ISBN: 978-93-48620-69-9

Bhumi Publishing, India

ECOLOGY & BIODIVERSITY

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Bhumi Publishing

Ecology and Biodiversity

(ISBN: 978-93-48620-69-9)

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Bhumi Publishing

February 2025

Title: Ecology and Biodiversity

Editors: Dr. Dipak Das

First Edition: February 2025

ISBN: 978-93-48620-69-9

Published by:

BHUMI PUBLISHING

Nigave Khalasa, Tal – Karveer, Dist – Kolhapur, Maharashtra, INDIA 416 207

E-mail: bhumipublishing@gmail.com

PREFACE

This book aims to provide a comprehensive overview of the latest developments in various fields of ecology and biodiversity which aims the scientific study of interactions between organisms and their environment. Ecology is closely linked to sustainable resource management and allows us to understand how ecosystems function and how species interact. This knowledge is vital for biodiversity conservation as it helps us identify endangered species and design conservation strategies. Ecologists also study the impact of climate change on ecosystems, analyzing how changes in climate affect biodiversity, nutrient cycles and other important ecological processes.

Each chapter in this book is authored by experts who are at the forefront of their respective fields, ensuring that the content is both authoritative and current. This book is intended to serve as a valuable resource for researchers, students, and professionals who are dedicated to advancing the field and contributing to attaining sustainable development goals and also hope that "Ecology and Biodiversity" will inspire new ideas, foster collaboration and drive the next wave of innovation in this field.

I extend my sincere gratitude to the contributors, whose expertise and dedication have made this book a comprehensive and insightful resource. Their efforts reflect the dynamic nature of ecology and biodiversity and its potential to transform lives. Thanks are also due to well wisher and institutional colleagues who helps immensely during the course of shaping this work.

- Dr. Dipak Das

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Ahamadul Hoque Mandal[1], Surajit Ghosh[1],
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Abstract:

In the field of agriculture, the nano-pesticides emerges as alternatives of conventional pesticides having more efficacy in pest control. Nanocarriers or nanosized small ingredients are widely used in nano pesticides formulation because of superior stability, high stability, good dispersal rate, and controllable release rate to the target organisms. Now a days the wide application of nano pesticides has adverse impact on non-target organisms, which may not often be considered by the developers. Nano pesticides cause mortality, decreased heart rate, increased heart rate and altered gene expression level. It causes morphological alteration tail deformation, lack of body parts, lordosis, bubbled head, weak or non-pigmentation. Additionally, fish lose some of their capacity to feed, flee from predators, maintain their current position in the river, and frequently are unable to withstand the temperature of the water, making them more vulnerable to illness. The Cu $(OH)_2$ nano pesticides causes neurotoxic effects such as reduction of serotonin, Dopamine, and Gamma Amino Butyric acid. The nano pesticides cause elevation of several organic acid involved in TCA cycle like Iso citrate dehydrogenase, and α-keto Glutarate in *Denio rerio*. Cypermethrin Nano Pesticides (CypNPs) causes elevation of Alanine Transaminase (ALT), Alkaline Phosphate (ALP) in *Channa Punctatus*.

Keywords: Nano Pesticides, Dispersal, Lordosis, Dopamine

Introduction:

By 2050, the world's population is predicted to have increased by almost 48%, hence attempts are being undertaken to find new ways to produce more food (Pardey *et al.*, 2014). Large-scale monocultures of the majority of crop varieties are the result of shrinking agricultural areas due to urban population growth and rising food demands; these monocultures cannot be maintained without the use of agrochemicals (Altieri, 2007). The use of agrochemicals (pesticides, fertilizers, growth hormones, etc.) is predicted to reach $266 billion worldwide by 2021 at an anticipated 4.5 percent annual growth rate. Despite the benefits and necessity for the agri-food industry, the widespread use of agrochemicals causes enormous amounts of hazardous chemicals to be released into the environment (Kumari, 2014). Additional issues include contaminated terrestrial and aquatic ecosystems, the use of pesticides to manage pest resistance, and toxic residues in food intended for human and animal consumption (Carvalho, 2017). Over the past few decades, many approaches to the more environmentally friendly control of agricultural pests have been put forth. Significant advances in nanoscience and nanotechnology in recent times have created new opportunities for a variety of industries in terms of new materials, procedures, and products (Ding *et al.,* 2023). These advancements offer the agri-food industry a fresh approach to achieving increased sustainability and precision. Any improvement in agrochemical (pesticide) efficiency through nano-scale formulation should be anticipated to lead to a decrease in the total amount of agrochemicals used globally. In comparison to conventional formulations using the same active ingredients, a study comparing the effectiveness of various pesticides with nano pesticides found that nano-scale formulations increased efficacy by 20–30% (Paradva & Kalla, 2023). When compared to traditional formulations, nano pesticides have been demonstrated to improve the stability and action of a range of herbicides due to their higher surface area and smaller particle size (Yadav *et al.,* 2022).

However, compared to traditional pesticides, nano pesticides may pose greater environmental risks, which cannot be disregarded (Xu *et al.,* 2022). Given the lessons learnt from previous environmental problems involving the use of pesticides like DDT (dichlorodiphenyltrichloroethane) or neonicotinoids, it is imperative to comprehend and assess the environmental danger of nano pesticides before their widespread agricultural usage. Since several recent studies have clarified the possible environmental risks connected to nano pesticides, it is appropriate to conduct a review in order to compile the results and outline the direction for further research (Mustafa & Hussein, 2020). Nanopesticides from industrial and agricultural wastewater runoff during a precipitation event enter the water supply through the soil-permeating leaching phenomenon, lowering its quality, extending human exposure times, and posing a threat to the ecosystem (Hayles *et al.,* 2017). Nanopesticides may have toxicological impacts on all creatures, but especially mammals, because of their high potential for diffusion and bioaccumulation in soil, water, and food, as well as their biomimetics qualities (Zhao *et al.,* 2017). Humans may experience both acute and long-term pathological manifestations, including respiratory, cardiovascular, lymphatic, autoimmune, neurological, and different types of cancer, as a result of a range of adverse effects linked to exposure duration and individual vulnerability to nanopesticides (Vurro *et al.,* 2019). Due to bioaccumulation and the unique characteristics of the nanopesticides, these symptoms may appear right away following exposure or years later (Konappa *et al.,* 2021).

Recent reviews of the literature have covered the benefits, prospects, and difficulties of using nanotechnology in agriculture. In contrast to traditional pesticides, we review here the development of nanopesticides that have better qualities or pose less of a risk to the environment. There is also discussion of the difficulties that currently exist and the prospects for the future in enhancing the evaluation of the advantages and environmental risks of nanopesticides.

Formulation of nano pesticides

The two processes that lead to the creation of nanopesticides are encapsulating the active ingredients in nanocarriers and directly processing them into nanopesticides (Pascoli *et al.,* 2019). In an ideal world, active ingredients would be protected and transported to the target sites by nanocarriers, which are nanopesticides that have the ability to entrap, absorb, attach, or encapsulate them and release them at a specific time (Yadav *et al.,* 2022). Among the many good qualities of nanocarriers are their ability to regulate the release of active ingredients, which prolongs the time at which pesticides are effective, increases the pesticide's wettability and dispersibility, and shields it from environmental influences (Gao *et al.,* 2021). Because the active ingredient is more stable and resistant to deterioration from the environment, more of it reaches the site of action, minimising needless losses and, in the end, lowering the dosage and enhancing the pesticide's effectiveness (Kah & Hofmann, 2014). Figure 1 describes several types of nanopesticides formulation processes. A pesticide nano-delivery system is usually formed by encasing the active components in an internal liquid core and encasing them in a natural or synthetic polymer shell or membrane. An oily nucleus and a shell or membrane structure make up a nanocapsule. The core-shell nanostructure has been recognized as a promising delivery structure. The majority of nanomicelles fall between 10 and 100 nm in size, primarily depending on the fabrication technique and the copolymer's molecular quality (Priyanka *et al.*, 2019). As bioactive nanocarriers, nanomicelles are perfect for encasing pesticides, particularly water-insoluble ones that may become lodged in the micelle's nucleus during micelle production. Because of their exceptional environmental stability, nanogels can be loaded with volatile materials. The study of pheromone nanogels against fruit pests demonstrated that they are superior than hydrogels because they are insoluble in water and do not expand or contract in response to variations in humidity. Due to their enormous specific surface area, tiny diameter, and long length, nanofibers offer a viable alternative for efficient controlled delivery systems (Kumar *et al.*, 2019). The application of nanofibers for plant protection has been studied recently. Compared to spheres or capsules, typical nanofibers may have the advantage of not experiencing the release spurt that happens when active components are irregularly distributed in the matrix of polymer (Lade *et al.*, 2019).

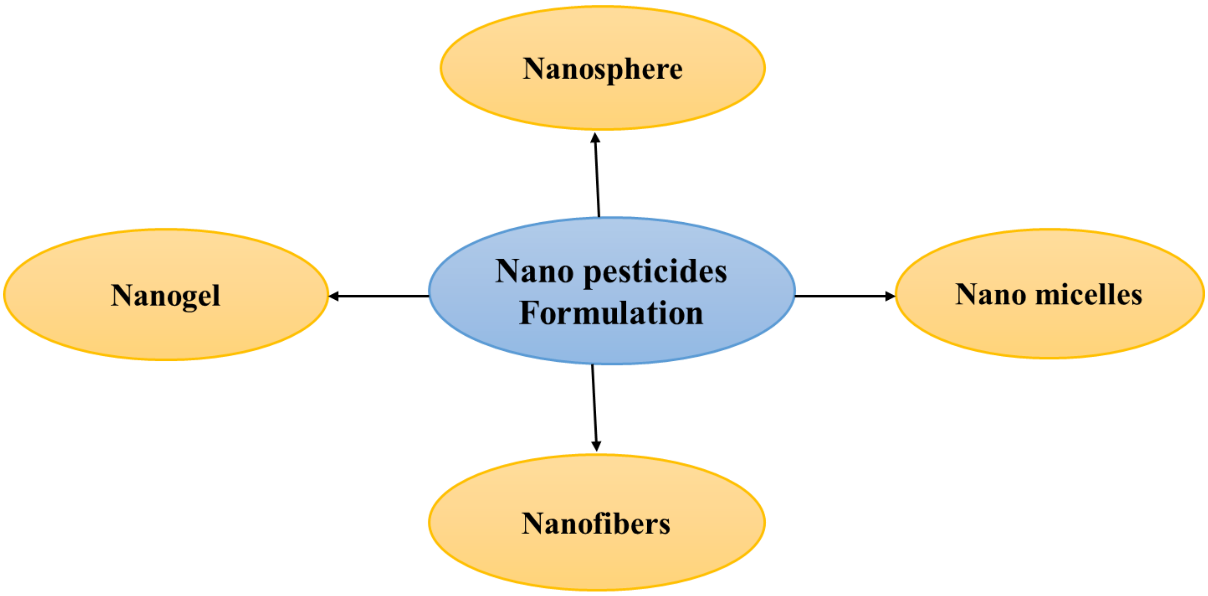

Figure 1: Types of Nano pesticides formulation i.e., nanogel, nanofibres, nano micelles and nanospheres

Application of nano pesticides

Numerous *in vitro* and *in vivo* investigations have assessed the efficacy of MNPs in managing fungal plant diseases, such as *Monilinia fructicola*, *Fusarium sp*., *Sclerotinia homoeocarpa*, *Aspergillus niger*, *Penicillium expansum*, and *Rhizopus stolonifer*. Nanopesticides can enhance the effectiveness of fungicides by improving their solubility, stability, and ability to penetrate fungal cell walls. Nanopesticides can be engineered to deliver fungicides directly to fungal pathogens, reducing the amount of fungicide needed and minimizing off-target effects (Ramesh *et al.*, 2018). By employing unique mechanisms of action or by delivering several active components, nanopesticides may be able to overcome fungal resistance to conventional fungicides.Nanopesticides can improve the adhesion of fungicides to plant surfaces, ensuring better coverage and longer-lasting protection against fungal diseases

(Djiwanti & Kaushik, 2019). Nanopesticides can be designed to release fungicides slowly over time, providing prolonged protection against fungal pathogens. By reducing the amount of fungicide needed and minimizing off-target effects, nanopesticides can help reduce the environmental impact of fungicide use (Grillo *et al.*, 2021).

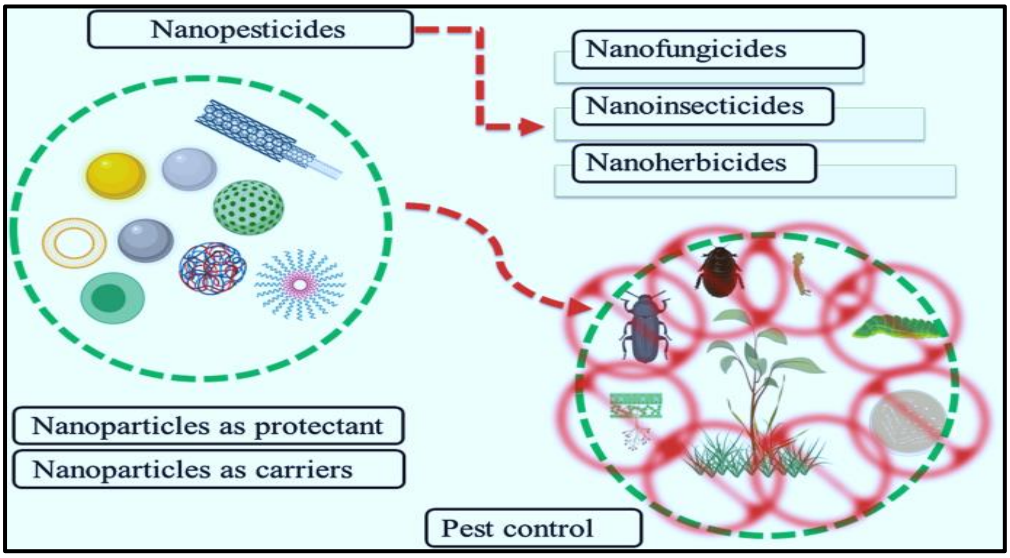

Figure 2: Different potential properties of nanopesticides

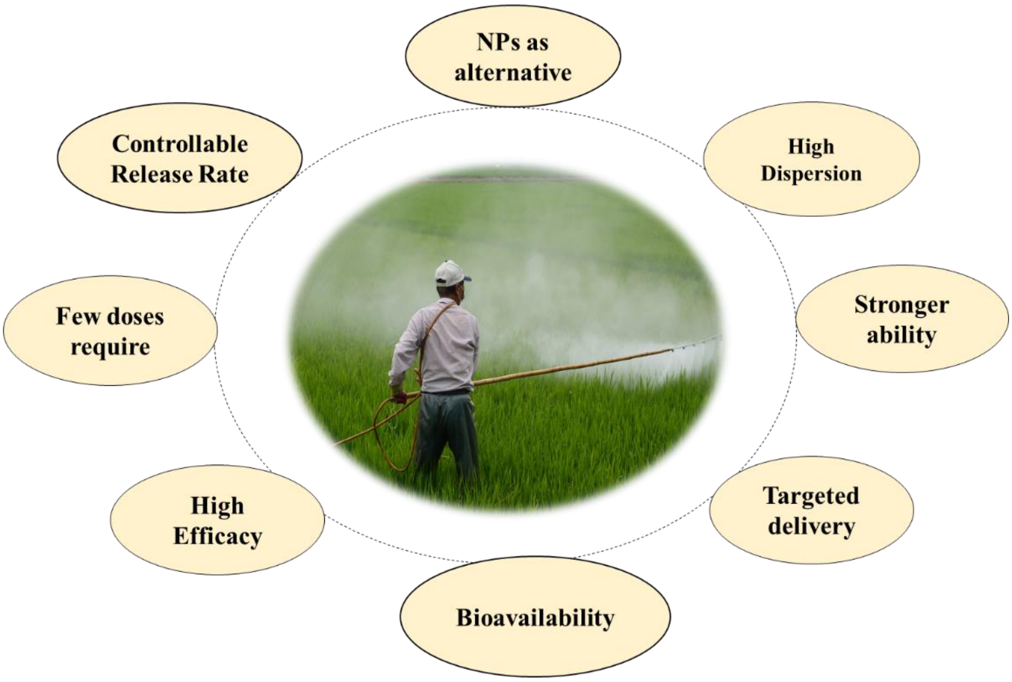

Figure 3: It may be possible to decrease the dosage needed for crop protection by extending the exposure of the target organisms through controlled release of the active ingredients in nanopesticide formulations

Possible advantages of nanopesticides over traditional pesticides

Pesticide formulations that are conventional and comprise various additives are typically diluted with water prior to application on the intended crops or the adjacent area. Figure 2 describes different potential properties of nanopesticides. The effectiveness of the active ingredients may be reduced by hydrolysis, photolysis, or degradation brought on by a variety of environmental conditions. It may be possible to decrease the dosage needed for crop protection by extending the exposure of the target organisms through the controlled release of the active ingredients from nanocarriers in nano pesticide formulations.

Environmental fate and toxicity in soil

The drawbacks of nanopesticides on the environment and living things should not be overlooked while emphasising their positive effects. Because of their smaller size than conventional pesticides, nanopesticides have a greater potential to enter non-target organisms and may therefore be ecotoxic to non-target organisms (Anandhi *et al.,* 2020). Both nanomaterials and active chemicals are present in nanopesticides, though, and the encapsulation of the nanomaterials improves the active ingredient's activity and bioefficacy. According to Coutris *et al.*2019, soil samples containing Ag-NPs affected by soil environmental media were more toxic to earthworms than Ag-NPs that were not, suggesting that NPs' toxicity is increased when they interact with organic matter. As a unique form that differs from conventional pesticides, nanopesticides can significantly alter toxicity and environmental fate when compared to conventional pesticides with the same active ingredients but no nanomaterials (Regina Assalin *et al.,* 2022). It has been demonstrated that organic matter can alter the toxicity and bioavailability of nanopesticides by forming surface coatings and adhering to the surface. According to certain research, there are situations when nanopesticides are almost ten times more toxic than traditional formulations. It has been demonstrated that in addition to killing target aquatic organisms, nanopesticides can also kill non-target organisms. Nevertheless, studies on non-target plants have demonstrated that the genotoxicity and phytotoxicity of nanopesticides did not differ significantly from those of conventional pesticides (Bocca *et al.,* 2020). This illustrates how the processes and mechanisms affecting how nanopesticides behave and affect the environment may be different from those affecting traditional pesticides. As a result, it may be necessary to modify or replace the techniques currently employed in risk assessment methods in order to account for these differences. A regulatory risk assessment system that takes into account more than just the individual (Dangi & Verma, 2021).

Toxic effect of nanopesticides on non-target organisms

The likelihood of non-target aquatic creatures being exposed to nanopesticides is growing as they are widely used. A permethrin nano emulsion's ecotoxicity was evaluated for zebrafish and other non-target species. The results indicated that when the concentration of pyrethroid nanometric emulsion exceeded 6.4 mg/L, zebrafish exhibited aberrant behaviors, such as unsteady swimming and reflex loss (Rajna & Paschapur, 2019). However, at concentrations below 6.4 mg/L, the permethrin nanoemulsion was shown to be non-toxic to creatures that were not the intended target, such as freshwater algae and zebrafish. This indicates that, like other toxicants, the amount of nanopesticide present in the aquatic ecosystem has a significant role in determining the environmental dangers (Balaure *et al.,* 2017). Contrary to the increased stability and extended duration of permethrin nanoemulsion shown in the field, its residue in the aquatic environment should be minimal in order to mitigate the environmental concerns of the product. In wetland mesocosms with increased nutrients Simonin *et al.* (2018) examined the effects of a commercial Cu $(OH)_2$ nanopesticide on aquatic primary producers.Algal blooms were encouraged and wetlands' eutrophication was accelerated by long-term exposure to low doses of Cu (OH)2 nanopesticide; these blooms lasted more than 50 days longer than those in the nutrient-only treatment (Ding *et al.,* 2023). At 1.0 mg/L, the same Cu $(OH)_2$ nanopesticide was also demonstrated to cause no developmental harm in zebrafish eggs and larvae. However, when doses were raised to 2.0–8.0 mg/L, various morphological defects in the embryos or larvae were seen, such as bubbling heads, deformed tails, and a loss of body components. Additionally, it was demonstrated that the Cu $(OH)_2$ nanopesticide treatment markedly raised the transcription level of genes linked to the immune system (IL-1, IL-8, TLR4, HSP70 and NF-B). Similarly, the effects of a commercial nanopesticide (Kocide 3000) on the expression of genes linked to the reproductive system (cut, cyp314, dmrt93, and vtg) and detoxification (cyp360a8, gst, P-gp, and hr96) in *Daphnia magna* were examined (Aksakal and Arslan, 2020). Cu (OH)2 nanopesticide's genotoxic effects on non-target species were documented by the notable down-regulation and up-regulation of these genes following a 24- or 48-hour exposure (Aksakal & Arslan, 2020). Similarly, the effects of a commercial nanopesticide (Kocide 3000) on the expression of genes linked to the reproductive system (cut, cyp314, dmrt93, and vtg) and detoxification (cyp360a8, gst, P-gp, and hr96) in *Daphnia magna* (Aksakal and Arslan, 2020). Cu $(OH)_2$ nanopesticide's genotoxic effects on non-target species were documented by the notable down-regulation and up-regulation of these genes following a 24- or 48-hour exposure (Chakoumakos *et al.*, 1979). *Leptocheirus plumulosus*, an estuary amphipod, was found to be observably harmful to copper nanopesticides in a recent study. In contrast, *Leptocheirus plumulosus* subjected to traditional ionic copper pesticide and micron-scale copper. This example highlights the need for more studies comparing the performances and possible impacts of nanopesticides with those of conventional pesticides.

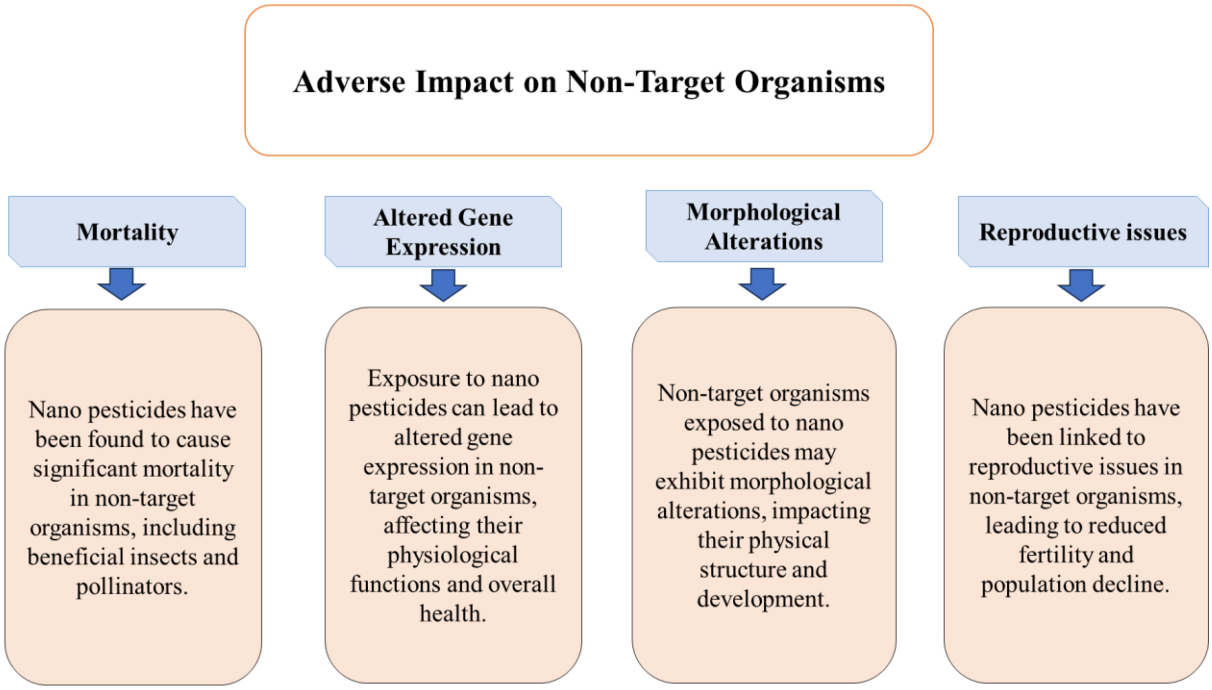

Figure 4: Adverse outcomes of nanopesticide toxicity in fish. Nanopesticides can lead to various adverse effects in fish, including oxidative stress, DNA damage, histopathological alterations in tissues, and disruption of immune function. These effects can ultimately result in decreased growth, impaired reproduction, and increased mortality in fish populations

A recent study examined the genotoxic responses of bullfrog tadpoles (*Lithobates catesbeianus*) exposed to solid lipid nanopesticides loaded with pyrethrum extract for 48 hours. The pyrethrum nanopesticide increased the number of leukocytes and erythrocytes, increased the frequency of DNA damage, caused abnormal erythrocyte nuclei, and ultimately resulted in cell death (Oliveira *et al.*, 2019). Remarkably, a recent study on the toxicity of nanoencapsulated bifenthrin to rainbow trout found that the nanoformulation can reduce the toxicity of bifenthrin in comparison to conventional bifenthrin; the former's 96-hour LC_{50} (11.2μg/L) was nearly twice that of the latter (6.2μg/L) (Blewett *et al.*, 2019).Given these results, it is evident that the environmental risks of nanopesticides rely significantly on the dose, ambient circumstances, and examined non-target organisms. This indicates that further research is necessary to fully understand the environmental dangers of nanopesticides. To encourage the sustainable use of nanotechnology in agriculture, makers of nanopesticides and environmental researchers should collaborate to balance the possible advantages and environmental dangers of these products. It has been discovered that Cu $(OH)_2$ nanopesticides lower serotonin levels in species that are not their intended targets, which can result in behavioral abnormalities and mood problems. It has also been demonstrated that these nanopesticides reduce dopamine levels, which may have an impact on reward systems and motor performance. Silver nanopesticides can harm fish in a variety of ways (Bhan *et al.,* 2018). The liver, brain, intestine, gills, and blood are among the organs where silver nanopesticides can build up (Sow & Samadder, 2021). Numerous evaluations of the literature indicate that silver nanopesticides are powerful enough to attach to cellular proteins and alter their functions (Xu *et al.*, 2022).

Conclusion:

The toxicity of nanopesticides is a complex and evolving area of research. While nanopesticides offer potential benefits in terms of increased efficacy and reduced environmental impact, there are concerns about their potential toxicity to humans, non-target organisms, and the environment. Several studies have shown that certain nanoparticles used in nanopesticides can cause adverse effects in humans, such as respiratory problems, skin irritation, and cell damage. Additionally, there is evidence to suggest that nanoparticles can accumulate in the environment and impact soil and aquatic organisms. However, the toxicity of nanopesticides depends on various factors, including the type of nanoparticles used, their size, shape, surface properties, and the specific formulation of the nanopesticide. More research is needed to fully understand the potential risks associated with nanopesticides and to develop guidelines for their safe use. In conclusion, while nanopesticides show promise as a tool for sustainable agriculture, their potential toxicity highlights the importance of further research and regulation to ensure their safe and responsible use.

Acknowledgement:

Ahamadul Hoque Mandal acknowledge the University Grant Commission (UGC) for funding support, Student id no: 211610105257. Surajit Ghosh acknowledges CSIR-HRDG [09/0025 (16571)/2023-EMR-I,dated 24/03/2023].

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EFFICIENCY OF *TRICHODERMA* AS BIOCONTROL AGENT

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Abstract:

Agriculture can help to reduce poverty, improve economy generation and perk up food security. Healthy, sustainable and inclusive food systems are decisive components to achieve the global development goals. Unfortunately, various biotic and abiotic factors are the major constraint on the noticeable reduction of productivity and safety of agricultural crops. The over-exploitation and reliance on synthetic pesticides and fertilizers are attributed to the development of resistant plant pathogens and the soil fertility diminution. In order reduce dependency on synthetic pesticides and fertilizers some alternative eco-friendly approaches such as the use of biocontrol agents and biofertilizers should be encouraged as substitutes to synthetic chemicals in this present day. In recent years *Trichoderma* has been proved as an indispensable asset to farmers for its huge impact in combating the malevolent pests that decrease yield. *Trichoderma* has the ability to penetrate the cell membrane by secreting lytic enzymes, releases several metabolites that are noxious to insects but safe for crops, directly attacks the pathogens, coils around the mycelium of fungal pests and by doing so kills reduces infection in hosts. Some times they also upregulate the levels of enzymes or secondary metabolites that boost the resistance of host towards phytopathogens. Therefore, the application of *Trichoderma* in agricultural field is not only efficacious against regulating plant pathogens but also against insect pests, nematodes, weeds representing a future alternative that reduces the dependency of farmers on synthetic insecticides, herbicides and aids in the development of the sustainable agricultural system.

Keywords: Agriculture, Biocontrol agent, *Trichoderma*, Biofertilizers.

Introduction:

Humans on earth need a continuous supply of food for their survival and hence enhance their dependency on the agriculture. Continuousimprovement of agricultural system is going on globally in order to maximize the production of agricultural productsto maintain sufficient supply of safe, nutritious, and high-quality food.But instead of colossal efforts made by the agriculturist several factors (biotic and abiotic) such as natural calamities, anthropogenic disturbances, pest, insects and phytopathogensthe growth and yield of crops are declined.Hapless agricultural losses are extremely wretched for the globe since it affectsfood security and safety leading to food scarcity and thus, negatively impact the economy generation of the countries dependent on agricultural products as the major source of their economy.The yield of crops has been reduced to about 10-16% every year, is a huge concern for the rapidly increasing population Ahmad *et al.* (2024).To compensate this massive loss the farmers are applying chemical pesticides, herbicides and weedicidesin order to combat phytopathogens and alleviate their deteriorating effects on the crops. But these chemical inputs have several negative impacts on our ecosystem (Bhagawati *et al.,* 2024). They directly or indirectly dissolve and spread every sphere of our globe, and disrupt our ecosystem stability. In humans, these chemicals show their extreme effects. Starting from disturbing the function of the body they induce several types of cancers, causes neural disruption, fertility reduction, kidney failure, colon, pancreases, liver, heart, lungs all are affected. Even the mental health of humans was also significantly devasted due to exposure to these pollutants Ahmad *et al. (*2024). Reports are also available on development of highly resistant pathogens and weed varieties due to frequent applications of pesticides and herbicides leading to induction of severe negative impacts on field crops Zhu and He (2024); Nguyen *et al.* (2024).Such problems raised due to application of harmful chemicals have impelled the need ofpiercing out harmless, inexpensive and sustainable alternatives such as biocontrol agents and biofertilizers as a substitute to synthetic chemicals. Scientists are curious and started exploring biological control measures towards pests and diseases since the beginning of 20thcentury Dash *et al.* (2024). The use of fungi as imperative biocontrol agents in agricultural practices has been reported globally as they improveplant growth and yield by imposing different mechanism of suppressing undesirable diseases caused by pests or pathogens. Among the fungi*Trichoderma* is considered as one of the most competentbiocontrol agent. The genus *Trichoderma*is a filamentous fungus with high availability, entomopathogenic in nature, antagonistic to microbes, potentialweedicides and most importantly safe to use in agricultural crops as it has no severe effects on plants.*Trichoderma* spp. do not havesevere effects on integrity and sustainability of our ecosystem as they are of biological nature Hassuba *et al.* (2024); Trizelia *et al.*(2024); Dou *et al.* (2024).The genus has been exploited to negate phytopathogens because of its efficiency to produce metabolites, enzymes that can degrade the cell membranes of phytopathogens. They compete with other pathogenic fungus in terms of space, nutrition which made the pathogens to die out of starvationNourian *et al.* (2024); Boukaew *et al.* (2024); Singh *et al.* (2024).*Trichoderma* directly attack the pathogens by coiling, penetrating, degrading the mycelium of pathogenic fungiAkbari *et al.* (2024); Tian *et al.* (2024).Sometimes they ameliorate the levels of phytocompounds, phytohormones and enzymes in plantsthat impart negative effects on the growth phytopathogens and thus, reduces disease severity and made crops resistant indirectly Joshi and Goswami (2024).

This present research work undertakes the screening of *Trichoderma*as potential biocontrol agent against phytopathogens and also offering a baseline for future research and application in the field of agriculture.

***Trichoderma*: An overview**

Kingdom: Fungi
Division: Ascomycota
Sub-division: Pezizomycotina
Class: Sordariomycetes
Order-Hypocreales
Family: Hypocreaceae
Genus: *Trichoderma*

Trichoderma is a non-pathogenic, filamentousfungus available globally has been explored aseffectual biocontrol agent against numerous phytopathogens that target economically valuable crops and induce malfunctioning in their metabolic process along with damaging vegetative structure ultimately leading to decline in yield Dou *et al.* (2024).This genusacquired convincingpathogen inhibiting mechanism, cost effectiveness and environment friendly nature.A large number of species belonging to this particular genus have been discovered from the soil, phyllosphere, endosphere and rhizosphere of economically pivotal plant species Elshahawy *et al.* (2024); Zanfano *et al.* (2024). In the rhizosphere they are capable of controlling a variety of phytopathogens including nematodes, fungi, bacteria etc. In addition, they are also capable of inhabiting the plant tissues as endophyte and by following different metabolic pathways perk up the molecular machinery for the enhancement of plant resistance, inhibition of pathogen growth, and improvementof vegetative and reproductive growth of the host plant. They have the capacity to inhibit the growth of plant pathogensupto80%, that infect commercially valuable plants Zandyavari *et al.* (2024).

