7864
Shanon- Wiener Index = 0.864
Evenness = 0.7864

Table 3a: Shanon- Wiener index for Panitras (Herb)

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Phyla nodiflora	80	80/448	0.1785	0.0318	-1.7231	-0.30757
Xanthium strumarium	10	10/448	0.0223	0.0005	-3.8031	-0.08480
Colocasia esculenta	40	40/448	0.0892	0.0079	-2.41687	-0.215584
Cyanodon dactylon	130	130/44	0.2901	0.08415	-1.2375	-0.35899
Eclipta prostrata	20	20/448	0.04464	0.0019	-3.1100	-.13883
Mikania micrantha	15	15/448	0.03348	0.11209	-3.3968	-1.13724
Wedelia trilobata	8	8/448	0.01785	0.00031	-4.0257	-0.07185
Typha elephantina Parthenium	45	45/448	0.10044	0.010088	-2.29819	-0.2308
hysterophorus	35	35/448	0.07812	0.0.0061	-2.5495	-0.1991
Rumex dentatus	25	25/448	0.05580	0.00311	-2.88598	-1.61037
Cardiospermum helicabum	10	10/448	0.02232	0.04981	-3.8022	-0.8486
Blumea lacera	18	18/448	0.04017	0.00161	-0.91204	-0.03663
Musa paradisiaca	12	12/448	0.02678	0.000717	-3.6200	-0.09694

Number of Species (S) =13
Total Number of Individual = 448

$$H = -\{(-0.307)+(-0.084)+(0.2155)+(-0.358)+(-0.138)+(-1.137)+(-0.0718)+(-0.230)+(-0.199)+(-1.610)+(-0.848)+(-0.036)+(-0.0969)\}$$
$$= 5.33$$

Hmax= ln(S) = ln (13) =2.564
E = 5.33/2.564 = 2.0787
Shanon wiener Diversity = 2.564
Evenness =2.564

Table 3b: Shanon- Wiener index for Panitras (Shrub)

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Senna occidentalis	23	23/122	0.188	0.035	-1.671	-0.314
Acanthus ilicifolius	53	53/122	0.434	0.188	-0.834	-0.361
Lippia alba	29	29/122	0.237	0.056	-1.439	-0.341
Justicia adhatoda	12	12/122	0.098	0.009	-2.322	-0.227
Ocimum sanctum	5	5/122	0.040	0.0016	-3.218	-0.128

Number of Species (S) = 5
Total Number of Individual = 122

$$H = -\{(-0.314)+(-0.361)+(-0.341)+(-0.227)+(-0.128)$$
$$= 1.371$$

Hmax= ln(S)= ln (5)= 1.609
E = 1.371/1.609 = 0.852
Shanon Weiner Diversity =1.371
Evenness = 0.852

Table 3c: Shanon- Wiener index for Panitras (Tree)

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Trewia nudiflora	3	3/29	0.103	0.010	-2.273	-0.234
Acacia nilotica	8	8/29	0.275	0.075	-1.290	-0.354
Phoenix dactylifera	7	7/29	0.241	0.058	-1.422	-0.342
Borassus flabellifer	9	9/29	0.310	0.0961	-1.171	-0.363
Azadirachta indica	2	2/29	0.068	0.004	-2.688	-0.182

Number of Species (S) =5
Total number of individual = 29

$$H = -\{(-0.234)+(-0.354)+(-0.342)+(-.363)+(-0.182)\}$$
$$= 0.767$$

Hmax = ln(S) = ln(5) = 1.609
E = 0.767/1.609
= 0.476
Shanon wiener Diversity= 0.767
Evenness = 0.476

Table 4a: Shanon- Wiener index for Panchpara, Kadamtala (Herb)

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Phyla nodiflora	60	60/572	0.1048	0.1098	-2.263	-0.235
Xanthium strumarium	20	20/572	0.0349	0.0012	-3.381	-0.114
Colocasia esculenta	54	54/572	0.09440	0.0088	-2.364	-0.222
Cyanodon dactylon	135	135/572	0.2360	0.0556	-1.443	-0.340
Eclipta prostrate	10	10/572	0.01748	0.0002	-4.074	-0.069
Mikania micrantha	26	26/572	0.0454	0.0020	-3.101	-0.139
Ipomea carnea	16	16/572	0.02797	0.0007	-3.611	-0.097
Alternenthera philoxeroides	43	43/572	0.07517	0.0056	-2.590	-0.194
Cleome viscosa	18	18/572	0.03146	0.0009	-3.473	-0.107
Polygonum hydropiper	68	68/572	0.1188	0.0139	-2.137	-0.252
Elusine indica	110	110/572	0.1923	0.0368	-1.650	-0.316
Commelina diffusa	12	12/572	0.2097	0.0436	-1.565	-0.327

Total Number of Species (S) = 12
Total Number of Individual(N) = 572

$$H = -\{(-0.235)+(-0.114)+(-0.222)+(-0.340)+(-0.069)+(-0.139)+(-0.097)$$
$$+(-0.194)+(-0.107)+(-0.252)+(-0.316)+(-0.327)\}$$
$$= 2.412$$

Hmax = ln(S) = ln(12)=2.484
E = 2.412/2.484
=0.9710
Shanon wiener Diversity= 2.412
Evenness= 0.9710

Table 4b: Shanon- Wiener index for Panchpara,Kadamtala (Shrub):

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Lippia alba	64	64/197	0.3248	0.1054	-1.124	-0.3650
Solanum torvum	22	22/197	0.1167	0.0131	-2.148	-0.2506
Ricinus communis	56	56/197	0.2842	0.08076	-1.2580	-0.3575
Senna occidentalis	24	24/197	0.12182	0.01484	-2.10521	-0.2564
Ocimum sanctum	3	3/197	0.015228	0.000231	-4.1846	-0.06372
Justicia adhatoda	28	28/197	0.1421	0.02019	-1.9512	-0.2772

Total number of species (S)= 6
Total Number Of Individual =197

H = -{(-0.365)+(-0.250)+(-0.357)+(-0.256)+(-0.063)+(-0.277)}
= 1.568

Hmax = ln(S)= ln (6)=1.791
E= 1.568/1.791=0.875
Shanon Wiener diversity = 1.568
Evenness = 0.875

Table 4c: Shanon- Wiener index for Panchpara,Kadamtala (Tree):

Species	Number	n/N	pi	pi2	ln pi	pi ln pi
Azadirachta indica	2	2/33	0.0606	0.00367	-2.8034	-0.1698
Mangifera indica	3	3/33	0.0909	0.00826	-2.397	-0.217
Trewia nudiflora	1	1/33	0.0303	0.00091	-3.49660	-0.1059
Neolamarckia cadamba	2	2/33	0.0606	0.00367	-2.8034	-0.16988
Sonneratia caseolaris	25	25/33	0.7575	0.5738	-0.2777	-0.210357

Total Number of Species (S) = 5
Total Number of Individual = 33

H = -{(-0.169)+(-0.217)+(-0.105)+(-0.169)+(-0.210)}
=0.87

Hmax = ln (S) =ln (5) = 1.609
E= 0.87/1.609
=0.54
Shanon Wiener Diversity = 0.87
Evenness = 0.54

4. **Similarity** :

Sorenson coefficient (CC) was used to Calculate similarity of two plant communities present in Rupnarayn river bank.

a. Sorenson coefficient for two plant communities present in Benapur and Panitras are:
   a. For Herb, Sorenson's Coefficient (CC) = 2C/(S1+S2) =2*8/(10+10) =0.5
   b. For shrub, Sorensons coefficient (CC) = 2C/(S1+S2) = 2*4/(6+5) = 0.727
   c. For Tree, sorensons Coefficient (CC) = 2C/(S1+S2) = 2*3/(3+5) = 0.75

b. Sorenson coefficient for two plant communities present in Benapur and Panchpara (Kadamtala) are:
   a. For Herb, Sorenson Coefficient (CC) = 2C/(S1+S2) =2*5/(10+12) = 0.454
   b. For shrub, Sorenson Coefficient (CC) = 2C/(S1+S2) =2*3/(6+6) = 0.5
   c. For Tree, Sorenson Coefficient (CC) = 2C/ (S1+S2) = 2*2/(3+6) = 0.44

c. Sorenson coefficient for two plant communities present in Panitras and Panchapara (Kadamtala)
   a. For herb Species, Sorenson Coefficient (CC) = 2C/(S1+S2) = 2*4/(10+10) =0.4
   b. For Shrub Species, Sorenson Coeffcient (CC) = 2C/ (S1+S2) =2*4/(5+6) = 0.727
   c. For Tree species, Sorenson Coefficient (CC) = 2C/ (S1+S2) =2*2/(6+5) = 0.363

Table 5: List Of Herbal Plants Collected For Nanoparticle Synthesis:

Sl. No	Scientific Name	Common Name	Family	Parts Used
1	*Acacia nilotica*	Babla	Fabaceae	Leaves
2	*Ocimum sanctum*	Tulsi	Lamiaceae	Leaves
3	*Azadirachta indica*	Neem	Meliaceae	Leaves
4	*Justicia adhatoda*	Basak	Acanthaceae	Leaves
5	*Mikania micrantha*	Rabonlata	Asteraceae	Leaves
6	*Phyla nodiflora*	-	Verbenaceae	Leaves
7	*Eclipta prostrate*	Kesuth	Asteraceae	Leaves
8	*Senna occidentalis*	Kalkesunda	Fabaceae	Leaves

Table 6: Antimicrobial Activity of Synthesized nanoparticles from Herbal plants

[*Klebsiella* sp (K. sp), *Bacillus cereus* (Bc), *Aspergillus niger* (An), *Rizopus stolonifer* (Rs)]

Samples	Leaf Extracts	Inhibition zone (mm)			
		Bacteria		Fungi	
		K sp	Bc	An	Rs
Copper Nanoparticle	*Acacia Nilotica*	7	8	-	-
	Ocimum sanctum	6	7	-	-
	Azadirachta indica	7	8	-	-
	Justicia adhatoda	5	9	3	-
	Mikania micrantha	3	9	-	-
	Phyla nodiflora	8	7	-	-
	Eclipta prostrata	13	6	6	-
	Senna occidentalis	7	5	5	6
Zinc Oxide Nanoparticle	*Acacia nilotica*	5	10	4	-
	Ocimum sanctum	3	7	2	-
	Azadirachta indica	3	5	5	-
	Justicia adhatoda	9	6	-	-
	Mikania micrantha	5	8	10	-
	Phyla nodiflora	5	8	-	-
	Eclipta prostrata	7	6	-	-
	Senna occidentalis	5	5	-	-
Silver Nanopaticle	*Acacia Nilotica*	7	17	2	-
	Ocimum sanctum	11	9	13	-
	Azadirachta indica	13	10	5	-
	Justicia adhatoda	10	12	10	-
	Mikania micrantha	2	4	-	-
	Phyla nodiflora	15	8	-	-
	Eclipta prostrata	--	5	10	-
	Senna occidentalis	-	11	14	-
Control (plant extracts and solutions)	*Acacia nilotica*	5	7	-	-
	Ocimum sanctum plant extract	-	-	1	-
	Azadirachta indica	4	-	-	-
	Justicia adhatoda	-	-	-	-
	Mikania micrantha	-	-	-	-
	Phyla nodiflora	-	-	-	-
	Eclipta alba	5	5	-	-
	Senna occidentalis	4	-	-	-
	Copper Sulphate solution	-	-	-	-
	Zinc sulphate solution	-	-	1	-
	Silver nitrate solution	-	-	1	-
	Distilled water	-	-	-	-