Assessment of agricultural loss

Every year a considerable number of agricultural crops were affected by pathogens that directly or indirectly effect their vegetative growth and ultimately reduce their yield to a greater extent. Approximately, 36% reduction in the productivity of economically potential crops has been witnessed globally due to the pest infection and illnesses (Hassan and Khalaphallah, 2024). Arthropods contribute 18–20% loss that worth over 470billion US Dollar Junaid and Gokce (2024). Whereas, about 4100 species of plant-parasitic nematodes were identified to induce negative influence on the commercially valuable crops leading to an estimated loss of 12.3% i.e.,157 billion US Dollar El-Deriny *et al.* (2024); Wang *et al.* (2024). In India, about40-60% losses of vegetable cropshave been reportedwhich is caused by pests and diseases Tripathi *et al.* (2024). Annually, 35-50% yield loss of potato was reported due to stem canker and black scurf diseases caused by *Rhizoctonia solani* Alshimaysawe *et al. (*2024). Cauliflower is an important vegetable crop in India. Nearly 30-50% loss has been estimated due to various diseases, out of which 5-30% were cause by *Alternaria brassicae* alone. The genus *Alternaria* can cause 20-80% losses in crop fieldsSharma *et al.* (2024). It was estimated that about 30-40% loss in the yield of tomato was caused by the pathogens like *Fusarium oxysporum*causing wilt and*Meloidogyne incognita*causing root knot disease, respectivelyAmala *et al.* (2024). *Allium* species like onion, garlic, chives highly prone to *Fusarium*sp. that can cause a yield loss of about 60% Yagmur*et al.* (2024). *Fusarium oxysporum*isa pathogenic fungus to cucurbits that causes *Fusarium* wilt, and is associated with loss of crop yield by 20-80% Akbari*et al.* (2024). Economically valuable fruit species like banana, strawberry, mangoes are affected by several diseases that cause loss in production. In European countries, strawberries are highly valuable crop which are reported to undergo 30-50% loss in yield due to strawberry-black root rot disease Elshahawy *et al.* (2024). Gray mold is another strawberry disease that significantly cause 20‒30% loss of harvested fruits. This value may increase up to 50% in case of unfavourable storage conditions such as poor ventilation, freezing temperature and excess humidity *Fan et al.* (2024). About 30-40% loss of harvested banana fruits was noted due to anthracnose Madushani *et al. (*2024). Another important tropical fruit namely, snake fruit is also reported to possess high percentages of post-harvest losses of about 20 – 50% which is due to black rot disease Napitupulu *et al.* (2024). In Thailand, Stem-end and anthracnose fruit rot disease cause yield loss ofupto60% of harvested mangos Nujthet *et al. (*2024). Deteriorating effect of various pathogens on valuable crops like lentils, cereals, oil crops, ornamentals were also been postulated. In India, Sugarcane smut disease caused by *Sporisorium scitamineum* is reported to induce production loss upto 50%. This disease is attributable with the reduction of sugar recovery from sugarcane tillers Joshi and Goswami (2024). *Colletotrichum capsici*, caused leaf spot disease of turmeric and trim down the crop yield upto15% - 60% Chandraprakash *et al. (*2024). More than 112 diseases caused by several phytopathogens are associated with Maize, another economically valuable crop of India. Iswati *et al.* (2024) mentioned leaf sheath blight disease can attain loss up to 100% in susceptible maize varieties. They also proclaimed thatdowny mildew and leaf-sheath blight are serious concern for cultivation of maize in Indonesia. Chowdhury *et al.* (2024) reported that sheathblight and bacterial leaf blight are the major diseases causingyield loss of 10–50% in India as well as at the global level. In Thailand, false smut disease of rice causes up to 70% loss in terms of production Seekham *et al.* (2024). Reddy *et al.* (2024) mentioned that *Fusarium* wilt can significantly decrease yield of pigeonpea depending on the stage at which infection transpire. At pre-podding stage, they cause 100% loss and after maturity they cause 30% loss in yield. Even grain yield can also be decreased by 100% in extreme cases. Besides pests and microscopic pathogens, weeds are another serious concern for the health of plants. They accounts for about 23% of the total agricultural loss, 31% decline in productivity of cereals and in rice fields they can achieve up to 60-70% reduction in yield Junaid and Gokce (2024).

Effect of chemical inputs on ecosystem

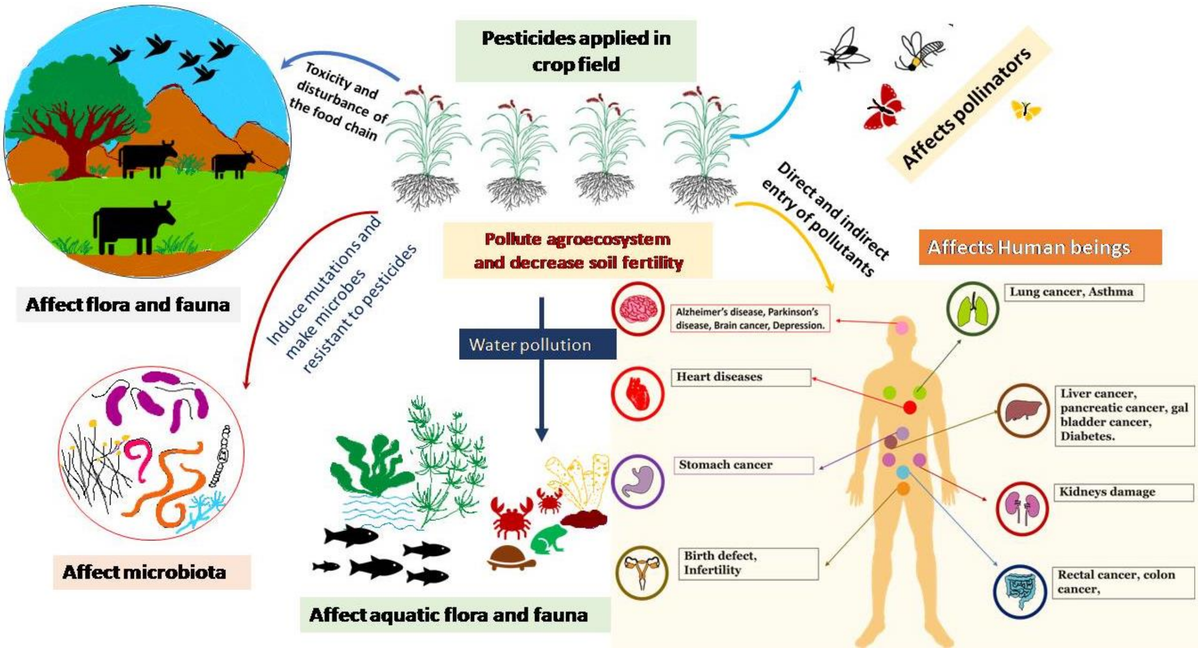

Figure 1: Effects of chemical on ecosystem Parven *et al.* (2024)

Aplenty of chemical inputs including pesticides, weedicides, fungicide and various other chemicals have been employed in the crop field to obstruct the growth and yield deteriorating factors. These chemical compounds persist into the ecosystem as such for a long period of time and also get magnified to higher tropical levels where they induce malfunctioning of different biological system. Sometimes they can be fatal also. Tiwari *et al.* (2024) mentioned that pesticides such as Chlordane, BHC, DDT, Aldrin, 2,3 6-Trichlorobenzene, Atrazine, Simazine, Diuron and 2,4-D have a persistence time of 12 years, 11 years, 10 years, 9 years, 2-5 years, 18 months, 17 months, 16 months and 2-8 weeks respectively.Ahmad *et al.* (2024) highlighted the extreme effects of pesticides on human body. They are reported cause neurological disorders like Alzheimer's and Parkinson's disease, devastating effect on the respiratory system like damaging bronchial mucosa and causes asthmatic conditions in children. They interfere with themicrobiota present in human gut, induce oxidative stress as well as inflammation, disturbs the lipid metabolismand all these pesticides induced malfunctioning ultimately leads to development of non-alcoholic fatty liver disease. They are also reported to have devastating effect on endocrine system and decrease the reproductive ability in both males and females, and even linked with abnormalities during or after birth. Development of cancer in breast, liver, brain, bladder and colon is another serious effect of these chemicals in human body. Herbicides are also reported to have similar effect on more or less every system of human body. Also, they induce harmful effect to both macroscopic as well as microscopic biota Parveen *et al.* (2024).Also, the frequent application of these chemicals leads to development of pathogenic strains and weeds that are resistant to these antimicrobial and herbicidal compounds Nguyen *et al.* (2024); Zhu and He, (2024).So, these chemical inputs are huge concern for our world and their use must be avoider or decreased to certain extent before they completely disrupt the entire balance of our ecosystem.These disadvantages of employing chemical inputs on agricultural ecosystem made the researchers to shift their choices towards an environment friendly, relatively cheap and sustainable mode of controlling phytopathogen *i.e.,* biocontrol.

Microscopic phytopathogens

Microscopic plant pathogens like fungi, bacteria, virus, and nematodes causing various plant diseases are attributable with the greater loss of crop production every year and therefore it is very important to deal with them with respect to their control measures. Aplenty of *Trichoderma* species have been tested in *in-vitro* conditions for corroboration of their inhibitory action against particular phytopathogen or group of pathogens. Reports are also available on mechanistic approaches of *Trichoderma* in relation with their potentiality against plant pathogens. Madushani *et al.* (2024) utilised *Trichoderma virens* to combat *Colletotrichum musae,* a pathogenic fungus causing anthracnose in the members of genus *Musa*. The outcomes confirmthat bioagent compete with the pathogen for resources like nutrients and space for growth. By doing so, *T. virens* successfully inhibit the radial growth of *C. musae* by 74.1 %. Sutthisa *et al.* (2024) also reported 50.76-74.85 % inhibition of growth of *Colletotrichum* spp. myceliumby *T. asperellum* that causes anthracnose in durian fruit. Nujthet *et al.* (2024) reported overgrowth of 5 *Trichoderma* strains over *Lasiodiplodia theobromae, C. gloeosporioide* that is responsible for Stem-end & anthracnose fruit rot formation in Mango. The bioagent depicts more than 80% inhibitory effect on these pathogens. Yusnawan *et al. (*2024) demonstrated *invivo* application of *T. virens*against soybean damping off disease and result in disease incidence reduction by 22-34%. They claimed that the disease reduction and increase in host growth parameters are due to the up regulated content of phenolic compound and peroxidase activity. Hamza*et al.* (2024) reported use of *T.harzianum*, *T. viride* and claimed above 60% inhibition of pathogenic *Botrytiscinerea* that causes grey mold in grape. However, Complete inhibition of *Botrytiscinerea* pathogen by *T. asperellum* has been reported by Fan *et al.* (2024). Volatile organic compounds (VOCs) released by *T. asperellum* damagedthe cell membrane permeability and cause cytoplasm leakage in *B. cinerea* pathogen that induce grey mold disease in strawberry. Seekham *et al.* (2024) reported above 80% reduction of false smut in rice by using *T. asperellum*and *T. harzianum*. Elshahawy *et al. (*2024) proclaimed *T. asperellum* upregulate the release defence enzymes like peroxidase and chitinase which leads to reduction of disease incidence and severity decrease by 59.3 -74.1 % and 72.5 - 75.2 % respectively. Some other recent researches on *Trichoderma* applications to combat diseasesin economically valuable crops are depicted (Table.1).

Table 1: *Trichoderma* as potential fungal biocontrol agents of several agricultural crops

***Trichoderma* spp**	**Crop**	**Disease**	**Pathogen**	**Biocontrol Mechanism**	**Outcomes**	**Reference**
Trichoderma virens	Banana	Anthracnose	*Colletotrichum musae*	Competition for nutrients and space.	Pathogen inhibition: 74.10±8.9 %	Madushani *et al.* (2024)
T. brevicompactum	Saffron	Corm rot	*Fusarium oxysporum* *F. solani* *Penicillium citreosulfuratum* *P. citrinum*	Multiple mechanism (Competition, Antibiotic production, destroy pathogen cell wall)	77.56, 76.7, 71.9 and 65.1%, inhibition of *F. oxysporum*, *F. solani*, *P. citreosulfuratum*, and *P. citrinum*	Tian *et al.* (2024)
T. virens	Soybean	Damping off	*Rhizoctonia solani*	Accumulation of phenolic compounds in infected areas.	Reduce disease incidence (22-34%)	Yusnawan *et al.* (2024)
T. asperellum	Jalapeno pepper	Fusarium wilt	*F. oxysporum*	Mycoparasitism and overgrew pathogen.	Pathogen inhibition: 40% - 87.5%	Perez-alvarez *et al.* (2024)
T. harzianum	Potato	Stem canker	*Rhizoctonia solani*	Inhibition of radial growth of *R. solani.*	44.5- 53% inhibition.	Alshimaysawe *et al.* (2024)
T. hamatum		Black scurf disease			56.5% inhibition	
Trichoderma spp.	Sugar cane	Sugarcane smut	*Sporisorium scitamineum*	Produce metabolite and hydrolytic enzyme, induced systemic resistance, competition	Smut incidence (22.8 to 66.9% reduction)	Joshi and Goswami (2024)
T. viride	Turmeric	Turmeric leaf spot	*Colletotrichum capsici*	-	Mycelial growth inhibition - 72.2%	Chandraprakash *et al.* (2024)
T. zelobreve	Apple	Apple canker	*Diplodia bulgarica*	Competition for nutrients and space, production volatile and non-volatile antibiotics	Inhibition percent: Dual culture (59.8%), Volatile antibiotics assay (42.1%) and Culture filtrate (39%)	Nourian *et al.* (2024)

T. atroviridae *T. koningiopsis*	Peanut	Peanut smut	*Thecaphora frezzii*	Metabolite secretion	>80%	Paredes *et al.* (2024)
T. asperellum	Durian	Anthracnose	*Colletotrichum* sp.	Inhibit mycelium growth.	50.76± 3.5 - 74.85± 2.5% inhibition	Sutthisa *et al.* (2024)
T. longibrachiatum, *T. harzianum,* *T. hamatum,* *T. asperellum,* *T. viride*	Mango	Stem-end and anthracnose fruit rot	*Lasiodiplodia theobromae* *Colletotrichum gloeosporioide*	Overgrew pathogen and inhibit radial growth.	Above 80% inhibition against both pathogens.	Nujthet *et al.* (2024)
T. sulphureum	*Rice*	Rice Blast	*Pyricularia oryzae*	Mycoparasitism, Competition, inhibit conidia production and mycelial growth.	Mycelial growth inhibition: 35-60%	Tshilenge-Lukanda *et al.* (2024)
T. brevicompactum	Maize	Maize sheath blight	*Rhizoctonia solani*	Both Competition and Antibiosis	51.19-77.4% inhibition	Iswati *et al.* (2024)
T. green,				Competition	46.67-59.52%	
T. ghanese				Antibiosis	57%	
T. dorothopsis				Competition	69.49%	
T. reesei				Competition	75.14%	
T. asperellum				Both	22.2- 77.4%	
T. harzianum	Cauli flower	Leaf spot	*A. brassicicola*	Radial growth inhibition.	80.64% inhibition	Sharma *et al.* (2024)
T. viride					78.49% inhibition	
T. koningii					57.14% inhibition	
T. viride	*Cucumis melo*	Damping off	*R. solani*	Increase protective enzymes release like APX, CAT, POD, & SOD.	90.48± 3.1% control efficacy	Dou *et al.* (2024)
T. viride, *T. asperellum* *T. harzianum*	Dragon fruit	Brown spot	*Neoscytalidium dimidiatum*	Coil formation around the pathogen by *Trichoderma* strains.	85.05% - 88.35% inhibition efficiency and 70.25–75.71% decline in disease index.	Nguyen *et al.* (2024)

T. harzianum, T. atroviride, T. virens	*Cucumis sativus*	Wilt	*F. oxysporum* f. sp. *cucumerinum*	Metabolites synthesis, competition, coils formation.	Above 70% inhibitory activity.	Akbari *et al.* (2024)
T. asperellum, T. harzianum	Rice	Seed rot and false smut,	*Bipolaris oryzae* *Curvularia oryzae* *F. semitectum*	Overgrew the radial growth of pathogenic species.	34.8% - 37.8% &>80% seed rot & false smut reduction respectively.	Seekham *et al.* (2024)
T. ghanense, T. citrinoviride	*Cucumis sativus*	Damping-off	*Pythium aphanidermatum*	Induce electrolyte leakage from pathogen mycelium.	31.3% - 44.6% inhibition	Al-Shuaibi *et al.* (2024)
T. asperellum	Straw berry	Grey mold	*Botrytiscinerea*	Volatile organic compounds (VOCs) damaged the cell membrane permeability and cause cytoplasm leakage.	76.9 - 100% inhibition	Fan *et al.* (2024)
Trichoderma harzianum	Snake fruit (*Salacca* sp.)	Black rot	*Thielaviopsis paradoxa*	Isoamyl alcohol (a VOC) inhibits pathogen.	71.14% inhibition	Napitupulu *et al.* (2024)
T.harzianum	Grapes	Gray mold	*Botrytiscinerea*	Competition, colonization, antibiosis, and mycoparasitism	67.5% inhibition	Hamza *et al.* (2024)
T. viride					64% inhibition	
T. harzianum	*Phaseolusvulgaris*	Leaf blight	*Pantoea eucrina*	Disrupt nutrient acquisition by pathogen.	53% inhibition	Hassan and Khalaphallah (2024)
T. viride					66% inhibition	
Trichoderma harzianum	Brinjal	Bacterial wilt	*Ralstonia solanacearum*	Peroxidase and flavonoid production	90% protection	Ahmad *et al.* (2024)
T. asperelloides, T. asperellum	Chili fruits (post-harvest)	Anthracnose	*C. gloeosporioides*	Competition, volatile and non-volatile compound synthesis.	>50% inhibition	Boukaew *et al.* (2024)
T. afroharzianum	Tomato	Leaf spot	*A. alternata*	Metabolites and enzymes production.	44.44% reduction in disease incidence	Philip *et al.* (2024)
T. virens *T. asperellum* *T. harzianum* *T. lixii*	Chickpea	Wilt and Collar Rot	*F. oxysproum* f. sp. *ciceri* *Sclerotium rolfsii*	Metabolite production and cell wall degradation by secretion of enzymes.	58.15–72.97% and 36.3–59.3% inhibition of *F. Oxysporum* and *S. rolfsii*	Kumari *et al.* (2024)

T. asperellum	Straw berry	Black rot	*Fusarium solani* *Rhizoctonia solani* and *Machrophomina phaseolina*	Upregulate the release of peroxidase and chitinase (defence related enzymes)	59.3 -74.1 % and 72.5 - 75.2 % disease incidence and severity decrease.	Elshahawy *et al.* (2024)
T. asperellum	Maize	Downy mildew	*Peronosclerospora spp.*	Trigger ROS production in plant tissue.	23% disease incidence.	Djaenuddin *et al.* (2024)
T. carraovejensis	Grapes	Grapevine trunk disease	*P. minimum* *P. chlamydospora* *D. seriata*	*T. carraovejensis* grew over the pathogenic strains.	15%, 21% and 34% inhibition of *P. chlamydospora*, *P. minimum*, and *D. seriata*, respectively.	Zanfano *et al.* (2024)
T. harzianum *T. asperellum*	Pineapple	Fruitlet rot	*Fusarium* spp.	Metabolite production	>51% inhibition.	Madrassi *et al.* (2024)
T. viride					53.7% inhibition	
T. harzianium *T. asperellum*	Pigeonpea	Wilt	*Fusarium udum*	Induced systemic resistance	>55% inhibition	Reddy *et al.* (2024)
T. harzianum	Onion	Basal rot	*F. oxysporum* f. sp. *cepae*	Mycoparasitism	13.58% disease suppression rate	Yagmur *et al.* (2024)
T. asperellum	Tomato	Fusarium Wilt,	*F. oxysporum* f.sp. *lycopersici*.	Radial growth inhibition	75.5 - 79.5% Fusarium, 64.57% disease incidence reduction	Amala *et al.* (2024)
T. harzianum	Rice	Sheath blight,	*R. solani*	Competition	60.4 - 68.7% inhibition	Singh *et al.* (2024)

Trichoderma spp. as biocontrol agent

In the beginning of the 20th century, Tubef and Smith for the first time put light on the term "Biocontrol" and linked it with phytopathogens. In 1983, Cook and Baker defined that "the process that reduces the number of microbes or pathogens without the assistance of outside humans is referred as Biological control Dash *et al.* (2024). Due to harmful side effects of chemical inputs employed in combating pest, disease and weeds, researchers are shifting their dependency towards biological agents for controlling pathogens and to sustain our environment. *Trichoderma* being cosmopolitan, non-parasitic has been favoured by scientists as an effective biocontrol agent that can have convincing combating effect against the concerns of agricultural productivity and various authors also agreed that they even have a mentionable boosting effect on the both vegetative as well as reproductive growth of crops Phillip *et al.* (2024). Before their application in particular field against particular disease in a particular crop or group of crops they are assessed in vitro to possess inhibitory effect on the growth of specific phytopathogen. These aided to investigate their mechanism towards the particular pathogen and also enable the research worker to calculate the values up to which these pathogens were affected or killed. Finally, planta analysis was performed under controlled environmental conditions to assess their efficiency to inhibit pest, combat disease and enhance vegetative, reproductive growth of crops Madrassi *et al.* (2024).*Trichoderma* as reported is known to have higher growth rate than the phytopathogens this enables them to utilize the nutrients quickly due to which they overgrow by creating a scarcity of nutrients and space for the pathogen to survive and thus inhibited as a result of competition. Besides the genus also secretes various secondary metabolites that are noxious to insects, microbes and unwelcomed herbs. They also boost the plants resistance systems like systemic acquired resistance, induced systemic resistance and hypertensive resistance by up regulating the levels of enzymes and phytocompounds within the host. In addition, they boost various growth parameters of their host such as root length, shoot length etc along with increased yield.

Insects and weeds management

Insect pests account for 26% of the agricultural loss at global level Junaid and Gokce (2024). These insects penetrate the host tissue and suck their phloem. Sometimes they may itself not be the culprits but they function as vector for those who infect and damage the plants Mohammed *et al.* (2024). Thus, there is a huge need to combat these perpetrator to alleviate their crumbling effect on their host. Entomopathogenic activity of *Trichoderma* species have been demonstrated in several previous research articles by Ibrahim *et al.* (2024); Wang *et al.* (2024); Mohammed *et al.* (2024) and many others. The authors put forwarded that the bioagent successfully enter the pest by penetrating the cuticle and then secrete variety of metabolites that has pesticidal effect.Some recent researches that utilize*Trichoderma* species as biopesticide is mentioned in Table 2.Whereas, weeds are the unwanted group of plants that grew in the cropland and compete with crops in terms of light, moisture, nutrients and space, ultimately stunt the growth of crops and can decrease production by 20-50% Parven *et al.* (2024).However, Junaid and Gokce (2024) highlighted that these unwelcomed group of plants can leads to a global loss in agricultural productivity by 23%. Weeds are a huge concern for cereal crops like rice, wheat, barley, oats, sorghum etc by reducing yield by 31%. Zhu and He (2024) reported the use of *T. polysporum* to infect *Avena fatua* which is a highly serious threat for agriculturally important crops. The authors assessed the genes that are responsible for inducing various metabolic pathways during weed infection. The outcomes confirmed that Glutamate dehydrogenase (GDH) gene was upregulated during *A. fatua* infection by the bioagent. Thus, indicating the involvement of the gene in synthesising metabolic compounds that aided *T. polysporum* to act as weedicides. While, *T. koningiopsis* as used by Camargo *et al. (*2024) to artificially synthesized bioherbicide and applied to soybean crops. This finding also confirmed that amylase, cellulase, laccase, lipase, and peroxidase are the enzymes that are present in synthesized bioherbicide are responsible for their weedicidal activity.

Table 2: *Trichoderma* spp. as potent pest control agent inagricultural crops

***Trichoderma* spp**	**Crop**	**Pest**	**Outcomes**	**Reference**
T. asperellum	Rice	*Nilaparvata lugens*	40-48% nymphs mortality.	Trizelia *et al.* (2024)
T. viride	Tomato	*Bemisia tabaci*	6.03 - 62.22% mortality	Mohammed *et al.* (2024)
T. longibrachiatum	Wheat	*Heterodera avenae*	38.43% nematode population reduction.	Wang *et al.* (2024)
T. *citrinoviride*	Wheat	*Trogoderma granarium*	69% larvalmortality.	Hassuba *et al.* (2024)
T. harzianum			46.3%	
T. asperellum			57.1%	
T. viride			19.4%	
T. viride	Brinjal	*Meloidogyne javanica*	71% reduction in nematode population	El-Deriny *et al.* (2024)
T. bevicrassum	Common bean	*M. incognita*	71% mortality and 68% ovicidal effect.	Ibrahim *et al.* (2024)
T. asperellum	Tomato	*M. incognita*	100% mortality & 88.4% ovicidal effect.	Amala *et al.* (2024)

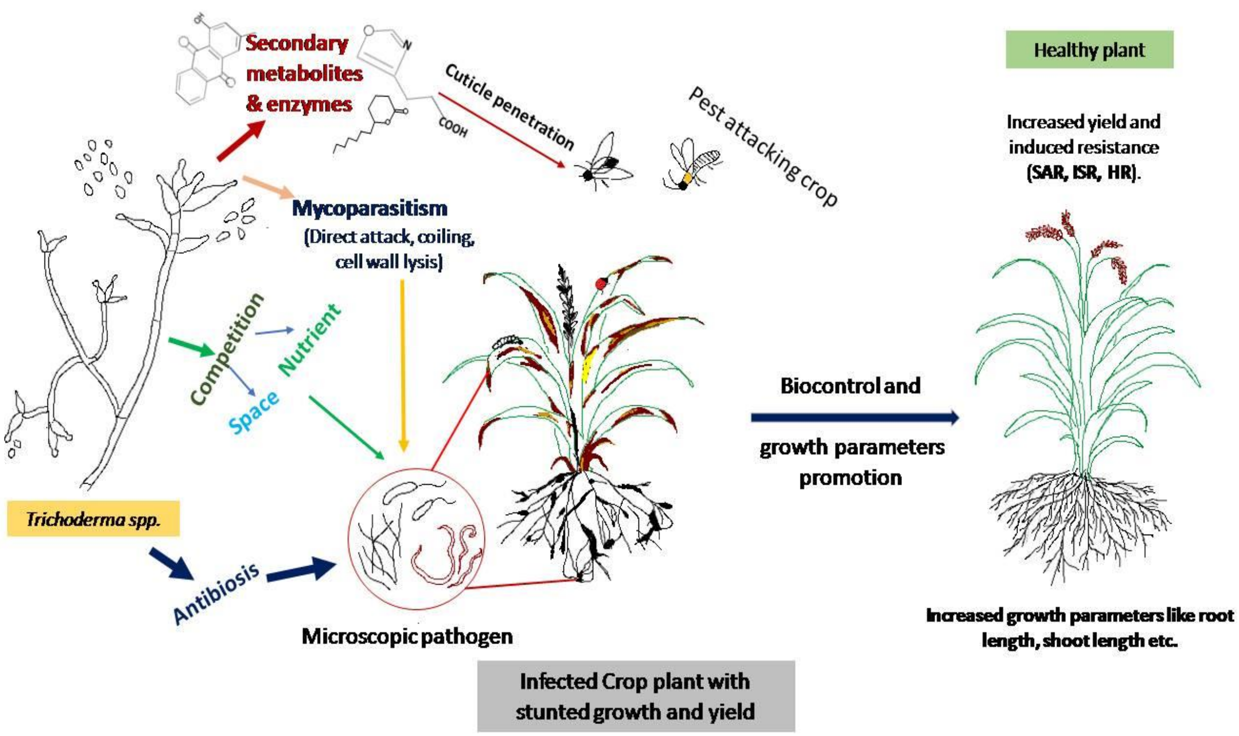

Figure 2: Biocontrol by *Trichoderma* spp.

Conclusion:

The use of biological agents are considered to be one of the preeminent and ecofriendly approaches for achieving agricultural success and pathogen inhibition without effecting the sustainability and stability of our ecosystem. In this connection, screening of new prospective biocontrol strains as a pre-emptive measure of emerging phytopathogens may be an important endeavour towards IPM strategies. Biocontrol mechanisms of various *Trichoderma* species have been well documented globally. They incarcerate the growth and proliferation of the phytopathogens through parasitism and antibiosis or by adopting different molecular approaches but our knowledge in this particular aspect till now is under infantry. The exploitation of the genus *Trichoderma* as a biocontrol agent in crop management program requires more detailed studies under *in-vivo* and *invitro* condition to unknot the concrete mechanistic approaches underlying its potentiality although its direct and indirect efficiency make it sustainable unconventional for the future in agricultural plant health.

Acknowledgements

The authors are thankful to Head, Department of Botany, Tripura University for assisting the laboratory facilities.

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AVIAN DIVERSITY OF KHAYRAMARI WETLANDS OF JALANGI BLOCK UNDER MURSHIDABAD DISTRICT, WEST BENGAL

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Abstract:

The avian world has always been a fascination to the human world and has been a subject of our studies. Mythological documents hold a number of examples of birds being worshiped as goods with magical powers by the ancient civilizations. Birds are great indicators of our environment and watching birds and their behaviors helps us to understand our nature better. Avifauna are important for the ecosystem as they play various roles as scavenger, pollinators, seeds dispersal agent and predators of insect pest and an important indicator to evaluate different habitats both qualitatively and quantitatively. Unfortunately, global diversity of birds is decreasing due to anthropogenic activities and climate changes. IUCN Red List of endangered birds has already recognized 1226 bird species as threatened globally and India with 88 threatened bird species. Earlier studies on avian biodiversity of the entire West Bengal province presented 949 bird species. But, avian diversity of various wetlands, lakes and pockets of landscapes of West Bengal still needs to be explored more, for conducting intensive research on the development of conservation strategies of avian population and diversity. No reliable literature is available about the wetland birds of Murshidabad. Therefore, an attempt was under taken to represent the unexplored bird diversity of adjacent Khayramari wetlands of Jalangi Block under Murshidabad district of West Bengal.

Keywords: Avian Diversity**,** Khayramari Wetlands, Murshidabad**,** West Bengal.

1. Introduction:

The avian world has always been a fascination to the human world and has been a subject of our studies. Mythological documents hold a number of examples of birds being worshiped as goods with magical powers by the ancient civilizations. Even today winged wonders continue to be the subject of our astonishment primarily because of their ability to fly, their ability to build extraordinarily intricate nests, and of course, the brilliant colour of their plumage – features that no human being can replicate. Taxonomically birds are categorized in “Orders” “Families” and “Genera” and “species”. But overall they are divided into two groups: Passeriformes (or Passerines) and Non Passeriformes (non passerines). At least 60% of all bird species are Passeriformes or song birds, their distinguishing characteristics being their specialized leg structure, vocal structure and brain-wiring, which allow them to produce complex songs. The non-passerine comprises 28 out of 29 orders of birds in the world. Throughout the world approximately 11,000 species are found. India is having 1301 species. West Bengal has 57.69% of the total avian fauna (750 species). Though there are many nomenclatures used by different people, we followed “Standardized common and scientific names of birds of Indian subcontinent by Manakadan and Pittie (2001). Identification of bird is generally based on combination of various characteristics. The bird anatomy includes the plumage colour, overall colour, head shape, beak shape, feet structure, the habitat character, season of occurrence, feeding behavior, flying behavior, display behavior and flaking are also important characters. Birds are great indicators of our environment and watching birds and their behaviors helps us to understand our nature better. Avifauna are important for the ecosystem as they play various roles as scavenger, pollinators, seeds dispersal agent and predators of insect pest and an important indicator to evaluate different habitats both qualitatively and quantitatively. Unfortunately, global diversity of birds is decreasing due to anthropogenic activities and climate changes. IUCN Red List of endangered birds has already recognized 1226 bird species as threatened globally and India with 88 threatened bird species.

Wetlands, locally known as ‘Beels’ are the most common and an integral feature of the fluvial landscape of West Bengal. Wetlands are those areas inundated or saturated by surface or ground water at a frequency and duration sufficient to support and that under normal circumstances, do support a prevalence of vegetation typically adopted for life in saturated soil conditions. Wetland generally includes swamps, marshes, bogs and similar areas. Wetland is a complex natural system that harbors a wide variety of flora and fauna, all of great economic, aesthetic and scientific importance. Wetlands are not wasteland at all, they are valuable natural wonderlands that keep the environment in a balance state. Wetlands of India, estimated to be 58.2 million hectares, are important repositories of aquatic biodiversity. According to Bird Life International (2001), the wetland of this area lies in Biome - 11 (Indo-Malayan tropical dry zone). Thirteen big fresh water wetlands, out of 23 (>100 hectare) in West Bengal, are present in different blocks of this district. In Bengal the large or small, permanent or seasonally waterlogged marshes are popularly known as “beel”. The wetlands of this region are generally palustrine (floodplains, seasonal waterlogged, marsh), lacustrine (Lakes) and riverine types. All these wetlands are directly or indirectly connected with the different rivers like Ganga, Babla, Jalangi, Bhairab etc. Wetlands are one of the most threatened habitats of the world. Wetlands in India, as elsewhere are increasingly facing several anthropogenic pressures. Thus, the rapidly expanding human population, large scale changes in land use/land cover, burgeoning development projects and improper use of watersheds have all caused a substantial decline of wetland resources of the country. Significant losses have resulted from its conversion threats from industrial, agricultural and various urban developments. These have led to hydrological perturbations, pollution and their effects. Unsustainable levels of grazing and fishing activities have also resulted in degradation of wetlands. The current loss rates in India can lead to serious consequences, where 74% of the human population is rural and many of these people are resource dependent. Healthy wetlands are essential in India for sustainable food production and potable water availability for humans and livestock. They are also necessary for the continued existence of India’s diverse populations of wildlife and plant species; a large number of endemic species are wetland dependent. Most problems pertaining to India’s wetlands are related to human population. Many species of fishes, amphibians, reptiles, birds and mammals depend on the wetland habitat for breeding, foraging and for their shelter supported by the diverse plant species. One of the best-known functions of wetlands is to provide habitat for birds which use wetlands for breeding, nesting and rearing of young ones, besides using them as a source of drinking water, for feeding, resting, shelter and social interaction.

Earlier studies on avian biodiversity of the entire West Bengal province (Sivakumar and Varghese *et al.,* 2006) presented 949 bird species. Various reports documented about the bird diversity and distribution in the northern and western region of West Bengal (Datta, 2011; Roy and Pal *et al.*, 2011; Patra and Chakrabarti, 2014). But, avian diversity of various wetlands, lakes and pockets of landscapes of West Bengal still needs to be explored more, for conducting intensive research on the development of conservation strategies of avian population and diversity. Few reports documented on birds of various parts of Murshidabaddistrict (De *et al.*, 2016; Dey, 2019; Dey, 2020). But no reliable literature is available about the Khayramariwetland birds of Murshidabad. Therefore, an attempt was taken hereby to represent the unexplored bird diversity of adjacent Khayramari wetlands of Jalangi Block under Murshidabad district of West Bengal.

2.1. The district:

Murshidabad (Bengali: মুর্শিদাবাদজেলা) is a district of West Bengal in eastern India. Situated on the left bank of the river Ganges, the district is very fertile. Covering an area of 5,341 km² (2,062 sq mi) and having a population 5.863m (according to 2001 census) it is a densely populated district and the ninth most populous in India (out of 640). Baharampur town is the headquarters of the district.The Murshidabad city, which lends its name to the district, was the seat of power of the Nawabs of Bangla. Historically, Nawab Siraj-ud-Daula lost to the British at the Battle of Plassey, the capital of Bengal was moved to the newly founded city of Calcutta.

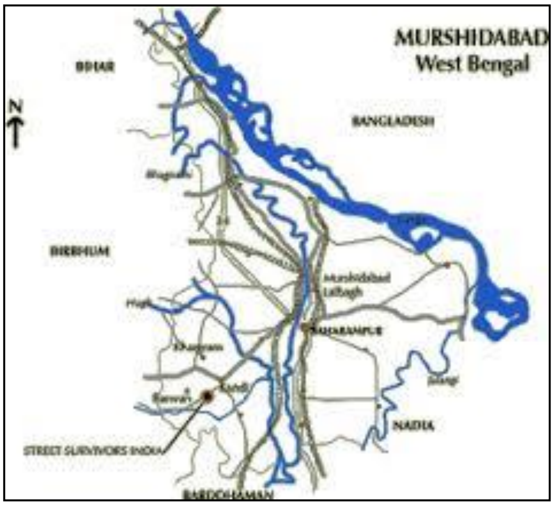
2.2. Geography:

Murshidabad borders Malda district to the north, Jharkhand's Sahebganj district and Pakur district to the north-west, Birbhum to the west, Bardhaman to the south-west and Nadia district due south. The international border with Bangladesh's Rajshahi division is on the east.

2.3. Landscape, Rivers and Vegetation

The district comprises two distinct regions separated by the Bhagirathi River. To the west lies the Rarh, a high, undulating continuation of the Chota Nagpur plateau. The eastern portion, the Bagri, is a fertile, low-lying alluvial tract, part of the Ganges Delta. The district is drained by the Bhagirathi and Jalangi rivers and their tributaries. Bhagirathi is a branch of the Ganges, and flows southwards from Farakka barrage where it originates from the Ganges. It flows southwards through the district and divides it into more or less equal halves. Most of the land is arable, and used as agricultural land. Commonly seen trees are Neem, Mango, Jackfruit.

2.4. Geology



Technically Murshidabad District is divided into three parts. Those are –

a) Open Shield Region: It seen some parts of the district.

b) Buried Shield Region: Some parts of Farakka and Suti-I block fall under this region. Ahiron Beel regionis a Buried Shield Region. It buried under the sediment of Bhagarathi River.

c) Rest part of Murshidabad District is shield and joint region of shield and geosynclines.

2.5. Climate

Murshidabad has a tropical wet-and-dry climate (Koppen climate classification). The annual mean temperature is approximately 27 °C; monthly mean temperatures range from 17 °C to 35 °C (approximate figures). Summers are hot and humid with temperatures in the low 30's and during dry spells the maximum temperatures often exceed 40 °C during May and June. Winter tends to last for only about two and a half months, with seasonal lows dipping to 9°C – 11°C between December and January. On an average, May is the hottest month with daily average temperatures ranging from a low of 27°C to a maximum of 40°C, while January the coldest month has temperatures varying from a low of 12°C to a maximum of 23°C. Often during early summer, dusty squalls followed by spells of thunderstorm or hailstorms and heavy rains cum ice sleets lash the district, bringing relief from the humid heat. These thunderstorms are convective in nature, and is locally known as Kal-baisakhi. Rains brought by the Bay of Bengal branch of South-West monsoon lash the city between June and September and supplies the district with most of its annual rainfall of approx 1,600 mm (62 in). The highest rainfall occurs during the monsoon in August approx 300 mm (12 in). Floods are common during Monsoon, causing loss of life, destruction of property, and loss of crops.

3.Study site and methodology:

The study was conducted near the Khayramari village area of Jalangi block under Murshidabad district of West Bengal. Wetlands, bills and lakes adjacent to Khayramari village were considered under the studied areas (Table.1) and the representative photographs are presented here in Fig.1 (study site) and Fig.2 (residential status of birds). Bird species observed and photographs were taken by Camera (SONY DSCHX 3000V) and represented in the Fig.3. Numbers of birds observed were used for Shannon Diversity Index for calculating diversity of species in a community under the studied area, where higher values of H indicate higher species diversity.The birds were counted by following the method described by Colin J. B. *et al.*, (2016) in Bird Census Technique (2nd Edition), Academic Press, pp. 1- 298.Birds wereidentified from the book "Hand Book of Indian Wetland Birds and their Conservation" by Kumar A *et al.*, (2005).

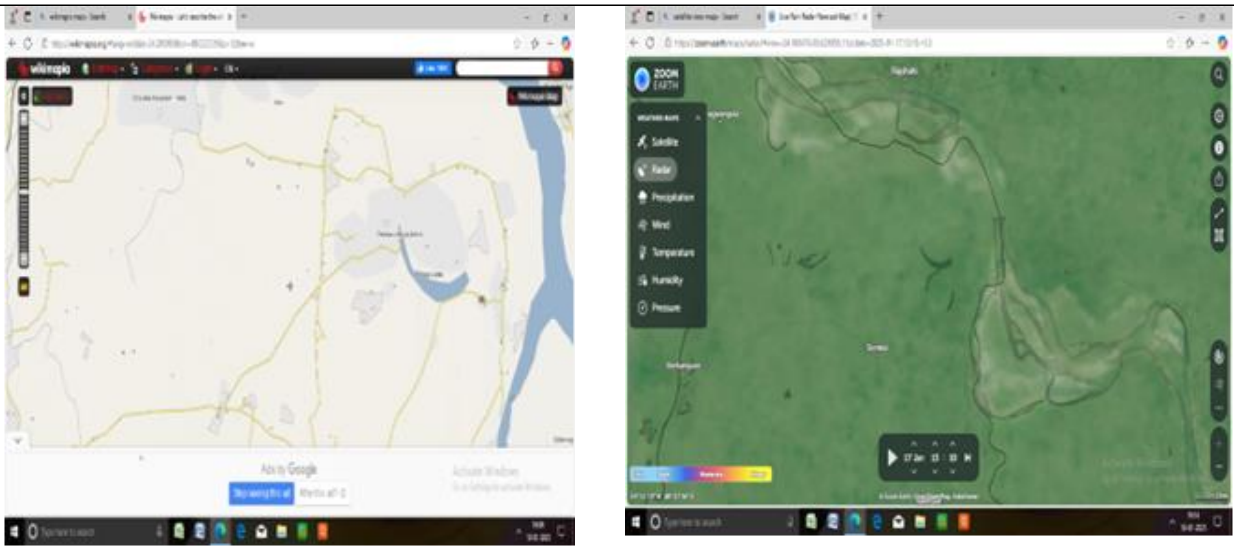


Figure 1: Google-Earth image of Khayramari wetlands

4. Result and discussion:

The earth ecosystem is disrupting day by day due to the extreme globalization throughout the world. Destruction of natural habitat of world fauna via anthropogenic settlements, urbanization and other development activities (Chalfoun and Schmidt 2012; Møller and Jokimäki *et al.* 2014) are the main reasons of extinction of faunal diversity of the world (Dıaz and Symstad *et al.* 2003). Birds are indispensable part of ecosystem which stabilizes the balance between various ecosystems. The studied site (Table.1) represented 34 bird species belonging to differentresidential status categories like: migrant (M), local migrant (Lm) and residential (R) (Figure.2). The common and scientific name of the 34 bird species with their family and order was also documented (Table.2). Shannon-Wiener index of bird species ofKhayramari wetland (Table.3) represented the value 3.033248 along with e^H value (equal distribution) 20.76, which demarcates that the species richness and abundance is quite well. The representative photographs of 34 bird species were documented in Figure.3.

Table 1: Physiography of the Khayramari study sites

No	Name of Water Body	Location Details	Type/ Approximate area	Surface Area Covered	Connectivity with other water body
1	Khayramari	24°10’36” N 88°39’53” E	Beel (5000 bigha ox bow)	Water Hyacinth (Partially)	Padma

Table 2: Bird species of Khayramari wetlands

Family wise Species with author and year	Common name	Residential status – migrant (M)/ local migrant (Lm)/ resident (R)
ANSERIFORMES: Anatidae		
Dendrocygna javanica	Lesser Whistling-duck	R
Netta rufina	Red-crested Pochard	M
Anas acuta	Northern Pintail	M
Mareca strepera	Gadwall	M
PODICIPEDIFORMES: Podicipedidae		
Tachybaptus ruficollis	Little Grebe	R
Podiceps cristatus	Great Crested Grebe	M
GRUIFORMES: Rallidae		
Amaurornis phoenicurus	White-breasted Waterhen	R
Porphyrio porphyrio	Purple Swamphen	R
Fulica atra	Common Coot	M
CICONIIFORMES: Ciconiidae		
Anastomus oscitans	Asian Openbill	R
Ciconia episcopus	Asian Woollyneck	R
Leptoptilos javanicus	Lesser Adjustant Stork	Lm
PELECANIFORMES: Threskiornithidae		
Threskiornis melanocephalus	Black-headed Ibis	R
PELECANIFORMES: Ardeidae		
Ixobrychus sinensis	Yellow Bittern	R
Ardeola grayii	Indian Pond-heron	R
Bubulcus ibis	Cattle Egret	R
Ardea cinerea	Grey Heron	R

Ardea purpurea	Purple Heron	R
Ardea alba	Great White Egret	R
Egretta garzetta	Little Egret	R
SULIFORMES: Phalacrocoracidae		
Microcarbo niger	Little Cormorant	R
Vanellus cinereus	Grey-headed Lapwing	M
Vanellus indicus	Red-wattled Lapwing	M
CHARADRIIFORMES: Jacanidae		
Hydrophasianus chirurgus	Pheasant-tailed Jacana	R
Metopidius indicus	Bronze-winged Jacana	R
CHARADRIIFORMES: Scolopacidae		
Tringa neblaria	Common Greenshank	Lm
ACCIPITRIFORMES: Pandionidae		
Pandion haliaetus	Osprey	Lm
ACCIPITRIFORMES: Accipitridae		
Circus aeruginosus	Western Marsh-harrier	Lm
Haliastur indus	Brahminy Kite	R
Milvus migrans	Black Kite	R
CORACIIFORMES: Alcedinidae		
Alcedo atthis	Common Kingfisher	R
Ceryle rudis	Pied Kingfisher	R
Pelargopsis capensis	Stork-billed Kingfisher	R
Halcyon smyrnensis	White-breasted Kingfisher	R

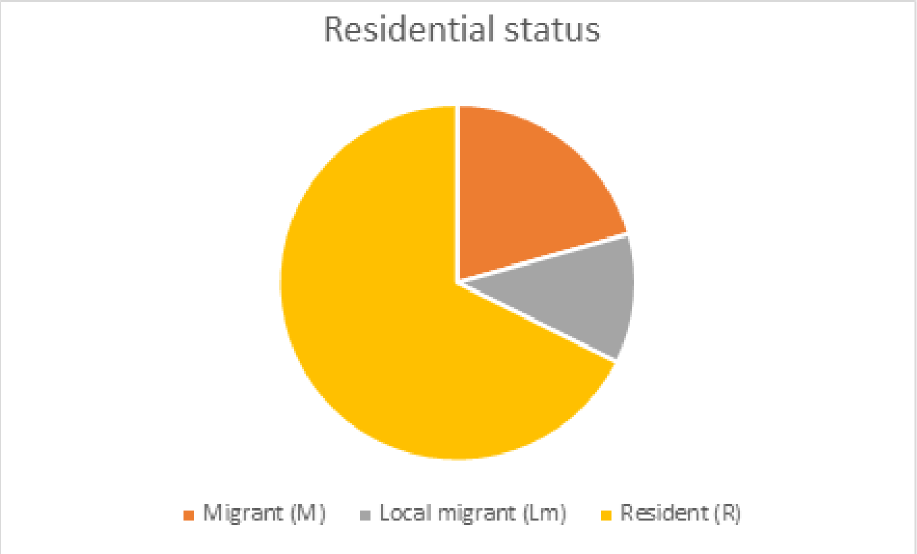


Figure 2: Residential status of bird species of Khayramari wetlands

Table 3: Shannon-Wiener index of bird species of Khayramari wetlands

Bird Species representing Shannon-Wiener Index			
Lesser Whistling-duck	0.104188	-2.26156	-0.23563
Red-crested Pochard	0.040858	-3.19765	-0.13065
Gadwall	0.012257	-4.40162	-0.05395
Northern Pintail	0.006129	-5.09477	-0.03122
Little Grebe	0.040858	-3.19765	-0.13065
Great Crested Grebe	0.001021	-6.88653	-0.00703
White-breasted Waterhen	0.035751	-3.33118	-0.11909
Purple Swamphen	0.061287	-2.79219	-0.17112
Common Coot	0.076609	-2.56904	-0.19681
Lesser Adjutant	0.003064	-5.78792	-0.01774
Asian Openbill	0.071502	-2.63804	-0.18862
Asian Woollyneck	0.020429	-3.8908	-0.07949
Black-headed Ibis	0.071502	-2.63804	-0.18862
Yellow Bittern	0.030644	-3.48533	-0.1068
Indian Pond-heron	0.015322	-4.17848	-0.06402
Cattle Egret	0.030644	-3.48533	-0.1068
Grey Heron	0.015322	-4.17848	-0.06402
Purple Heron	0.030644	-3.48533	-0.1068
Great White Egret	0.030644	-3.48533	-0.1068
Little Egret	0.040858	-3.19765	-0.13065
Little Cormorant	0.020429	-3.8908	-0.07949
Grey-headed Lapwing	0.008172	-4.80709	-0.03928
Red-wattled Lapwing	0.030644	-3.48533	-0.1068

Pheasant-tailed Jacana	0.102145	-2.28136	-0.23303
Bronze-winged Jacana	0.030644	-3.48533	-0.1068
Common Greenshank	0.030644	-3.48533	-0.1068
Osprey	0.004086	-5.50024	-0.02247
Western Marsh-harrier	0.002043	-6.19338	-0.01265
Brahminy Kite	0.002043	-6.19338	-0.01265
Black Kite	0.010215	-4.58395	-0.04682
Common Kingfisher	0.001021	-6.88653	-0.00703
Pied Kingfisher	0.004086	-5.50024	-0.02247
Stork-billed Kingfisher	0.002043	-6.19338	-0.01265
White-breasted Kingfisher	0.012257	-4.40162	0.012257
			-3.03325
			3.033248
	eH		20.76456


Red crested pochard


Black Headed Ibis


Lesser Adjustant Stork


Ospray


Lesser Whistling Duck


Common Coot

Figure 3: Photographs of some important bird species of Khayramari wetlands

Conclusion:

The report is a first-line initiative to present the avian diversity of Khayramari wetlands. Although, avian diversity of various wetlands, lakes and pockets of landscapes of West Bengal still needs to be explored more, for conducting intensive research on the development of conservation strategies of avian population and diversity. Therefore, this preliminary attempt brings the scope of finding check-list of the bird speciesof Khayramari wetlands of Jalangi Block under Murshidabad district of West Bengal.

Acknowledgement:

The authors are thankful to Principal, Rammohan College, Kolkata for encouragement and moral support.

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A SYSTEMATIC REVIEW ON THE PLANT-POLLINATOR INTERACTIONS IN INDIA

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Abstract:

Plants pollinator interactions are important because they are mutualistic relationship that helps plant reproduce and diversify. Pollination supports the biodiversity as approx. 87% of flowering plants rely on pollinators. Through this interaction plant and pollinators exchange their benefits such as: food for pollinators and efficient vectoring of sexual reproduction for plants. The objective of the present study was to gather a comprehensive information on plant-pollinator interaction interactions of Indian flora based on two major database such as web of science and Scopus. A search for papers was done that examine the Plant-pollinators interaction or the pollination of plants which are included in Indian flora Spanning from 2010-2023. The papers which do not meet the criteria that they have the records of pollinator interaction in flowers and/or animal-mediated pollination in plant species to be found in India or the study site is located in India were excluded and those papers which meets the above criteria were included in this study. PRISMA protocol was followed for data collection and screening of data from literature. A total of 38 published reportsre presenting 48 families of pollinators were observed and 505 interactions were collected. Among the 48 families highest number of pollinators observed in Nymphalidae followed by Apidae. Among plant species belonging to the family Lamiaceae, Fabaceae, Plumbaginaceae and Acanthaceae attract pollinators most. This review provided a comprehensive information on plant-pollinator interactions associated with plant occurring in India which may enhance our understanding of this important ecosystem services.

Keywords: Plant-pollinator interactions, Pollination, PRISMA, Bees, Butterflies

Introduction:

Plant-pollinator interaction dynamics play a pivotal role in the reproductive success of flowering plants occurring across the globe (Ollerton *et al.,* 2011). In this mutualistic interaction, insects play an important role in pollinating the majority of angiosperms and the subsequent evolution of the reproductive systems. India is the home of more than 91,200 animal and 45,500 plant species which is almost 7 to 8 % of the world's species. And India is also consists of 4 biodiversity hotspots among the 34 (Orr *et al.*, 2021). Among the four biodiversity hotspot Himalayan hilly range played important role to maintain the ecological balance in whole country but decreasing number of domestic/native pollinator effects the pollination of several plants of this particular area (Ahmed *et al.*, 2006). Due to anthropogenic venture and the practices of different agriculture methods several pollinators especially non-bee species are declining rapidly in outer Himalayan regions. Plants do have multiple pollinators (Ollerton *et al.*, 2009) which can be explored only through studying plant-pollinator interaction networks, its nothing but a study of the ecological behavior of different species that interact among themselves (Pasquaretta *et al.*, 2014). Pollination of weedy species are studied widely in India (Varalakshmi and Raju 2013; Budmajji and Solomon Raju 2018; Deeksha *et al.* 2021).

Flowering plants have evolved several floral structures/arrangements that favour different types of breeding systems and produce higher fruit sets, fruit length, and the emergence of seedlings, which show more affinity with cross-pollination. On the other hand for their morphological features, some plants avoid cross-pollination which is considered as self-compatible plants. The third type of flower style was shorter than the stamens due to which stigma were away from the lobes and the fourth type of flower style was longer than the stamens. Trichomes were unicellular and non-glandular which were present on the ovarian surface and inner surface of corolla and calyx. Peltate scales were also present on these surfaces. They have secondary pollen which promotes out-crossing (Rohitash & Jain 2010). Most plants are pollinated by various insects including bees, butterflies and moths, belonging to the order Lepidoptera, Diptera, and Hymenoptera. Bumblebees and solitary bees dominate in temperate forests whereas honeybees, long-tonged solitary bees, and stingless bees dominate in tropical rainforests (Kato *et al.*, 1990). And those flowers that have deep and long flower tubes are self-incompatible, which means they depend on various pollinators. Example- In temperate forests, bumblebees were predominantly distributed while in tropical rain forestslong-tongued solitary bees are widely present (Kato *et al.*, 1990; Sakai *et al.*, 1999) and honeybees who pollinated mostly canopy trees (Momose *et al.*, 1998; Roubik *et al.*, 2005). However, honeybees are widely seen during only in flowering season (Dyer and Seeley, 1994) and during this season honeybees increase their family member (Itioka *et al.*, 2001).

Endangered Species are largely found in India especially inthe North-eastern region (Venugopal & Marbaniang, 2015). Degradation of natural ecosystems, urbanization, agrochemicals, climate change, habitat disruption, wide use of agricultural methods (Winfree *et al.*, 2009), habitat loss (Brown & Paxton, 2009) negatively affects the biodiversity (Ellis, 2011) a/w/a pollinators population and ecosystem services (Williams & Winfree 2013). Global warming affects the plant-pollinator interaction, flowering phenology and the appearance of several pollinators such as butterflies and birds (Williams &Winfree 2013).

Due to globalization and other developmental projects crises have been seen for many species in the environment and pollinators are one of them. So, conservation and protection of them are very necessary. The present study was therefore undertaken to gather all the information on plant-pollinator interaction representing different plants across India. Specifically, this study aimed to collect information on 1) Plant-pollinator interactions for different plants occurring across India, 2) Pollinator visit behaviors and 3) Conservation implication of plant-pollinator mutualistic interactions.

Literature survey and data collection

A search for papers that examine the Plant-pollinators or the pollination of plants Indian flora was conducted spanning from 2010-2023. The references included in this review were sourced from the Web of Science™ and Scopus databases. The search terms used during the survey includes: “India* pollinat*”, “floral visitors*”, “India* and pollinat*”, “Floral visitors * and flower and India*”, and “Pollinator interaction* and India” was conducted. This resulted in 499 unique papers (Fig. 1). Papers had to meet the criteria that they recorded pollinator interaction in flowers and/or animal-mediated pollination in plant species to be found in India or the study site is located in India. The papers that reported pollinator interacting with species belonging the flora of Indian were included in this study. After review, 38 papers were included in the final analysis (Fig. 1). Papers that were excluded were reviews and not reported plant-animal interactions.

PRISMA protocol was followed for data collection and screening of data from the literature (Fig. 1). We have also extracted data on study location and year, species and family of plant, pollinator taxon, pollinator group (e.g. bee, butterfly, fly, bird) and interacting behaviour of pollinators with their respective plants. These data were used to interpret the result of this systematic review. The accepted names of plants were validated based on online databases such as GBIF, Plants of the World Online (https://powo.science.kew.org/) etc.

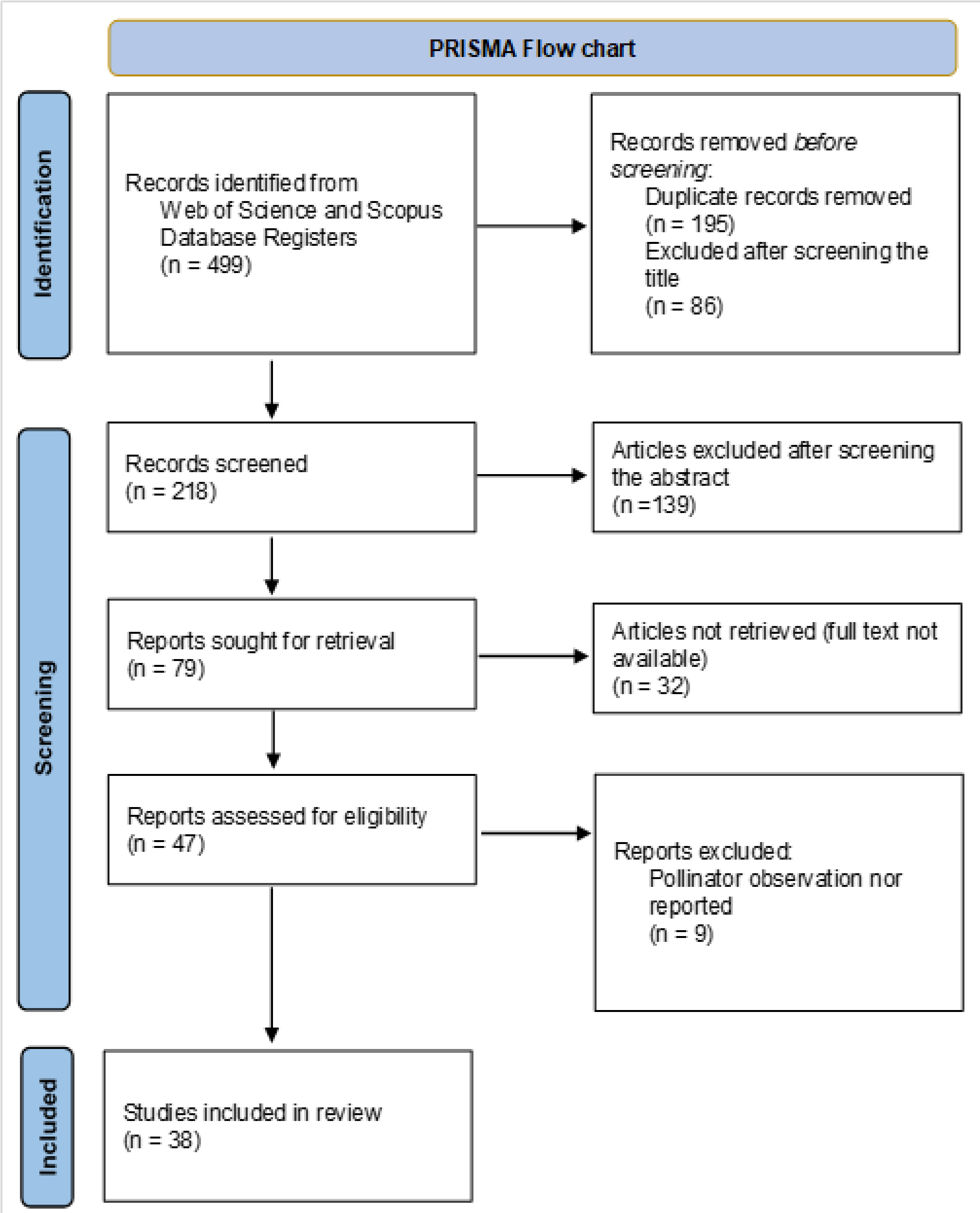

Figure 1: Flow diagram depicting the search (spanning 2010-2023) and selection of the study process according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement

Results:

The literature survey was conducted during January-March, 2023 using two predominantly used database viz., Scopus and Web of Science (WoS). A total of 499 published records were identified after screening two databases. The study followed PRISMA methods to search and select the most relevant papers to be included in the study. The duplicate reports (n=195) were excluded from screening the titles. During the survey, a total of 86 papers were further excluded from this review as their title was not related to the keywords used to search papers. A total of 139 papers were excluded from analysis after screening the abstract of these papers, those papers that do not represent relevant information regarding plant-pollinator interactions were excluded. The study was now left with 79 papers, which were again searched for the availability of full text, and for 32 papers full text was not available and excluded from the analysis. Furthermore, nine papers were excluded from the present study as these papersdo not report pollinator visitation data and the study included a total of 38 papers for the systematic review.

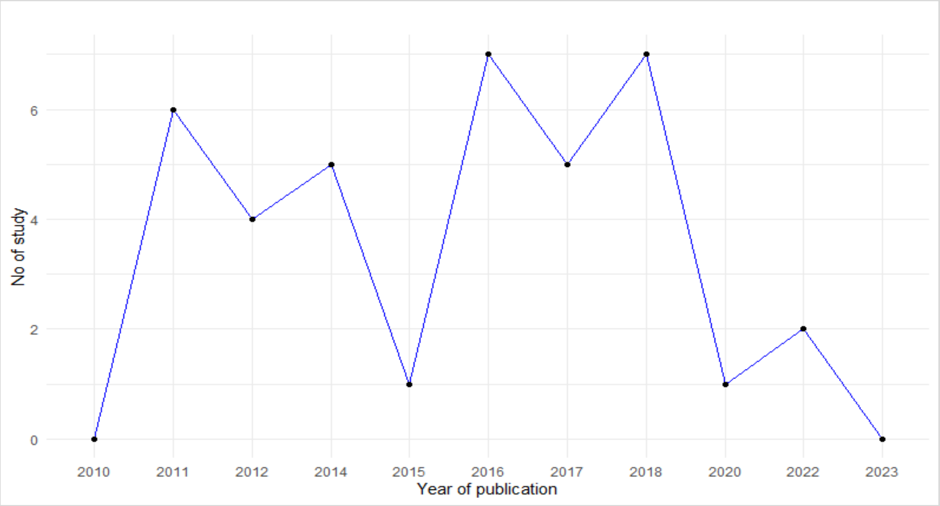

Figure 2: Growth of research effort through time on plant–pollinator interactions of Indian flora (from 2010-2023). For the year 2023 only January and February was considered.

The study recorded a total of 505 plant pollinator interaction data representing different plant species distributed across India. The survey considered published reports from 2010-2023, given a total of 38 published reports that fall on the study criteria. In the year 2016 and 2020 represented with highest number of published reported with n=7 papers each, followed by year followed by year 2011 and 2014 with six and five studies each (Figure 2).

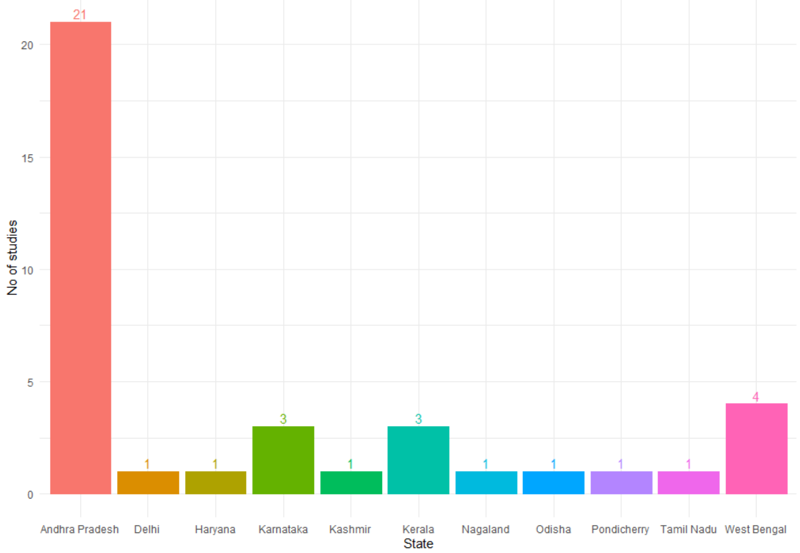

Figure 3: Different states of India representing study reports surveyed during 2010-2023 using Web of Science and Scopus database.

Table 1: Dominating insect species recorded to interact with different plant species of India

Insect species	Family	Common name
	Hymenoptera	
Apis dorsata	Apidae	Giant honey bee
Trigona iridipennis Smith	Apidae	Dammer Bee
Xylocopa latipes Drury	Apidae	Tropical carpenter bee
Xylocopa pubescens	Apidae	Carpenter bee
Apis cerana	Apidae	Asian honey bee
Apis florea	Apidae	Red dwarf honey bee
Vespa cincta	Vespidae	Greater banded hornet
Eumenes petiolata	Vespidae	Wasp
*Eumenes conica*F	Eumenidae	Potter wasp
	Lepidoptera	
Macroglossum variegatum	Sphingidae	Hummingbird
M. corythus	Sphingidae	Syrphid fly
Euploea core	Nymphalidae	Common crow
Tirumala limniac	Nymphalidae	Blue tiger
Catopsilia pomona F.	Pieridae	Lemon emigrant
Junonia lemonias L.	Nymphalidae	Lemon pansy
Acraea violae F.	Nymphalidae	The Tawny coster
Danaus chrysippus	Nymphalidae	African queen
Everes lacturnus	Papilionoidea	Indian cupid
Danaus genutia	Nymphalidae	The common tiger
	Diptera	
Helophilus sp.	Syrphidae	Syrphid fly
Chrysomya megacephala	Calliphoridae	Oriental blue fly
Eristalinus arvorum	Syrphidae	Hoverfly
Sarcophaga sp.	Sarcophagidae	Flesh flies
Eristalinus arvorum	Syrphidae	Hoverfly

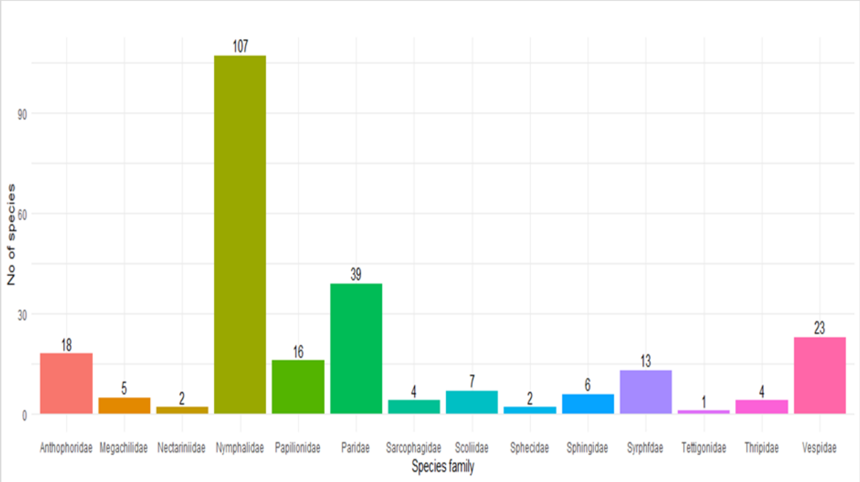

Figure 4: Dominating insect families recorded during the present Plant-pollinator interaction survey (data period: 2010-2023).

The present study recorded plant pollinator interaction among different flora of India represented with 48 families. Among them the most dominating family was Nymphalidae and Apidae, represented with 107 and 104 no of species respectively (Figure 4). The order Paridae, Vespidae, Anthophoridae and Papilionidae represented with 39, 23, 18 and 16 studies each, respectively.

In the present study, a total of 34 species represented by 18 different families were recorded (Figure 4). Most number of species studied were reported for the family Lamiaceae (n=5), followed by Fabaceae (n=4), Plumbaginaceae (n=3) and Acanthaceae (n=3). While the family Apocynaceae, Balsaminaceae, Burseraceae Convolvulaceae, and Myrtaceae represented by two study species each (Figure 5).

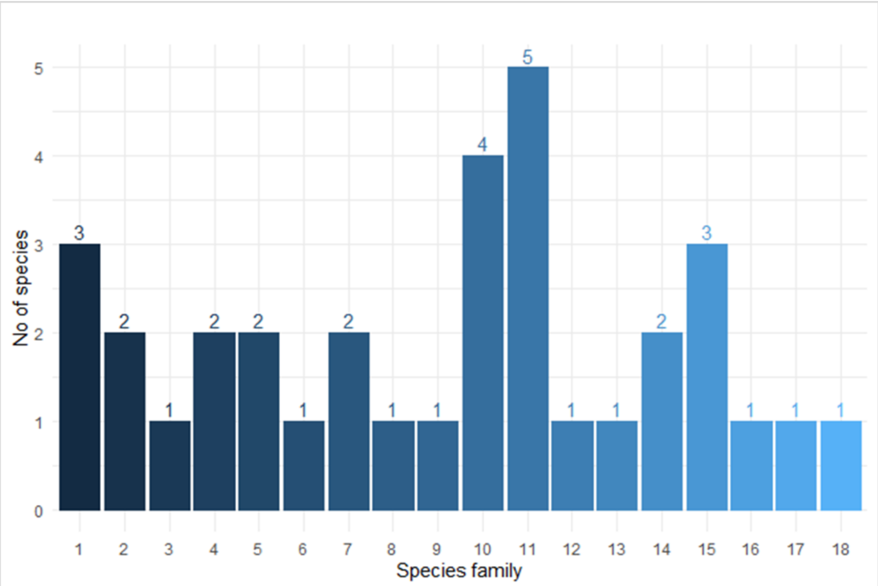

Figure 5: Dominating plant families represented by the number of species studied during the time period 2010-2023 based on Scopus and Web of Science database search. 1) Acanthaceae, 2) Apocynaceae 3) Asteraceae, 4) Balsaminaceae, 5) Burseraceae, 6) Caesalpiniaceae, 7) Convolvulaceae, 8) Cucurbitaceae, 9) Dipterocarpaceae, 10) Fabaceae, 11) Lamiaceae, 12) Malvaceae, 13) Melastomataceae, 14) Myrtaceae, 15) Plumbaginaceae, 16) Rubiaceae, 17) Sterculiaceae and 18) Zingiberaceae

Table 2: Plant species and the major group of insects that interact with each other

Plant species	Bees	Butterflies	Flies	Beetle	Wasp	Others	References
Impatiens cuspidata Wight &Arn.	+	+	+	_	_	+	Sreekala *et al.*, 2011
Eriolaena hookeriana Wight &Arn.	+	+	_	_	+	+	Raju *et al.*, 2014
Shorea roxburghii G.Don	+	+	_	_	_	+	Raju *et al.*, 2011
Boswellia ovalifoliolata N.P.Balakr. &A.N.Henry	+	+	+	_	+	+	Raju *et al.*, 2012
Avicennia L. species	+	+	+	_	+	_	Raju *et al.*,2012
Caesalpinia crista L.	+	_	_	_	_	_	Raju & Raju,2014
Syzygium alternifolium (Wight) Walp.	+	+	_	+	+	+	Raju *et al.*, 2014
Clerodendrum inerme (L.) Gaertn.	+	+	+	_	+	+	Raju & Kumar, 2016
Pavetta indica L.	+	+	_	_	_	+	Raju *et al.*, 2016
Premna latifolia Roxb.	_	+	_	_	+	+	Kumar *et al.*, 2018
Merremia tridentata (L.) Hallier f.	+	+	_	_	_	_	Lakshminarayana& Raju, 2018
Cucumis sativus L.	+	+	+	+	_	+	Hanif *et al.*, 2022
Alstonia scholaris (L.) R.Br.	+	+	_	_	+	+	Chauhan &Nisha,2018
Curcuma aeruginosa Roxb.	+	+	_	+	_	+	Aswani&Sabu, 2017
Abrus precatorius L.	+	+	+	_	_	+	Choudhury *et al.*, 2017
Osbeckia wynaadensis C.B.Clarke	+	_	_	_	_	_	Simi & Sunil,2018
Pterocarpus marsupium Roxb.	+	+	_	_	_	+	Pal & Mondal,2018
Syzygium caryophyllatum (L.) Alston	+	+	+	+	+	+	Geethika& Sabu,2017
Acanthus ilicifolius Lour.	+	+	_	_	+	_	Raju *et al.*, 2017
Aegialitis rotundifolia Roxb.	+	+	_	_	+	+	Raju & Jonathan,2018
Derris trifoliate Lour.	+	+	_	_	_	_	Raju & Kumar,2016
Emilia sonchifolia (L.) DC.	_	+	+	_	+	_	Rao Medabalimi *et al.*, 2017
Evolvulus nummularius (L.) L.	+	+	_	_	_	_	Lakshminaraya& Raju., 2017
Rauvolfia serpentina (L.) Benth. ex Kurz	+	+	+	+	+	+	Anoosha *et al.*, 2018
Alpinia blepharocalyx	+	_	+	_	_	_	Chaturvedi *et al.*, 2020
Bidens pilosa	+	+	_	_	+	+	Budmajji& Raju, 2018

Discussion:

In the sexual reproduction of many angiosperms, animal pollinators play crucial roles (Ollerton *et al.* 2011; Ratto *et al.* 2018). The evolutionary and ecological outcomes of the interaction between plants and pollinators are geographically transient (Hiraiwa & Ushimaru, 2017; Johnson *et al.,* 2017; Ollerton, 2017; Zanata *et al.,* 2017). However, the global variation in interactions between plants and pollinators is yet inadequately traversed (Ollerton 2012). For instance, some studies about plant reproductive ecology and interactions between plants and pollinators on a global level consisted of very few or no East Asian examples due to insufficient data (Ollerton *et al.* 2009; Ollerton 2012; Johnson *et al.* 2017; Zanata *et al.* 2017). Moreover, in East Asia pollinators such as nectar feeding-birds and hawkmoths have been studied poorly (Johnson *et al.* 2017; Ren *et al.* 2018).