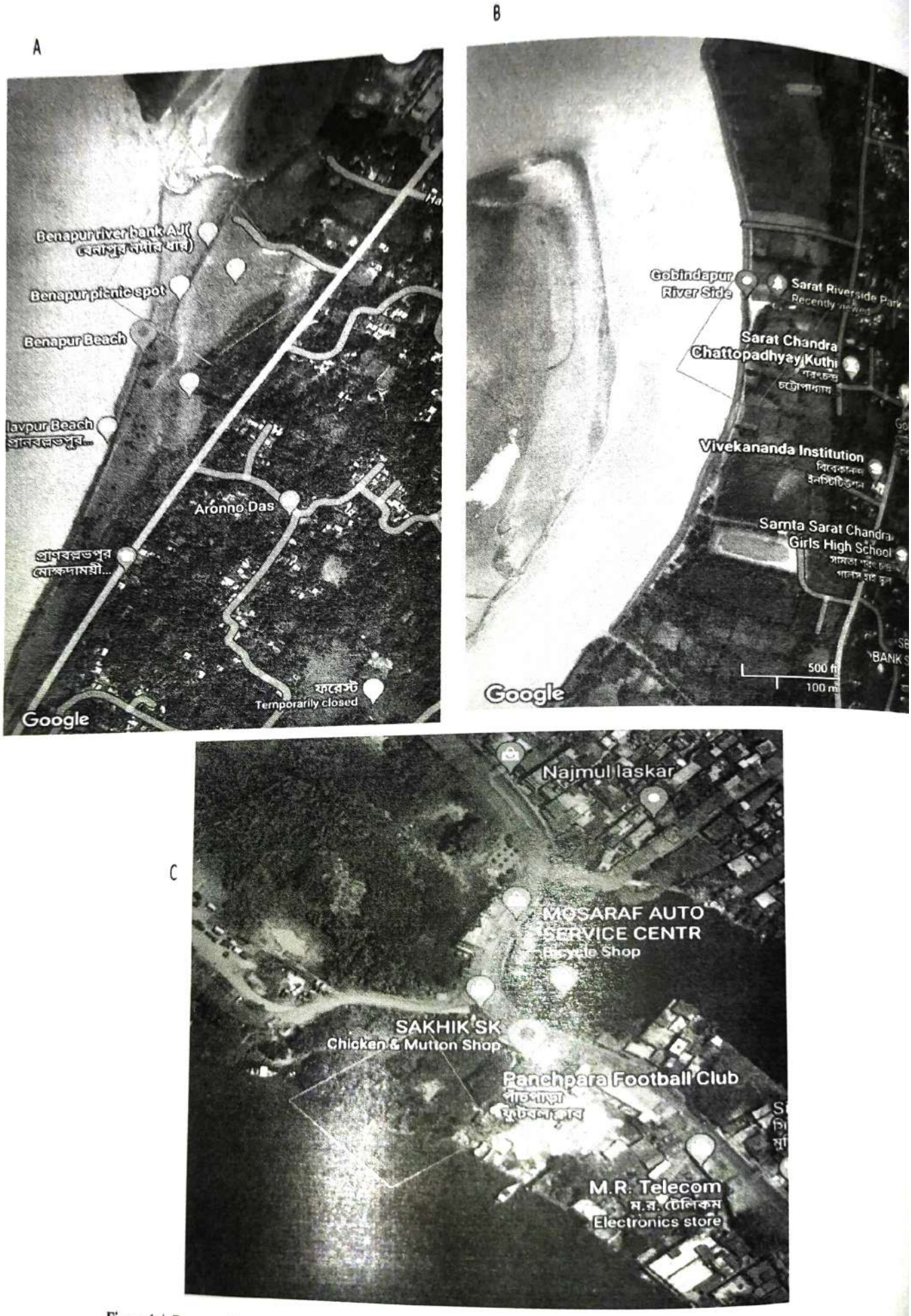


Figure 1 A Benapur Sampling Site B Panitras Sampling Site C Panchpara Sampling Site



Figure 2 Vegetation at collection sites A- Benapur B- Panitras C- Panchpara

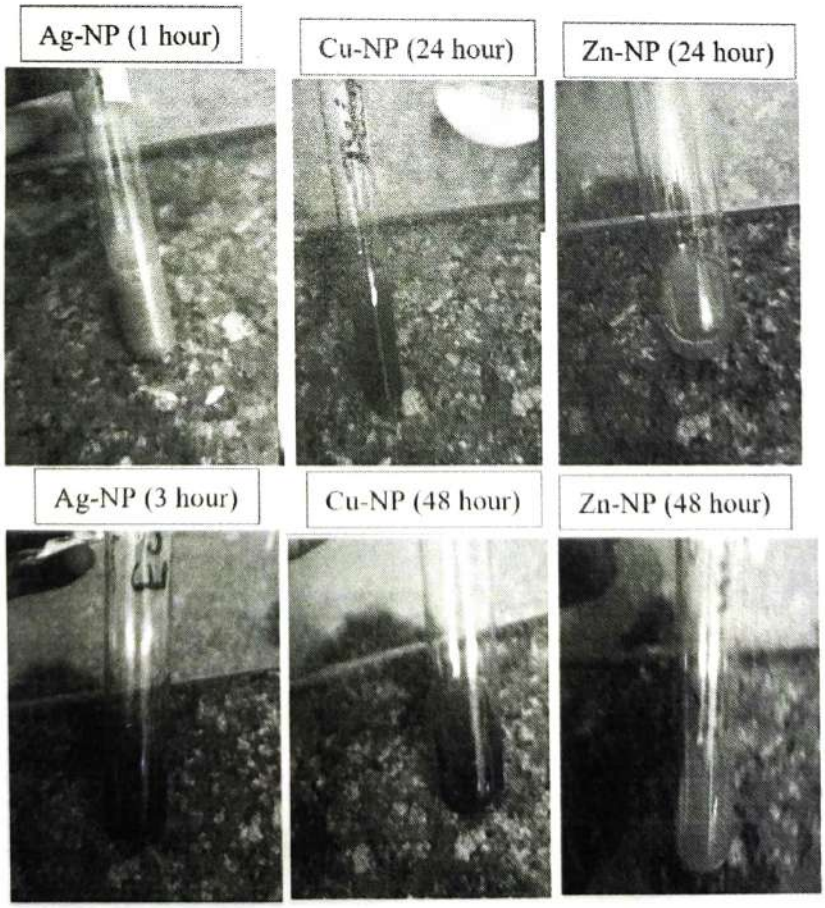


Figure 3 Color changes indicating synthesis of Silver (Ag), Zinc (Zn) and Copper (Cu) Nanoparticles at different intervals

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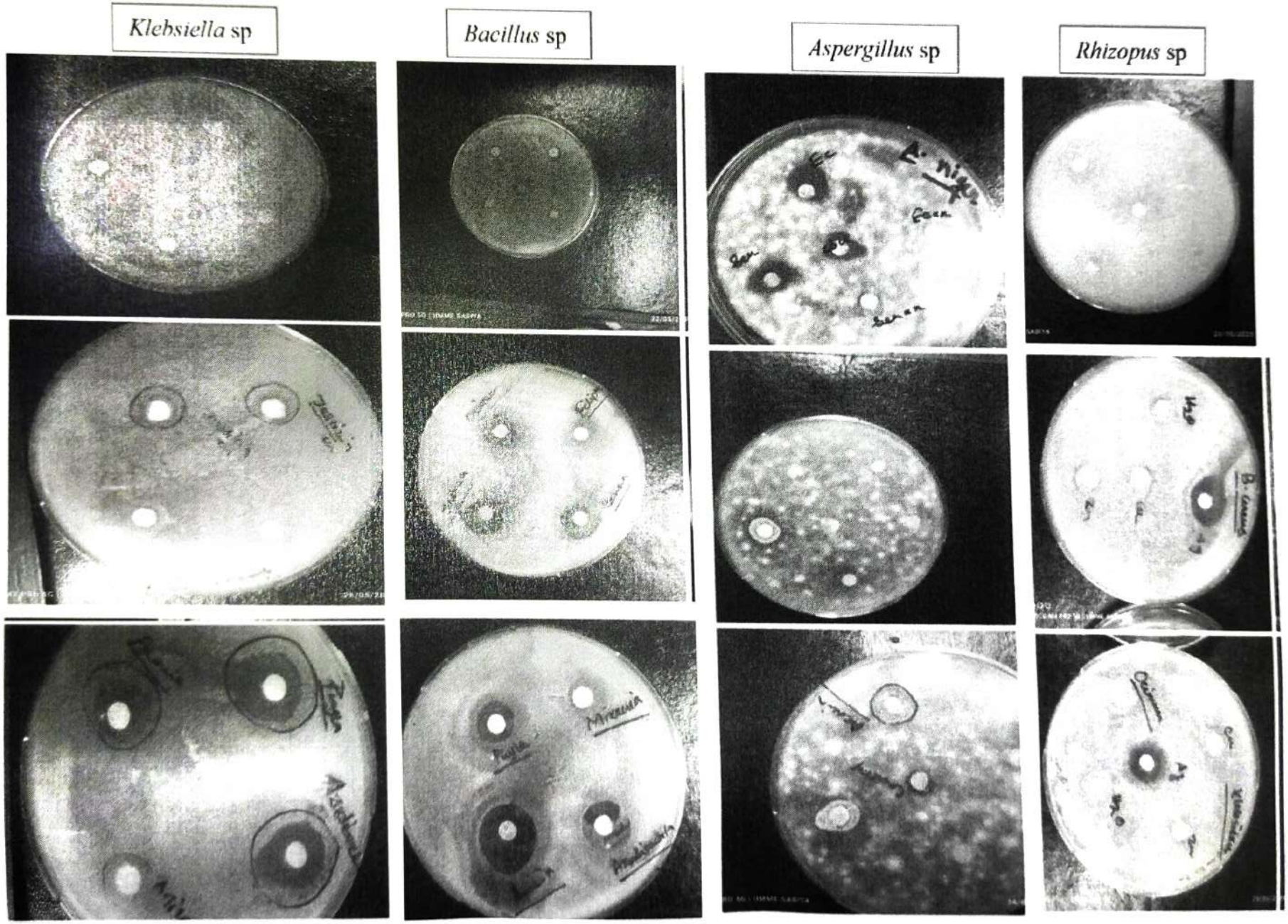


Figure 4 - Zone of inhibition using Ag , Cu and Zn nanoparticles (top to bottom) synthsized from different herbal plants against four microbial strains

4. Conclusions

The ecological study was conducted to assay the medicinal plant diversity from two selected areas of West Bengal. The change in vegetation pattern with respect to medicinal plants was recorded by comparison with collected data and literature. The effect of climatic changes over vegetation occurrence needs further elaborate studies for conclusive analysis. Detailed study to establish the effect of edaphic and climatic conditions on secondary metabolite production may be taken up during future studies. Use of nanomedicine demands adequate evaluation of the associated safety and risk factors. Nanophytomedicine holds the potentiality of treatment of diseases with reduced side effects. Screening and phytochemical extraction have long been associated with problems such as low amount, variable distribution depending on plant age and tissue types as well as surrounding environmental conditions. Due to extreme size reduction and material interaction, alterations in the physicochemical and structural properties of herbal molecules may lead to decreased efficacy and toxicological effects (Das and Sharangi 2020, Ansari et al 2012). Enhancement of bioavailability by designing a delivery system which will release a proper dose of the drug at the target site is needed (Shakeri and Sahebkar 2016). This will not only help to bypass allergic and hypersensitive responses but also internally strengthen the patient (Bonifacio et al. 2014). Use of nano-dosage form of herbal medicines aims at better solubility, sustained delivery, protection from physical and chemical agents, reduced toxicity, and improved tissue macrophages. The present study is a preliminary attempt to synthesize nano particlescapable of targeting therapeutically important secondary metabolites to microbial cells. The study has been entirely done using *in vitro* system. Various advanced techniques for identification and characterization of nanophytomedicine are being utilized (Das and Sharangi 2020). Amalgamation of traditional herbal remedies and futuristic nanotechnology paves way for disease combat in the coming days.