The present study provides an extensive literature survey of studies published on the interaction between Plants and pollinators and pollination of different plant species which is found in India. Pollination is a vital phase in the life cycle of plants and it has been estimated that around 75 % of all the crop species that are used for consumption by human being globally needs pollination by insects (Klein *et al.,* 2007) and the ratio of total agricultural land occupied by crops which are dependent on insect pollinators has been gradually increased from the year 1961 to 2016 (Aizen *et al.,* 2019). Understanding the influences of drought on species that are pollinated by insects and the interaction betweenplants and pollinators is an economically significant, but highly neglected issue. This service provided by the ecosystem is vital for the conservation of biodiversity; the communities of plants are maintained by pollinators, through the production of seeds and fruits that sustain a significant proportion of endangered species and biodiversity. In temperate regions, pollination of approximately 78% of plant species is done by animals, and most of these animals are insects, particularly bees (Ollerton *et al.,* 2011).

In the tropical monsoon forest, *Amegilla* bees possessing long tongues were key pollinators of undergrowth perennial plants with deep flowers as it was in the tropical rain forest (Kato, 1996; Wardhaugh *et al.,* 2015). Although, the metasoma band coloration of these bees varied with one being brown and the other blue. In contrast to the shade-loving brown-banded *Amegilla* bees (subgenus *Glossamegilla*) which remain confined to the dark forest floor (13), blue-banded *Amegilla* bees (subgenus *Zonamegilla*) exhibit a preference for sunny environments and exploit sunlit habitats. This behavioral disparity aligns with the distinct light environments found on the forest floor, characterized by perpetual darkness in tropical rain forests but relatively bright conditions in tropical monsoon deciduous forests, particularly during the dry season. In addition to visiting understory flowers, blue-banded *Amegilla* bees were also observed on flowers in sun-exposed habitats, encompassing the canopy layer. However, the present study showed that Nymphalidae was the most dominating family among 48 recorded families.

Previous studies on plant-pollinator interactions revealed that *Xylocopa*, Megachilids, and small bees were also pivotal pollinators of a wide range of plant species. The majority of these bees are solitary exception of the relatively rare *Trigona* species. Some of the families (Hyalaeinae, Xylocopinae, and Megachilidae) nesting holes in the stem, and others such as Halictidae nest underground. The population density of stem hollow-nesting bees correlates positively with the abundance of bamboo species, which serve as primary nesting sites. The plants of Fabaceae exhibited the highest diversity at our site, with a majority of its species relying on solitary bees for pollination. Certain canopy tree species bearing large flowers (*Afzelia*, *Rothmania*, *Dillenia*, and *Cassia*) were found to be pollinated by large *Xylocopa* bees, which also play a dominant role in pollinating canopy trees in the neotropical regions (Bawa, 1990).

Another prevalent system of pollination in the tropical monsoon forest was psychophily, which is rarely seen in tropical rainforests (Momose *et al.*, 1998). Subcanopy lianas, shrubs, and trees belonging to families such as Capparidaceae (*Capparis*), Apocynaceae *Alstonia*, *Melodinus* and *Aganonerion*), Oleaceae (*Jasminum*), Fabaceae (*Bauhinia*), Rubiaceae (*Ixora, Catunaregam, Pavetta, Mitragyna, Vangueria* and *Rothmannia*), Verbenaceae (Clerodendron) and Sterculiaceae (*Melochia* and *Pterospermum*) were visited primarily by butterflies. The richness of papilionid, danaid, and pierid butterflies was positively correlated with the availability of their respective host plants (Rutaceae, Apocynaceae, and Fabaceae, respectively). Certain host plants can grow even in disturbed habitats (*Cassia* and *Aganonerion*) or some host plants are cultivated (*Citrus*) which enables these butterflies to provide pollination services in managed forest ecosystems. Some plant species (*Globba*, *Mitragyna*, and *Aganonerion*) rely mainly on bees for pollination in addition to pollination by butterflies also; making them more resilient to habitat changes (Macgregor *et al.*, 2015).

Conclusions:

The present study provides a systematic review of plant pollinator interactions recorded for the flora distributed across India. Literature survey based on Web of Science and Scopus resulted in 499 published reported and after screening all of them using PRISMA method, a total of 38 published study were included in this study. Plant pollinator interaction data were collected representing eleven different states of India, where Andhra Pradesh with highest published studies (n=21).The present study recorded plant pollinator interactions of different animals representing 48 families, among them Nymphalidae and Apidae, were most dominant and represented with highest no of interactions.In the present study, a total of 34 plant species represented by 18 different families were recorded, where Lamiaceae was dominating family with highest number of published reports.

Acknowledgments:

The authors thank the Heads, Dept. of Botany, MBB, and other authorities of Tripura University for providing the necessary facilities to carry out this study. SP thanks the University Grant Commission (UGC), New Delhi, India for providing a non-NET PhD fellowship.

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PRELIMINARY STUDY OF URBAN MANGROVE PATCH IN MARVE, MUMBAI

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Abstract:

Mangroves offer a variety of environmental advantages and reduce the impact of high tides. They play a major role in carbon sequestration, reduce salinity in nearby water bodies and provide an ecosystem for local flora and fauna to reside in. Periodic and regular assessment of the mangrove ecosystem is crucial for its maintenance and preservation. For this study, a patch of Urban-Mangroves in Marve-Malad was selected. The selected area being close to anthropogenic activities and easily accessible for sample collection. In the location, three stations were selected for sampling, each 100 meters apart. Water and soil samples were collected and analysed for various physico-chemical parameters. The water samples were tested for salinity, pH, nitrates, silicates and phosphates. The soil samples were studied for moisture content, texture, pH, and organic content. The studied parameters enable us to get a comprehensive perspective of the conditions prevailing in this patch of urban mangroves.

Keywords: Mangroves, Moisture, Salinity, Coastal Biodiversity

Introduction:

Mangrove ecosystem is a vital zone between the aquatic and terrestrial regions. It has an intricate web of roots, high diversity, and is an extraordinary carbon sink. It is important for coastal protection, and is home to many kinds of plants and animals. Soil and water play an integral part of mangrove ecosystems, which is a very delicate balance. The tidal currents, salinity, and organic matter dynamics create a unique interaction between the soil and water, which is essential for the ecosystem's health.

According to historic records, Mumbai was initially made of several islands. After clearing the mangroves, the British united the islands to form Greater Bombay (Sarkar, 2017). Ever since, the mangroves of Mumbai metropolitan area are subjected to strain from a variety of human activities including industrial pollution, urban sprawl, and the over exploitation of resources. Today, major mangrove areas are found in Thane and Vasai creeks, Manori and Malad, Versova, Mahim-Bandra, Mumbra-Diva, and a few more locations in Mumbai. The Marve mangrove patch in Mumbai suburb is a crucial ecosystem that benefits both the population and the environment. Assessing the soil and water samples from the Marve mangrove patch can provide valuable insights into the ecological processes at play. The purpose of this investigation is to perform a preliminary examination of the soil and water of the Marve mangrove ecosystem in order to assess its condition and identify areas of conservation.

Materials and Methods:

The location of this study is the Mangrove patch in Marve, Malad. The Latitude is 19.182755, and the longitude is 72.840157. From the selected location, soil and water samples were collected from three stations (S1, S2 & S3) at 6 cm depth, each at a distance of 100 meters from the other. From each station, five samples were taken for the study. The samples were brought to the lab and analysed for various physical and chemical parameters. The soil samples were tested for moisture, organic content and pH. The water samples were analysed for nitrates, pH, phosphates, salinity and silicates using standard methods.

Results and Discussion:

The moisture content of the samples ranged from 35.1% to 45.2%. All the soil samples had organic content ranging from 0.168% to 0.294%, the sample from S2 had the least organic content. The pH of the soil samples was alkaline, ranging from 8.5 to 9.0 (Table 1).

Table 1: Analysis of soil samples

Sample	Moisture Content	Organic Content	pH
S1	45.2%	0.294%	9.0
S2	35.1%	0.168%	8.5
S3	38.4%	0.24%	8.6

Soil in the mangrove ecosystem is subject to several interactions between abiotic and biotic factors that may alter within short distances. The various attributes of the soil are crucial in determining the flora and fauna of the region (Otero *et al.,* 2006, 2009). Soil moisture is an important ingredient of soil for filling part of the pores between the solid particles (Ataullah *et al.,* 2017). In mangrove ecosystems, soil moisture is essential for controlling climate change and sequestering carbon. Saturated soil conditions slow down the breakdown of organic matter, which eventually causes sediments rich in carbon to build up. Sufficient soil moisture is necessary for the complex root systems of mangroves, which serve as anchors for the trees as well as facilitating gas exchange and nutrient uptake. Soil moisture supports the growth of soil microbes and serves as shelter and breeding grounds for fishes and crustaceans. Optimal soil moisture levels promote biodiversity and increase the ecosystem's ability to withstand changes in its surroundings.

Mangrove soils are distinguished by an abundance of organic matter, which is mostly made up of litter including debris, roots, and decomposing plant matter. They cover the soil's surface and gradually break down to produce organic matter, which promotes the transfer of nutrients and boosts microbial biomass. The breakdown of plant litter adds nutrients to the soil and encourages the establishment of a wide range of microorganisms that maintain the overall health of the ecosystem. Soil organic matter may control soil quality which determines the sustainability and productivity of soils of mangroves and its abundance or absence alters the soil health dynamics (Swezey *et al.*, 1998).

Soil pH is an indicator of several chemical processes within the soil and alters the availability of essential elements (Joshi and Goshe, 2003). Therefore, the distribution of mangrove species differs with varying levels of pH and organic content. Analysis of these parameters serves as an useful tool in making management decisions concerning the conservation of the region. Various studies of mangrove soils worldwide indicates that the pH may be either acidic or alkaline ranging from 2.87-8.22 (Rambok *et al.,* 2010; Ferreira *et al.*, 2010; Moreno and Calderon, 2011; Hossain *et al.*, 2012; Das *et al.*, 2012). The results from the soil analysis give a good idea of the ecological balance of the mangrove region. This preliminary study indicates that the mangrove environment is a healthy one and has good growing and developing conditions.

The water samples collected from the three sampling stations exhibited notable differences in salinity, nitrate, phosphate and silicate content (Table 2). The salinity content of the sample from S3 was found to be the highest among the three. Similarly the levels of nitrates and silicates were maximum in S2. The primary type of nitrogen in natural waterways is nitrate, which is also an essential ingredient for plant growth. Nitrate-nitrogen is stable and readily dissolves in water (Reis et.al., 2017). The ideal oxidation of nitrogen molecules in the water produces this chemical. An essential step in the nitrogen cycle is nitrification, which is the process by which microorganisms convert ammonia to nitrite and nitrate (Kristensen *et al.*, 2008). Nitrates are highest in S2 as compared to S1 and S3, suggesting that S2 may have a more favourable environment for nitrogen-fixing organisms. The phosphate content was the highest in S3. It was nearly thrice than that of S2 and four times that as in S1. For aquatic species, phosphorus in the form of phosphate is an important micronutrient that is required in modest levels. Lack of phosphate can also prevent plants from growing (Kolliopoulos *et al.*, 2015).

Table 2: Analysis of Water Samples

Sample	Nitrates (µg/L)	pH	Phosphates (µg/L)	Salinity (ppt)	Silicates (µg/L)
S1	286.6	8.5	480	15	2600
S2	3066.6	8.0	580	18	3380
S3	2666.6	8.5	1529.4	20	3120

The results of the analysis revealed that the pH level of the soil sample was slightly alkaline, indicating a favorable environment for mangrove growth. The organic content of the soil was high, indicating a rich source of nutrients for mangrove species. The water samples contained high levels of silicates, nitrates, and phosphates, which are essential nutrients for mangrove growth. The levels of phosphates in water samples fluctuates during the monsoon season (Kumar et.al., 2012). Numerous indicators of the declining state of the Manori Creek environment have been reported in relation to the Water Quality Index and different biotic community patterns (Kulkarni et. al., 2010). The general findings of the study show that there is a significant variation in the availability of nutrients and soil characteristics among the sampled sites. The differences in the silicate, nitrogen, and phosphorus content in the water samples indicate that each station probably has a different environment which would in turn support different types of flora and fauna. The organic matter content and moisture content in the soil samples imply that the soil may require additional nutrients or amendments to support plant growth. The pH levels indicate that the soil is fairly good for a large variety of plants.

Conclusion:

Preliminary analysis of the mangrove ecosystem can provide information about the current status and is vital for conservation practices in order to keep the mangrove ecosystem healthy for years to come. The physicochemical analysis of water and soil samples from urban mangrove areas will provide the necessary baseline data for environmental monitoring and conservation strategies. Initiatives such as restoring degraded habitats, implementing sustainable resource management practices, and promoting eco-friendly tourism can subsequently be taken up on need. The analysis of soil and water parameters is crucial in evaluating the health and functionality of the mangrove ecosystem. Soil parameters such as pH, nutrient content, and organic matter can indicate the fertility and productivity of the soil, while water parameters like salinity, turbidity, and dissolved oxygen levels can reveal the water quality and its impact on the ecosystem.

Acknowledgement:

The authors thank the Management, Principal and all the staff members of the Zoology Department for the encouragement and support rendered during this study.

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POLLINATION ECOLOGY AND COMPATIBILITY SYSTEM OF *ARGYREIA CAPITIFORMIS* (POIR.) OOSTSTR.

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Abstract:

Pollinator composition, behaviour and breeding strategies of a plant are crucial factors as it directly influences the reproductive success of a plant. *Argyreia capitiformis* (Poir.) Ooststr.is a climber, having funnel-shaped, attractive purple-coloured flowers, often found in roadside edges, forest, river banks and home gardens. The species is highly medicinal and one of the home garden plants which have huge potential in horticulture. The pollination biology and mating system of *A. capitiformis* is not explored. Therefore, the pollinator composition and mating strategy is analysed in this study. *A. capitiformis* opens around 7:00-7:30. *Xylocopapubescens* was found to be the only pollinator of *A. capitiformis* in this study. Fruit set was formed even in the absence of pollinators indicating that *A. capitiformis* is self-compatible but is dependent on pollinators for higher reproductive success. This type of breeding strategy indicates a mixed mating type of breeding system wherein the plant is both self-pollinating as well as outbreeder i.e., facultative xenogamous.

Keywords: Pollination, Mixed Mating, Climber.

Introduction:

Pollination ecology examines the interactions between pollination, pollinators, and environmental conditions. Pollination is the process by which pollens are transferred from a flower's anther to the stigma, enabling the flowers to produce seeds for reproduction. Numerous factors, including wind, insects, birds, and bats, are involved in pollination and serve as dispersers of pollen, spores, and seeds from a variety of plants. Because most plants rely on insects to pollinate them, biodiversity has expandedFaheem *et al.* (2004).

Convolvulaceae also referred to as morning glory family, a family of dicotyledonous flowering plants comprising about 60 genera and roughly 1650 species, extensively spread around the world, primarily in tropical and subtropical parts of Asia and America, is a vast one with a variety of floral morphologies, breeding strategies and pollinatorsHassa *etal.* (2023). Members of this family are well known for being both nuisance weeds and beautiful garden plants having horticulture potential while some members hold great medicinal value O'Neill and Rana (2016).

Argyreia Lour.is one of the largest genera having 142 accepted species POWO (2024) in the Convolvulaceae family and is mostly found in tropical Asia. Among the tropical Asian Convolvulaceae, *Argyreia* presently seems to be the most species-rich genus and is found throughout tropical Asia Staples and Traiperm (2017). The genus *Argyreia* contains a wide variety of phytochemical compounds that have been identified, including glycosides, alkaloids, amino acids, proteins, flavonoids, triterpenes, and steroids and possess numerous biological activities Prasanth *et al.* (2017).

Tripura is a part of Indo Burma biodiversity hotspot, surrounded by Eastern Himalaya Das *et al.* (2023). For this unique position the floral diversity of this state is very rich. According to Deb (1981) and with recent distribution report, total species of Convolvulaceae is 36 in this state Kensa (2016); Das *et al.* (2024) and there are just three species of *Argyreia*, namely; *A. capitiformis*, *A. argentea*, *A. splendens* in Tripura. Among them the distribution of *Argyreiacapitiformis* is less common or rare in this stateDeb (1981).*A. capitiformis* is a climbing shrub also known as Flower-head morning glory in English, Bish-dharak in Assamese. It can be found at elevations of 100–2200 meters in the Eastern Himalayas, which stretch from Northeast India to Yunnan and Southeast AsiaPadhi *et al.* (2013). It is a significant plant due to its invaluable pharmacological properties and is widely utilized in traditional medical systems Chowdhury*et al.* (2024). This species is also frequently and extensively grown as ornamental plant in many tropical nations. The mature capsules are often used in decorative dried flower arrangements because they are attractive and long-lasting Chao and Der Marderosian (1973).

Only a few reports on floral and pollination ecology by Jirabanjongjit*et al.* (2021, 2024) on *Argyreiasiamensis*, *Argyreia versicolor* and *Argyreiamekongensis* are available. The floral biology, pollinators, and reproductive biology of *A. capitiformis* are poorly understood and considering the species' potential ornamental and pharmaceutical properties owing to the future of human health care, further expertise of its reproductive biology for its fruitful cultivation and conservation is necessary. Considering the aforementioned facts, the main objectives of this study are: 1)To study and understand the reproductive strategies and compatibility system of studied species, and 2) To study and understand the pollinator composition and pollination ecology.

Materials and Methodology:

1. Study Site

The study work was conducted between November and January, 2023-2024 (Winter season), amid the height of its blooming season in Tripura University campus, Suryamaninagar, Tripura, India.

2. Study species

Argyreiacapitiformis (Poir.) Ooststr. is a climber, climb up to 20-30 metres, having funnel-shaped, attractive purple-coloured flowers, often found in roadside edges, forest, river banks and home gardens.

3. Floral morphology

Flowering of *Argyreiacapitiformis*occurred from Mid-November to January 2023. In the peakblooming period, the flower duration and antherdehiscencewere observed andrecorded. At least 30 flowers were randomly selectedat the mature flower stage and dissected to measuretheir morphological parameters including the floraldiameter, the length of the corolla tube, the length and the width of the calyx, the lengthof the androecium, pistil, style andthe antherwith scale in millimetre at the peak blooming period.

4. Pollination Biology

To determine the assemblages of pollinators, three quadrates (each of 2 m^2) were set up at the study site with 15–50 flowers present in each quadrate. Observations of flower visitors were conducted in natural population at peak flowering season from November to January. Total 4 h of observation from 8.00 to 12.00 hr on daily basis, we performed total 28 h (4 h/day for 7 days) of observation to record the presence of all visitors foraging on flowers during observation event. Each individual visitor was closely observed in order to determine whether they deposited a pollen grain into stigma of visited flower.

5. Breeding system

5.1. Artificial pollination experiment

To determine the breeding strategies of *A. capitiformis*, we performed different pollination treatments to the flowers at both the study sites. Pollen grains were collected 30-35 minutes after anther dehiscence for hand cross pollination and hand self-pollination. A minimum of 20 inflorescences for each treatment were labelled and bagged in fine-mesh nylon bags when the flowers were opened up, for (i) Autonomous self-pollination (ASP): mature flower buds were bagged to keep animal visitors away, and no other procedures were carried out. (ii) Hand Self-pollination (HSP): Mature buds were emasculated with tweezers, labelled, and bagged in fine-mesh nylon bags. After the anthers dehisced, the stigmas were pollinated using pollen from the same flower. (iii) Hand Cross-pollination (HCP) treatment: mature flower buds were emasculated and placed in a fine-mesh nylon bags, then the flowers were pollinated using pollen from other *A. capitiformis* flowers that were blooming at least 10 meters away. The flowers were then re-bagged. (IV) Natural pollination (NP) treatment as a control: 20 buds were labelled and were left open for natural pollinators to access.

5.2. Pollen-to-ovule (P/O) ratio

To count the number of pollens and ovules, flowers were utilized when they were still in the buds. At the bud stage, flowers were randomly taken from various plants. An anther was crushed over a glass slide, supplemented with a few drops of lactophenol, then covered with a cover slip to measure the pollen count. Counting was performed under light-microscope OLYMPUS CX 23. The total number of pollen grains produced by a single anther was multiplied with the total number of anthers in that flowerto get the total number of pollens produced by a single flower. Fifty distinct blooms were counted to determine the total number of ovules. The total amount of pollen grains produced by a flower divided by the total number of ovules per flower yielded the pollen/ovule ratio, as stated by (Cruden 1977).

Data analysis:

Mean and standard deviation for all data were calculated, afterward all data were standardized. We performed Anova to different groups of data. These analyses were performed in the R statistical software program using vegan Oksanen (2017) and ggplot2 packages. All these statistical analyses wereperformed using the R statistical software program ver. 4.2.0 R Core Team (2022).

Result:

1. Floral characterization:

The flowering period of *A. capitiformis* lasts forapproximately 75 days from mid-November to February. However, the actual floweringtime is slightly different, depending on the plantgrowing environment and climate.

The flowers of *A. capitiformis*are bisexual. The mean diameter of the flower was approximately28.3±0.70 mm.The length and width ofthe sepals reach approximately11.82±0.02 and2.7±0.08mm. Width of the entrance of the flower was approximately 21.75±0.55 mm. The length of the corolla tube was about 34.16±0.44 mm. All five stamens are off white in colour and their approximate length is about 22.23±0.99 mm. The length and width of the anthers were 4.17±0.19 and 2.32±0.04 mm respectively. The pistil is slightly longer than the stamen. The length of the pistil is about27.7±0.50 mm. The length of the style is about 21.7±0.70mm. The length and width of the stigma was 2.75±0.05 and 4.7±0.10 mm respectively. The morphology of the*A. capitiformis*is summarized in Table 1

Table 1: Statistical analysis of morphological characters of *Argyreia capitiformis* flowers.

Floral trait (mm)	Site 1	Site 2	Mean
Diameter of flower	29.00±3.54	27.60±5.15	28.3±0.70
Width of calyx	2.78±0.33	2.62±0.37	2.7±0.08
Length of calyx	11.80±1.54	11.84±0.99	11.82±0.02
Width of the entrance	22.30±1.87	21.20±1.87	21.75±0.55
Length of corolla tube	33.72±11.81	34.60±9.79	34.16±0.44
Length of stamen	23.22±10.48	21.24±8.84	22.23±0.99
Length of anther	4.36±0.93	3.98±1.96	4.17±0.19
Width of anther	2.36±0.93	2.28±0.58	2.32±0.04
Length of pistil	28.20±2.92	27.20±4.30	27.7±0.50
Length of style	22.40±3.74	21.00±4.47	21.7±0.70
Width of stigma	4.60±2.55	4.80±1.00	4.7±0.10
Length of stigma	2.70±2.92	2.80±1.00	2.75±0.05

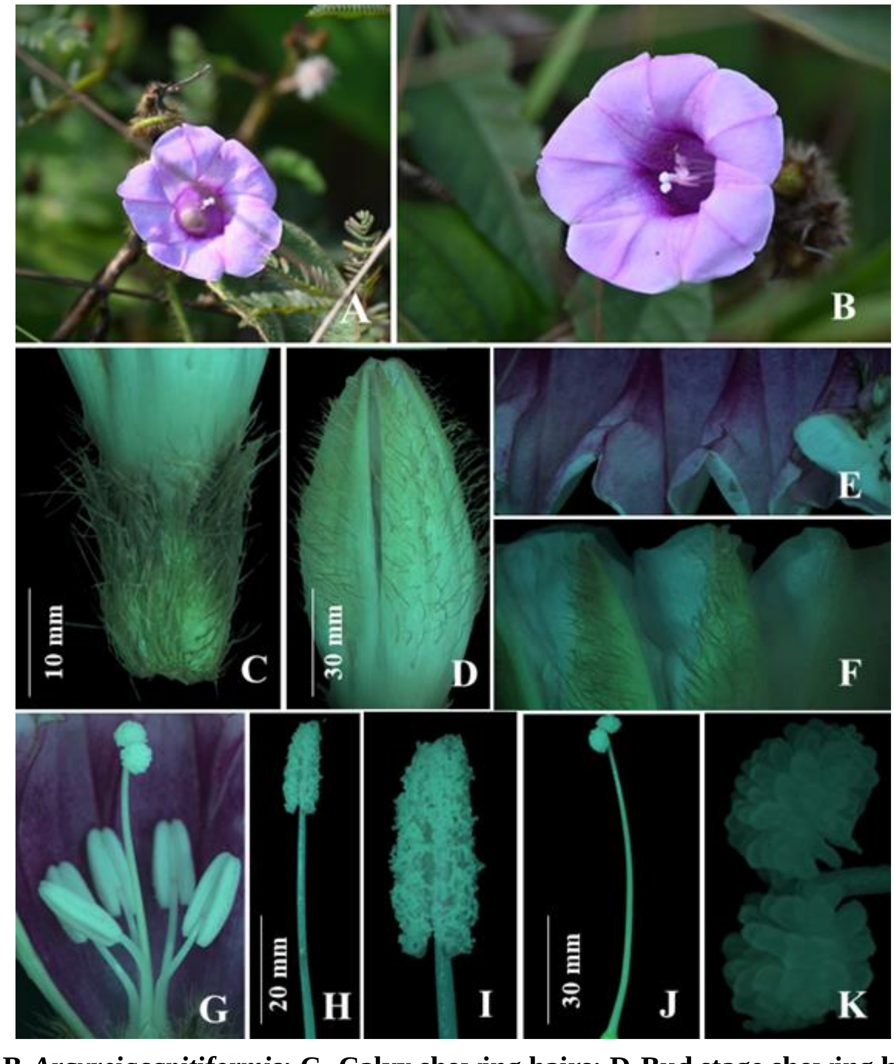

Figure 1: A-B-*Argyreiacapitiformis*; C- Calyx showing hairs; D-Bud stage showing hairs on outer part of petals; E-Inner portion of petals; F-Outer portion of petals; G-Androecium and Gynoecium; H-Androecium; I-Anthers showing pollen grains; J-Gynoecium; K-Stigma.

2. **Pollination biology**

Pollinators accumulate in the morning as pollination initiate. Despite the attractive flowers of *A. capitiformis*, the frequency and rate of visitation of pollinators and floral visitors were extremely low. The major and one & only pollinator of *A. capitiformis* was found to be *Xylocopapubescens*. The pollinator visitation commenced from 8:30-9:00 a.m. and peaked around 9:00-9:30 a.m. Before 8:30 hr no visitation of *X. pubescens* was observed. However, with gradually increasing time, the visitation frequency of *X. pubescens* steadily increases. The highest visitation frequency of *X. pubescens* was observed between 9:00 to 9:30 hr followed by 9:30 to 10:00 hr. After 10:30 hr, no visitation of *X. pubescens* was observed during the study. In this study, it was observed that, the associated species with *A. capitiformis* get higher pollinator visitation along with rich pollinator diversity

Figure 2: Foraging behaviour of *Xylocopa pubescens* on *A. capitiformis*; A-D- *X. pubescens*

3. Breeding system

3.1. Pollen/ovule (P/O) ratio

The average number of pollen grains of *A. capitiformis* is 7159±408.33, the ovule number is 4.00±0.00. Therefore, the pollen-to-ovule ratio of *A. capitiformis* is 1789.75±102.08According to the pollen to ovule ratio (Cruden 1977), the breeding system of *A. capitiformis* is facultative xenogamy or mixed mating system.

3.2. Artificial Pollination Experiment

Fruit-set production significantly varied among all the treatments (F value = 40.17, $P < 0.00$). The highest number of fruit-set was observed in natural pollination treatment (87.50±5.10), followed by hand cross pollination treatment (73.27±2.82), pollinator efficiency treatment (62.62±2.41), hand self-pollination treatment (57.41±2.70) and the lowest number of fruit-set was observed in autonomous self-pollination (31.10±2.73). Further, Tukey test revealed significant differences between the treatments showing the highest variation between Natural Pollination-Autonomous Self-Pollination (P value < 0.000).

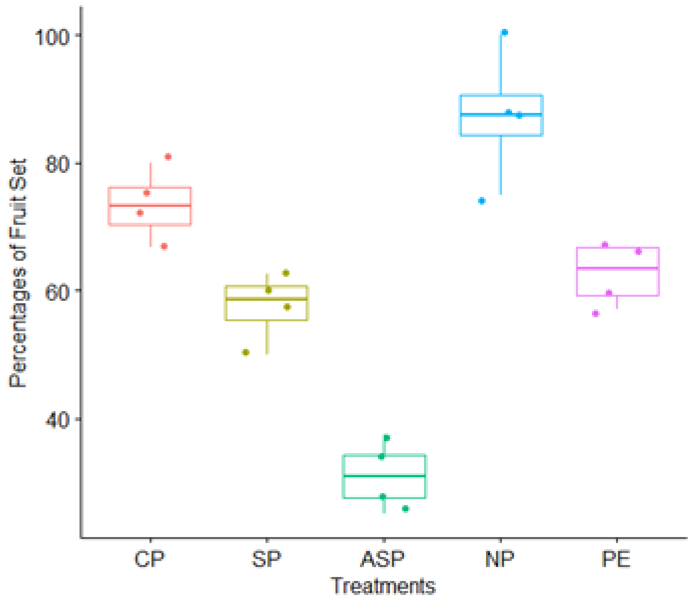

Figure 3: Showing the percentages of fruit set among different breeding treatments.

Discussion:

The Knowledge of floral traits are important in determining pollination, influencing pollinator visitation and efficiency Armbruster *et al.* (2013).Plant compatibility, pollination processes, and pollinator behaviour are all strongly correlated with the shape and size of flowersHarder and Barrett (1995).Plants will steadily modify the existing floral properties to attract and adapt to competent pollinators so as to ensure that pollination activities proceed successfully Xiu *et al.* (2013).In this study, less variability in the floral morphological characters of *A. capitiformis* was observed. *A. capitiformis* has large funnel-shaped, purple-coloured bisexual flowers. However, the flower size of other species of *Argyreia*e.g. *A. versicolor*, *A. mekongensis*, *A. gyrobracteata*are larger Jirabanjongjit*et al.* (2024) in comparison to *A. capitiformis*. The selective pressure for quick plant development may have led to the evolution of the reduced size flowers, or it may have resulted from insufficient resources Sicard and Lenhard (2011).

Despite the attractive flowers of *A. capitiformis*, the frequency and rate of visitation of pollinators and floral visitors were extremely low. Pollinator observations in this study indicate that *A. capitiformis* was pollinated by only a single species of carpenter bee, i.e.,*Xylocopa pubescens*. It was also observed that, the associated species with *A. capitiformis* get higher pollinator visitation along with rich pollinator diversity but *A. capitiformis* was specifically pollinated by only *X. pubescens*. Pollination studies of *Argyreia*are limited. Prior research has typically indicated that bees are the primary pollinators of Convolvulaceae species Hassa *et al.* (2023). Our findings correlate with the findings ofUdayakumar *et al.* (2023), wherein, another species of *Argyreia*, *A. nervosa* was visited by only two pollinators *viz.*, *Lithurgus atratus* and *X. fenestrata* but another species *A. cuneata* which was in close proximity to *A. capitiformis*, was visited by seven different species of bees with a relatively higher abundance of *T. macroceps*. The lower pollinator abundance on *A. capitiformis* might be because of the lower flower abundance wherein opening of a single flower in a flower cluster was commonly observed. The fact that *A. capitiformis* was visited almost exclusively by *Xylocopa* bees might indicate that *A. capitiformis* is specialist in terms of pollinators.However, more extensive research is needed to come to any conclusion. Conversely, *Xylocopa* have been demonstrated to be species-level generalist foragers, visiting a wide variety of plant types Stewart *et al.* (2018). Specialist species often engage with generalist species Memmott *et al.* (2004) as seen in this study. Though the reports of carpenter bee pollination in Convolvulaceae is uncommon, but the large flower diameter of *A. capitiformis* accommodatescarpenter bee pollinators. *X. pubescens* was observed to crawl within the corolla tube to feed on the pollen.

The enormous floral diversity among higher plants is largely attributed to mating systems. The most important adaptation for plant propagation is still the attraction and utilization of vectors for outcrossing Schluter (2000). Pollen-to-ovule ratio is a method used to investigate the breeding system in plantsAtasagun*etal*. (2021), the pollen to ovule ratio of *A. capitiformis* revealed that the plant exhibits facultative xenogamy or 'mixed mating' system. However, in the artificial pollination experiment it was found that the hand cross pollinated flowers produced more fruit sets than the flowers which were hand self-pollinated and were bagged to check autonomous self-pollination. This shows that *A. capitiformis*is weakly self-compatible but cross pollination significantly increases fruit set as flowers in the bagged and hand self-pollinated treatments produced significantly fewer fruits than flowers in the open and hand cross-pollinated treatments.

The findings of this study are similar to the findings of Hassa *et al.* (2023). Mixed mating breeding system has also been reported in other species of Convolvulaceae such as *Ipomoea triloba* Paul *etal*. (2023), *I. Hederacea*, *I. aquatica* Hassa *et al.* (2020). Convolvulaceae family is highly diverse with different mating systems including self-incompatible breeding system such as in *A. versicolor* and *A. mekongensis* and *A. siamensis*Jirabanjongjit*et al.* (2024, 2021).

Conclusion:

Here, our aim was to look at *A. capitiformis*'s compatibility system and pollination ecology. There is only one species that visits the species. The species was also shown to be self-compatible with a mixed mating system, according to the results. This species has a great deal of potential for horticulture and medicine, and the pollination and breeding studies shown here may help with future research.

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OCIMUM BASILICUM (SWEET BASIL): HISTORY, CULTURE, USES AND CULTIVATION

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Abstract:

Plants of Lamiaceae (Labiatae) or mint family are the best source of essential oils with unique fragrance. *Ocimum* are most important members of Lamiaceae which includes medicinally important species. Many species of *Ocimum* finds place in the culture and history of India. *Ocimum basilicum* or Sweet basil is used world-wide in culinary, perfumes, rituals, and religious ceremonies. The present chapter provides a comprehensive account on *O. basilicum.* The etymology, distribution, synonyms, vernacular names and description of *O. basilicum* has been given. Large number of cultivars of *O. basilicum* has been developed in past. Here, some famous cultivars have been discussed with a table providing details of quantity of purple compound anthocyanin. Traditional uses of sweet basil in different preparations have also been given. Climatic conditions, irrigation, soil conditions required for cultivation are given. Harvesting time and recovery of essential oil also discussed.

Introduction:

Plants of Mint family or Lamiaceae (Labiatae) present the richest source of essential oils with characteristic aroma. Some genus of Lamiaceae which areimportant sources of essential oils are *Ocimum*, *Lavandula*, *Mentha*, *Nepeta*, *Hyptis*, *Thymus*, *Rosmarinus* and *Pogostemon*. Genus *Ocimum* L. are economically very important. It has religious and cultural importance in the history of India and other South Asian countries since ancient times. Many species of *Ocimum* are considered sacred in different parts of the world. *Ocimum* are considered as "The incomparable one " (Tulasi means, matchless), "Elixir of life". Tulsi is native to India and is cultivated commonly in all Indian provinces.

To have the potential to cure health problems it is called as “Herb for all problems”, “The king of herbs” or "Queen of the herbs". It is commonly referred to as "Herbe Royale" in French, indicating the favorable opinion that people hold of it. All the parts of this plant are of medicinal importance including Leaves, inflorescence, seeds, and essential oil (Khair-ul-Bariyah, *et al.*, 2012).

Etymology: According to most of the sources the generic epithet, *Ocimum* has been derived from the Greek word “*Okimon*” which stands for “Smell”. The term used first by great botanists of ancient times, Theophrastus and also by Dioscorides for aromatic property of this plant.

Distribution: Genus *Ocimum* growing mostly in tropical parts of the world. According to Harley, *et al.*, (2004) it is pantropical in distribution. It grows mostly in the warmer parts of the globe. Some species are cultivated around the world for medicinal use, for religious, rituals and beliefs.

Species: About 67 according to "World checklist of vascular plants" (https://wcvp.science.kew.org/taxon/21070-1). 40 according to "Flora of British India" (https://www.biodiversitylibrary.org/item/13817#page/611/mode/1up).

Indian Species of *Ocimum*:

Most of the important Indian species are under cultivation (*O. tenuiflorum*, *O. basilicum* and *O. gratissimum*) and *O. americanum* and *O. filamentosum* are growing only as wild in natural habitat in India. *O. americanum* is growing thought the country from north to south, while *O. filamentosum* only occurs in the southern India.

- ***Ocimum tenuiflorum* L. syn. *Ocimum sanctum* L.** Holly Basil or Sacred Basil (Cultivated throughout India).
- ***Ocimum gratissimum* L.** Ram Tulsi or Tree Basil (Wild in south India, Cultivated throughout India).
- ***Ocimum americanum* L.** American Tulsi (Growing as wildthroughout India).
- ***Ocimum basilicum* L.** Sweet Basil or Marua (Cultivated throughout India).
- ***Ocimum* x *africanum* Lour.**African Basil (Wild).
- ***Ocimum kilimandscharicum*** Gurke Camphor Basil (Wild).
- ***Ocimum filamentosum* Forssk.** (Wild in South India).

According to Darrah (1974), there are two well-known and commonly grown cultivars of *Ocimum tenuiflorum*, the one with green leaves (known as Rama Tulsi or Radha Tulsi in India) takes more height and common in USA but the other cultivar with purple colored leaves (known as Shyama or Krishna Tulsi in India) was less known in USA.

O. x *africanum* Lour.is a natural hybrid species originated by hybridization between *O. basilicum* and *O. americanum*in wild. Seed setting is rare in this species. It is generally planted by stem cutting. It is vigorously growing and strongly scented.

There are two subspecies and one variety of *O. gratissimum*viz- *O. gratissimum* sub sp. *gratissimum*; *O. gratissimum* sub sp. *iringense* and *O. gratissimum* var. *macrophyllum*.

O. gratissimum sub sp. *gratissimum* is distinct from *O. gratissimum* var. *macrophyllum* in having tomentum on both side of leaf (Suddee *etal*., 2004).

Almost all Indian species of *Ocimum* are important. In the present chapter we are specially emphasizing on the Sweet basil, *O. basilicum*. Focus has been given to cover all aspects from etymology, taxonomy, culture and history, medicinal value, essential oil diversity and economic importance.

***Ocimum basilicum* L. the famous sweet basil**

Ocimum basilicum L. was first of all published by Linnaeus in species plantarum (Sp. Pl. 2: 597, 1753). It is one of the most economically important, widely cultivated and most appreciated basil for its culinary uses in religion and culture of many countries (Vazquez, *et al.*, 2013; Ivanova, *et al.*, 2023). It cultivated for more than three thousand years and distributed in different parts of world with Asians and Europeans. There are a number of myths associated with "Basil". Basil, the royal plant, is also the plant of extreme poverty, venom, and healing. It has been said to have grown on a real cross and transformed into a monster. It is very easy to keep its magic going. The etymology of "Basil" is enigmatic; nevertheless, a number of possible sources provides the possible root of term and may have been derived from the Greek basileus, or king. Basil's affiliation with the crown may be in part due to its use in royal medicine. Sweet Basil is a widely grown plant because of its well-known capacity to flourish in a variety of climates and geographical areas (Barickman *et al.*, 2021). Its fragrance is very strong due to which insects and mosquitoes do not wander near it. It is advisable to install these in summer so that mosquitoes and insects stay away from the house.

This plant looks just like Tulsi.It has many benefits. This is a panacea for mosquitoes. Although it has frequently been proposed that many herbs and spices were first consumed as a sign of aristocracy (as with Indian spices) or as a necessity (herbs), some observers have been inclined to speculate that basil may have been consumed merely for its deliciously aromatic unique flavor (Spence, 2021). According to Sherman and Hash (2001) mention "We hypothesize that people first used pungent species either because they produced pleasurable psychological sensations or because their flavors were delightful (e.g., cinnamon, basil)."

Figure 1: *Ocimum basilicum*

Basil may come from the Latin basilisk, or dragon; this etymological connection may explain the symbolic connection between basil and scorpions. The flora of British India vol 4 page. 609, mentioned (*O. minimum* L. (Benth. in DC. Prodr. xii. 33), is a very small cultivated form probably of *O. basilicum* (with which it agrees in all essential characters), to which Linnaeus has assigned Ceylon as a habitat.

Taxonomy:

Systematic position: Kingdom- Plantae, Division- Magnoliophyta, Class- Magnoliopsida, Order- Lamiales, Family- Lamiaceae, Genus- *Ocimum*, Species- *Ocimum basilicum*

Synonyms of *Ocimum basilicum*:

O. thyrsiflorum L.; *Ocimum basilicum* var. *thyrsiflorum* (L.)Benth.

O. basilicum var. *difforme* Benth.

O. bullatum Lam. *Ocimum medium* Mill.

O. basilicum var. *glabratum* Benth. *O. basilicum* var. *majus* Benth.

Vernacular names: Sweet basil, Basil, Ram tulsi, Kali tulsi, Babui tulsi, Bhu tulasi, Ban tulsi, Burg firanjmishk, Basile, Ziya-apyu, E tia, Great Basil, Pabri, Basilico, Balanoy, Deban-Shab.

Description: Erect branched herb 24-36 cm tall. Stem quadrangular, green, woody at base glabrous, more or less hispid, hairs on nodes directed upward, young shoots hairy only on adaxial side. Minute pubescence present on inflorescence axis. Leaves 2-3.5 inch long, lamina with dotted glands, ovate, hairs on midrib and on veins on the both surfaces, lamina glabrous, entire or more or less serrately toothed with obtuse to acute apex, on upper side of petiole minute hairs present. Inflorescence loose, bracts petiolate, younger purple in color, lowermost green in color and leaf like, petiole 2mm, blade 8.5-4mm, on stalk hairs on adaxial side and present only on basal part, bracts hairy along margins on lamina and very short hairs present on both side of lamina. Pedicel 4mm. Calyx 5.5-3.5mm, enlarging in fruit, upper lip 3.5mm, pubescent, glandular, lower teeth lanceolate, lateral smaller, upper lip rounded, 4mm across to 3.5mm, calyx hairy within, hairs pointing outward. Corolla white, funnel shaped, 8mm long 4.5mm wide, tube 2mm wide, hairs on outside of lobes. Stamens exerted from corolla, 6mm in length, posterior pair with hairs at base, minute hairs also present on base of filaments below upper hairy outgrowth. Ovary 1mm wide, glabrous, style glabrous, 7mm long, stigma bifid. Nutlets black, oval. Seeds are dark brown, lustrous with pitted surface.

Distribution: *O. basilicum* is native to India. West Asia, Malaysia, Africa, Tropical parts of India, widely cultivated. Lower hills of Punjab, Aitchison; Flora of British India, throughout India. Most of the scientific journals cites references for its native distribution, but all of these references are from non-taxonomic works and mainly focused on its medicinal or chemical properties.

Famous cultivars of *Ocimum basilicum*:

During 19th century, French and English plant growers developed up to 60 different cultivars of *O. basilicum*. Darrah (1974) did intensive work on the varietal diversity of *O. basilicum*. Majority of cultivars are distinct in having characteristic aroma and coloration (Spence, 2024). Some with slammer leaves and bushy habits. The most appreciated coloration developed by breeders was Purple due to production of anthocyanin pigment in leaves. These purple colored cultivars have been used as ornamental. But studies on these purple colored cultivars suggests that this purple coloration is not fixed over generation and may eventually revert back to original parental green coloration. The purple pigmentation have also been reported in almost all species (Darrah, 1974). Many of them assessed cultivars are members of the "sweet" basil group, with "Genovese," "Italian large leaf," "Mammoth," "Napoletano," and "Sweet" controlling the fresh and dry culinary herb markets in the United States. Despite having smaller leaves, several other basils, such as "Sweet Fine," resemble "Sweet" basil.The flowering pattern in these varieties also differs considerably. Since many of these cultivars are not under cultivation and herbarium specimens of these cultivars were not prepared for future perspective, the details published in horticultural literature about these cultivars only provides obscure descriptions of them. Because large number of basil variants is known to exist, it is not easy task to fix which cultivar or variety is being mentioned in literature or past studies (Raguso and Pichersky, 1999). Furthermore polyploidization and natural intraspecific hybridization also generate progenies with mixed morphological and chemical characteristics, which are hard to fix to a particular plant type (Matthew, *et al.*, 2022; Lawrence, *et al.*, 1980). Representative specimens of different varieties raised and used by Darrah (1974) have been housed in the herbaria of Bailey Hortorium aCornell Universityand theUnited States National Arboretum at Washington.

The cultivars "Lemon" which smells like lemon and "Lemon Mrs. Burns" are differs in oil components and flowering pattern, both variants contains citral as major essential oil content. Another notable “The Maenglak Thai” lemon basil is a beautiful ornamental that differs from other lemon scented basils types. The "Osmin Purple" and "Red Rubin Purple Leaf" are popular purple variety in terms of coloration. Some dwarf-growing varieties, as "Bush," "Green Globe," "Dwarf Bush," "Spicy Globe," and "Purple Bush," were developed as ornamental plants. Collection ornamental basils for instance "Anise," were selected for and named based on spicy black licorice flavor of essential oil.

A number of cultivars are available with variations in leaf size, shape, color, and aroma. The growing pattern, flowering, leaf, stem colors, and scents of commercial basil cultivars also vary greatly. Although there is a slight hint of cloves, the aroma of fresh basil leaves is strong and distinctive, unlike any other spice. Apart from the "Mediterranean type," which is most prevalent in Numerous other cultivars or varieties with distinct flavors, many of which are hybrids, are available in the West. India's

"Sacred Basil" (*O. sanctum* = *O. tenuifolium*) has a strong, slightly strong scent, while Thailand's sweet basil smells like licorice. Gardeners in the West can purchase varieties of cinnamon basil, camphor basil, anise basil, and spice basil, the latter of which has a warm, complex, and pleasantly pleasant flavor.

Culture and history: In the English translated version of Pliny's Naturalis Historia (vol VI), the English author William Henry Samuel Jones (1961) mentioned the beliefs of ancient Greeks. The opinion of Greek philosopher Chrysippus was that this herb is very bad for human consumption and can cause severe problems like- stomach disorder, urinary and eyes and can cause madness if taken. Pliny also mentioned and in fact he was first to emphasize on the positive physiological effects and put forward the advocacy of Plistonicus and Philistion of Locri about good beneficial treatments by using basil as a remedy. Cultural importance can be seen in ancient history of Italy. It is mentioned especially in a emotionally unfortunate story by the famous Italian renaissance writer and poet Giovanni Boccaccios's world famous novel "The Decameron" (1353) Day fourth-novel V. The translated version of "The Decameron" by Rigg, (1903) depict the emotional narrative connected to Basil in the form of following lines-

A thief he was, I swear,
A sorry Christian he,
That took my Basil of Salerno fair,
That flourished mightily,
Planted by mine own hands with loving care
What time they reveled free:
To spoil another's goods is churlish spite.

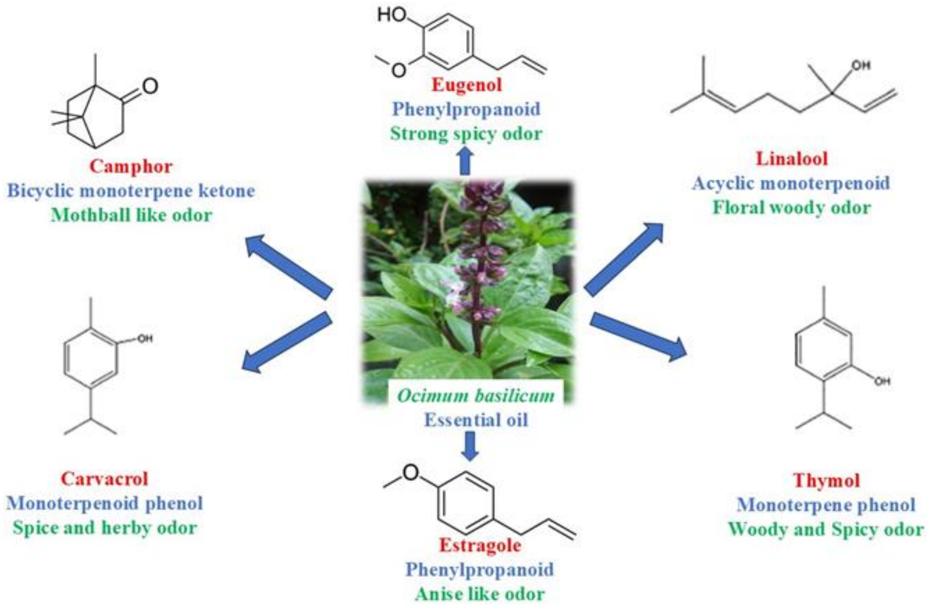
English Romantic poet John Keats depicted the story of Isabella of "The Decameron" in the form of a poem entitled "Isabella, or the Pot of Basil".

According to Sutton (2023) Sweet Basil has been used for funerals, cemetery ornamentation, and as a fragrant garland that the deceased hold before being buried. Sutton (2023) also explains how other types of religious events make use of water flavored with

Anthocyanins containing cultivars: Cultivars rich in anthocyanin are found in dark red foliage of certain famous basil types. The leaves of certain types of basil have 200 μg of anthocyanins per g of fresh weight. Phippen and Simon used spectral data, high performance liquid chromatography, and other techniques to analyze the anthocyanins found in purple basils.

Traditional uses: *O. basilicum* has been a part of cuisine in Liguria province of Italy. Pesto, the famous Italian dish originated from somewhat similar but ancient Roman preparation called "moretum" first mentioned in the "*La cuciniera genvese*" in 1863 by Ratto. *Ocimum basilicum* is the main flavouring ingredient of pesto. Ancient philosopher and physicians mentioned its uses in the treatment of inflammation, jaundice, dysentery, in removal of warts etc. Some varieties are used for landscaping, fore making specific vinegars and as insect-controlling agents.

Essential oil production: *O. basilicum* accounted for about half (42.5 tonnes) of the approximately 100 tonnes of essential oil produced worldwide (Makri and Kintzios, 2008).According to Lawrence (1998). The taste and aromatic profile of sweet basil depends on the growing conditions and the stage at which the plant is harvested (Slougui, *et al.*, 2015).



Major phytochemicals: Major characteristic phytochemical of *O. basilicum* are **estragole** or **methyl chavico**l, **methyl-eugenol** (Simon, *et al.*, 1990; Lewinsohn, *et al.*2000; Ozcan and Chalchat, 2002; Tyagi, *et al.*, 2022), **linalool (**El-Soud, *et al.*, 2015), **α-cubebene** (El-Soud, 2015; Ozcan and Chalchat, 2002). According to (Costa, *et al.*, 2015; Vina and Murillo, 2003), beside above mentioned phytoconstituents of essential oil some important components like- methyl cinnamate, ***β***-bourbonene, geranial, δ-cadinene and nerol are less in amount and distribution amongst the cultivars of *O. basilicum*. Lawrence (1998) recognized four major chemotypes between *O. basilicum* varieties, viz- linalool (terpene alcohol), methyl chavicol or estragole, methyl cinnamate (methyl ester of cinnamic acid) and allylveratrol or methyl eugenol. Bozin, *et al.* (2006) analyze the essential oilcomponents and study revealed thatmethyl chavicol and Linalool are major EOs components.

Beside essential oils other important component are rosmarinic acid (characteristic phenolic acid of sub-family Nepetoideae; Guan, *et al.*, 2022), ferulic acids, quercetin, naringenin as dominant compounds as well as chlorogenic, p-hydroxybenzoic, vanillic and cinnamic acids.

Table 1: Some famous purple cultivars of *O. basilicum* with quantity of purple compound anthocyanin.

Cultivar	Phytochemical	Anthocyanin contents	References
Ocimum basilicum 'Dark Opal'	Anthocyanins, cyanidin-3-(di-p-coumarylglucoside)-5-glucoside and peonidin	18 mg per100g	Phippen and Simon (1998)
Ocimumbasilicum'Red Rosie'	Anthocyanin	9.58 mg per 100g	Mc Cance (2016)
Ocimumbasilcum 'Purple Ruffles'	Anthocyanin	18.8 mg per100g	Mc Cance (2016)
Ocimumbasilicum var. *purpurascens* 'Red rubinbasil'	Cyanidin-3- (6,6'-di-p-coumaroyl)-sophoroside-5-glcucoside	40.8 mg per 100g	Fernandes *et al.*, (2019)
Ocimum basilicum'Sweet Petra Dark Red'	Anthocyanin	9.10 mg per 100g	Mc Cance (2016)

Medicinal properties: Majority of research articles mainly focused on the antioxidant properties are based on comparative studies in reference to a specific antioxidant compound, and less number of researches are that have been focused to find particular phytochemical constituents and their antioxidant potential. The rosmarinic acid present in Sweet basil have memory protective effect (Fonteles, *et al.,* 2016). The chemical structure of the antioxidant phenylpropanoid rosmarinic acid (-o-caffeoyl-3,4-dihydroxyphenylactic acid)was determined in rosemary extracts.

Table 2: Therapeutic potential of *Oscimum*

Therapeutic potential	Part used	References
Cardiac stimulant	aerial part	Muralidharan and Dhananjayan (2004)
Antioxidant	aerial part	Kaurinovic, *et al.,* (2011) Gulcin, *et al.,* (2007).
Anti-Excitability of nervous system	leaves	Venancio, *et al.,* (2016)
Insecticidal	-	Keita, *et al.* (2001)
Antifungal	Leaves/aerial part	El-Soud, *et al.* (2015)
Antibacterial	Leaves and flowers	Wannissorn, *et al.* (2005) Crovic-Stanko, *et al.* (2010)
Antimicrobial	aerial parts	Bozin, *et al.* (2006); Sakkas and Papadopoulou (2017)
Memory retention	Leaves	Sarahroodi, *et al.* (2012)
Antigirardial	Leaves	Ameida, *et al.* (2007)
Antidepressant	Leaves	Abdoly, *et al.* (2012)

Table 3: Compounds in *Ocimum*

	Phenolic compound	Part	Concentration	References
Caffeic acid	*Ocimum basilicum*	blossoms	0.0158 (µg/mL)	Alkhateeb, *et al.,* (2021)
	Ocimum basilicum Indian purple inflorescence	Leaves	3.27mg/100 g	Bajomo, *et al.,* (2022)
	Ocimum basilicum "Italiano Classico"	Leaves	0.97mg/g	Romano, *et al.,* (2022)
Rosmarinic acid	*Ocimum basilicum* Indian purple inflorescence	Leaves	0.78mg/100 g	Bajomo, *et al.,* (2022)
	Rosmarinic acid *O. basilicum* var. *purpurascens* (purple-green leaves)	Aerial parts	4.41 mg/ml	Moghaddam and Mehdizadeh, (2015)
	Ocimumbasilicum"Italiano Classico"	Leaves	8.08mg/g extract	Romano, *et al.,* (2022)
	Ocimum basilicum	Leaves	2.80g/100 g	Juliani, *et al.,* (2008)
	Ocimum basilicum Green Dark Opal	Leaves	4.4g/100 g	Juliani, *et al.,* (2008)

Rosmarinic acid biosynthesis entails the pathway of phenylpropanoid. Razzaque and Ellis used *Coleus blumei* cell suspensions to validate the biosynthesis pathway. Tyrosine and phenylalanine are the two precursors used in this biosynthesis process. Rosmarinic acid synthase, the final enzyme in the chain, was identified and isolated by Petersen in 1989.

O. basilicum is one of the most famous and widely cultivated species of genus *Ocimum* cultivated in almost all temperate parts of the globe. It is commonest pot herb among the "basils". Earlier opinions of ancient peoples and Philosophers of Greek were very scared of its use. For instance, the Tetun people in Indonesia's East Nusa Tenggara province commonly use raw, fresh sweet basil leaves as medicine for malaria (Taek *et al.*, 2018). Basilsare good source of β-carotene and inorganic elements like magnesium, iron, calcium, potassium, and ascorbic acid (Gebrehiwot, *et al.* 2015).

Hybridization: Cross-pollination is common in genus *Ocimum (*Masi, *et al.*, 2006). Studies have shown the when *O. basilicum* var. *crispum* and *O. sanctum* seedlings were raised together. The resultant plant resembled *O. basilicum* var. *crispum* inoverall morphology except the morphology of inflorescence, which resembled *O. sanctum* in size, pigmentation and aroma. The seeds produce in this hybrid plant were not found viable (Darrah, 1974).

Cultivation: Sweet Basil cultivated in field as an annual crop. For cultivation its seedlings can be transplanted in prepared field or sown directly from seed. For maintaining good vegetative growth and bushy habit of pant, pinching of young inflorescence is an excellent way. Pinching also results in increasement in the number of side growths and hence number of leaves. Pruning strongly affected purple basil growth which altered essential oil composition. Vazquez, *et al.*, (2013) performed experimental work on growing *O. basilicum* in autumn-winter season in greenhouse. Essential oil contents decreased slightly in comparison to plant growing under optimum conditions.

Climate: Plant growth and yields of oil have been demonstrated to benefit from long days and high temperatures. It requires temperate climatic conditions for healthy growth and high yield of essential oil. In contrast to temperate climate sweet basil generally grows as a perennial plant in tropical climatic conditions. In sub-temperate climatic condition as in northern Uttar Pradesh it shows retardation of growth during winters. Sweet Basil requires less moisture and direct sunlight or fully sunny conditions for better growth, as in the case of almost all species of the genus *Ocimum*. During winters when temperature becomes very low it should be shielded or covered over by some cloth or sheet because it is very sensitive to frost. If it is growing in the pot at home or in the garden it is very easy to shift pot and place it under some shade of tree canopy of house. Direct exposer of leaves to frost is very harmful because the leaves fall within a short time after exposer due to chilling stress. Rapid Growth occurs during July and maturation of seeds continuing until full winters. In sub-tropical condition stocks produce new growth at the time of spring.

Soil condition: Sweet basil can be grown on a wide range of soil types. Rich loamy, poor laterite, saline and alkaline to slightly acidic soils can provide good conditions suited for basil cultivation. Porous soil with well-draining capacity helps to take better vegetative growth. Standing of water in crop or water logging can cause rotting of root.

Propagation: Sweet basil is propagated through seeds. Seeds will get deteriorated over generations, due to its high crosspollination. Hence, for fresh plantings, the growers have to take fresh seeds from the pedigree stock.

Manure and Fertilizers: Application of Organic manure or decomposing organic matter compost in soil generally increase the herbaceous parts and leaves (Khalid, *et al.* 2006). Application of Nitrogen generally beneficial for improving the number and growth of leaves (Ndzingane, *et al.*, 2022).

Irrigation: Essential oil production generally depends on the seasonal variation of moisture contents and type of soil. Water stress influence the production of essential oil in aromatic plants (Burbott and Loomis, 1969). In summer weekly irrigations is preferred and in other seasons should be irrigate when required. In rainy season when no irrigation is required. According to Khalid (2006) water stress treatments enhance amount of essential oil. Radacsi, *et al.,* (2020) also reported that drought conditions significantly increased the essential oil percentage in *O. basilicum*.

Harvesting: Harvest time is very important for yield of leaves. According to Daramola *et al.*, (2018) plant height and branches in *O. basilicum* increased significantly with increasing time of harvest from 30-60 days after transplantation leaf number, surface area, and plant biomass but declined 90-120 days after transplantation. Mostly, sweet basil is cultivated for the leaves and the extraction of essential oil, for this plant is cut 15-20 cm above the surface leveland harvested at full bloom stage to get best quality and percentage of oil. Young leaves contain more essential oil percentage and oil diffuse into air as the leaves mature (Abewoy, 2021). Time of day is also very important for extracting essential oil from leaves.

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NEW AI MODEL FOR DETECTION AND ATTRIBUTION OF ANIMAL BIODIVERSITY: A SHORT REVIEW

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Abstract:

AI-based biodiversity monitoring is crucial because it makes it possible to analyse large volumes of data effectively, giving detailed information on species distribution and ecosystem health and supporting well-informed conservation decisions. Forestry practices are required on a global scale to support sustainable development objectives, which aim to maintain and grow forests as green infrastructure and as carbon sinks and habitats for biodiversity. The industry is assisting in achieving sustainable development objectives thanks to new technology innovations in the management, monitoring, and conservation of forests and their resources. Globally, more and more nations are implementing precision forestry and smart forest practices, which employ digital, satellite, sensor, and artificial intelligence (AI) innovations to manage, safeguard, and sustainably use forest resources. Adoption of these advances, however, is primarily restricted to affluent nations and a small number of developing nations whose forests are managed for profit.

Keywords: AI Detector, Animal Biodiversity, Conservation of Forests, Ecosystems, Remote Sensor.

Introduction:

The diversity of life on Earth, or biodiversity, is vital to the health of our planet (Chivian, 2002). Ecological balance and ecosystem preservation depend heavily on the study and monitoring of animal species. Artificial intelligence (AI) has become a potent tool for biodiversity protection as technology develops (Silvestro *et al.*, 2021). The broad field of computer technology known as artificial intelligence (AI) aims to build intelligent machines that can speed up, automate, and support critical daily tasks that typically need human intelligence (Lu *et al.*, 2018). It entails pattern extraction, anomaly detection, and "future state" prediction. The fields of e-commerce, social networks, agriculture, education, environmental sustainability, healthcare, preventing information manipulation, social care and urban planning, public safety, transportation, environment conservation, and many more have all seen an increase in the application of artificial intelligence (AI) due to computational, technological, and research advancements in the field (Shivaprakash *et al.*, 2022). In this article, we will explore the use of AI models in detecting and monitoring animal biodiversity, showcasing their potential benefits and discussing notable references in the field.

1. **Remote Sensing and Image Analysis:**

AI-driven technologies, particularly those utilizing remote sensing and image analysis, have revolutionized the way we observe and monitor animal populations. Remote sensing has been used to determine the terrestrial faunal diversity, with special emphasis on methodologies, while exploring prospective challenges for the conservation and sustainable use of biodiversity dealing with the faunal taxa mammals, birds, reptiles, amphibians, and invertebrates into five classes of surrogates of animal diversity: (1) habitat suitability, (2) photosynthetic productivity, (3) multi-temporal patterns, (4) structural properties of habitat, and (5) forage quality. It is observed that the most promising approach for the assessment, monitoring, prediction, and conservation of faunal diversity appears to be the synergy of remote sensing products and auxiliary data with ecological biodiversity models, and a subsequent validation of the results using traditional observation techniques. Satellite imagery, unmanned aerial vehicles (UAVs), and camera traps generate vast amounts of data that can be overwhelming for manual analysis. AI models, such as convolutional neural networks (CNNs), have shown remarkable capabilities in processing these data to identify and classify animals based on visual cues (Norouzzadeh*et al.,* 2018). Richards and Richards (2022) reported that the techniques for processing and interpreting remotely sensed picture data are covered in detail in Remote Sensing Digital Picture Analysis. While many of the fundamentals of the algorithms used for the interpretation of remote sensing data have remained mostly unchanged, there have been notable and ongoing improvements in the last ten years.

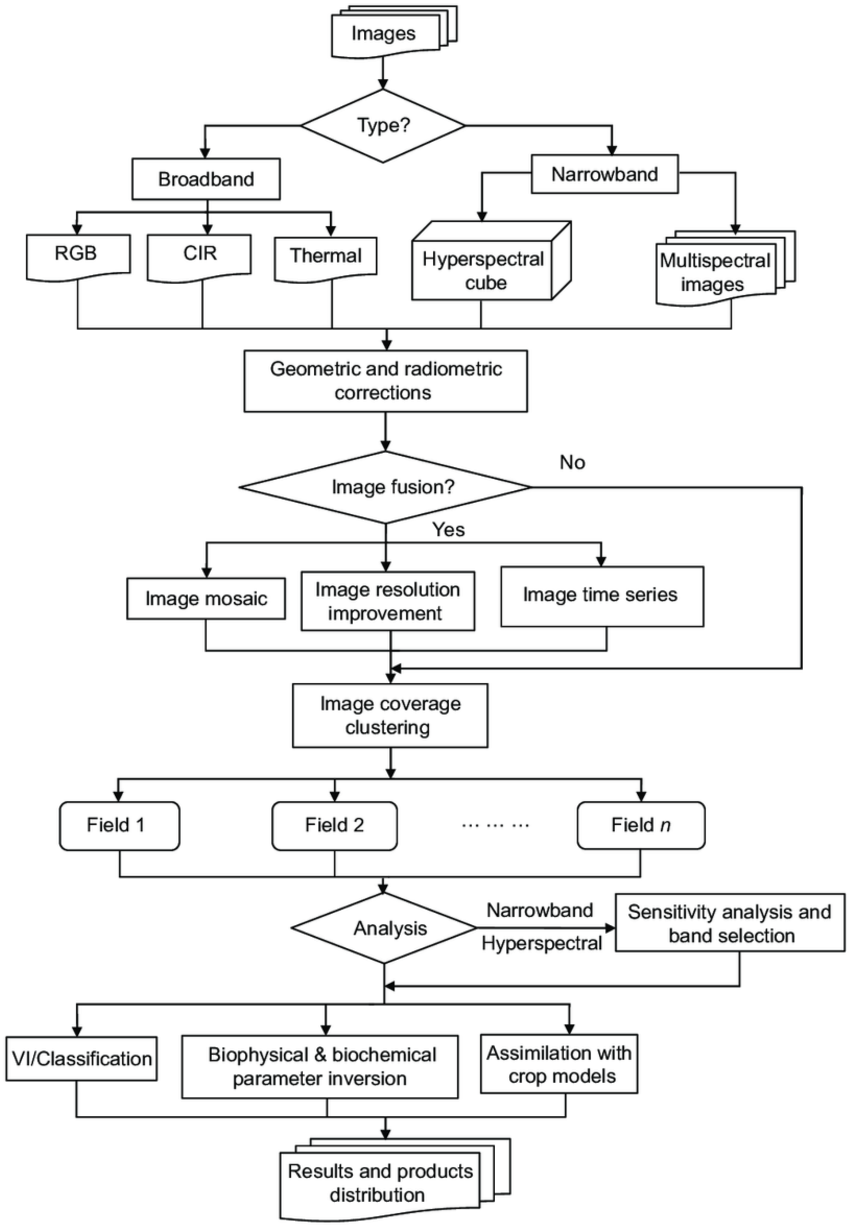


Figure 1: Remote sensing image processing, analysis and management flow for supporting precision agriculture (Source: Huang *et al.*, 2018)

Table 1: Examples of ecological variables and data sources useful for quantifying and modeling biodiversity (Turner *et al.*, 2003).