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Qualitative Phytochemical Profiling of Secondary Metabolites in Hydroalcoholic Extracts of Medicinal Plants: A Comparative Study of Ocimum sanctum, Azadirachta indica, and Withania somnifera

Supriti Paul[1], Angira Chaudhuri[2]

[1]Assistant Professor, Department of Chemistry, Bethune College.

[2]Student, Department of Chemistry, Bethune College

Abstract

Secondary metabolites—such as alkaloids, flavonoids, terpenoids, tannins, and phenolics—constitute the cornerstone of the pharmacological efficacy of traditional medicinal plants. This review investigates qualitative phytochemical screening methodologies for detecting these bioactive compounds in hydroalcoholic extracts of Ocimum sanctum, Azadirachta indica, and Withania somnifera. These Ayurvedic plants are widely utilized in ethnomedicine and have been studied for their antimicrobial, antioxidant, and anticancer properties.

The present work synthesizes findings from recent literature (2024–2025) and critically examines rapid colorimetric and precipitation-based assays, which serve as preliminary but valuable techniques in natural product discovery pipelines. These techniques, though classical, remain relevant in modern pharmacognosy due to their accessibility, cost-effectiveness, and utility in guiding chromatographic and spectrometric analyses.

This review also explores the synergistic use of traditional phytochemical methods with advanced tools such as high-performance liquid chromatography (HPLC) and liquid chromatography–mass spectrometry (LC-MS/MS), fostering a holistic approach to metabolite profiling. A comparative analysis in the form of tables and schematic charts presents the qualitative diversity of metabolites across the selected plant species.

Limitations related to solvent selection, extract variability, and assay specificity are discussed, along with proposed future directions that emphasize method standardization and the application of hyphenated analytical technologies. By bridging classical phytochemical analysis with contemporary pharmacological insights, this review underscores the enduring scientific relevance of qualitative phytochemical screening in the discovery and validation of plant-derived therapeutics.

Keywords : Plant secondary metabolites, Bioautography, TLC-DB, Hydroalcoholic plant extract, Antimicrobial b autography assay.

1. Introduction

Medicinal plants have historically played a pivotal role in traditional healthcare systems, from Ayurveda a Traditional Chinese Medicine to African and Indigenous pharmacopoeias. In recent decades, the global resurgence interest in plant-based therapeutics has been driven by increased recognition of the ecological and therapeu significance of secondary metabolites (Kumar et al., 2024).[1,2]

Unlike primary metabolites, which are directly involved in growth and metabolic maintenance (e. carbohydrates, proteins, and lipids), secondary metabolites are specialized compounds synthesized as adapti responses to environmental stimuli. These include alkaloids, flavonoids, tannins, saponins, terpenoids, steroids, a phenolic compounds. [2,4]Their ecological roles span defense against herbivores and pathogens, UV protection, a interspecies communication. Importantly, these compounds exhibit a wide range of bioactivities includi antimicrobial, antioxidant, anticancer, anti-inflammatory, and immunomodulatory properties (Sharma & Gupta, 20 Harborne, 2017).

The World Health Organization (2024) has emphasized the urgency of discovering new antimicrobial agents response to escalating antibiotic resistance. Concurrently, the demand for plant-derived, sustainable, and biocompati therapeutic agents continues to grow[12,13 and 17]. These trends have reinvigorated the domain of phytochemi screening as a foundational step in natural product-based drug discovery.

Hydroalcoholic extraction—typically employing ethanol-water mixtures in 70:30 or 80:20 v/v ratios—h

gained prominence due to its efficacy in extracting both polar and moderately nonpolar secondary metabolites (Patel & Singh, 2024). Ethanol's GRAS (Generally Recognized As Safe) status makes it a preferred solvent in both pharmaceutical and nutraceutical applications.

Qualitative phytochemical screening involves simple, rapid, and cost-effective assays that employ visual detection of color changes or precipitate formation as indicators of specific metabolite classes. These include Mayer's test for alkaloids, alkaline reagent tests for flavonoids, and Salkowski's reaction for terpenoids. Despite limitations in sensitivity and specificity, these tests provide preliminary data essential for selecting extracts for further bioassay and structural elucidation via high-resolution analytical techniques such as LC-MS/MS and nuclear magnetic resonance (NMR) spectroscopy (Jones et al., 2025).

Notably, a 2024 investigation in Phytochemistry revealed novel flavonoids in O. sanctum exhibiting significant anti-inflammatory activity. Similarly, terpenoidal fractions from A. indica demonstrated potent antibacterial activity against multidrug-resistant strains (Smith et al., 2024). These examples illustrate the relevance of ethnomedicinal leads in contemporary drug development pipelines.[21]

This review aims to (i) consolidate qualitative screening methodologies for hydroalcoholic extracts, (ii) evaluate their pharmacological significance in validating traditional claims, and (iii) highlight methodological advances and future directions in the domain of plant-based drug discovery.

2. Materials and Methods

2.1. Plant Material Collection and Authentication

Three medicinal plants were selected based on their widespread use in traditional Indian medicine and documented pharmacological profiles:

- *Ocimum sanctum (leaves)*
- *Azadirachta indica (bark)*
- *Withania somnifera (roots)*

Plant materials were collected from verified botanical sources and authenticated by a certified taxonomist. Samples were washed thoroughly with distilled water to remove surface contaminants, shade-dried at ambient temperatures (25–30°C) to prevent photodegradation of labile constituents, and then pulverized using a mechanical grinder to obtain a uniform coarse powder (Patel & Singh, 2024).[11,12]

2.2. Hydroalcoholic Extraction

Extraction was carried out using two methods with ethanol:water (70:30 v/v):

- Maceration: 100 g of powdered plant material was soaked in 500 mL of the solvent mixture for 48 hours at room temperature. The mixture was filtered using Whatman No. 1 filter paper and concentrated using a rotary evaporator at 40°C.
- Soxhlet Extraction: 50 g of plant powder was continuously extracted with 300 mL of solvent over 6–8 hours using a Soxhlet apparatus. The extracts were concentrated and stored at 4°C in airtight, amber-colored containers to prevent degradation.

2.3. Qualitative Phytochemical Screening

The concentrated extracts were subjected to standard qualitative tests as described by Harborne (2017) and corroborated by recent literature:

Metabolite	Test	Positive Indication
Alkaloids	Mayer's Test	Creamy white precipitate
Flavonoids	Alkaline Reagent Test	Yellow color, reversible with HCl

Tannins	Ferric Chloride Test	Blue-black or green precipitate
Saponins	Foam Test	Persistant froth upon shaking
Terpenoids	Salkowski's Test	Reddish-brown interface
Steroids	Libermann-Burchard Test	Blue-green coloration

Table 1 standard qualitative tests of concentrated plant extracts

All results confirmed in triplicate screening, adapted from preliminary phytochemical screening techniques descril by Harborne(2017)

3. Results and Discussion

3.1. Metabolite, Profiling and Distribution

Qualitative assays confirmed the presence of diverse secondary metabolites in all three plant extracts. T results are summarized in Table 3.O. *sanctum* exhibited a high abundance of flavonoids and phenolics (~95% correlating with its reported antioxidant potential. *A. indica* demonstrated strong reactivity for tannins (~80%) a terpenoids, supporting its traditional use as an antimicrobial and anti-inflammatory agent. *W. somnifera* show significant alkaloid content (~90%), suggesting a mechanistic basis for its adaptogenic and immunomodulatory effects

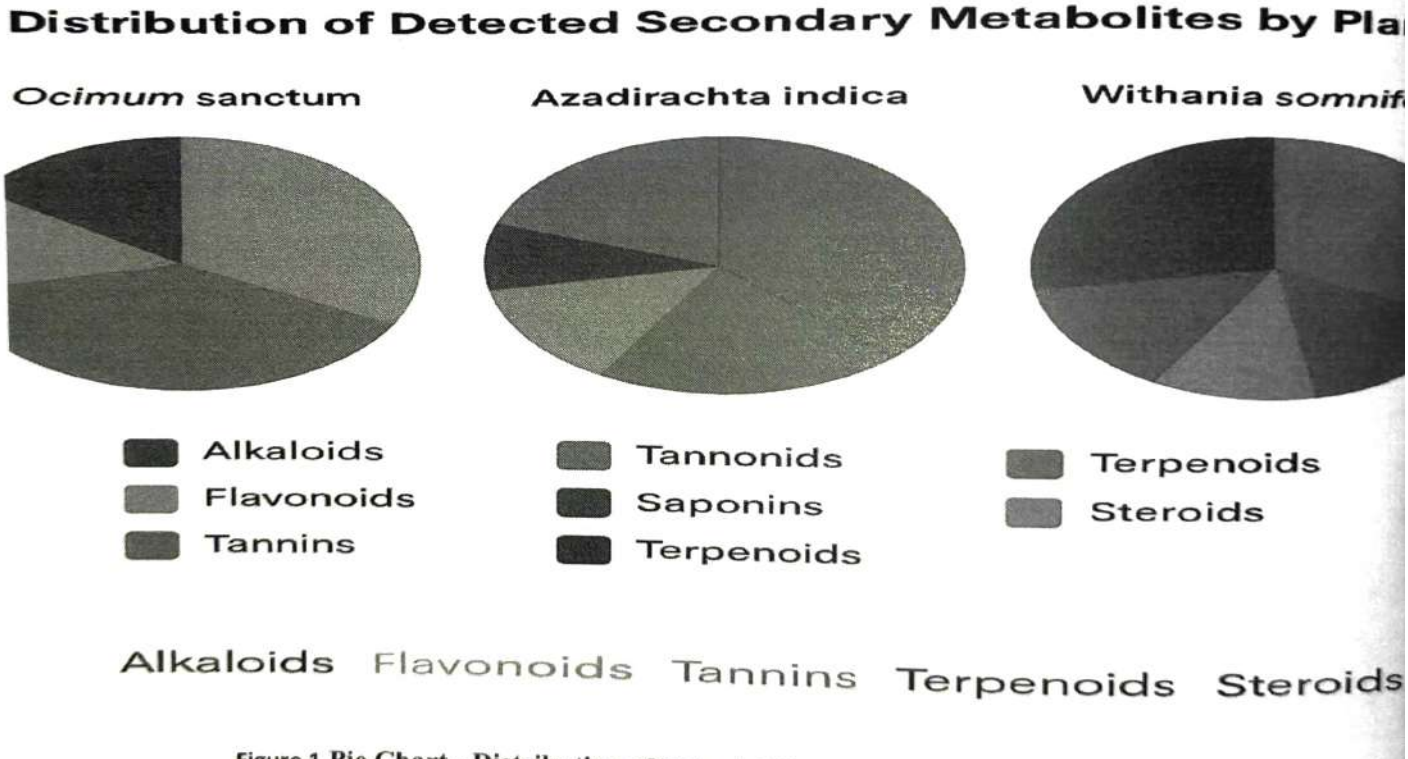


Figure 1 Pie Chart - Distribution of Detected Secondary Metabolites by plants

Phytochemical Group	Octimum sanctum (Leaves)	Azadirachta indica (Bark)	Withania somnifera (Roots)
Alkaloids	+ + (Moderate)	+ (Mild)	+ + + (High)
Flavonoids	+ + + (High)	+ + (Moderate)	+ (Mild)
Tannins	+ (Mild)	+ + + (High)	+ (Mild)

Saponins	+ + (Moderate)	+ (Mild)	+ + (Moderate)
Terpenoids	+ + (Moderate)	+ + + (High)	+ + (Moderate)
Steroids	+ (Mild)	+ + (Moderate)	+ + + (High)
Phenolics	+ + + (High)	+ + (Moderate)	+ + (Moderate)

Table 2 presence of diverse secondary metabolites in all three plant extracts

Note: + = Mild presence

+ + = Moderate presence

+ + + = High presence

All screening confirmed in triplicate screening. (n=3)

Adapted from preliminary phytochemical screenning techniqes describrd by Harborne(2017)