Ecological variable	Sensor[b] Space (S)/ Airborne (A)	Spatial resolution	Revisit time	Spectral resolution	Description	Website
Direct approaches						
Species composition	TM/ETM + (S), ALI (S), HYPERION (S), ASTER (S), IKONOS (S), Quickbird (S), AVIRIS (A), CASI (A)	< 1–30 m	16 days (ETM, ALI, Hyperion); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird); N/A for aircraft	V/NIR, SWIR, ASTER also has TIR	These sensors are being tested for their ability to measure directly canopy community, and perhaps species, type based upon unique spectral signatures	c–i
Land cover	MODIS (S), TM/ETM + (S), ASTER (S), ALI (S), IKONOS (S), Quickbird (S)	< 1–1000 m	1–2 days (MODIS); 16 days (TM/ETM +); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird)	V/NIR, SWIR, MODIS and ASTER also have TIR	Can discriminate different land surfaces at various resolutions; land cover classification is considered a first-order analysis for species occurrence	c–e,h,i,k
Indirect approaches						
Primary Productivity						
Chlorophyll	SeaWIFS (S), MODIS (S), ASTER (S), TM/ETM + (S), ALI (S), Hyperion, (S), IKONOS (S), Quickbird (S), AVIRIS (A), CASI (A)	< 1–1000 m	1 day (SeaWiFS); 1–2 days (MODIS); 4–16 days (ASTER); 16 days (TM/ETM + , ALI, Hyperion); 2–5 days (IKONOS); 2–4 days (Quickbird); N/A (AVIRIS, CASI)	V/NIR, SWIR, MODIS and ASTER also have TIR	Measure reflectance to assess presence/absence of vegetation and relative greenness measures enabling detection of ocean and land surface chlorophyll useful for calculating productivity and plant health	c,d,f–k
Ocean color and circulation	TOPEX/Poseidon (S), AVHRR (S), MODIS (S), SeaWiFS (S)	1–10 km	10 days (TOPEX/Poseidon); 1 day (AVHRR); 1–2 days (MODIS); 1 day (SeaWIFS)	TOPEX/Poseidon; (microwave) AVHRR, MODIS, SeaWiFS (V/NIR, SWIR, MODIS and AVHRR also have TIR)	Circulation patterns can be inferred from changes in ocean color, sea surface height, and ocean temperature, important for understanding larval transport and movement of pathogens and sediment	j–m
Climate						
Rainfall	CERES (S), AMSR-E (S)	20–56 km	1–2 days (CERES, AMSR-E)	Microwave	Enable detection of precipitation and surface moisture at coarse resolutions; such data parameterize models of species occurrence based on drought tolerance	n,o
Soil moisture	AMSR-E (S)	5.4–56 km	1–2 days	Microwave	Can be estimated over rel. large areas; data parameterize models of species occurrence based on moisture requirements	o
Phenology	MODIS (S), TM/ETM + (S), ASTER (S), ALI (S), HYPERION (S), IKONOS (S), Quickbird (S)	1–1000 m	1–2 days (MODIS); 16 days (TM/ETM + , ALI, Hyperion); 4–16 days (ASTER); 2–5 days (IKONOS); 2–4 days (Quickbird)	V/NIR, SWIR, MODIS and ASTER also have TIR	Information on leaf turnover and flowering/fruiting cycles can be inferred from comparisons of time series of images. Provides for identification of species tied to certain phenological events	c–e,h,i,k
Habitat Structure						
Topography	SRTM (S), ATM (A), ASTER (S), IKONOS (S), SLICER (A), LVIS (A)	90 m SRTM; 30 m/15 m ASTER; 1–15 m IKONOS, SLICER, LVIS	N/A (SRTM); 4–16 days (ASTER); 2–5 days (IKONOS); N/A (SLICER, LVIS)	Microwave SRTM; V/NIR and SWIR for others	Digital elevation models derived from radar signals via interferometry (SRTM); image stereo pairs (ASTER) or discrete-return (usually) LIDAR signals. Many species are constrained by microhabitats resulting from changes in altitude; elevation also determines watershed flows	e,h,p–s

Due to the intricacy and regularity of remote sensing monitoring—particularly LARS monitoring—for precision agriculture, enormous amounts of data need to be processed and analysed. This is the next frontier in agricultural remote sensing big data. Processing and analysis tools were kept apart from the management of remote sensing data for precision agriculture, which was previously done in file-based systems. As data from all time dimensions (year, quarter, month, daily, hourly, and even minutely) as well as spatial location and spectral range accumulate, managing remote sensing data for precision agriculture necessitates organising, processing, and analysing the data within a single framework. This allows for the sharing of the processed, stored, and analysed data and products on a local, national, and international level. The data can be fed into the FLTL framework and streamlined into the data processing, analysis, and management flow as indicated in Fig. 1 in order to satisfy the requirements (Huang *et al.,* 2018).

Remote Sensing in Biodiversity Conservation:

Unmanned aerial vehicles (UAVs), aircraft, and satellites are examples of remote sensing technologies that collect enormous volumes of spatial data that are crucial for biodiversity research. These data sources offer details on topography features, vegetation indices, and land cover. Convolutional neural networks (CNNs) in particular are excellent AI models for identifying patterns and features in these intricate datasets (Pettorelli *et al.,* 2014).

Image analysis and species identification:

Advanced image analysis techniques are now necessary due to the volume of visual data that is being acquired by UAVs, camera traps, and other imaging equipment. AI models, like CNNs, make it easier to automatically identify and categorise different species using their visual characteristics. This facilitates the monitoring of elusive or endangered species that are difficult to directly observe in addition to speeding up the analytical process (Fairbrass *et al.,* 2019).

Habitat mapping and change detection:

Over time, change detection and habitat mapping are made easier by AI-powered image analysis. It is possible for researchers to evaluate changes in land use, deforestation, and habitat fragmentation by comparing satellite imagery or aerial photographs taken at different times. This knowledge is essential for comprehending how human activity affects biodiversity and putting into practice practical conservation measures **(**Turner *et al.,* 2015).

Biodiversity hotspot identification:

For focused conservation efforts, identifying biodiversity hotspots—areas with unusually high levels of endemism and species richness—is essential. By examining environmental factors, habitat features, and species distribution data, remote sensing and AI-driven algorithms help identify and prioritise these hotspots (Jenkins *et al.,* 2013).

Challenges and future directions:

There are still difficulties in remote sensing, image processing, and AI applications for biodiversity conservation, despite tremendous advancements in these areas. We need to keep focusing on issues like data availability, accuracy, and ethical considerations. In order to improve the dependability and efficiency of AI-driven tools in biodiversity research, it will be imperative to address these issues.

AI's ability to combine picture analysis and remote sensing has completely changed the way that biodiversity conservation is done. These technologies offer a scalable and effective way to identify species, track changes in habitat, and monitor ecosystems. The cooperative synergy between remote sensing and AI holds significant promise for improving our understanding and conservation of the Earth's rich biodiversity as AI algorithms continue to advance and data collecting techniques advance.

2. **Acoustic monitoring:**

AI has been used in audio monitoring, in addition to optical data, to identify and recognise different animal species through vocalisations. Machine learning techniques can be used to analyse bioacoustic data, such as bird songs, insect sounds, and marine mammal calls. Using this method, researchers may evaluate the distribution and abundance of different species without having to make direct visual observations (Pavan *et al.*, 2022).

3. **Citizen science and AI collaboration:**

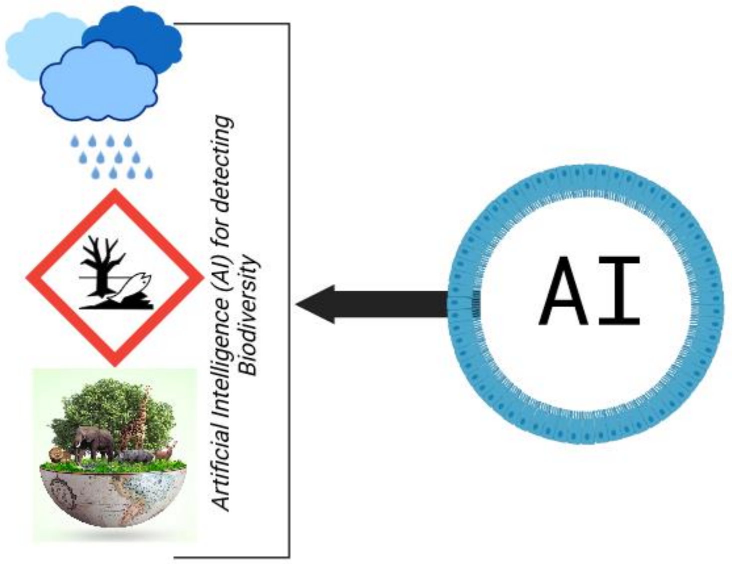
AI can support citizen scientific activities in biodiversity monitoring, which have grown in popularity. Through apps and platforms, the public can participate in data collection, which allows AI models to handle and analyse data more effectively. In addition to involving communities in conservation efforts, this cooperative strategy offers useful datasets for AI model training (Silvertown, 2009).

4. **Conservation drones:**

Drones equipped with high-resolution cameras and AI algorithms have proven effective in surveying and monitoring wildlife populations. These unmanned aerial vehicles enable researchers to cover large areas quickly and access remote or challenging terrains. AI-powered object detection and classification algorithms enhance the efficiency of drone-based surveys (Anderson and Gaston, 2013).

5. **Challenges and ethical considerations:**

While AI models offer immense potential for animal biodiversity monitoring, there are challenges and ethical considerations to address. These include the need for robust datasets, potential biases in training data, and the ethical use of AI in wildlife research. Striking a balance between technological advancement and ethical considerations is crucial for the responsible application of AI in conservation.



Conclusion:

Artificial Intelligence models have emerged as essential instruments for the identification and tracking of animal species. These technologies, which range from image analysis and sound monitoring to citizen science collaboration and the usage of conservation drones, are revolutionising our understanding of and approach to protecting our planet's rich biodiversity. Future initiatives to integrate artificial intelligence with biodiversity conservation hold enormous promise as academics continue to improve AI models and tackle ethical issues.

Acknowledgments:

We express our sincere gratitude for the preliminary manuscript assessment, and for the use of BioEnder software in creating the scientific illustration.

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THREE NEW ADDITIONS OF PLANT SPECIES IN THE FLORA OF TRIPURA, NORTH EAST INDIA

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Abstract:

Three plant species viz., *Kalanchoe daigremontiana* Raym.-Hamet & H. Perrier *(*Crassulaceae), *Hyptis brevipes* Poit. (Lamiaceae) and *Cuphea carthagenensis (*Jacq.) J.F. Macbr. (Lythraceae) are reported here from Tripura for the first time. A brief botanical description, along with distribution, habitat, ecology, original photographs of the collected specimens and taxonomic keys to the species in Tripura are given here as follows.

Keywords: *Kalanchoe daigremontiana; Hyptis brevipes; Cuphea carthagenensis;* New Record; Tripura

Introduction:

During an extensive floristic survey, the authors collected some interesting plant specimens which were later identified to be of *Kalanchoe daigremontiana* Raym. -Hamet & H. Perrier *(*Crassulaceae), *Hyptis brevipes* Poit. (Lamiaceae) and *Cuphea carthagenensis (*Jacq.) J.F. Macbr. (Lythraceae). These three species are not recorded in the Flora of Tripura (Deb, 1981, 1983). Thus, these species are reported here for the first time from Tripura.

The genus *Kalanchoe* Adans. consists about 150 species distributed in Madagascar, east and South Africa, tropical and Southeast Asia and 10 species in India (Deb,1983; Descoigns, 2003). Earlier, the genus *Kalanchoe* was divided into three genera: *Kalanchoe* Adans., *Bryophyllum (*Salisb.) Boiteau and *Kitchingia* J.G. Baker. But today, most botanists recognize it as one genus under the family Crassulaceae (Burrows and Tyrl, 2001). The plant is well known by 'Mother of millions' or 'mother of thousands because it enhanced by vigorous vegetative propagation through pseudobulbils that arise from the margin of their leaves. Deb (1983) recorded 3 species in the book "The Flora of Tripura State" namely *K. laciniata (*L.) DC., *K. integra* (Medik.) Kuntze and *K. pinnata* (Lam.) Pers. (2) and additionally the species *Kalanchoe daigremontiana* Raym. -Hamet & H. Perrier is new record for Tripura state.

The genus *Cuphea* P. Browne belongs to the family Lythraceae which comprises approximately 260 species (Graham, 1989) and widely distributed from to North and Central America, Asia, Australia, and Africa. It has been first reported to India by 1959 where it was found in Assam, Arunchal Pradesh and in Nagaland in 1976 (Naithani and Bennet,1990). In Assam (India), it is a dominant weed of paddy field (Randhawa *et al.,* 2006). The genus *Cuphea* is newly introduces for the flora of Tripura state with two species *C. carthagenensis (*Jacq.) J.F. Macbr. and *C. hyssopifolia*. Kunth. *C. carthagenensis* is grown in unprotected areas where *C. hyssopifolia* is gardening in Tripura for it pleasant. *Cuphea carthagenensis* is first time report from Tripura state.

The genus *Hyptis* Jacq. belongs to the family Lamiaceae which includes about 280 species predominantly confining in New World with few species in Old World (Harley *et al.,* 2004). Mukerjee (1940) reported 4 species under the genus viz. *Hyptis capitata* Jacq., *H. pectinata* (Linnaeus) Poit., *H. suaveolens* Poit. and *H. brevipes* Poit. from India. Out of these, only *H. suaveolens* is spread throughout

India and considered as an invasive weed and remaining species are restricted in small geographical areas (Mukerjee, 1940; Devi *et al.*, 2008; Sharma *et al.*, 2009). In Tripura only two species namely *H. capitata* and *H. suaveolens* are recorded by Deb (1983). The species *Hyptis brevipes* Poit. is newly introduced species for the state of Tripura.

Methodology

Herbarium sheets were made following standard methodology (Jain and Rao, 1977) and were deposited in the Herbarium of the Department of Botany, Tripura University. Later on, they were identified using regional Flora and another published literature.

Taxonomic accounts

***Kalanchoe daigremontiana* Raym.-Hamet & H. Perrier. Ann. Mus. Colon. Marseille, ser. 3. 2: 128. 1914.**

Perennial, monocarpic, succulent, terrestrial, purple-mottled herbs. Stems simple. Leaves exstipulate, opposite to alternate, simple, lanceolate to ovate, 20 cm in length, serrate at margins, glaucous, cuneate at base, acute at apex, abaxially purple-blotched; bulbils in notches of margins; bulbiferous spoon shaped; petioles subterete. Inflorescence in compound paniculate cymes. Pedicles c. 1.5 cm. Flowers bracteate, pedicellate, actinomorphic, bisexual, tetramerous, pendulous, hypogynous. Bract small. Sepals free or basally subconnate, usually shorter than corolla. Corolla pink or orange pink colour, salverform, gamopetalous; tube 5 mm long, lobes 4, obovate, acute at apex; lobes equal or sometimes longer than tube. Stamen 8, in two whorls, adnate to corolla; anther dithecous. Ovary superior; carpel 4, unilocular, slightly connate at base; style usually shorter than ovary; stigma capitate. Fruits follicular; follicles 4; seeds minute, many, oblong with longitudinal striae (Fig 1).

Flowering and fruiting: January to May.

Distribution: The plant species *Kalanchoe daigremontiana* is native in Madagascar and distributed in Florida, Mexico, Italy, Cuba, the West Indies, New Caledonia, Venezuela, Puerto Rico, Venezuela, Hawaii, Portugal, Spain, Australia, South Africa, several islands in the Pacific and India (Karnataka and now in Tripura state)

Habitat and Ecology: *Kalanchoe daigremontiana* is succulent in nature and well adapted in dry and arid environments. The plant can survive prolonged periods of drought with little water or no water.

Specimen examined: INDIA: Tripura, Shibnagar, Agartala, Latitude 23º49´50´´N Longitude 91º18´01´´ E., 27.9.2018. *Deb & Datta* TUH-2305.

***Hyptis brevipes* Poit. Ann. Mus. Hist. Nat. 7: 465. 1806.**

Terrestrial, erect, annual, herbs, height c. 1 m. Stem quadrangular; angles pilose. Leaves opposite; blade narrowly ovate to oblong to lanceolate, 5–8 × 1–2.5 cm, greenish beneath, pilose, margin serrate at margins, acuminateat apex, cuneate at base; petioles, c. 5 mm long, Inflorescence in axillary globose capitula; peduncle 0.5–1.6 cm long, densely appressed pilose; flowers in dense spurious heads, bracteate, zygomorphic; bracts lanceolate, 4–6 mm long, entire at margins. Calyx subcampanulate, 5-toothed, hispid; teeth as long as tube, subulate at apex; fruiting calyx dilated. Corolla white, slightly 2 lipped, c. 3.5 mm long, pubescent, throat up to 1 mm wide; lobes circular, reflexed; middle lobe of lower lip larger, concave, circular, constricted at base, recurved; lateral lobes triangular, reflexed. Stamens 4, exert; filaments free; anther 2-celled. Ovary 4-partite, style glabrous, bifid. Nutlets dark brown, ovoid, adaxially ribbed, with 2 basal white scars (**Fig 2).**

Flowering and fruiting: Throughout the year

Distribution: It is native to the American continent i.e., Argentina, Bolivia, Brazil, Colombia, Guyana, Mexico, Paraguay, Peru and naturalized in Asia i.e., Indonesia, Malaysia, Philippines, Singapore, Taiwan, Thailand, Vietnam and India (Assam, West Bengal and new in Tripura State)

Habitat and Ecology: *Hyptis brevipes* Poit. is an herb which well developed in arid and wet environments. It is also found in moderate elevations and low land dry fields.

Specimen examined: INDIA: Tripura, Padmabil, Dharmanagar, Latitude 24º17´56.7´´N Longitude 92º12´21.1´´ E. 30.10.2018. *Sarma & Datta* TUH-2313.

***Cuphea carthagenensis* (Jacq.) J.F. Macbr. Publ. Field Mus. Nat. Hist., Bot. Ser. 8: 124. 1930. Basionym: *Lythrum carthagenense* Jacq., Enum. Syst. Pl. 22. 1760**

Herbs terrestrial, perennial, erect, branched. Stem viscid-pilose, with glandular and non-glandular hairs, bristle present. Leaf exstipulate, opposite, elliptic to ovate, 1.5–6 cm long, acute at apex, entire at margins; petioles short. Inflorescence monochasial cymes; hypanthium campanulate or tubular like; flowers small, bracteates, arising from leaf axils, solitary, actinomorphic, hermaphrodite; floral tube sparsely pubescent, green, glandular hairs present inside tube, perigynous. Calyx lobes unequal, triangular or ovate, short hairy tipped, valvate, persistent. Corolla inserted at top of hypanthium; petals 6, 2–3 mm long, linear-elliptic, valvate. Stamens 11, not protruding out, anthers 2-loculer, longitudinally dehiscent. Pistil syncarpous; ovary superior, cylindric; placentation axile; style simple; stigma discoid. Fruit a capsule, partly or completely surrounded by persistent floral tube, 4-seeded. Seed exalbuminous, 2 mm long, lenticular, without endosperm, olive to brown with pale edges. (**Fig 3**).

Flowering and fruiting: Throughout the year.

Distribution: Asia, Africa, North America, Central America and Caribbean, South America, Oceania. In India it is distributed in Eastern part of Assam. In Tripura it is distributed at North Tripura district and Dhalai districts.

Habitat and Ecology: The plant is grown in high land and road side areas.

Specimen examined: INDIA: Tripura, Padmabil, Dharmanagar, Latitude 24º19´18.8´´ N; Longitude 92º12´37.6´´ E. 03.09.2018. *Sarma & Datta* TUH-2316

Plant Photos

Figure 1: *Kalanchoe daigremontiana* Raym.-Hamet & H. Perrier*:*
A: Habitat, B: vigorous clonal propagation from leaf lamina

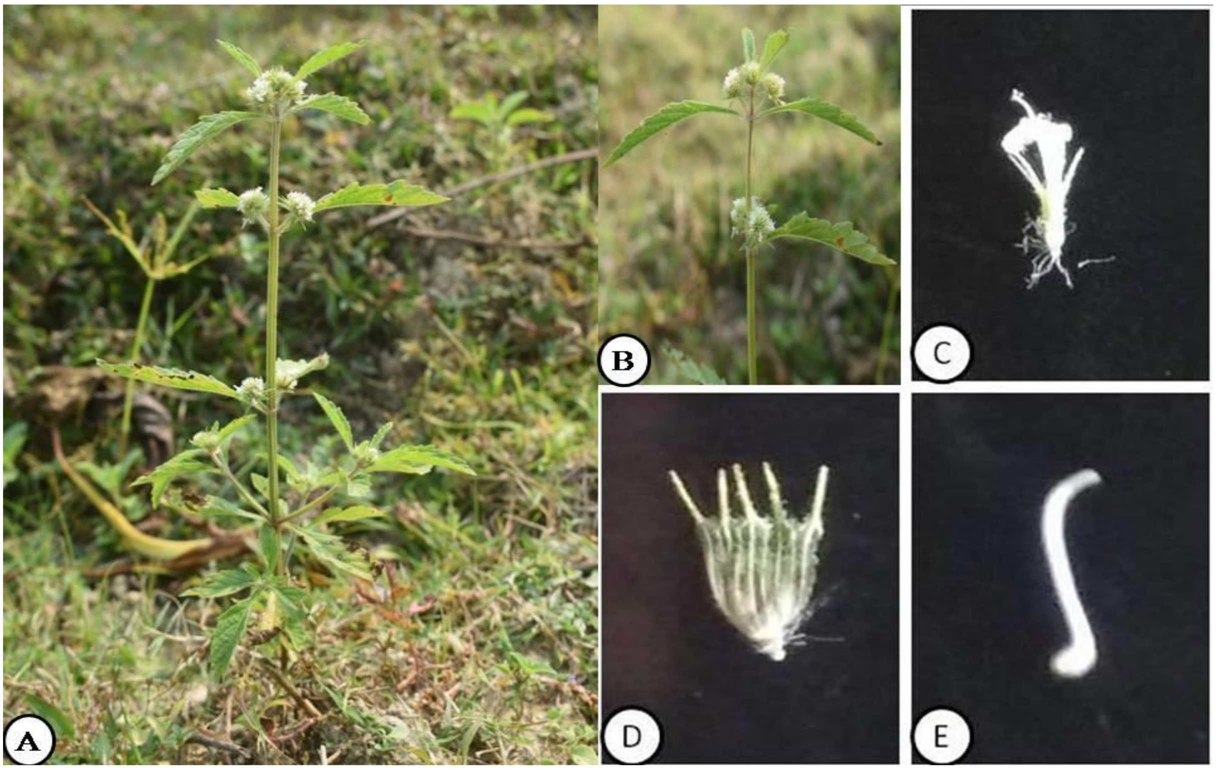

Figure 2: ***Hyptis brevipes*** **Poit.: A: Habitat, B: Flowering twig, C: A complete flower, D: Calyx, E: Androecium**

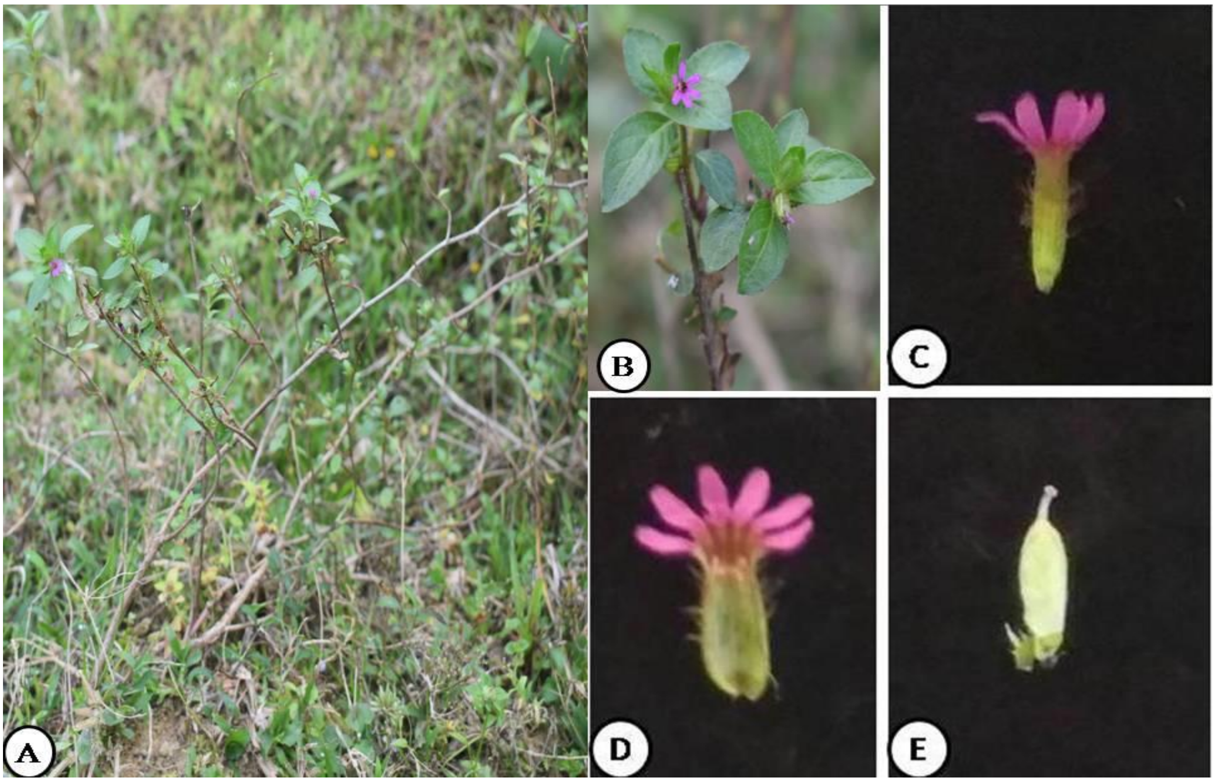

Figure 3: ***Cuphea carthagenensis*** **(Jacq.) J. F. Macbr.: A: Habitat, B: Flowering twig, C: A complete flower, D: Petal, E: Gynoecium**

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VARIATION IN DIVERSITY, SPECIES SELECTION AND MANAGEMENT PRACTICES WITHIN TRADITIONAL AGROFORESTRY SYSTEMS PRACTICED BY TRIBAL AND NON-TRIBAL COMMUNITIES OF TRIPURA, INDIA

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Abstract:

A study was conducted in traditional agroforestry systems practiced by Chakma, and Bengali communities of Tripura, India. The study reveals that the agroforestry systems of Tripura are diverse with a great deal of socially valuable plant species. The selection of principal crop species varied between the ethnic communities and depends largely on their traditional ecological knowledge. The farmers of these traditional systems use to maintain multistoried system. However, they categorize the plants indigenously on the basis of light requirement. The farmers of the study sites are maintaining a good tree-crop association in their field. The multi-storied systems were observed in most of the agroforestry sites. The plants prevalent in different agroforestry systems consist of the three layers i.e. upper, middle and ground storey. Species composition of the traditional agroforestry systems also varied with residue management, soil and climate of sites. The structure and size of the systems also played important role in species diversity of the agroforestry system. Though not much difference was observed in the plant diversity across the sites, however, difference in tradition and culture was significant in selecting the plant to be grown in the traditional agroforestry system. The intimate mix of diversified agricultural crops and multipurpose tree species fulfils most of the basic needs of the local inhabitants while the multi-storied configuration and high species diversity of the agroforestry system helps to reduce the environmental hazards that is commonly associated with rubber plantation in the state. An understanding of indigenous practices, therefore, offers excellent opportunities for finding solutions to the problems of self reliance in agricultural development of the region.

Keywords: Traditional Agroforesty System, Woody & Herbaceous Plants, Bengali and Chakma Communities of Tripura.

Introduction:

Agroforestry has the potential to improve livelihood as it offers multiple alternatives and opportunities to farmers to improve farm production and income and also provide productive and protective (biological diversity, healthy ecosystems, protection of soil and water resources, terrestrial carbon storage) forest functions to the ecosystems while protecting the natural environment. Sustainability-enhancing practice that combines the best attributes of forestry and agriculture. Different community practices and manage different types of agroforesty system; ultimately all are promoting them to huge income sources. These systems are essentially man-made and reflect the evolution of human culture with aspects of location, climate, and other ecological parameters carefully considered in their establishment. Schultz (1964) said ‘Farming based wholly upon the kinds of factors of production that have been used by farmers for generations can be called traditional agriculture’. Traditional agroforestry systems are managed indigenously, with practices having been evolved by the farmers through trial and error over long periods of time (Rai and Proctor, 1986). Therefore, traditional cropping patterns also vary, since they have evolved in response to prevailing soil and climatic conditions and social and ethological preferences (Ruthenburg, 1976).

A great number of different traditional grain crops, rhizomatous crops, pineapple, coffee, tea and vegetables are being grown with a number of fruits and other trees in the traditional agroforestry systems, which are valuable for the farmers' everyday life as they provide a greater diversity of food and also act as a good source of commercial outlets in addition to household consumption. Agroforestry has the combine's production of multiple outputs with production of resource base and places emphasis on indigenous, multipurpose trees and shrubs and also more concerned with socio- cultural value than most other land uses systems (Nair 1993). In agroforestry systems, both biotic and abiotic environments can be modified by the different crop/pasture-tree configuration (Chang *et al.*, 2002; Yunusa *et al.*, 1995).

Materials and Methods:

Study sites

The study was conducted in four traditional agroforestry systems in south district of Tripura state, located between 23°13´ N latitude and 91°.6´ E longitude at an altitudinal range of 39-162 m a.s.l and Sepahijala district of Tripura state located. After a preliminary reconnaissance in several villages like Maichara, Joychandpur, Sonaichari, Gobarchara, Ratanpur of South Tripura District and Bishramganj of Sepahajala District were selected for the detailed study (**Figure 1**). The average area of the agroforestry farms varied between 0.2 to 40ha.

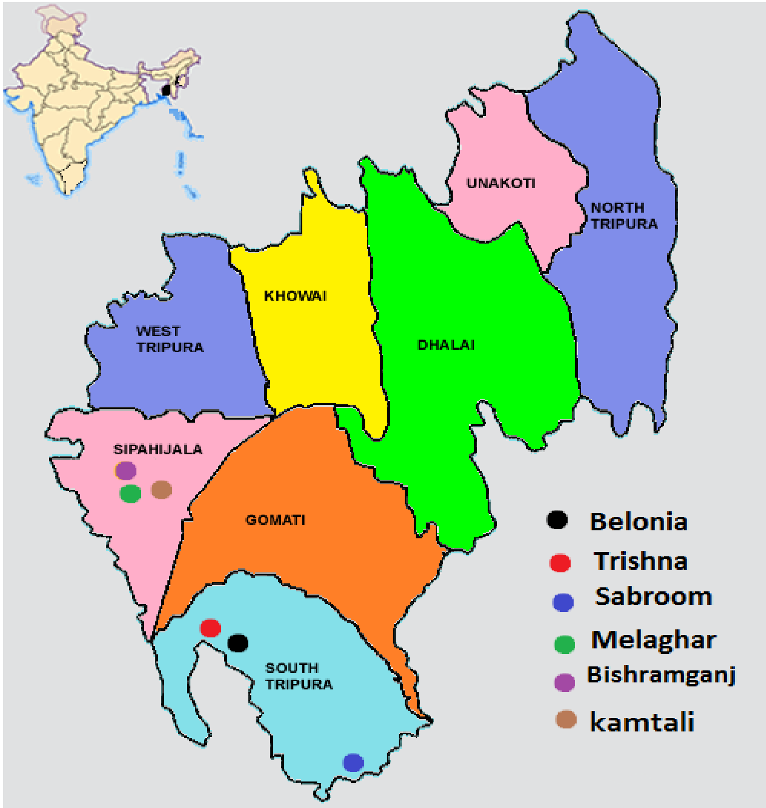

Fig. 1: Map showing the different location of Shipahijala and South Tripura Dist.

Field methodology

Five sites were identified out of all agroforestry sites for detailed vegetation study. Diversity of plant species in traditional agroforestry systems were measured using three randomly placed quadrates

(10m x 10m) for woody species and herbaceous (1m x 1m) species. Nomenclature of the plant species followed Deb (1981 &1983). The vegetation data were analysed for relative frequency, relative dominance and relative density (Phillips, 1959). The sum of relative frequency, relative dominance and relative density was calculated as importance value index (IVI) of individual species (Curtis, 1959). Species richness index was measured by Menhinic (1964). Species diversity (Margalef, 1968) was calculated as: H'= -Σ { (ni/N) loge (ni/N)}, where H'=Shannon index of general diversity, ni=IVI of a species, N= Total IVI of the community (i.e. 300). The dominance index (Simpson, 1949) of the community was calculated as: C=Σ { (ni/N) 2}, where C=dominance index, ni and N are same as for Shannon's index. Pielou's (1966) evenness index (e) was calculated as: e= H'/logS, where H'= Shannon's index of diversity, and S= Total number of species. 17

Results:

Structure of agroforestry systems practised by Chakma (Tribe)

Agri- Silvi- Piscicultural system is an age-old agroforestry practice adopted by the Chakma community of Tripura observed in Ratanpur and Gaubarchara villages in South Tripura. This is one of the productive systems, where different agroforestry components are cultivated on the same land management unit. Farming is the mainstay of their economy. The farmers choose the crops and crop combinations based on their own wisdom and perceptions acquired over generations of experiences, the criterion being their day-to-day requirements of food, fuel, fodder and timber. The Chakmas plough their field with bullocks. The bullocks, however, incur high cost of feed and fodder. Hybrid and local varieties of paddy, vegetables (cabbage, carrot, cauliflower, chilli, pumpkin), specific trees, shrubs and palms are deliberately planted on the cultivated lands. From the socio-economic and cultural viewpoint, some species were maintained and utilized as cash crops. For example *Hevea brasiliensis* Muell. – Arg. plays a vital role in the economy of the local society. They also prefer Sugarcane, pineapple, Capsicum as the labour input for managing these plants is less than that for many other crops, which makes it an ideal for the people engaged in other occupations. The economic advantage of the system is derived from the cash-sale of the plant products. The family income is greatly improved, as the farmers save the cash that otherwise would have been spent on food. The system also provides a more or less full-time employment to most participants who have no other source of income. The Chakmas also maintain fish ponds in the farmyard. Trees are planted surrounding the fish pond, and crops inter-planted forming an integrated biological production system. Common carps, silver carps and grass carps are generally preferred by the traditional society. The litter of many plants like *Leucaena leucocephala* (Lamk.) de Wit, *Moringa oleifera (*L.) Lamk. has been found to serve as a good fish-feed when offered as pellets and improved the fish production. Further, the trees and shrubs in the traditional systems play an important role in regulating the microenvironment of the system. They are the principal source of rural energy and provide countless fuel wood products used in the households.

Structure of agroforestry systems practised by Bengali (Non-Tribe)

Agri-horti-silvi-cultural system is a common agricultural system practised in the foothills by the 'Bengali' in Bishramganj and Trishna site respectively. It is one of the most common and age-old farming practices in Tripura. In this system, the local people plough (2-3 times) their field with bullocks and grow traditional crop species such as *Oryza sativa* L., *Zea mays* L. etc. Among the tuber crops, *Manihot esculenta* Crantz, *Dioscorea* bulbifera L., C*olocasia esculenta* (L.) Schott. etc. are the most widespread and chief subsidiary food crops. Vegetables include *Capsicum annuum* L., *Colocasia esculenta* (L.)