3.2. Pharmacological Correlations

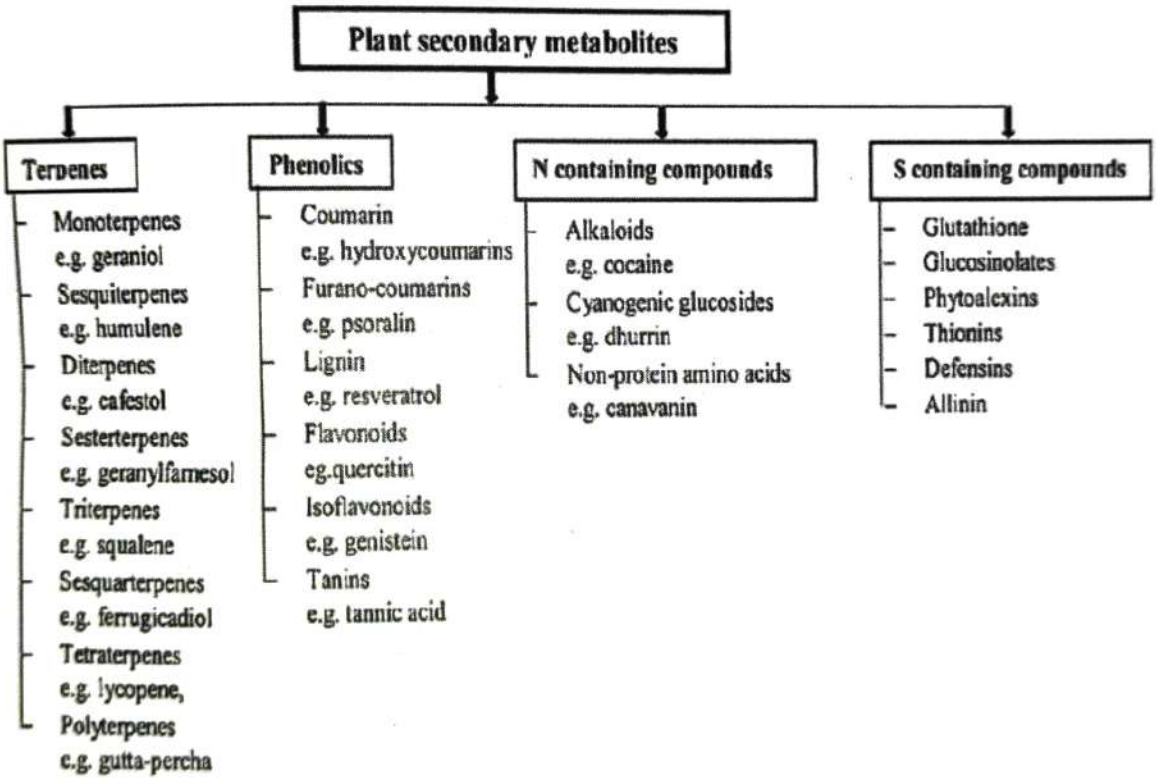


Figure 2 Types of Secondary Metabollites found in Plant Extracts

- Alkaloids in *W. somnifera* are associated with antimicrobial and antistress activity, confirmed by a 2024 Journal of Ethnopharmacology study.
- Flavonoids and phenolics in O. sanctum have demonstrated ROS-scavenging activity, in line with data from Phytochemistry Letters (2025).
- Tannins in A. indica exhibit protein

3.3. Methodological Challeneges and Advances

While qualitative assays offer quick results, they are inherently nonspecific. Their subjective nature and reliance on visual end points make them unsuitable for quantitative profiling. Additionally, environmental factors such as soil quality, climate, and harvest time significantly influence metabolite concentrations, underscoring the need for standardized protocols.[5,6]

Modern analytical techniques such as gas chromatography-mass spectrometry (GC-MS), LC-MS/MS, and capillary electrophoresis offer improved resolution, sensitivity, and specificity. Hyphenated techniques, especially LC-MS/MS, enable the identification of structurally complex and bioactive constituents in mixed plant matrices.

4. Conclusion

This review affirms the utility of qualitative phytochemical screening in the preliminary evaluation of medicinal plant extracts, specifically hydroalcoholic fractions of Ocimum sanctum, Azadirachta indica, and Withania somnifera. The confirmed presence of bioactive classes such as alkaloids, flavonoids, terpenoids, tannins, and saponins supports the ethnomedicinal use of these species and provides a rational basis for their pharmacological applications.

Despite their limitations, qualitative assays continue to serve as indispensable tools in natural product research due to their ease of execution and cost-effectiveness. However, to ensure scientific rigor and reproducibility, these methods must be complemented by chromatographic and spectrometric analyses that enable compound-specific identification and quantification.

Future research should focus on the standardization of extraction protocols, integration of chemometric analysis, and in silico screening for bioactivity prediction. Furthermore, interdisciplinary collaborations between phytochemists, pharmacologists, and bioinformaticians will be essential in advancing the field of plant-based drug discovery.

By bridging traditional phytochemical techniques with modern analytical technologies, researchers can more effectively harness the therapeutic potential of medicinal plants, thereby contributing to the development of novel, sustainable, and biocompatible therapeutic agents.

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Star Type Classification Using Hertzsprung-Russell Diagram, and Machine Learning Technique

Saptarshi Mondal

Department of Statistics, Bethune College, Kolkata

Abstract:

This paper aims to classify stars based on their properties using a combination of the Hertzsprung-Russell (H-R) diagram and a machine learning algorithm. This paper utilizes a data set containing observations of stars. The analysis begins with the creation of the Hertzsprung-Russell diagram using the observed data. To further enhance the classification accuracy, random forest technique is employed. The results provide valuable insights into the classification of stars based on their properties.

Keywords : Hertzsprung-Russell Diagram, Machine Learning, Random Forests.

1. Introduction

Astrophysics and astronomy significantly rely on the classification of stars to comprehend stellar evolution and the attributes and actions of diverse star types. The Hertzsprung-Russell (H-R) diagram (Figure 1.1) visually represents stellar populations, showing the distribution and characteristics of stars across different regions. This diagram highlights key features such as the main sequence, giant stars, white dwarfs, and other evolutionary stages providing extensive information on the nature and life cycle of stars. Traditionally, star classification has been based on spectral characteristics, determined by analysing emitted starlight.

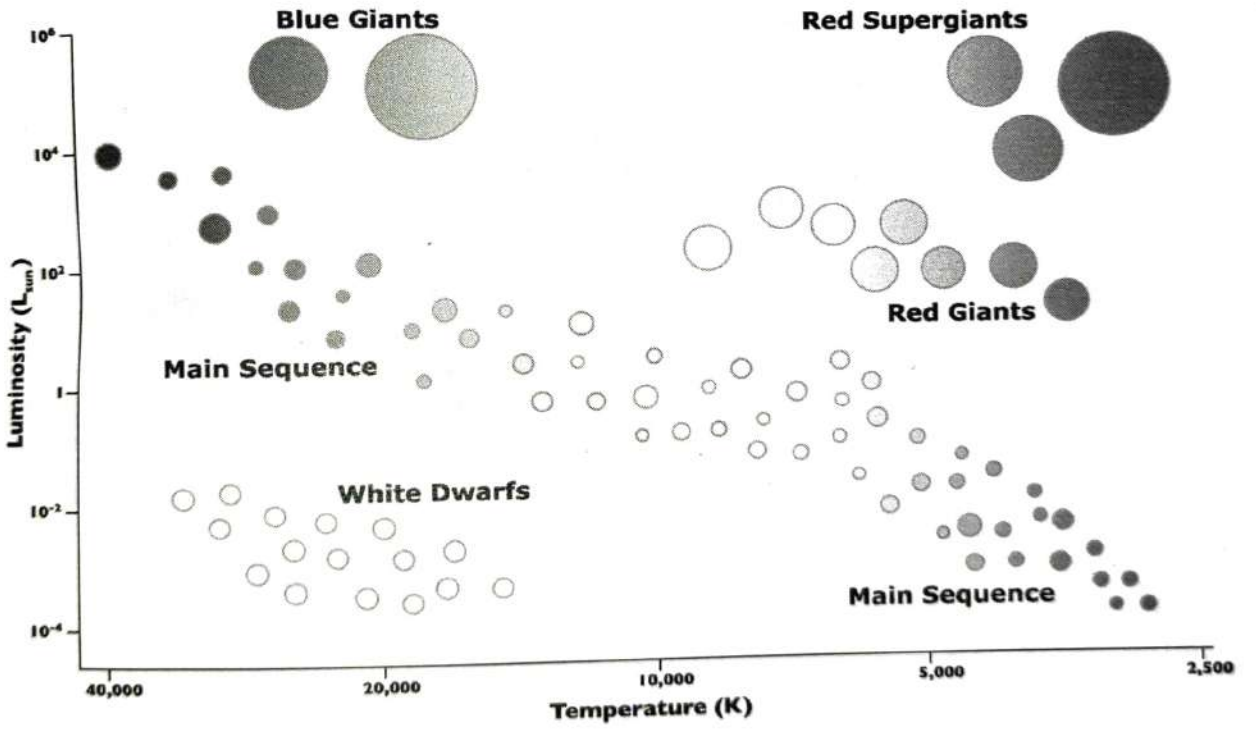


Figure 1.1: Hertzsprung-Russell diagram

This paper aims to classify stars based on their properties using a combination of the Hertzsprung-Russell (H-R) diagram and a machine learning algorithm. The study explores various regions of the H-R diagram and their corresponding star types, examining the characteristics and properties of each category. Furthermore, it leverages a machine learning technique to develop a classification model that accurately categorizes stars based on observable properties. This approach could automate the classification process and enhance the efficiency of identifying star types. The findings of this research have implications for astrophysics and astronomy, as accurate star type classification

advances our understanding of stellar evolution. The integration of the Hertzsprung-Russell diagram and machine learning techniques also paves the way for more precise and efficient classification methods in the future.

The classification of stars (Figure 1.2) is a cornerstone of astrophysics, offering profound insights into their evolution, physical properties, and the dynamics of galaxies. Historically, stellar classification relied on spectral analysis, categorizing stars based on their emitted light. The advent of the Hertzsprung-Russell (H-R) diagram marked a significant leap, providing a graphical tool to understand stellar populations by plotting luminosity against temperature. This diagram visually groups stars into distinct evolutionary stages such as the main sequence, giants, and white dwarfs, revealing fundamental relationships between their properties.

In recent years, the intersection of astronomy and machine learning has opened new avenues for more accurate and efficient star classification. Machine learning algorithms, particularly random forests, have shown promise in handling large astronomical datasets and identifying complex patterns that might be missed by traditional methods. This approach is poised to automate classification processes, improving the speed and reliability of star type identification.

Several recent studies highlight the growing trend of using machine learning for stellar classification. For instance, a 2023 study by E. Paunzen et al. in *Astronomy & Astrophysics* explored machine learning methods for classifying chemically peculiar stars, demonstrating the effectiveness of these techniques in distinguishing subtle stellar characteristics. Similarly, a 2022 article by S. R. Maji et al. in *Monthly Notices of the Royal Astronomical Society* utilized deep learning for spectroscopic classification of stars, showcasing how neural networks can accurately categorize stars based on their intricate spectral features. The application of random forests specifically has been a recurring theme due to its robustness and ability to handle high-dimensional data. A 2021 paper by C. M. A. Costa et al. in *Astronomy & Computing* presented a random forest model for classifying variable stars, emphasizing its interpretability and high accuracy. These works collectively underscore the increasing reliance on sophisticated computational techniques to augment and, in some cases, revolutionize classical astronomical classification methods. The integration of the H-R diagram with machine learning, as proposed in the current study, aligns with these contemporary advancements, promising a synergistic approach to enhance our understanding of stellar populations.

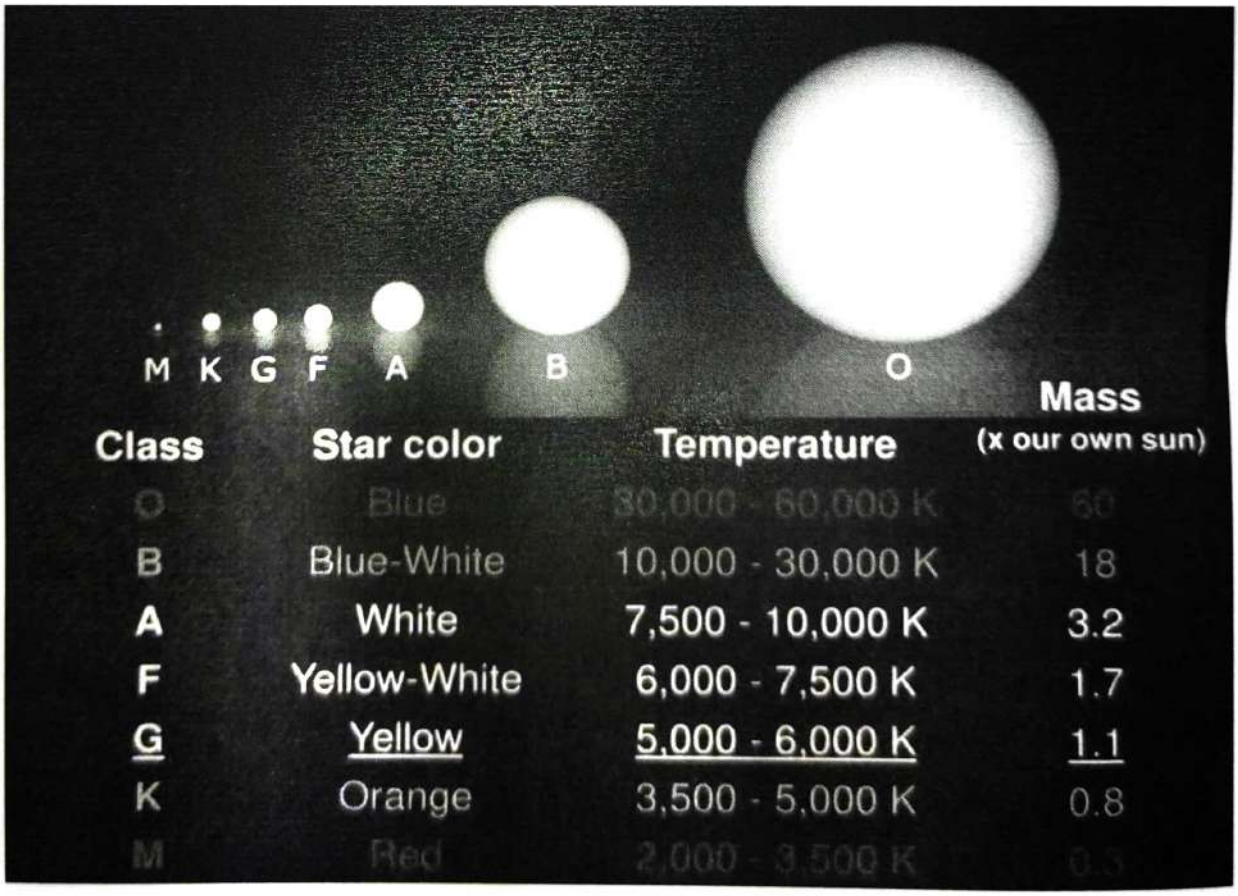


Figure 1.2: Star Classification

2. Methods

2.1. Data Collection

A comprehensive data set of stars has been identified and gathered withknown properties, including temperature, luminosity, spectral class, and other relevant features. The data set covers a diverse range of star types to ensure a representative sample.

2.2. Definition

Let us define the specific data requirements for star type classification:

1. **Temperature :** Temperature of a star refers to its thermal energy or heat. The temperature scale used in stellar astronomy is typically expressed in Kelvin (K). The surface temperature of stars can range from a few thousand Kelvin for cooler stars (such as red dwarfs) to tens of thousands or even millions of Kelvins for hotter stars (such as blue giants or white dwarfs).
2. **Luminosity:** Luminosity of a star is one of the key properties used to describe and classify stars. It is often expressed in units of watts (W) or solar luminosity, where 1 solar luminosity is equivalent to the luminosity of our Sun.
3. **Radius :** Radius of a star refers to the distance from the centre of the star to its outer boundary. It is a measure of the star's size or extent and is an important parameter used to characterize and classify stars. The radius of a star is typically expressed in units of kilometres (km) or solar radii, where 1 solar radius is approximately equal to the radius of our Sun.
4. **Absolute magnitude :** It refers to the measure of luminosity, independent of its distance from the observer. It is a standardized measurement. The formula for determining absolute magnitude (M) is: $M = m - 5(log_{10}(d) - 1)$, where m is the observed apparent magnitude, and d denotes the distance to the star.

2.3. Data Exploration

An initial overview of the data set was conducted to understand its structure, size, and format. After examining it was found that the number of instances (stars) was 240 and the types of features available was 7. Visualization techniques were applied to gain insights into the data. This includes pairs plot, histograms to explore the relationships, and distributions. A pairs plot, also known as a scatter-plot matrix or pairwise scatter-plot, is a visual representation of the relationships between multiple variables in a data set. It displays scatter plots of every pair of variables against each other, forming a grid-like matrix. Each cell in the matrix represents the scatter plot of two variables. The pairs plot allows for the simultaneous examination of multiple variable interactions, making it a useful exploratory tool in data analysis. It enables the assessment of correlations between variables, allowing for insights into their interdependencies. In a pairs plot, each point on a scatter plot represents an observation in the data set, and the positioning of points in relation to the axes indicates the values of the corresponding variables.

In this work, a pairs plot has been created to visualize the relationships and interactions between temperature, luminosity, radius, and absolute magnitude.Four histograms have been created to explore the distribution of four key variablesin the dataset, namely, temperature, luminosity, radius, and absolute magnitude. The histograms allowed for the visualization of the distribution of each variable.

2.4. Hertzsprung-Russell diagram

The collected data was plotted on the Hertzsprung-Russell diagram, with luminosity on the y-axis and effective temperature (or colour) on the x-axis. The distribution of stars was visualized and key features such as the main sequence, giant stars, white dwarfs, and other evolutionary stages were identified.

2.5. Machine Learning Model Selection

In machine learning, instead of explicitly programming rules, the computer is trained to learn patterns. The performance of the models is typically evaluated using metrics such as accuracy, precision etc. This part of the paper involves identifying a model which is suitable for the classification of stars. The goal is to select a model that can effectively learn from the Hertzsprung-Russell diagram features and accurately classify stars into their respective types. Random forests have been chosen as an appropriate machine learning algorithm for star type classification.

Random Forests: The Random Forest technique (Figure 2.1) is helpful in enhancing classification accuracy due to several key characteristics:

- **Ensemble Learning (Wisdom of the Crowd) :** The core idea behind Random Forests is the concept of "wisdom of the crowd". Instead of relying on a single decision tree, Random Forests build multiple decision trees and combine their predictions through voting or averaging. This ensemble approach generally leads to more stable and accurate predictions compared to individual decision trees.
- **Reduced Overfitting :** Random Forests are less prone to over fitting compared to individual decision trees. Overfitting occurs when a model learns the training data too well, leading to poor performance on unseen data. By averaging predictions across multiple trees, the Random Forest model becomes more robust to noisy or complex data.
- **Handling Large Datasets with Outliers and Missing Data :** The technique can effectively handle large datasets that contain outliers and missing data. This is achieved by the averaging of predictions across its multiple constituent trees.

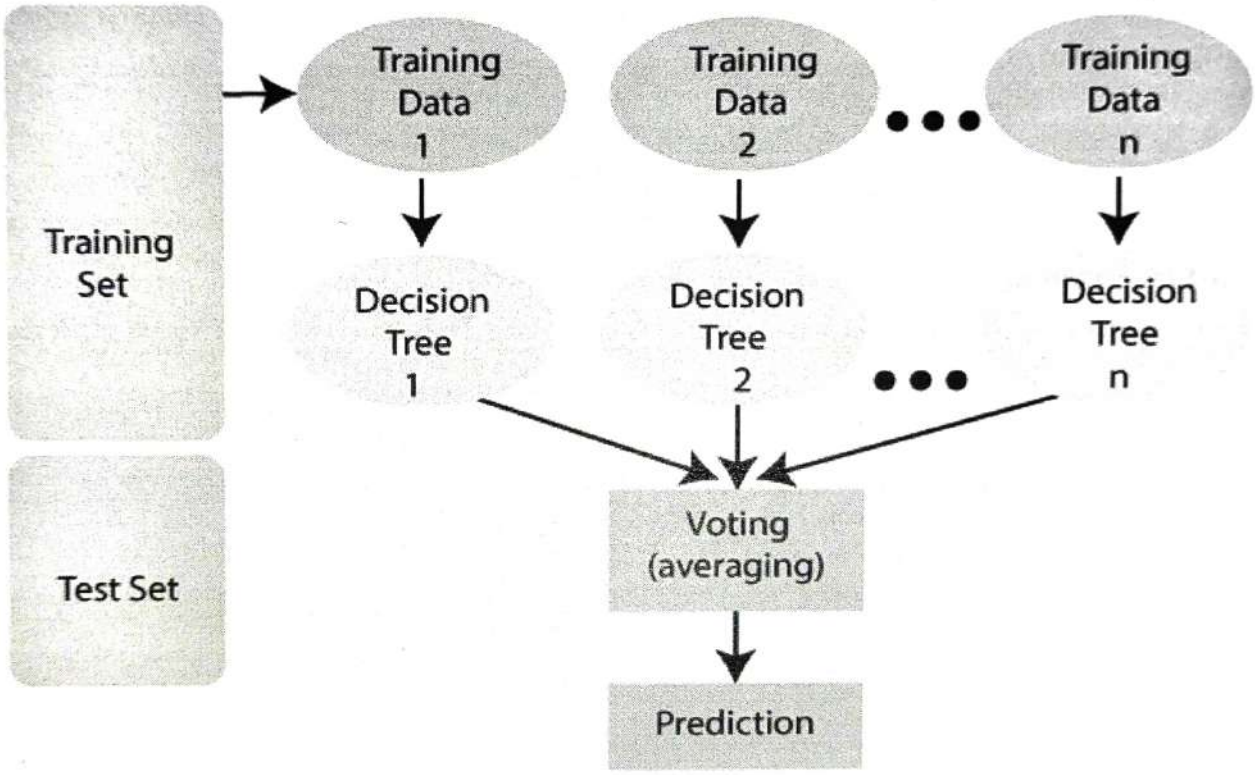


Figure 2.1: Random Forests Classifier

Training and Testing: This part involves dividing the available data into two parts (train and test), and using them to evaluate the model. The following steps were carried out:

1. **Data Split :** The available data, consisting of Hertzsprung-Russell diagram features and corresponding star type labels, was divided into 70% training and 30% testing sets.
2. **Training Data :** Different features extracted from the Hertzsprung-Russell diagram served as the input variables, and the corresponding star types were the target variable.
3. **Model Training :** Next, the random forests model was trained using the training data.
4. **Model Evaluation :** The testing set was used to assess its performance on unseen instances. The model made predictions on the testing data, and the predicted star types were compared with the actual star types.
5. **Performance Assessment :** Finally, the model's performance was analysed and compared against predefined criteria.