Schott, *Solanum tuberosum* L., *Solanum melongena* L. etc. Pineapple is a common floor crop grown along with the vegetables in the homesteads. A number of cultivars of banana are also cultivated. The farmers cultivate tree species on the boundary and agricultural crops in the middle. Hence, this farming practice is predominantly subsistence-oriented. The farmers have poor resource-base, their landholdings are small and fragmented, and they have diverse requirements of food, fodder, fuel and timber.

In addition, other species that provide leaves, spices and condiments (*Betel vine L, Piper longum* L., *Zingiber officinale* Rose., *Ocimum sanctum L.*, *Azadirachta indica* A. Juss. etc.) are also cultivated. In practical terms, the main expectation from an intercropping system in a perennial plantation cropping system is that the overall return from a unit piece of land is increased without adversely affecting either the current or the long-term productivity of the main (perennial crop). At the same time, the returns from the additional crops should justify the adoption of the intercropping practice and should contribute to the long-term productivity of the system.

Species diversity and important value index

The detailed vegetation analysis of two agroforestry systems dominated by Chakma and Bengali community were studied. Altogether 26 woody species and 36 herbaceous species belonging to 30 plant families were recorded from the two communities based traditional agroforestry systems; 11 species were common to all sites. Overall, the plants were distributed contagiously. The density of tree species was greater in Chakma community as compared to the Bengali community. More or less the genus to species ratio remained 1:1. *Hevea brasiliensis* Muell. – Arg.was dominant in Sonaichera and Sabroom site, whereas *Areca catechu* L. in Bishramganj site. *Capsicum annuum* L, *Solanum melongena* L. and *Vigna sinensis (*L.) Hassk. were common to all the study sites, showing significant differences in IVI among the study sites. Herbs like *Imperata cylindirca (*L.) P. Beaur., ferns and Grasses were abundant in all the study sites. Although not significant, the density of tree species was higher in Chakma community and herbs species in Bengali community respectively. Nevertheless, the genus to species ratio remained 1:1 for both the sites. The Bengalis choose ‘arecanut’ to a larger degree in their traditional agroforestry system. However, dominance of other species like mango, banana, chillies and cereals cannot be completely ruled out in the study sites. Cereal crops (*e.g*. Maize) were seldom planted. Nonetheless, angiospermic weeds, monocotyledonous grasses, pteridophytic ferns and mosses, were abundant on the floor. Interestingly, some rows of pineapple plant and piper plant were exclusively found in Bishramganj site, and conversely *Albizia procera (*Roxb.) Benth. and *Mitragyna rotundifolia (*Roxb.), O. Ktze in Chakma dominated Gaburchora sites.

Woody plant diversity was greater in Bishramganj due to abundant arecanut palms and *Cajanus cajan* L. that occupied over 1/6 of the total importance value *i.e.* 300. However, trees like *Albizia procera (*Roxb.) Benth. and *Manilkara achras (*Mill.), Fosberg had larger diameter individuals thus registering greater basal area in Gaburchara site (Table 1). Tree species dominance index varied from 0.12-0.14 and diversity index 2.18-2.45

High species composition in Bishramganj site might be due to difference in their species composition, it mainly occurred in large home gardens. In Bishramganj, by virtue of their larger size of agroforestry (Four times bigger than Gaburchora), the local farmers were more aware and able to grow more species. Whereas low diversity encountered in Gaburchara villages may be attributed to smaller size and also the products are primarily meant for household consumption.

Table 1: The woody and herbaceous plant diversity in traditional agroforests

Woody Plants Herbaceous Plants

Parameters/ Community	Bengali	Chakma	Bengali	Chakma
Species	19	13	28	13
Genus	19	-	28	-
Family	16	-	17	-
Individuals	121	146	554	205
Simpson Dominance index	0.1207	0.1415	0.1542	00.129
Shannon diversity index	2.453	2.189	2.458	2.245
Evennexx index	0.612	0.6867	0.4174	0.7259
Menhinick species richness index	1.727	1.075	1.19	0.908
Equitability index	0.8332	0.8535	0.7378	0.8751
Fisher alpha_ diversity	6.33	3.449	6.222	3.087
Berger Parker	0.2314	0.2397	0.3357	0.2341

Table 2: Important Value Index (IVI) of woody species in traditional agroforests

			Bengali Community				Chakma Community			
Sl. No	**Species**	**Family**	**RF**	**RD**	**RBA**	**IVI**	**RF**	**RD**	**RBA**	**IVI**
1.	*Albizia procera*	Mimosaceae	7.14	3.31	8.63	19.08	20	23.97	41.29	85.26
2.	*Anacardium occidentale*	Anacardiaceae	3.57	2.48	8.33	14.38	-	-	-	-
3.	*Anogeissus acuminata*	Combretaceae	3.57	0.83	0.60	4.99	5	2.74	1.00	8.74
4.	*Anthocephalus chinesis*	Rubiaceae	-	-	-	-	5	1.37	26.08	32.45
5.	*Areca catechu*	Arecaceae	7.14	14.88	2.21	24.23	-	-	-	-
6.	*Artocurpus chaplasa*	Moraceae	3.57	0.83	0.53	4.92	-	-	-	-
7.	*Azadiracta indica*	Meliaceae	-	-	-	-	5	2.75	5.50	13.24
8.	*Cajanus cajan*	Papilionaceae	7.14	23.14	0.63	30.91	10	17.81	0.37	28.18

9.	*Citrus maxima*	Rutaceae	7.14	2.48	0.69	10	-	-	-	-
10.	*Clerodendrum viscosum*	Verbenaceae	-	-	-	-	5	8.22	0.07	13.29
11.	*Ficus hispida*	Moraceae	3.57	1.65	0.05	5.28	-	-	-	-
12.	*Gliricidia sepium*	Papilionaceae	3.57	4.96	15.24	23.77	-	-	-	-
13.	*Gmelina arborea*	Lamiaceae	3.57	1.65	2.18	7.40	-	-	-	-
14.	*Hevea brasiliensis*	Euphorbiaceae	10.71	16.53	3.44	30.68	-	-	-	-
15.	*Litchi chinensis*	Sapindaceae	3.57	3.31	23.06	29.93	-	-	-	-
16.	*Mangifera indica*	Anacardiaceae	7.14	6.61	0.49	14.24	-	-	-	-
17.	*Manihot esculenta*	Euphorbiaceae	-	-	-	-	5	2.74	0.07	7.81
18.	*Manilkara achras*	Sapotaceae	3.57	4.96	30.46	38.99	-	-	-	-
19.	*Microcos paniculata*	Tiliaceae	3.57	2.48	0.04	6.09	-	-	-	-
20.	*Mitragyna rotundifolia*	Rubiaceae	7.14	3.31	0.54	10.99	15	16.44	9.78	41.22
21.	*Moringa olifera*	papilionaceae	-	-	-	-	5	1.37	0.15	6.52
22.	*Musa sp.*	Musaceae	-	-	-	-	5	3.42	0.72	9.15
23.	*Saccharum officinarum*	Poaceae	-	-	-	-	5	10.27	0.12	15.40
24.	*Syzygium cumini*	Myrtaceae	3.57	0.83	0.69	5.09	-	-	-	-
25.	*Tectona grandis*	Verbenaceae	7.14	4.96	0.30	12.41	5	3.42	4.65	13.07
26.	*Toona ciliata*	Meliaceae	3.57	0.83	1.91	6.31	10	5.48	10.19	25.67

Table 3: Herbaceous stand structure and Relative Important Value (RIV) in traditional agroforests

			Bengali Community			Chakma Community		
Sl. No	**Species**	**Family**	**RF**	**RD**	**RIV**	**RF**	**RD**	**RIV**
1.	*Abelmoschus esculentus*	Malvaceae	1.61	0.18	1.79	-	-	-
2.	*Acalypha indica*	Euphorbiaceae	1.61	3.25	4.86	-	-	-
3.	*Ageratum conyzoides*	Asteraceae	-	-	-	7.14	0.98	8.12
4.	*Annanus comosus*	Bromiliaceae	8.06	5.23	13.30	-	-	-
5.	*Blechnum sp.*	Blechnaceae	1.61	0.18	1.79	-	-	-
6.	*Capsicum frutescens*	Solanaceae	3.23	0.90	4.13	7.14	7.80	14.95
7.	*Colocasia esculenta*	Araceae	3.23	2.89	6.11			
8.	*Crysopogon sp.*	Poaceae	-	-	-	7.14	6.34	13.48
9.	*Cucurbita pepo*	Cucurbitaceae	-	-	-	7.14	1.46	8.61
10.	*Cymbopogon sp.*	Poaceae	-	-	-	7.14	15.12	22.26
11.	*Cynodon dactylon*	Poaceae	-	-	-	4.14	4.88	12.02
12.	*Digitaria ascendens*	Poaceae	3.23	3.97	7.20	-	-	-
13.	*Dryopteris pseudocalcarata*	Polypodiaceae	1.61	0.72	2.33	-	-	-
14.	*Eupatorium odoratum*	Asteraceae	-	-	-	7.14	10.73	17.87
15.	*Grasses*	Poaceae	17.74	33.57	51.32	-	-	-
16.	*Imperata cylindrica*	Poaceae	4.84	9.03	13.86	14.29	13.66	27.94
17.	*Lindernia sp.*	Rubiaceae	1.61	1.08	2.70	-	-	-
18.	*Luffa acutangula*	Cucurbitaceae	3.23	0.54	3.77	-	-	-
19.	*Mikania cordata*	Asteraceae	3.23	1.44	4.67	-	-	-
20.	*Mimosa pudica*	Mimosaceae	1.61	0.54	2.15	-	-	-
21.	*Musa paradisiaca*	Musaceae	6.45	1.44	7.90	-	-	-
22.	*Oryza sp.*	Poaceae	3.23	4.69	7.92	-	-	-
23.	*Oryza sativa*	Poaceae	-	-	-	7.14	23.41	30.56
24.	*Panicum sp.*	Cyperaceae	-	-	-	4.14	7.80	14.95
25.	*Pavetta indica*	Rubiaceae	1.61	0.54	2.15	-	-	-
26.	*Peperomia pellucida*	Piperaceae	1.61	1.62	3.24	-	-	-
27.	*Phylanthus sp.*	Euphorbiaceae	1.61	0.36	1.97	-	-	-
28.	*Piper longum*	Piperaceae	1.61	0.54	2.15	-	-	-
29.	*Sesamum indicum*	Lamiaceae	1.61	1.62	3.24	-	-	-
30.	*Solanum melongena*	Solanaceae	3.23	0.54	3.77	7.14	3.90	11.05
31.	*Spermacoce hispida*	Rubiaceae	6.45	14.08	20.53	7.14	1.95	9.09
32.	*Spilanthes paniculata*	Asteraceae	6.45	2.89	9.34	-	-	-
33.	*Synedrella nodiflora*	Asteraceae	3.23	1.62	4.48	-	-	-
34.	*Vigna sinensis*	Papilionaceae	3.23	0.72	3.95	7.14	1.95	9.09
35.	*Zea mays*	Poaceae	1.61	0.72	2.33	-	-	-
36.	*Zingiber officinale*	Zingiberaceae	1.61	5.05	6.67	-	-	-

Variation in species selection and management practices

Different management practices have been observed during field survey in traditional agroforestry systems of Tripura. These are as follows:

1. The farmers of Bengali community use cow dung and other bio fertilizers in their field, which might have enhanced the soil organic matter. They also cultivated N_2-fixing plants like *Cajanus cajan* L., *Erythrina indica* Lamk. and *Bauhinia variegata* L. mostly in their agricultural field.
2. The farmers of the Chakma community (Gaburchera village) are more aware about the management of the system and able to grow more fruit trees than other agroforestry systems.
3. In Chakma community, it was observed that the nursery raising plot of *Oryza sativa* L. is used for Mashcolai cultivation as the area is considered no more suitable for paddy cultivation for 1-2 years.
4. In Chakma community after harvesting sugarcane plant, the field is kept as such for one year for regeneration of sugarcane plant from its rhizome. The residue of sugarcane is burnt in the field itself which is considered good for soil health. They feel that burning of the plant residue will destroy all earlier year's pathogens from the field, whereas others feel that burning contributes more nutrients to the soil.
5. Fecal matter of poultry and piggery is used for agroforestry field as well as in fish pond in animal based agroforestry systems. Fecal matter of goat is specifically used as fertilizer for Cucurbita and Pumpkin plant.
6. Few plants are used in slope land like cashewnut, pineapple, bamboo, etc. Hill variety of Sugarcane is also used for sloppy land.
7. Farmers feel that crops can be grown with rubber in first 3 years whereas after that period it is difficult to grow any other crops due to dense crown cover of rubber plant.
8. On the other hand in Sonaichari site, farmers prefer to cultivate timber-yielding plants that may have more coarse roots in their field, and they are less aware of biofertilizer application. Poor management practices such as frequent burning and cutting, grazing by animals also observed in this field.
9. In Bishramganj site farmers are more aware about the management of the system and able to grow more trees and agricultural crops than other agroforestry systems.
10. The ashes collected after cooking are also used in the field and on the leaf of brinjal and Cucurbita plant as pesticides
11. Fruits are preferred by Benglai community whereas vegetables by Chakma community. *Phaseolus mungo* L., *Cajanus cajan (*L.)Millsp., *Vigna sinensis (*L.) Hassk., *Dolichos lablab* L. are nitrogen fixing plants found in the agroforestry field.
12. Rubber plantation as cash crops observed more in Sabroom, Sonaichori, Ratanpur and Trishna. Rubber plantation is mostly practiced by Bengali community whereas timber is preferred by Chakma and other tribal community.

Discussion:

The present study on traditional agroforestry systems revealed that the systems were diverse with a great deal of socially valuable plant species. Not surprisingly, the selection of principal crop species varied between the ethnic communities and depends largely on their traditional ecological knowledge. So, in this context, safeguarding of traditional farmers' knowledge seems critical. The traditional societies are often closely linked with and dependent upon the rich biodiversity that surround them (Ramakrishnan, 1996). The farmers of these traditional systems use to maintain multi-storeyed system. However, they categorize the plants indigenously on the basis of light requirement. Over all, the numbers of medium light-demanding and shade-loving plants were more than the strong and moderate light adaptable plants in the traditional agroforestry system. The crucial part of any agroforestry systems is its selection of suitable tree for crop, because only the good combination of tree and crop can give a good output of the agroforestry systems. The farmers of the study sites are not doing this selection in any scientific way, but still they maintain a good tree-crop association in their field. Different types of vegetables are cultivated in different seasons in these traditional agroforestry systems. Vegetables and fruits are common in all the sites studied. However, Chakma villages (Nirjuli and Doimukh) had lesser concentration of cash crop plantation like than the Bengali dominated Bishramganj site. Instead of rubber, people of tribal dominated sites prefer to grow timber and fuel wood (*Albizia procera*) in their agroforestry systems.

Conclusion:

From the above discussion, it has been observed that traditional agroforestry and related indigenous knowledge system of different communities of Tripura provide ample opportunities for agricultural diversification as well as escalation while simultaneously ensuring a large degree of endogeneity. The intimate mix of diversified agricultural crops and multipurpose tree species fulfils most of the basic needs of the local inhabitants while the multi-storied configuration and high species diversity of the agroforestry system helps to reduce the environmental hazards that is commonly associated with monoculture production system. It is now increasingly felt that major impetus to be exercised to make this traditional system a more sustainable, conducive and pragmatic. An understanding of indigenous practices, therefore, offers excellent opportunities for finding solutions to the problems of self reliance in agricultural development of the region.

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*HODGSONIA MACROCARPA (*CUCURBITACEAE): A VULNERABLE TRADITIONAL NUT AND POTENTIAL HIGH-YIELD OIL SEED FROM TRIPURA, NORTHEAST INDIA

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Abstract:

*Hodgsonia macrocarpa (*Blume) Cogn., a climbing liana of the Cucurbitaceae family, embraced significant ecological, cultural, and economic value in the tropical evergreen forests of Tripura, Northeastern India. Well-known for its large, oil-rich seeds, the plant is deeply embedded in the traditional practices of the Reang and Chakma tribes, where its kernels are roasted as a nutritious snack, and its leaf ashes are used in wound treatment. Field surveys conducted in South Tripura, revealed extensive ethnobotanical knowledge that has been passed down through generations. *H. macrocarpa* demonstrates remarkable horticultural adaptability, with propagation studies reporting 50% survival rate from cuttings and 90% success rate via air layering. This makes it suitable for cultivation in home gardens and agroforestry systems. Furthermore, the seeds exhibit impressive oil content, positioning the species as a promising biodiesel source with high yield potential. Despite its utility, the species faces threats to survival and has been classified as vulnerable by the FRLHT's ENVIS Centre on Medicinal Plants (2015). This research highlights the need for targeted conservation initiatives to protect *H. macrocarpa* while exploring its broader applications as a sustainable food resource, biodiesel alternative, and ornamental plant. Its dual potential in traditional medicine and modern industries highlights the importance of integrating indigenous knowledge with contemporary conservation strategies to ensure the sustainable utilization of this valuable species.

Keyword: *Hodgsonia macrocarpa*, Ethnomedicine, Traditional Knowledge, Biodiesel, Sustainable agriculture, Conservation.

Introduction:

Hodgsonia macrocarpa (Blume) Cogn. is a climbing plant belonging to the Cucurbitaceae family, well–known for its diverse uses and ecological importance Wang *et al.* (2015). *H. macrocarpa* is native to South Indochina and West Malesia. The genus *Hodgsonia* Hook. f. and Thomson was first describe in 1854 (pp.257); further studies by deWilde and Duyfjes (2001) and later by C. Jeffrey (2001). This Asian genus now comprises three species: *H. heteroclita* (Roxb.) Hook. f. and Thomson – Found in India, China, Myanmar, Indochina, and northern Thailand; and *H. macrocarpa* (Blume) Cogn. is distributed in Peninsular Thailand and West Malesia. And recently, a new species, *H. tsaii* has been found in Xizang, China and also in Arunachal Pradesh, India Shen *et al.* (2022; Chowlu *et al.* (2024). Both the species, *H. heteroclita* and *H. macrocarpa* are notable for their large seeds, which are rich in oil. In regions such as northern Thailand and China, *H. heteroclita* is cultivated specifically for its oily seeds De Wilde and Duyfjes (2008). The nuts and oil of *H. heteroclita* are noted for their unique flavor, resembling pork fat, which has led to the plant being locally referred to as the "pork fat nut" Chien (1963). In India, particularly in the Northeastern regions, *H. macrocarpa* flourish in tropical evergreen forests, which are characterized by their humid climate and dense vegetation. These forests offer the perfect conditions for the growth of this species, contributing significantly to the region's rich and diverse flora. *H. macrocarpa* have been studied and reported from various regions such as Tripura, Arunachal Pradesh, Assam, Meghalaya, Sikkim, and West Bengal Chowlu *et al.* (2024); Deb (1981); Semwal *et al.* (2014); Sinha and Dash (2020); Pandi and Babu (2022). Accordingly, it is an essential species for its ethnobotanical and ecological contributions and its role in traditional medicine in many Southeast Asian countries. Its therapeutic applications and ecological adaptability highlight its potential for further research and conservation efforts.

Traditional knowledge highlights the medicinal value of *H. macrocarpa*, with various parts of the plant being employed to treat a range of ailments. The leaves are traditionally used to alleviate nasal issues and reduce fevers Sharma *et al.* (1991). The ash derived from burned leaves is applied to wounds, aiding in their healing Changkija (1999). And also the fleshy bulb of the fruit is utilized to combat bacterial infections, particularly those affecting the feet, showcasing the plant's diverse therapeutic applications Panda *et al.* (2018). While its medicinal value is well–documented in other regions, *H. macrocarpa* serves a more modest yet delightful purpose in their culinary practices besides having Aesthetic and Cultural significance. The seeds of the plant are highly special such as Seasonal Treat during the fruiting season; the seeds are harvested, roasted, and relished as snacks Changkija (1999).

One of the significant challenges with *H. macrocarpa* is its low fruiting frequency. The plant fruits only once *i.e.,* annually making its seeds a rare seasonal treat. *Hodgsonia* has become increasingly rare in Asia's tropical forests due to extensive harvesting for medicinal purposes Semwal *et al.* (2015). Despite its underutilization in medicinal or large–scale economic contexts, the plant holds potential for broader applications, including exploring its seeds as a sustainable food resource or its ornamental values. *H. macrocarpa* is more than just a decorative plant in Tripura's home gardens, it is a testament to the cultural and culinary ingenuity of the Reang and Chakma tribes, who have found ways to cherish and sustain its use despite its limited yield. Further research and awareness about its potential could pave the way for its greater integration of its role in both traditional and modern contexts.

Materials and Methods:

Study area

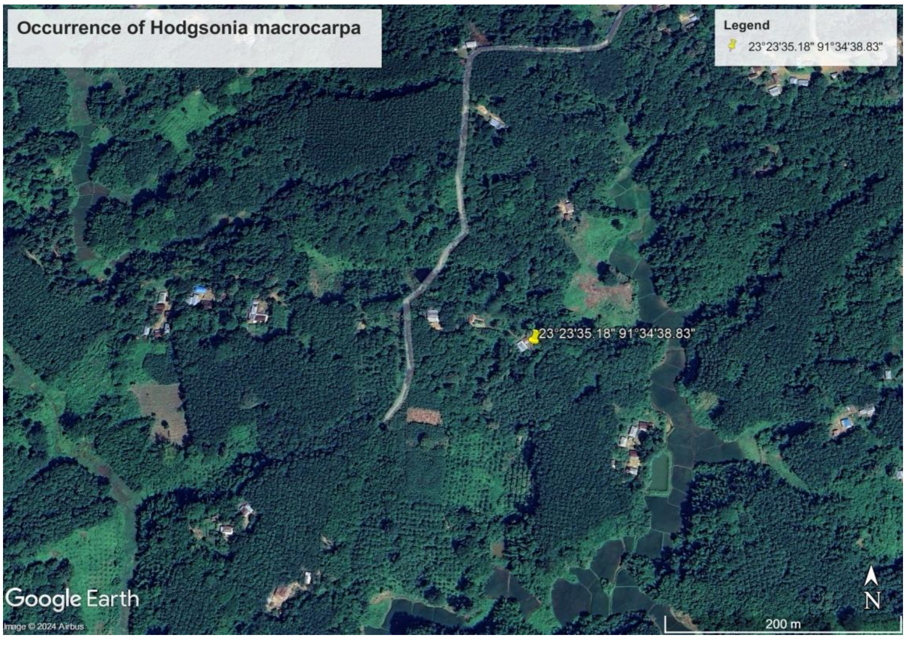

Figure 1: Map showing occurrence of *H. macrocarpa* in a village of South Tripura

Data were collected within the village of Debipur, South Tripura (23°23'35.18"N, 91°34'38.83"E), at elevation 350 m (approx.). The area features a mosaic landscape dominated by extensive rubber plantations, interspersed with small–scale agricultural fields, settlements, and patches of secondary forest. This land–use pattern reflects the significant anthropogenic modification of the region's natural forest cover. Trails connecting the plantations and agricultural fields are visible, highlighting the accessibility within this semi–rural area. The region experiences a tropical humid climate, with a major rainy season between late June and late September and a major dry season from November to February. The annual precipitation is approximately 2000 mm, and the average temperature is 26°C.

Collection of information on *Hodgsonia macrocarpa*

Information related to this wild edible plant was primarily obtained through household surveys, using semi–structured interviews and informal discussions with elderly people from the local community. Basic information such as vernacular names, parts used, areas of extraction, and traditional uses was collected.

Indigenous knowledge and ethnobotany

A rapid rural appraisal survey was conducted to gather baseline information about the species, including their uses, ethnobotany, phenology of fruits and flowers, and distribution. Data were collected through formal and informal discussions with knowledgeable individuals in the community and ethnic members to obtain authentic information about phenological events, appropriate fruiting times, and traditional medicinal uses of the fruits and other edible parts. Published literature was consulted to validate and refine the information collected.

Results and Discussion:

Occurrence

Hodgsonia macrocarpa is a perennial climber capable of reaching lengths of up to 30 meters and a lifespan exceeding 70 years Cao and Zhang (2015). In the wild, it often climbs the trunks of trees, forming a symbiotic relationship with its host. In Tripura, studies by Darlong and Bhattacharyya (2014) reported its presence in Kanchancherra and Moracherra (Dhalai District) and Hmunpuii and Jolai (North Tripura District). Biswas *et al.* (2018) also documented its occurrence in the Manu region of Dhalai District. Recent findings from our research have identified its presence in Debipur, South Tripura.

Taxonomic treatment

The leaves of *H. macrocarpa* are typically three–lobed with smooth margins. The underneath may be slightly hairy, with small glands near the base. The petiole measures 3–7 cm in length. Male flowers are borne on clusters with stalks 12–30 cm long, white petals (2–3 cm) with rusty hairs at the base. Female flowers have a stalk length of 3–4 cm, a throat 7–10 mm wide, and an ovary 10–12 mm in diameter, containing 6 ovules (De Wilde and Duyfjes, 2008). The fruits are round, 10–18 cm in diameter, and yellowish orange with a rough or hairy surface, occasionally marked with dark spots and exudates sticky thick sap. Each fruit contains 6 hard seeds (pyrenes) 6–9 cm, each having a single seed. The fruit stalk is 4–8 cm long and 1–1.5 cm thick.

Ethnobotanical uses

The seeds kernels of *H. macrocarpa* are rich in fat and are traditionally roasted for consumption. Additionally, the ashes of burnt leaves are used to treat wounds Sharma *et al.* (1991).

Phenology

Flowering occurs between February–March, continuing throughout the summer. Fruits ripen in the autumn and winter months, typically from November–December Sharma *et al.* (1991); Darlong and Bhattacharyya (2014).

Germination

The seeds germinate with the root, stem, and leaves remaining enclosed within the seed covering, while a shoot emerges from the base. Studies have reported a 50% survival rate from cuttings and a 90% success rate through air layering methods demonstrating a remarkable horticultural compliance Hu (1964); Lalmuanpuii *et al.* (2024).

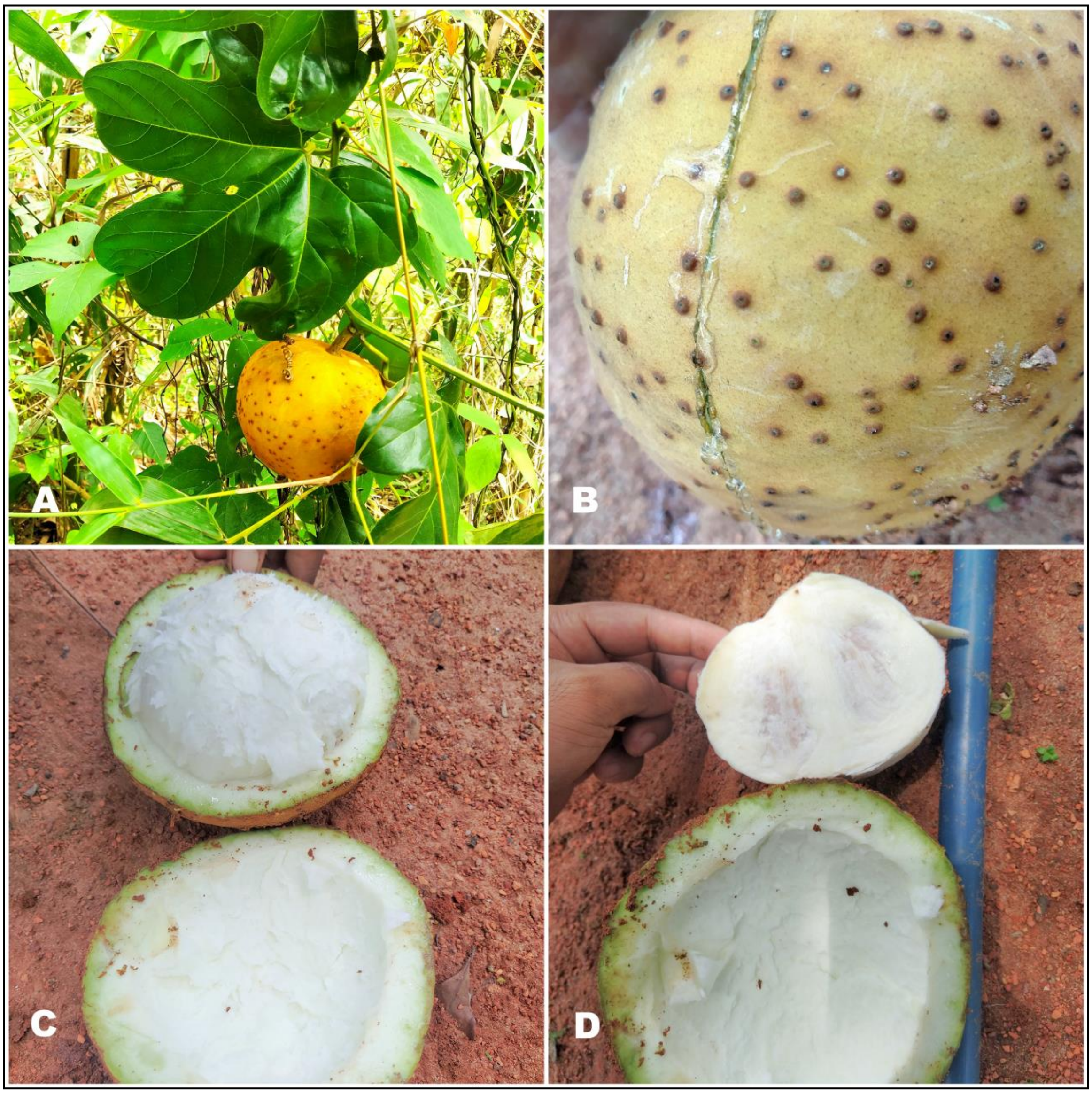

Figure 2: (A) Fruit of *Hodgsonia* sp (B) Fruit exudates sap
(C) Inside of the pulp showing six seeds (D) Half cut seeded pulp

Ethnobotanical significance in Tripura

H. macrocarpa, known locally as "**Thaibai**" among the *Reang community* and **"Pela Gula"** among the Chakmas, is a climber of quiet prominence in the home gardens of Tripura. With a nutty flavor, the roasted seeds are a favorite among children, often gifted by older members of the community.

For preservation, the fruit after peeling and cleaning, the seeds are dried and stored in kitchens, ensuring a supply of this nutritious snack throughout the year. A study by Sharma *et al.* (1991) revealed through chemical analysis that the seeds consist of 49.27% kernel, which contains the following nutrient composition: fat (62.71%), protein (31.25%), and fiber (2.41%). Further examination of the oil's fatty acid profile identified the presence of palmitic acid (17.28%), stearic acid (9.36%), oleic acid (21.76%), linoleic acid (33.90%), hexadecenoic acid (7.25%), arachidic acid (6.86%), and myristic acid (3.56%).

Although widely appreciated for its aesthetic value by the region's ethnic tribes, *Hodgsonia macrocarpa* remains underutilized to its broader potential. Its vibrant flowers and unique fruits, which appear only once a year, create a rare and captivating spectacle. The plant holds significant promise as an ornamental species. Its lush foliage and striking flowers make it a cherished addition to the home gardens of Reang and Chakma households. The fruit, with its distinctive grooves and red–orange color, is an equally eye–catching feature that complements the plant's decorative use. This plant can be identified by its large, lobed leaves that create a dense canopy. The flowers are unisexual with separate but equally striking male and female flowers. They exhibit a unique color combination, with brown petals on the exterior and a bright yellow hue on the interior.

Mode of preparation

Figure 3: Steps for Roasting of *Hodgsonia* seed– (A) Pealing of skin (B) Roasting of Seed (C and D) Cooked seed and its endosperm

Preparation of the fruit

Begin by thoroughly cleaning the mature fruit to remove any dirt or debris. Once cleaned, carefully peel away the outer layers to reveal the inner pulp.

Reaching the seed

After accessing the pulp, peel it further to uncover the hard seed coat. This step requires precision to separate the pulp from the seed without damaging the latter.

Roasting the seeds

The cleaned seeds are then placed in a bed of hot charcoal or exposed to an open flame. Roast the seeds evenly, turning them occasionally to ensure they are properly cooked. The roasting process enhances the nutty flavor and makes the outer coat easier to remove.

Extracting the edible kernel

Once roasted, allow the seeds to cool slightly. Carefully crack open the hard outer coat to extract the edible kernel inside. The kernels are now ready to be consumed and can be enjoyed as a nutritious snack with a rich, nutty flavor.

From forest to future: Evolving local utilization with modern innovation

In China, research conducted by Cao and Zhang (2015) highlighted the potential of *Hodgsonia macrocarpa* as a biodiesel source. The seeds, with an impressive oil content of 71.65%, were processed into biodiesel using simple methods, achieving a high yield. The fuel demonstrated excellent safety and performance in cold conditions. With minor enhancements, it met quality standards, positioning *H. macrocarpa* as a cost–effective and efficient option for biodiesel production in China and its subtropical regions.

The threat assessment conducted by FRLHT's ENVIS Centre on Medicinal Plants has identified *H. macrocarpa* as a rare medicinal plant, categorizing it as vulnerable (2015). This highlights its ecological importance and potential value in traditional medicine; thereby encouraging the necessity for targeted conservation efforts and sustainable utilization of this unique species. In prospective of biodiversity conservation, domestication of such wild edible resources is viable option for resource management Catarino *et al.* (2024); Lalmuanpuii *et al.* (2024). This aspect needs to be studied thoroughly, so that economically important species are promoted for domestication. Domestication of these species will not only improve the economic condition of the local people but will also help in the conservation of biodiversity.

Conclusion:

Hodgsonia macrocarpa represents a unique convergence of traditional knowledge and modern potential, embedded with cultural significance, ecological importance, and industrial viability. Its rich oil content, biodiesel production adaptability, and traditional food and medicine use highlight its multifaceted value. Studies in China have demonstrated the plant's high oil yield and cost-effectiveness for biodiesel production, presenting a compelling opportunity to explore similar applications in Tripura, Northeast India. However, its vulnerable status necessitates immediate conservation actions to preserve this species for future generations. Integrating indigenous practices with scientific innovation offers a sustainable pathway for its utilization, ensuring ecological balance while unlocking its potential as a biodiesel source and a valuable resource in agroforestry and home gardens. By encouraging awareness and promoting targeted conservation efforts, *H. macrocarpa* can serve as a model for sustainable biodiversity management and economic development in tropical ecosystems.

Acknowledgements

The authors are thankful to Head, Department of Botany, Tripura University for assisting the laboratory facilities.

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FLORAL COMPOSITIONS AND HONEY BEES INTERACTION IN HOME GARDENS WITH SPECIAL REFERENCE TO APICULTURE

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Abstract:

Apiculture is one of the most underutilized resources in India. The scope of apiculture or beekeeping is enormous for sustainable living. Home gardens are very important resources in rural or peri-urban areas as these gardens contain many plants that attract honeybees and many other pollinators. This study surveys different home gardens that practice beekeeping activities or apiculture. The floral structure of home gardens and the interaction of honeybees with plants were noted. Further net income from apiculture (annually) was also discussed.