3. Results

This section of the paper presents the findings and outcomes of the classification analysis. It highlights the performance of pairs plot, histograms, Hertzsprung-Russell diagram. Random Forests and its ability to accurately classify star types based on the selected feature are also highlighted. Let's have a look at the summary statistics (Figure 3.1) of the data.

```
  Temperature       Luminosity          Radius          Absolute_magnitude
Min.   : 1939   Min.   :      0.0   Min.   :   0.0084   Min.   :-11.920
1st Qu.: 3344   1st Qu.:      0.0   1st Qu.:   0.1027   1st Qu.: -6.232
Median : 5776   Median :      0.1   Median :   0.7625   Median :  8.313
Mean   :10497   Mean   :107188.4   Mean   : 237.1578   Mean   :  4.382
3rd Qu.:15056   3rd Qu.:198050.0   3rd Qu.:  42.7500   3rd Qu.: 13.697
Max.   :40000   Max.   :849420.0   Max.   :1948.5000   Max.   : 20.060
```

Figure 3.1: Summary Statistics

A concise numerical summary of the main characteristics or features of the variables of the dataset can be seen.

3.1. Visualization Results

Visual representations of the data include pairs plot (Figure 3.2) and histograms (Figure 3.3), showing the relationships and distributions of the variables.

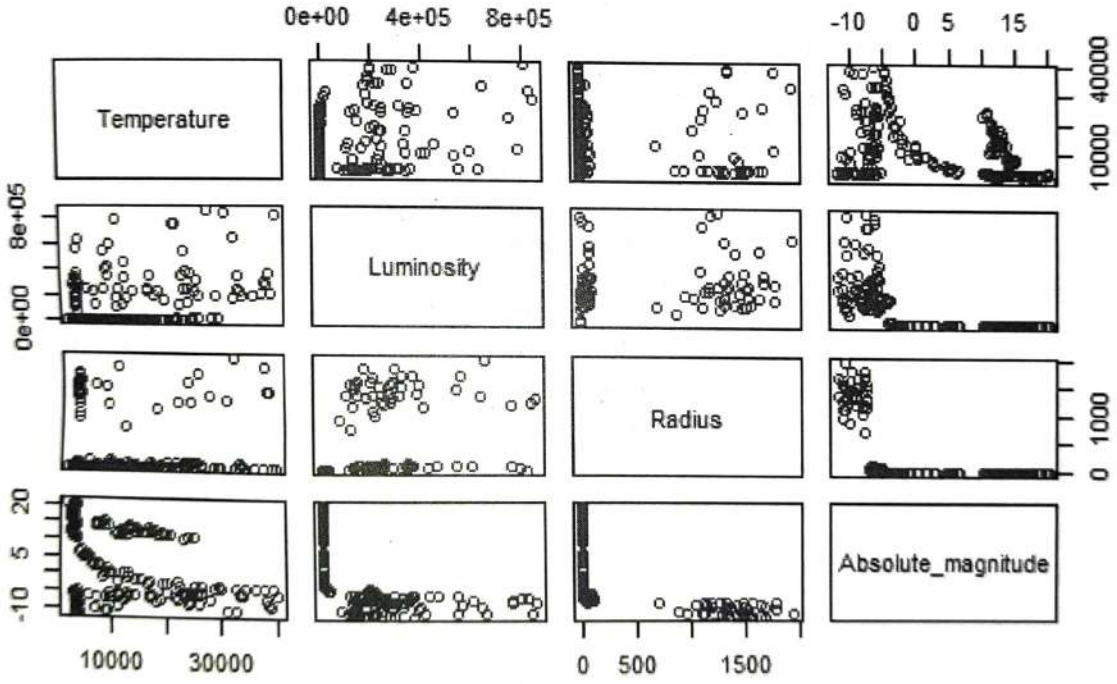


Figure 3.2: Pairs plot

These visuals provide an intuitive understanding. The patterns in the scatterplots indicate the nature of the relationship between variables. Temperature-Luminosity and Temperature-Radius have no common patterns, whereas Temperature-Absolute Magnitude shows a nonlinear relation-ship (curved pattern). scatterplots of Luminosity-Radius, Luminosity-Absolute Magnitude and Radius-Absolute Magnitude show clusters or groups of points, or no discernible pattern (random scattering).

Interpreting a histogram involves analysing the distribution and characteristics of a single variable. No histogram is bell-shaped distribution known as a normal or Gaussian distribution. The distributions of Temperature, Luminosity and Radius are asymmetrical, viz. positively skewed (tail to the right). Skewness indicates the presence of outliers or the influence of certain factors. The number of peaks or modes in the distributionsare identified.

Temperature, Luminosity and Radius are unimodal distributions i.e., they have one peak, while the Absolute Magnitude has two distinct peaks, so it is a bimodal distribution.

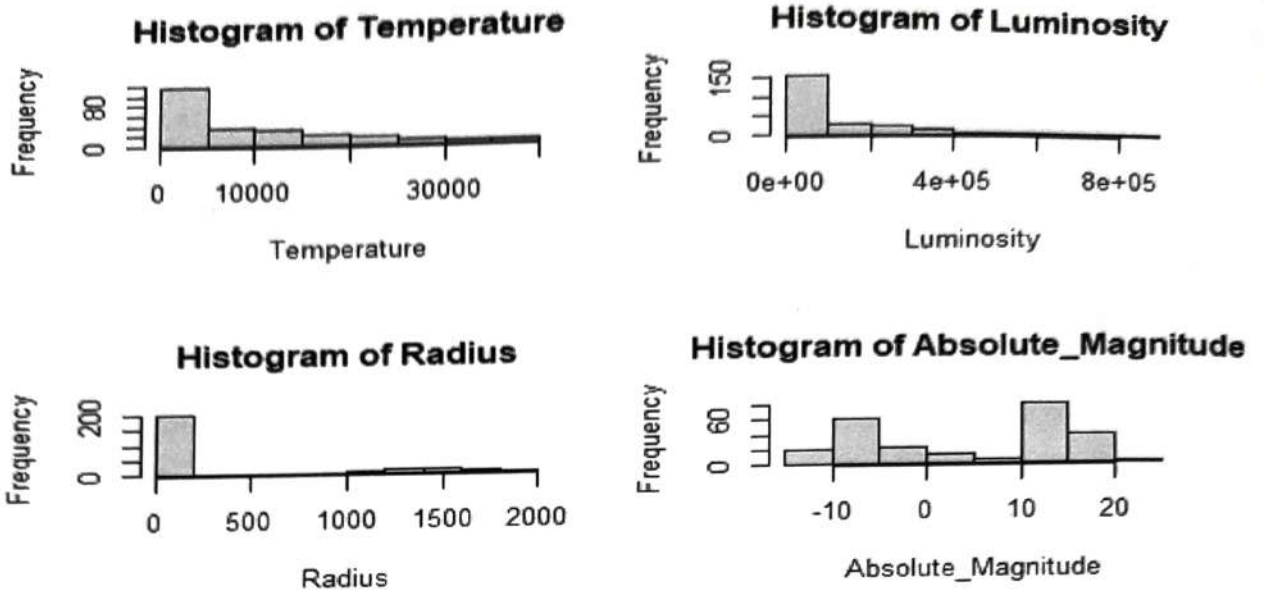


Figure 3.3: Histograms

3.2. Hertzsprung-Russell diagram Results

Interpreting the H-R diagram (Figure 3.4) involves analysing the patterns and groupings of stars in different regions of the plot. The H-R diagram (Figure 3.4) illustrates a general correlation between a star's luminosity and its temperature. It shows that hotter stars are typically more luminous, while cooler stars are less luminous. This relationship helps to classify stars into different spectral classes. The H-R diagram provides insights into the life cycle of stars. The H-R diagram allows us to classify stars based on spectral classes. The notations, such as O, B, A, F, G, K, and M, represent the hottest to the coolest stars. Stars of different spectral classes occupy specific regions on the H-R diagram, providing a way to categorize and study stellar populations. The H-R diagram also reveals information about stellar populations. Different regions of the diagram may contain clusters of stars that share similar properties. For example, globular clusters, which are dense collections of old stars, form distinct branches in the H-R diagram. Some stars exhibit variability in their luminosity over time.

3.3. Random Forests Results

Interpreting random forests involves understanding its key characteristics and the information it provides. Here,168 observations out of 240 trained the decision tree using a random selection (70%) of features. In this case, the accuracy is 86%, which provides more stable and accurate predictions compared to individual decision trees. The confusion matrix (Figure 3.5) illustrates the distribution of predicted and actual star classes. It indicates that the classification error for each star type is significantly low, suggesting a good prediction. Looking at the "class.error" section, the error for White Dwarf is 0.000000. The error for Brown Dwarf is 0.19354839. The error for Hyper Giants is 0.40000000. The error for Main Sequence is 0.03571429. The error for Red Dwarf is 0.11111111. The error for Super Giants is 0.40000000.

The confusion matrix also shows the following counts for actual vs. predicted classes:

- **Brown Dwarf:** 25 correctly predicted Brown Dwarfs, 6 incorrectly predicted as Red Dwarf.
- **Hyper Giants:** 15 correctly predicted Hyper Giants, 10 incorrectly predicted as Super Giants.
- **Main Sequence:** 1 incorrectly predicted as Brown Dwarf, 27 correctly predicted Main Sequence, 2 incorrectly predicted as Super Giants.
- **Red Dwarf:** 3 incorrectly predicted as Brown Dwarf, 24 correctly predicted Red Dwarf.
- **Super Giants:** 10 incorrectly predicted as Hyper Giants, 18 correctly predicted Super Giants.
- **White Dwarf:** 27 correctly predicted White Dwarfs.

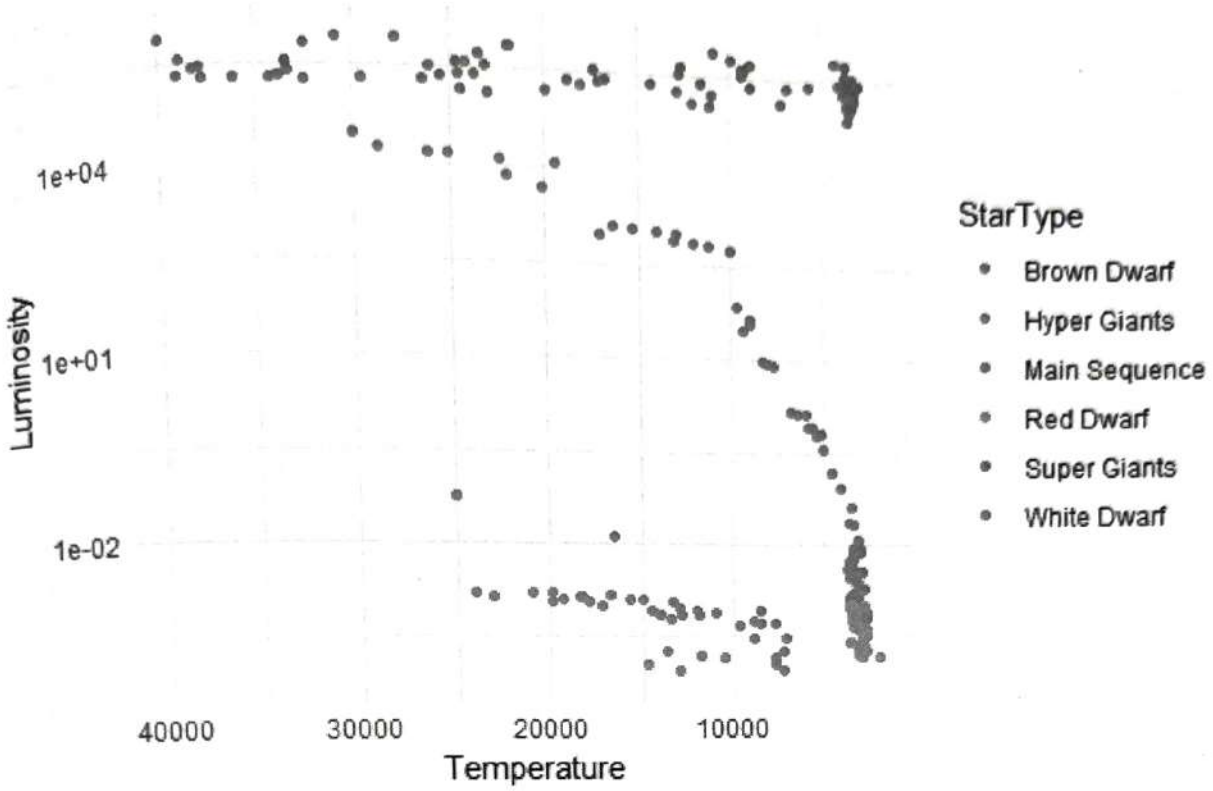


Figure 3.4: H-R diagram

4. Discussion

This study demonstrates that combining traditional astrophysical tools such as the Hertzsprung-Russell (H-R) diagram with Random Forests, provides a powerful framework for star type classification. The patterns revealed in the H-R diagram matched established stellar evolution sequences, validating the dataset and method. Notably, the Random Forest classifier achieved an accuracy of 86%, confirming its reliability for classifying stars based on observable features.

The findings are consistent with recent research efforts. For instance, Bhatti et al. (2021) utilized deep learning to improve classification accuracy on large stellar datasets, while Zhang et al. (2022) emphasized the advantage of ensemble models like Random Forest in distinguishing overlapping spectral types. Compared to these approaches, this method maintains a balance between interpretability and accuracy, making it suitable for educational and research purposes alike. Future studies could extend this work by incorporating additional features such as metallicity and stellar variability, and exploring the use of deep neural networks, which have shown success in related tasks. Further validation with more extensive datasets like those from Gaia and SDSS could also enhance the robustness and generalizability of the model.

In conclusion, this study confirms that the integration of statistical visualization tools and supervised machine learning models contributes meaningfully to the ongoing efforts in automated star classification, supporting both academic exploration and practical applications in astronomy.

Confusion matrix:

	Brown Dwarf	Hyper Giants	Main Sequence	Red Dwarf	Super Giants	White Dwarf	class.error
Brown Dwarf	25	0	0	6	0	0	0.19354839
Hyper Giants	0	15	0	0	10	0	0.40000000
Main Sequence	1	0	27	0	0	0	0.03571429
Red Dwarf	3	0	0	24	0	0	0.11111111
Super Giants	0	10	2	0	18	0	0.40000000
White Dwarf	0	0	0	0	0	27	0.00000000

Figure 3.5: Confusion Matrix

5. Acknowledgement

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Global Status of Insects as Food and Feed Source with Indian Aspects: A Review

Dipanwita Sarkar (Paria) [1], Nibedita Maji[2]

[1]Associate Professor, Department of Zoology, Bethune College, Bidhan Sarani, Kolkata-700006

[2]Research scholar, Department of Zoology, The University of Burdwan, Rajbati, Burdwan-713104

Abstract:

The term entomophagy refers to the practice ofeating insects, a widespread behaviour all over the world. With increasing population growth, the production of sufficient protein from livestock, poultry birds and fish aredealing with a great challenge. Scientific researches showed that edible insect is a good source of essential proteins and a variety of nutrients. Insect intake might help in revolution in food insecurity and replacement of animal sources. This review evaluates the potency of insects as animal feed and human food. It is noted that over 2200species of insect are consumed in worldwide. Certain species of insects are cultivated using organic by products. It helps to reduce environmental pollution and transforming waste into protein feed. Insects are used in various ways in India by tribal people as food, medicine and ornaments. Insect is more affordable source of protein than meat and fish because they are full of high protein content and easily digestible. Insect also contains various essential minerals, lipids, vitamins and carbohydrates. Globally many ethnic groups eat insects as food based on their cultural practices, culinary preferences and accessibility. In India insects of Order Coleoptera, Orthoptera, Hemiptera, Hymenoptera, Odonata, Lepidoptera, Isoptera and Ephemeroptera account for respectively 34%, 24%, 17%, 10%, 8%, 4%, 2% and 1% of total insect consumption. Considering the socio-economic, ecological and nutritional value of this traditional and ethnic food source, public awareness for misconception about edible insects deserve more attention in worldwide.

Keywords : Ethno-entomophagy, insect protein, culinary practices, tribal culture, animal feed.

1. Introduction:

The fate of food industries is facing increasing uncertainty that is co-related with population growth and a surge in demand for nutritious food. Due to growing costs of animal proteins, insecurity of food, growth of population and rising demand for protein-rich food in developing countries, it is a significant need for substitute sources of protein. Edible insects could perform a crucial role in the world food system because they offer a great food transformation ratio, a low ecological footprint, rapid growth rates and high nutritional utility. Yet there are substantial knowledge gaps about diversity, distribution, and nutrient content of edible insects. The consumption of edible insects began approximately seven thousand years ago (Ramos-Elorduy, 2009). Some important groups of insect species that are included in human diets are grasshoppers, winged termites, caterpillars, beetles, ant brood, honey bees, cicadas, and various aquatic insects (Bodenheimer, 1951). Interestingly, more or less two billion people in 113 countries consume edible insects regularly (Jongema, 2017).This review provides a comprehensive analysis of both the positive and negative impacts of using insects as a food source of human and feed source of animal. It points out on the benefits of edible insects for health and economic growth, their cultivation, and their nutritional value in comparison with poultry meat, pork and beef. Additionally, this study addresses challenges related to applying insects as food, including microbial, physicochemical, allergic, parasitic and toxicological threats. It is proved that over 2200 species of insects are consumed across 128 countries globally. Consuming insects is often connected to traditional cultures of people in Africa, Asia and American continents. United Nations recommended insect ingestion as a possible solution to the scarcity of global food stocks (van Huis, 2013). This review highlights opportunities and challenges related to insect consumption in respect to malnutrition and food security.

1.1 History of entomophagy :

It is evident that human ancestors used insects as food as nutrition source (van Huis, 2017). Before the discovery of food-hunting tools, insects played a significant role in the diets of ancient humans, as evidenced by fossilized faeces known as coprolites (Hardy et al., 2017). Yi et al. (2010) noted that insects were consumed in China even 3200 years back. Locusts were served at banquetsin the royal mansion of Ashurbanipal, a king of an ancient Mesopotamian civilization named Assyrian (van Huis et al., 2013). In 2010, Feng et al. reported that use of wasps in Chinese culinary traditions dates back to ancient times, as recorded in texts from Tang Dynasty period. Aristotle first mentioned entomophagy in Europe in his book "Historia Animalium," noting that female cicadas are particularly tasty after copulation for the presence of fertilized eggs (Akhtar and Isman, 2018).Larvae of great Capricorn beetle (*Cerambyx cerdo*) was popular among the ancient Romans which was described by Pliny in the book named Natural History. In 1550 Leo Africanus, a renowned writer of Morocco documented that migrant in Arab and Libya ate locusts and stored insect flour for future while Ulisse Aldrovandi wrote about the ingestion of silkworms by German soldiers (van Huis et al., 2013). "Donguibogam" a famous historical book of edible insects written by Jun Heo who elaborated more or less 95 kinds of edible insects.

1.2 Reasons for using Insects as food:

There are several reasons to human for accepting insects as food sources.

- ***Nutritional Value***: Insects are rich in essential nutrients, including protein, healthy fats, vitamins, and minerals. They provide a valuable source of complete protein with essential amino acids which is especially important in regions where protein deficiency is a concern. Insects also contain nutrients like iron, zinc, and B vitamins, including vitamin B12, which can be scarce in vegetarian diets.
- ***Cultural Tradition***: Insect consumption has a long history in many tribal and rural communities in the world, especially in India. In these areas, insects are considered as a traditionally and culturally significant food source. They are often integrated into local culinary practices and rituals, making them an integral part of the cultural heritage
- ***Availability***: Insects are readily available in many regions in worldwide, particularly during specific seasons. The ease of harvesting or collecting insects from the environment contributes to their accessibility as a nutritive source.
- ***Sustainability***: Insect is an environmentally sustainable protein source. They require minimal land and water resources and produce lesser amount of greenhouse gas compared to common livestock. As sustainability becomes an increasing concern, the low environmental impact of insect farming has garnered attention.
- ***Flavour and Texture***: Insects offer unique flavours and textures that appeal to some palates. Their crunchiness or earthy taste can be a source of culinary intrigue and enjoyment.
- ***Culinary Creativity***: Indian cuisine is renowned for its diversity and creativity. Chefs and home cooks alike have found innovative ways to incorporate insects into a vast range of delicacies, from snacks to main courses and condiments. This culinary creativity has contributed to the popularity of insects as a dietary source.
- ***Health Benefits***: Nutritional benefits of insects are enriched protein content and dietary profile that take partin perceived health benefits. Sometimes they are referred as a wholesome and nutritious dietary choice.

1.3 Major edible insect groups in the world:

Globally, the most usual insect order ingested by human is beetles (31%) (van Huis et al., 2013). The Ingestion of caterpillar in sub-Saharan Africa is approximately 18%. Hymenopteran ants, bees and wasps come in the third place with 14% consumption rate and this practice especially founds in Latin America. Insects of Order Orthoptera, Hemiptera, Isoptera and Odonata account for respectively 13%, 10%, 3% and 3%(van Huis et al., 2013). Lepidopteran insects like butterflies and moths are ingested in their larval condition. In contrast, members of the Coleoptera (beetles) and Hymenoptera (wasps, bees, and ants) families are typically eaten in larval or pupal condition of their life cycle. Meanwhile, insects from the Orthoptera (grasshoppers and crickets), Homoptera (aphids and cicadas), Isoptera (termites)and Hemiptera (true bugs) Orders are usually consumed in their adult forms (Cerritos, 2009).

1.4 Coleoptera:

Among the Order Coleoptera, there is a wide variety of edible beetles. In 2009, Ramos-Elorduy and colleagues identified 78 edible species of aquatic beetles, primarily from the families Dytiscidae, Gyrinidae, and Hydrophilidae. One of the most popular edible beetles in tropical regions is the palm weevil, specifically the genus *Rynchophorus*, which is found in Africa, southern Asia, and South America (van Huis et al., 2013). The species *Rynchophorus phoenicis* inhabits tropical Africa, *Rynchophorus palmarum* occurs in the equatorial America and *Rynchophorus ferrugineus* is found in tropical Asia. Delicious flavour of Genus *Rynchophorus* is attributed to its fat content (Cerda et al., 2001). Fallen palms serve as breeding sites, and as a result, palms are often intentionally cut down. This practice is traditional in Ghana (Anankware et al., 2013).

1.5 Lepidoptera:

Lepidopteran insects like butterflies and moths are ingestedduring their larval condition. It was reported that ancient peoples of Australia used to consume moths of the cutworm *Agrotisinfusa* (Flood, 1980) and in Democratic Republic, native peoples have been observed to intake hawkmoths including Genus *Daphnis* and *Theretra* (Van Itterbeeck and van Huis, 2012). *Imbrasia* is a globally popular as well as economically important edible caterpillar. In the mopane forests of many African countries like Angola,Mozambique,Botswana, Namibia, Zambia, Zimbabwe and South Africa, the territory for caterpillars spans approximately 384000 km² of forest (FAO, 2003). It is estimated that more than nine billion caterpillars are collectedper yearfrom mopane forests of southern African countries, a farming valued at 85 million US dollar (Ghazoul, 2006). In the year 1997, 38 variety of species of edible caterpillars are identified by Malaissethroughout the Democratic Republic of Congo, Zimbabwe and Zambiawhile 23 different edible insect species are documented by Latham in the Bas-Congo in the year 2003.

1.6 Hymenoptera:

It was reported by Del Toro et al. in 2012 that Hymenopteran insects such as several species of honey bees, ants and wasps are also popular delicacies in several countries of the world. For example, weaver ant is a very popular food item in many parts of Asia. In 2006, Shen et al. discovered that another edible insect *Polymachis dives*, commonly called black weaver anthas a vast distributionin subtropical countries such as India, Malaysia, China, Sri Lanka and Bangladesh. In China, black weaver ant is used indietaryproductsas well as medicinal tonics. Since 1996, State Food andHealth Ministry and Drug Administration of China have given consent to 30 plus health products that made with ants. For instance, larvae of yellow jacket wasp (*Vespula sp.*) ingestion are very common in Japan. In the course of Hebo Festival, the dishes contain with wasp's larvae are popular cuisines and often wasp's larvae are imported from Australia and Vietnam (Govorushko, 2019).

1.7 Orthoptera:

Most of the Orthopteran species are edible. Nearly 80 species of grasshoppers consumed worldwide. In Africa, people mainly eat desert, migratory, red, and brown locusts. In 2013, van Huis et al. demonstrated that often farmers apply pesticides to control locusts as agricultural pests so there are risks involved. For instance, locusts which are collected for cuisine in Kuwait contained high levels of organophosphorus pesticide residues (Saeed et al., 1993). In America, chapuline is the most common and popular palatable grasshopper. For several decades, grasshopper was a staple food in local cuisine and remains popular in multiple regions of Mexico (Cohen et al., 2009).

1.8 Hemiptera:

In Malawi, cicada insects including *Ioba, Pycna*and *Platypleura*are highly preferable as food. Homopteran products like red coloured carmine dye which is originated from *Dactylopius coccus*, commonly called cactuscochineal bug frequently used in dietary products (Yen, 2005). In addition, humans also intake a sugary crystal-like secretion called lerp, produced by the psyllid in their larval phase. A variety of bugs belongs to the Family Pentatomidae are eaten across the world, particularly in southern countries of Africa. In Sudan, roasted *Agonoscelis versicolor*, a pest of rain-fed sorghum is consumed. Edible oil is also produced from Hemipteran insects and is applied in various food preparations and for healing scab disease in cattle, especially in camel. Apart from this, a famous Mexican delicacy,

ahuautle is prepared from the dried eggs of at least seven different types of aquatic species, particularly belongs to the Corixidae Family of the Order Hemiptera.

1.9 Isoptera:

Most commonly eaten termites are *Macrotermes* species. In 2013, renowned scientist van Huis reported that, local people in Africa beat the surrounding area of termite hills to induce termites to come out. *Syntermes*is the largest termite groups Consumed by the native people of Amazon. They introduce a palm leaf rib near the nesting sites to collect the insects (Paoletti and Dreon, 2005). Usually, termites are vended at markets ofnorthern provinces of Ghana (Anankware et al., 2013).

2. Applications :

2.1 Medicinal applications of edible insects:

Insects hold significant nutritional value and serve as remedies for various diseases in several countries of the world. Since from the ancient era, tribal healers have traditionally used insects in medicine to treat a variety of conditions, including fever, scabies, haemorrhages, epilepsy, headaches, bronchitis, and dog bites. Insects are also employed to treat wounds, protect against gangrene, and increase milk production in lactating women (Tango M., 1994). Furthermore, the chemicals produced by edible insects for self-defence are utilized in the production of anticancer drugs. For instance, a purified protein named pierisin, derived from the pupal stage of the cabbage butterfly, has been found to exhibit a huge cytotoxic effect against various carcinoma cells in human by inducing apoptic cell death. Similarly, cecropins, a group of antimicrobial peptides discovered in the haemolymph of the *Hyalophora cecropia* moth has been reported to be cytotoxic against mammalian lymphoma and leukaemia cells (Srivastava and Gupta, 2009).

2.2 Farming of edible insects:

Maximum edible insects are collected from their natural habitat. Common examples include silkworms and honey bees, which are harvested primarily for their derivatives but both insects itself are edible. Carminic acid, a naturally occurring red pigment used as a food colorant and extracted from one more domesticated insect *Dactylopius coccus*, commonly called cochineal. This substance is also used in the pharmaceutical as well as cosmetic industries. In Peru, this insect is cultured in pear trees andin Mexico they are raised in controlled micro tunnels contain with transparent plastic (Aldama-Aguilera et al., 2005). Environmental influence in edible insect farming is considered as semi-cultivation practice. For instance, harvesting of aquatic hemipterans in Mexico. In that case deliberately cut palm trees to trigger egg laying by palm weevils (*Rhynchophorussp.*), influencing host tree distribution, movement of cultivation area, applying fire regimes, controlling host tree conservation and manually adding caterpillars to a selected area (Van Itterbeeck and van Huis, 2012). Current examples of edible insect farming for trading includes crickets, palm weevils (*Rhynchophorus ferrugineus*), giant water bugs (*Lethocerus indicus*) and aquatic beetles (Jach MA, 2003). However, promoting insects as human food and animal feed requires the development of policy for extensive farming. The major issues in mass production are quality control and cost-effectiveness. Additionally, some insects like silkworms (*Bombyx mori*), drugstore beetles (*Stegobium paniceum*), and termites (*Macrotermes subhyalinus*) have been identified as potential candidates for space-based agricultural insects due to their ability to recycle waste material (Katayama et al., 2008).

2.3 Uses of insect powder in food and beverage industries:

There are so many uses of edible insects in the food and beverage formulation. Primary applications of edible insects are in baked products including cookies, breads and pasta. For instance, the powder made from roasted speckled cockroach (*Nauphoeta cinerea*) is primarily used to increase the protein content of wheat flour in bread formulations. In 2017, De Oliveira et al. reported thataddition of insect powder has demonstrated significantly improved nutritive features, including a higher protein content of 22.6% compared to 9.7% in regular flour, and a higher fibre content of 2.3% versus 2.0%. Additionally, the acceptability index for bread made with insect powder exceeds 75%. Exchanging 5% of wheat flour with insect powder produced from crickets (*Acheta domesticus*), mealworms (*Tenebrio molitor*) and black soldier flies (*Hermetia illucens*)ensured in bread loaves with reduced water uptake, as well as improved dough production and stability (Gonzalez et al., 2018).Breads that include cricket flour offer a greater nutritive value in aspects

of fatty acids, essential amino acids and protein composition compared to traditional wheat bread (Osimani et al., 2018). Several companies are currently working on extracting insect proteins for various food ingredients, such as dissolved protein powders designed for beverages and as alternatives to meat, eggs, or dairy in baking and food processing industries. Insects are also used to create meat substitutes, including ham and sausages. Additionally, a variety of beverages, protein supplements and energy bars are made from insect flour.Foods produced from insects have a bunch of advantages in alter to conventional options, including easy production, a lower risk of aflatoxin contamination, and improved nutritional profiles. Recently, Insects have been targeted for use in space food, particularly for missions to Mars, where they can be cultivated in controlled environments. Furthermore, lipids derived from the insect species *Hermetia illucens* and *Tenebrio molitor* are being explored as alternative sources for margarine or butter (Smetana et al., 2020). In another research it was found that cookies made with insect oils were found to contain greater levels of omega-3 fatty acids, vitamin E, and flavonoids compared to those made with plant oils.

2.4 Insects as animal feed:

The demand for animal feed has been increasing, but the growing human population puts pressure on natural resources and ecosystems to produce animal protein. Insects have a high nutritional value that can enhance the productions of cattle. According to Alltech Global Feed Survey (2017), the manufacture of feed for different domestic animals are nearly 450 million tons for poultry birds, 272 million tons for pigs, 220 million tons for ruminants, 40 million tons for aquatic animals, 25 million tons for domestic pets, 8 million tons for horses and 14 million tons for others. Nutritive value of insects is so high that it can easily substitute the components used in feed production. *Hermetia illucens* or black soldier fly, maggot of *Musca domestica* or housefly, *Bombyx mori* or silk producing worm and *Tenebrio molitor* or yellow coloured mealwormare referred as important insect species tomanufacture feed for trading purpose (Oonincx et al., 2015). Ravindran and Blair in 1993 reported that insects which aremainly used in growth of poultry production arecicadas, grasshoppers, scale insects, cockroaches, termites, crickets, stink bugs, aphids, psyllids, caterpillars, beetles, flies, honey bees, ants and wasps. For example, ancient villagers of India and Guinea, alive termites are given to fowl and ostriches for farming. In several countries like Russia, Nigeria, Cameroon, Togo and South Korea, larvae of the common housefly are utilized as poultry feed(Hwangbo et al., 2009). Studies indicate that maggots have ability to substitute fish meal in the production of broiler chickens. However, shortage of food sources like soybeans and *Zea maize*obstruct the production of animal feed (van Huis, 2013). Additionally, many fish species also consume insects. Mormon cricket meal produced from *Anabrus simplex*is applied not only in aquaculture but also in farming of pig in China.

2.5 Consumer's acceptability:

Usually two different psychological thoughts for insects have worked regarding on insect food consumption. In several countries insect ingestion is a common practice and insects are taken as a valuable protein source as well as local wisdom about edible insect species and their distributions has carried forward through generations. In contrast, Western food cultures often view foods that contain insects as dirty and toxic. This perception is reinforced by Western media, particularly through some reality shows like "Fear Factor,". In this program contestants are required to consume raw insects to demonstrate their boldness and advance in the competition.

2.6 Ethno-entomophagy in India:

Termites are consumed by native tribes in Karnataka (Forbes J., 1813). In Arunachal Pradesh, it was reported that 81 insects are consumed by Nyishi and Galo tribes (Chakravorty et al., 2011). A nutritional examination of Muria tribes in Madhya Pradesh documented that peoples of this region intake chin kara or specific ant species with several food items(Roy and Rao, 1957). Termites with wings, also known as eesal are consume as food by Irumbars tribe in Tamil Nadu and Karnataka(Rajan, 1987). In some tribal groups of Karnataka, weak kids used to eat uncooked queen termites. Termites are also consumed in Odisha with rice (Srivastava et al., 2009). In 2005, Wilsan and reported about the eating practice of at least five different species of insects such as bees, ants and termites in Kerela. The Negrito tribe of Andaman intake insects as a food source (Kavita, 2010).

2.7 Challenges of using insects as food:

Not all insect species are safe for human consumption. Several risks must be considered, including microbial, physicochemical, allergenic, parasitical and toxicological hazards. Additionally, consuming insects at inappropriate developmental stages or failing to prepare them correctly can pose further risks. Many edible insects may carry harmful bacteria, which can jeopardize human health. Some of these bacteria include *Pseudomonas aeruginosa*, *Bacillus cereus* and *Acinetobacter calcoaceticus* among others. (Hernandez-Flores et al., 2015).In addition, histamine poisoning was also happened because of the intake of roasted insects. For example, in 2018 Feng et al. reported that allergic reactions were found after ingesting of insects like cicadas, silkworm and crickets in China. According to Govorushko, Maximum cases of insect related allergy are occurred from the stings of insects belong to the Order Hymenoptera (2013). Insect allergen may be correlated with body components such as the haemolymph and cuticle, as well as body parts including exuviae, setae, and scales (Sun-Waterhouse et al., 2016).

3. Conclusion:

Over two thousand different types of insect species are ingested by people across the world. Insects offer various benefits as dietary source because they are enriched with essential proteins, minerals, vitamins, fats, fibres and amino acids. Promoting insects as food also has a positive impact on nature because they reduced the amounts of greenhouse gases (GHGs) and produced less amount of ammonia compared to other conventional livestock, such as pigs. Edible insects offer enormous benefits in terms of nutrition and environmental sustainability. However, they remain a food source primarily consumed by rural populations in developing countries. Unfortunately, the importance of these insects is often overlooked by food and agricultural researchers and stakeholders. In many developed nations, the consumption of insects is still stigmatized, with some cultures viewing them as "food of slaves" or categorizing them as "low-prestige food. There are several challenges that need to be addressed in order to integrate insects into the mainstream food system. These include cultural barriers, consumer's acceptance of insects as food, and safety concerns. To tackle these issues effectively, more researches are needed on diversity and abundance of edible insect species, their nutrient quality, rearing and cultivation methods and conservation efforts.

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4. Size of letters: i) Paper title: 12 points, bold; ii) Authors name: 10 points, bold; iii) Affiliations: 10 points, iv) subheadings: 10 points, v) Text: 10 points, vi) References: 8 points.
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