Keywords: Beekeeping, Honey, Homegardens, Plants, Income

Introduction:

Apiculture is an important opportunity and source of sustainable income for many people worldwide FAO (2018). The products derived from honeybees of the *Apis* genus and native stingless bees have been part of the cultural heritage of many indigenous people Ayala *et al.* (2013); Quezada-Euán*et al.* (2018). Apiculture is a crucial allied agriculture activity in rural, urban, and peri-urban areas. It has now emerged as an extra profit opportunity for the people Raja *et al.* (2022). Honeybees are essential not only for apiculture but also for the ecosystem. Bees are mainly reared for their honey. Beekeeping practices are identical in the urban environment to those in the rural one, but the emphasis on certain aspects is critically essential Prodanović *et al.* (2024). The diversity of different plants often brought into urban areas artificially seems to affect honeybee populations more than anything else. Plant diversity lets honeybees feed on many other plants and develop a more robust immune system than bees with limited diets Di Pasquale *et al.* (2016). The goal of offering more floral resources for bees in urban areas can be achieved by encouraging the growing of ornamental bee plants alongside native plants from a gardening, landscaping, and sustainability perspective Matteson *et al.* (2008). Plants known as ornamental are distinguished by their leaves and flowers' attractive shapes and colors. They are part of numerous groups of cultivated and wild species, including representatives of various botanic families Bown (1995). In urban areas, bee plants maintain the diversity of bees. The goal of offering more floral resources for bees in urban areas can be achieved by encouraging the growing of ornamental bee plants from a gardening, landscaping, and sustainability perspective Matteson *et al.* (2008). Botanical families such as Fabaceae, Asteraceae, Solanaceae, Rosaceae, Lamiaceae, Cactaceae, Malvaceae, Verbenaceae, and Bignoniaceae are majorly represented by Frankie *et al.* (2008). *Ipomoea*, *Calliandra*, *Passiflora*, *Prunus*, *Senecio*, *Tibouchina*, *Begonia*, and *Rosa* are potential major genera in ornamental plant presence da Silva Mouga *et al.* (2015). Floral resources can significantly influence the presence of bee diversity in certain areas.

For this purpose, this study was conducted to analyse floral resource diversity within bee-keeping areas and their interaction with the surrounding plants.

Materials and Methodology

Study site: For this study, we screened out some places and selected one study site (Anandanagar, West Tripura) where people often practice apiculture for their livelihood. Further, we visited ten home gardens occasionally during the study period 2022-2023.

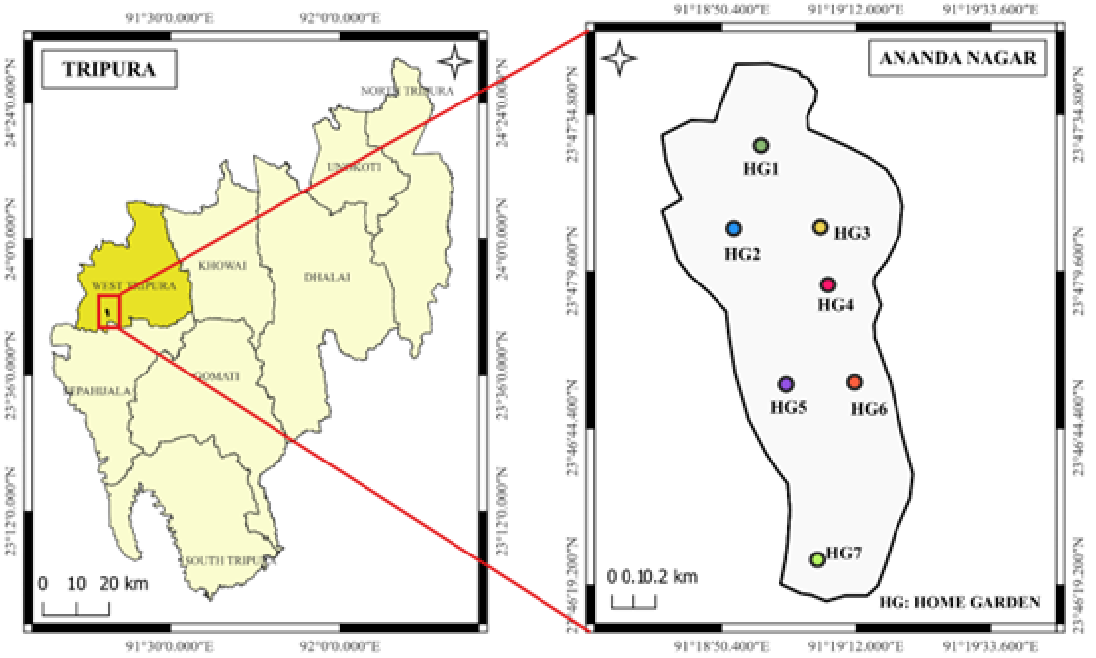

Figure 1: Study map

Plant sample collection and identification

During this study, the composition of plants in the home garden apiculture area was noted carefully and collected for further work. Later, plants were identified with the flora of Tripura and POWO.

Plant species compositions

During the survey, all the plant species were noted down, and further, the composition of the floral structure of each home garden was analysed.

Bees and Plant interaction

Close observation was conducted on bees and their interaction with the plants. Throughout the day, the foraging behaviours of bees were monitored during the study time. During each visit to different plants, all the plants were noted down.

Results:

A total of fifty-two species from forty-five genera belonging to thirty families among seven home gardens were found (Table 1). Further, these plants were categorized based on their features. Twenty-two species were used as flowering plants, followed by Seventeen species used as crops, nine as fruiting plants, and four used for medicinal functions (Table 1).

Table 1: List of Plants species found in different Home Gardens (Plants were categorized as their uses, HG- Homegardens)

Plants Name	Family	HG	Type
Hygrophila auriculata (Schumach.) Heine	Acanthaceae	5	Medicinal
Thunbergia coccinea Wall. ex D.Don	Acanthaceae	3	Flowering plant
Hymenocallis littoralis (Jacq.) Salisb.	Amaryllidaceae	5	Flowering plant
Mangifera indica L.	Anacardiaceae	1,4,5,7	Fruit
Allamanda cathartica L.	Apocynaceae	5	Flowering plant
Calotropis gigantea (L.) W.T.Aiton	Apocynaceae	3,7	Flowering plant
Catharanthus roseus (L.) G.Don	Apocynaceae	2,3,7	Flowering plant
Tabernaemontanadivaricata (L.) R.Br. ex Roem. & Schult.	Apocynaceae	7	Flowering plant
Agave amica (Medik.) Thiede &Govaerts	Asparagaceae	6	Flowering plant
Tagetes erecta L.	Asteraceae	6	Flowering plant
Brassica campestris L.	Brassicaceae	2,3,5,6	Crop
Carica papaya L.	Caricaceae	2,3,4	Crop
Combretum indicum (L.) DeFilipps	Combretaceae	3	Flowering plant
Ipomoea nil (L.) Roth	Convolvulaceae	7	Flowering plant
Ipomoea quamoclit L.	Convolvulaceae	3,5	Flowering plant
Hellenia speciosa (J.Koenig) S.R.Dutta	Costaceae	7	Medicinal
Benincasa hispida (Thunb.) Cogn.	Cucurbitaceae	4,5,7	Crop
Cucurbita pepo L.	Cucurbitaceae	4,7	Crop
Elaeocarpus serratus L.	Elaeocarpaceae	6	Fruit
Cajanus cajan (L.) Huth	Fabaceae	1,4,6,7	Crop
Clitoriaternatea L.	Fabaceae	2,3,4,5,7	Flowering plant
Crotalaria spectabilis Roth	Fabaceae	4	Flowering plant
Lablab purpureus (L.) Sweet	Fabaceae	4,7	Crop
Sesbania grandiflora (L.) Poir.	Fabaceae	1,3,7	Crop
Corchorus olitorius L.	Malvaceae	4	Crop
Hibiscus mutabilis L.	Malvaceae	1,6	Flowering plant
Hibiscus sabdariffa L.	Malvaceae	3	Flowering plant
Hibiscus × rosa-sinensis L.	Malvaceae	2,6,7	Flowering plant
Azadirachta indica A.Juss.	Meliaceae	6	Medicinal
Tinospora cordifolia (Willd.) Hook.f. & Thomson	Menispermaceae	5	Medicinal
Artocarpus heterophyllus Lam.	Moraceae	2,6	Fruit
Morus rubra L.	Moraceae	2	Fruit
Moringa oleifera Lam.	Moringaceae	4	Crop
Psidium guajava L.	Myrtaceae	2,6	Fruit
Syzygium cumini (L.) Skeels	Myrtaceae	5	Fruit
Mirabilis jalapa L.	Nyctaginaceae	4	Flowering plant
Nyctanthesarbor-tristis L.	Oleaceae	2	Flowering plant
Sesamum indicum L.	Pedaliaceae	2,5,7	Crop

Ziziphus jujuba Mill.	Rhamnaceae	2	Fruit
Ziziphus mauritiana Lam.	Rhamnaceae	2	Fruit
Rosa rubiginosa L.	Rosaceae	2,6	Flowering plant
Ixora chinensis Lam.	Rubiaceae	6	Flowering plant
Bergerakoenigii L.	Rutaceae	1,5,6	Crop
Citrus maxima (Burm.) Merr.	Rutaceae	2,3	Crop
Citrus × limon (L.) Osbeck	Rutaceae	1,6	Crop
Litchi chinensis Sonn.	Sapindaceae	1,6	Fruit
Brugmansia suaveolens (Humb. &Bonpl. ex Willd.) Sweet	Solanaceae	1,3	Flowering plant
Capsicum annuum L.	Solanaceae	1,4,5,7	Crop
Datura innoxia Mill.	Solanaceae	2,6	Flowering plant
Solanum lycopersicum L.	Solanaceae	1,3,7	Crop
Solanum melongena L	Solanaceae	1	Crop
Talinum fruticosum (L.) Juss.	Talinaceae	5	Crop

During the observation, it was noted that Honey bees only interacted with a few plants. A total of twenty plant species from different home gardens were noted down where honeybees interacted (Table 2).

Table 2: Number of plants that are visited by Honey bees

Plants Name	**Family**	**Frequency of Interaction**
Mangifera indica	Anacardiaceae	Less frequent
Calotropis gigantea	Apocynaceae	Less frequent
Tagetes erecta	Asteraceae	Less frequent
Brassica campestris	Brassicaceae	Very frequent
Carica papaya	Caricaceae	Less frequent
Elaeocarpus serratus	Elaeocarpaceae	Very frequent
Cajanus cajan	Fabaceae	Very frequent
Lablab purpureus	Fabaceae	Very frequent
Crotalaria spectabilis	Fabaceae	Less frequent
Azadirachta indica	Meliaceae	Less frequent
Tinospora cordifolia	Menispermaceae	Very frequent
Psidium guajava	Myrtaceae	Less frequent
Syzygium cumini	Myrtaceae	Very frequent
Sesamum indicum	Pedaliaceae	Less frequent
Ziziphus jujuba	Rhamnaceae	Very frequent
Ziziphus mauritiana	Rhamnaceae	Very frequent
Citrus maxima	Rutaceae	Very frequent
Citrus × limon	Rutaceae	Less frequent
Litchi chinensis	Sapindaceae	Very frequent
Solanum melongena	Solanaceae	Less frequent

During the survey, the Beekeeper mentioned that an average of 12kg of honey per box is generated annually, and the average profit income generated from apiculture is around 28000₹

Table 3: Total income generated through beekeeping (Annually)

Non-recurring cost (₹)	
Five beehive boxes	4500
Honey extractor	1800
Smoker	200
Face veil	150
Knife	100
Queen excluder	200
Bee brush	50
Total	**7000**
Recurring Cost	
Cost of sugar @5 kg/unit during lean period @60/kg	300
Miscellaneous expenses/Unit	200
Total	500
Income (₹)	
Realization through honey yield @60kg/unit/year and 600/kg	36000
Realization through bee'swax @3 kg/unit/year and 100/kg	300
Total	36,300
Net income (₹) C (Income)-B (Recurring cost)	28,800

Discussion:

Floral compositions are essential to indicate the area's capabilities for beekeeping Singh *et al.* (2023). Home gardens in urban areas hold significant value as they are rich in floral structure. In the current study, we find a total of 52 plant species in seven different home gardens where apiculture is practiced. The most plant species were found in Fabaceae and Solanaceae, followed by Apocynaceae and Malvaceae. Further, it was noted that among 52 plant species, only 20 species were visited by honey bees (Table 2).

Figure 1 A. Beekeeping box, B. Bees inside the box, C. Workers with Queen honey bees., D. Immerging of Queen. E. Bees visiting the flowers of *Litchi chinensis*.

Honey Bees start their foraging in the early morning, and the peak foraging is observed at noon. It was also observed that, in some plants, honey bees are less frequently visited and, in some plants, they see very often. The highest visitation was observed in *Brassica campestris*, *Elaeocarpus serratus*, *Cajanus cajan*, *Lablab purpureus*, *Tinospora cordifolia*, *Syzygium cumini*, *Ziziphus jujuba*, *Ziziphus mauritiana*, *Citrus maxima*, *Litchi chinensis*. The study of Bees' flora is critical for Apiculture, as it will provide an idea about the interaction of honeybees with plant species Adal *et al.* (2015).

Apiculture is one of the essential and critical sources of income for sustainable living in rural or peri-urban areas. The scope of apiculture is vast in India as well as in Northeast India; however, the process or techniques of apiculture are still lacking in this region. Further study and government projects can build this underutilized resource.

Acknowledgments

We are thankful to Mr. Dipak Das, Beekeeper and resident of Anandanagar, West Tripura, for his guidance and the valuable information he provides for this study. We are also thankful to Antara Bose, research scholar, Department of Botany, Tripura University, for building the study area map.

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PLANT DIVERSITY AND ETHNOMEDICINAL WONDERS OF UNAKOTI HILLS, TRIPURA, NORTH-EAST INDIA

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Introduction:

Northeast India, which includes the Eastern Himalayas and portions of the Indo-Burma biodiversity hotspot, is one of the world's most ecologically varied regions. This area is distinguished by its abundant flora and wildlife, diverse topography, and temperate temperature. Because of its distinct geographic and climatic circumstances, Northeast India has an extraordinary biodiversity, including many indigenous plant and animal species. It encompasses eight states, each adding to the region's natural diversity: Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, and Sikkim. Northeast India's natural environment includes tropical rainforests, subtropical forests, and alpine habitats at higher elevations. This gradient supports various habitats, including thick evergreen forests in Arunachal Pradesh and the grasslands and marshes of Assam's Brahmaputra Valley. The region's natural complexity leads to its high species richness, which includes rare and endangered animals like the red panda (*Ailurus fulgens*), phayre's langur (*Trachypithecus phayrei*), hoolock gibbon (*Hoolock hoolock*), and one-horned rhinoceros (*Rhinoceros unicornis*) etc.

The nation's economy and living things greatly depend on trees, the most precious natural resources. Tropical and sub-tropical forests support the planet's greatest plant species diversity (WCMC 1992). Tropical forest ecosystems rely heavily on trees for structural and functional support (Sandhyarani *et al.* 2007). There are many commercially significant and therapeutic plants available in these forests. Forests play a key role in biodiversity conservation and provide many ecosystem services. They prevent soil erosion, provide water for irrigation and drinking, provide food, and maintain the wood supply (Boyd & Banzhaf 2007). However, worldwide, most tropical forests are extremely threatened by human activity. (Curranet *et al.* 2004; Sahu *et al.* 2010). However,jhum cultivation (slash-and-burn agriculture), rapid urbanization, and habitat damage from deforestation are major ecological issues facing the region. The delicate balance of these ecosystems is also threatened by climate change and over-exploitation of natural resources. To make room for farming or to harvest trees for fuel and wood products, an estimated 177,000 km2 of forests and woodlands are cleared each year. More than 3% of forests have been clear-cut during the 1990s alone, with the globe losing roughly half of its forests over the preceding 8,000 years. (WWF 2017). Determining the condition of tree populations, regeneration, and diversity is made much easier for conservation purposes by evaluating the structure and composition of forest ecosystems. Many people in developing nations gather wild plants from nearby forests for food, vegetables, fruits, medicine, fodder, fuelwood, building materials, and other necessities. The indigenous populations of India are varied and possess a wealth of knowledge on medicinal plants. Traditional medical systems like Ayurveda rely heavily on these herbs to cure various illnesses. Native communities worldwide have always been exceedinglyeducated about their native flora and other natural resources they rely on so heavily (Hamilton, 1995). Various initiatives, such as the Tribal Rights Act (2006), acknowledge tribal and forest-dwelling people's role in forest management. This law provides communities the legal rights to utilize and maintain forests, perethnoforestry concepts. Traditional ecological knowledge is a body of information about how living things, including humans, relate to their environment and to one another that has been passed down through the generations via cultural transmission and evolved through adaptive processes (Berkes *et al.* 2000). Plants also hold spiritual and ceremonial significance, important in maintaining cultural well-being and identity (Karst *et al.* 2010). Located in Northeast India, Tripura is a small, landlocked state with a total population of 36, 71,032 and a land area of 10492 square kilometres (as per census 2011). There are a total of eight districts in Tripura.These are Dhalai, Gomati, Khowai, North Tripura, Sepahijala, South Tripura, Unakoti, and WestTripura. The subjected Unakoti hills fall under the Unakoti District.

Geographical location:

The third-smallest state in India, Tripura shares borders with Bangladesh to the north, west, and south. It is located between 22° 56' N and 24° 32' N and 91° 09' E and 92° 20' E. With alternating synclines, the state's five anticline hill ranges stretch primarily from north to south. The state's elevation ranges from 15 meters above sea level in the western regions to 780 meters in the northeast (Hussain *et al.* 2024). In the Northeastern region of India, the small hilly state of Tripura is located in the 9B-North-East Hills biogeographic zone (Champion & Seth, 1968). The diverse forest of Unakoti hills lies between 24°19′18.33"N 92°05′04.65"E.

Climatic condition:

In northeastern India, the Unakoti hill range of Tripura has a tropical monsoon climate with three distinct seasons. Summers (March to May) are often hot and humid, with temperatures ranging from 24°C to 36°C. Pre-monsoon showers, known as "Kal Baishakhi," frequently provide a temporary reprieve from the heat. Because of the southwest monsoon winds, the monsoon season (June to September) brings a lot of precipitation, with an average of 2,100 to 2,500 mm yearly. The temperature remains moderate, ranging from 20°C to 30°C, while the humidity remains high. Winter (October to February) is mild and pleasant, with temperatures ranging from 10 to 25 degrees Celsius and clear skies. This is the best season, despite the occasional cold waves that drop the temperature, especially in the hilly areas. Tripura's climate, influenced by its rivers, forests, and hilly terrain, is ideal for forestry and agriculture and sustains a rich biodiversity. However, during the monsoon season, the state experiences problems like landslides and floods, especially in low-lying areas.

Topographic features:

Surrounded by the rugged terrain of Northeast India, Tripura's topography is characterized by a mix of plains, valleys, and hills. Fertile valleys are dotted by a sequence of hills and ridges that run north-south, giving the state its distinctive topography. The main mountain ranges are Jampoi, Atharamura, Sakhan tang, and Long Tarai, reaching 939 meters at Betlingchhip, the highest point in the state. However, the western part of Tripura is dominated by low plains, where most of the population lives and engages in agriculture. Several rivers, such as Gomati and Manu, flow through the valleys, supporting irrigation and contributing to the state's natural drainage system. The topography ofTripura, a combination of rugged hills and agricultural plains, creates climate, agriculture, and biodiversity while posing a challenge for infrastructure development and vulnerability to landslides during the wind. The geographic location of Unakoti has a diversified topography with undulating, sloppy tiles that are hilly in the center.High-relief structural hills and ridges with steep slopes and mild dissections represent these hilly regions.

Edaphic characteristics:

Tripura state's soils were mapped and categorized into 43 soil family association units. (Bhattacharyya *et al.*1996). The soil type of the hilly terrain of Unakoti is mostly laterite type. This kind of soil, widely distributed in India's tropical forests, falls under the oxisols category of soil classification. Tripura's soils are often acidic in composition. The state receives too much rainfall, which results in a significant leaching of exchangeable base material from surface soils, which causes the pH of the soils to decrease (Saha *et al.* 2017).

Floristic diversity:

Tripura's tropical forests are vital to the region's ecological balance because they sustain watersheds, stop soil erosion, and provide a home for various plant and animal species. Numerous floras in these forests are employed by indigenous tribes for ritualistic, culinary, and medicinal purposes, giving them cultural significance. *Debnath et al.* (2024) explore the Tree species diversity, population dynamics, and regeneration status of tropical forests of Unakoti District, Tripura,North-eastern India. They followed the quadrate sampling method to identify the forest's diversity indices. Theystudied 1696 trees belonging to 42 species from 35 genera and 20 families. The Shannon-Weiner, Simpson, and Margalef indices for species richness were used to calculate the species diversity. The dominant tree species in Unakoti Hills was *the Tectona grandis, with an* Importance Value Index (IVI) of 50.34

Their research also showed that the hill is abundant in a variety of tree species, including fruit, fodder, timber yielding, and medicinal. It is clear from their studies that Unakoti Hills has a high biodiversity.

Exploration of ethnomedicinal plants and traditional knowledge with their importance:

The floristic richness of Tripura is noteworthy, particularly when considering ethnobotany, since the state's Indigenous communities mostly depend on local plants for everyday necessities, medicinal care, and cultural practices. According to research, 80% of people worldwide rely on traditional medicines, especially plant-based ones, for primary medical care (Kala *et al.,* 2006). In the forests of the State, there are 266 species of medicinal plants, 379 tree species, 320 shrubs, 581 herbs, 165 climbers, 16 climbing shrubs, 35 ferns, 45 epiphytes and 4 parasitic (ERT. 2011). Indigenous people have the ability to utilize a range of plant foods, which are typically separated into categories such as green vegetables, "root" fruits, vegetables, and more plant-based meals, such as the inner bark of trees and plants that are used to flavour and make beverages (Andre *et al.* 2006). The commonly used important medicinal plants in Unakoti Hills are described below with their uses:

1. Botanical name: *Abrus precatorius* L.
   Localname: Gunch
   Family: Fabaceae; Growth form: Shrub
   Parts used: Roots, Seeds, and Leaves
   Uses: Leaves are used against leucoderma and skin disease. Roots are used to treat urinary troubles. Seeds are used to makejewellery.
   Conservation status: N/A
2. Botanical name: *Achyranthus aspera* L.
   Local name: Apang or Apamarg
   Family: Amaranthaceae; Growth form: Shrub
   Parts used: Whole plant and root

Uses: It is anti-inflammatory, used against cough, skin eruptions, piles, and externally used in dog bites.

Conservation status: N/A

3. Botanical name: *Justicia adhatoda* L.

   Local name: Basak

   Family: Acanthaceae; Growth form: Shrub

   Parts used: Leaves are rich sources of Vitamin C. Leaves are antiseptic and have alkaloids used to control cough, cold, and asthma.

   Conservation status: Least Concern

4. Botanical name: *Aegle marmelos* L.

   Local name: Bael

   Family: Rutaceae; Growth form: Tree

   Parts used: Root, leaf and fruit

   Uses: Fruit is an astringent, digestive, laxative, anti-diabetic, and stomachic. Fruit tonic is good for the heart and brain.

   Conservation status: Least Concern (LC)

5. Botanical name: *Amorphophallus companulatus* (Roxb.)

   Local name: Oal

   Family: Araceae; Growth form: Tuberous herbaceous plant

   Parts used: Tuber

   Uses: Culm is used to control dysentery and piles. It is stomachic and laxative and is used in elephantiasis and rheumatism.

   Conservation status: N/A

6. Botanical name: *Annona sqamosa*L.

   Local name: Aata phal

   Family: Annonaceae; Growth form: Small tree

   Parts used: Stem, fruit and root

   Uses: Ripe fruits are antidiarrheal, insecticidal and antihelminthic. Leaves are used against ulcers.

   Consrvationstatus: N/A

7. Botanical name*:* *Andrographis paniculata* (Burm.f.)

   Local name: Chirata

   Family: Acanthaceae; Growth form: Herb

   Parts used: Whole plant

   Uses: Traditionally used against jaundice, skin disease, arthritis, cold etc.It has antipyretic and anti-inflammatory properties.

   Conservation status: N/A

8. Botanical name: *Ailanthus excelsa* Roxb

   Local name: Unknown

   Family: Simaroubaceae; Growth form: Tree

   Parts used: Bark and stem

   Uses: *Ailanthus excelsa* has been used to treat various health problems, including asthma, bronchitis, fevers, and wounds.

Conservation status: N/A

9. Botanical name: *Microcos paniculata* L.
   Local name: Pislii
   Family: Tiliaceae; Growth form: Shrub
   Parts used: Leaves
   Uses: Traditionally used to treat dyspepsia, insect bites, and jaundice.
   Conservation status: Least Concern
10. Botanical name: *Artocarpus lakoocha* Roxb.
    Local name: Dhewa
    Family: Moraceae; Growth form: Tree
    Parts used: Fruits and seed
    Uses: Barks and seeds are used as laxatives, cure boils, skin problems, etc. Fruits are edible to humans.
    Conservation status: N/A
11. Botanical name: *Azadirachta indica* A. Juss
    Local name: Neem
    Family: Meliaceae; Growth form: Tree
    Parts used: Seeds, bark and leaves
    Uses: Because of its strong antibacterial, anti-inflammatory, and antioxidant qualities, Neem is frequently used in traditional medicine. While Neem oil is used to heal wounds, reduce inflammation, and repel insects, its leaves are frequently used to treat infections, eczema, and acne. Due to its antibacterial properties, Neem bark treats fevers, digestive problems, and oral health.
    Conservation status: Least Concern (LC)
12. Botanical name: *Alstonias cholasris* (L.)
    Local name: Chatim
    Family: Apocyanaceae; Growth form: Tree
    Parts used: Bark
    Uses: *Alstonia scholars* hold great value in ethnomedicine due to its many therapeutic uses. Fever, malaria, and respiratory conditions like bronchitis and asthma are all traditionally treated with the bark, which is high in alkaloids, as a bitter tonic. It can also be used to treat wounds and skin infections because of its antibacterial and anti-inflammatory properties. The bark is also utilized in traditional medicine to treat digestive issues like diarrhoea and dysentery.
    Conservation status: Least Concern (LC)
13. Botanical name: *Parkia speciosa* Hassk.
    Local name: Yongchak
    Family: Fabaceae; Growth form: Tree
    Parts used: Pods
    Uses: Commonly used as a nutritious vegetable.
    Conservation status: Least Concern (LC)
14. Botanical name: *Artocapus heterophyllus* Lamk.
    Local name: Kathal
    Family: Moraceae; Growth form: Tree

Parts used: Stem, pulp

Uses: The fruits, leaves, and barks of *Artocapus heterophyllus* have all been extensively utilized in traditional medicine due to their anticarcinogenic, antibacterial, antifungal, anti-inflammatory, wound healing, and hypoglycemic properties.

Conservation status: N/A

15. Botanical name: *Allamanda cathartica* L.

    Local name: Ghantaphool

    Family: Apocyanaceae; Growth form: Woody climber

    Parts used: Leaves

    Uses: Leaves are cathartic. The extract is good for fighting colic and wound healing. Large doses are poisonous to animal including human.

    Conservation status: N/A

16. Botanical name: *Calotropis gigantea* (L.) R.Br.

    Local name: Akanda

    Family: Apocyanaceae; Growth form: Shrub

    Parts used: Root, flower and leaf

    Uses: Decoction of flowers is used to treat cough and asthma. Leaves are commonly known for alleviating pain in joints. The latex is used to treat toothache, stings, and ringworm.

    Conservation status:

17. Botanical name: *Cassia fistula* L .

    Local name: Badarlathi or Amaltas

    Family: Fabaceae; Growth form: Tree

    Parts used: Bark and pod

    Uses: In traditional medicine, this tree is used to cure various diseases such as fever, leprosy, dry cough, skin disease, constipation, diabetes, malaria, stomach disorder, and burning sensation.

    Fruit juice is useful for jaundice.

    Conservation status: N/A

18. Botanical name: *Cinnammomum tamala* (Buch.-Ham.)Th. G. G. Nees

    Local name: Tejpata

    Family: Lauraceae; Growth form: Tree

    Parts used: Leaf

    Uses: Leaves are carminative and colic, diarrhoea and rheumatism. Reduces blood sugar levels and is used as a condiment.

    Conservation status: Least Concern (LC)

19. Botanical name: *Colocasia esculenta* (L)

    Local name: Kochu

    Family: Araceae; Growth form: Underground stem

    Parts used: Rhizome and leafy stem

    Uses: Fresh edible leaves are rich sources of proteins, vitamins, dietary fibre, and minerals. The juice of the plant leaf is useful in internal haemorrhages.

    Conservation status: Least Concern (LC)

20. Botanical name: *Neolamarckia cadamba* (Roxb.)
    Local name: Kadam
    Family: Rubiaceae; Growth form: Tree
    Parts used: Woody parts mainly
    Uses: Commonly used for timber and fuel wood. Bark of *Neolamarckia cadamba* is used in various skin problems, blood diseases, mouth ulcers, and irritable bowel syndrome.
    Conservation status: N/A
21. Botanical name: *Sesbania grandiflora* (L.)
    Local name: Bak Phul
    Family: Fabaceae; Growth form: Tree
    Parts used: Leaves, flowers and wood
    Uses: The leaves and flowers are high sources of vitamins and mineralsthat tribal people consume as vegetables. Woods are very light in weight. Therefore, they are used as fuel for wood purposes.
    Conservation status: Data Deficient (DD)
22. Botanical name: *Centella asiatica* (L.) Urb.
    Local name: Thankuni
    Family: Apiaceae; Growth form: Herb
    Parts used: Whole plant
    Uses: As a brain tonic, stimulant, laxative, hair tonic, and rejuvenator. It has anti-anxiety and anti-stress properties.
    Conservation status: Least Concern (LC)
23. Botanical name: *Cinnamomum zeylanicum* Blume.
    Local name: Dalchini
    Family: Lauraceae; Growth form: Tree
    Parts used: Bark and leaves
    Uses: In both ethnomedicine and food preparation, Cinnamon is highly valued. Cinnamon is used ethnomedicinally to treat respiratory conditions like colds and coughs and help with digestion and inflammation reduction. It helps control diabetes because it is also known to have blood sugar-lowering properties. Cinnamon is highly valued as a spice because it adds warmth, sweetness, and an accent of spice to savory and sweet foods.
    Conservation status: N/A
24. Botanical name: *Dillenia indica* L.
    Local name: Chalta
    Family: Dilleniaceae; Growth form: Tree
    Parts used: Root, bark leaf and fruit
    Uses: The parts of *Dillenia indica* possess some medicinal activity such as anti-microbial, anti-oxidant, anti-inflammatory, and anti-diabetic activity. Fruit juice combined with water and sugar is a cooling drink for fevers. Additionally, ripe fruit is eaten as a potent stimulant to fight weakness.
    Conservation status: Least Concern (LC)
25. Botanical name: *Cynodon dactylon* Pers.
    Local name: Durba
    Family: Poaceae; Growth form: Herb

Parts used: Whole plant
Uses: Reduce bleeding from the nose, toothache, and piles and strengthen nerves.
Conservation status: N/A

26. Botanical name: *Datura metel* L.
Local name: Dhatura
Family: Solanaceae; Growth form: Shrub
Parts used: Leaves and flower
Uses: Despite its strong and harmful qualities, traditional medicine uses *Datura metal* cautiously. Its leaves, seeds, and flowers can be used to treat pain, asthma, and muscular spasms because they have analgesic and antispasmodic properties. Due to its toxicity, *Datura metal* must be administered under expert supervision to avoid poisoning. In controlled dosages, it helps ease respiratory disorders by relaxing bronchial muscles.
Conservation status: N/A

27. Botanical name: *Eclipta prostrata* (L.)L.
Local name: Bhringaraj
Family: Asteraceae; Growth form: Herb
Parts used: Whole plant
Uses: It is popularly used for all kinds of hair-related problems in males and females. Roots of *E. prostrata*mixed with coconut oil are a combination of potent hair rejuvenators.
Conservation status: Least Concern (LC)

28. Botanical name: *Elaeocarpus serratus* L.
Local name: Jalpai
Family: Elaeocarpaceae; Growth form: Tree
Parts used: Bark, leaf and fruit
Uses: Traditional medicine values *Elaeocarpus serratus* as a nutritious fruit. In ethno medicine, its leaves and fruits treat stomach problems and are a mild laxative to manage digestive disorders. The fruit is utilized in certain cultures to promote liver health and treat skindisorders. Regarding nutrition, *Elaeocarpus serratus* is a good source of minerals and vitamins, especially vitamin C, which promotes skin health, immunity, and antioxidant defences.
Conservation status: N/A

29. Botanical name: *Holarrhena antidysenterica* Wall.
Local name: Kurchi
Family: Apocyanaceae; Growthform: Small tree
Parts used: Bark and leaf
Uses: The plant extract is popularly used as an herbal medication for dysentery, amebiasis, colitis, and killing intestinal worms.
Conservation status: Least Concern (LC)

30. Botanical name: *Lawsonia inermis* L.
Local name: Henna
Family: Lythraceae; Growth form: Tree
Parts used: Leaf, flower, and seed

Uses: Traditionally, this plant's leaf paste has been used to dye skin, hair, and nails. It also reduces premature greying of hair and possesses anti-bacterial properties.

Conservation status: Least Concern (LC)

31. Botanical name: *Emblica officinalis* Gaertn

    Local name: Amlaki

    Family: Euphorbiaceae; Growth form: Tree

    Parts used: Fruit, bark, root

    Uses: Amla is well known for its health advantages in traditional medicine. Rich in antioxidants and vitamin C, it promotes immunological function, facilitates digestion, and reduces inflammation. It is frequently used to boost skin and hair health, control blood sugar, and improve liver function. In addition to its anti-aging qualities, amla is known to improve cardiovascular health by lowering cholesterol. It is also beneficial for several skin and scalp disorders due to its antibacterial and antifungal qualities.

    Conservation status: Least Concern (LC)

32. Botanical name: *Lagerstroemia speciosa (*L.) Pers.

    Local name: Jarool

    Family: Lythraceae; Growth form: Tree

    Parts used: Bark, leaves

    Uses: Because of its actions similar to insulin, it is mainly used to control blood sugar levels. Tea from its leaves treats renal disease, diabetes, and urinary dysfunction. It is also well-known for its anti-inflammatory and antioxidant qualities, which promote heart health and overall well-being.

    Conservation status: Least Concern (LC)

33. Botanical name: *Leucas aspera* (Willd.) Link

    Local name: Danda kalash

    Family: Lamiaceae; Growth form: Herb

    Parts used: Whole plant

    Uses: In traditional medicine, it is frequently used to treat respiratory conditions like asthma, colds, and coughs. Because of their antibacterial qualities, its leaves and flowers are administered topically to wounds, bug bites, and skin infections. Many traditional medicines also use it as an analgesic to treat fever and inflammation.

    Conservation status: N/A

34. Botanical name: *Artocarpus heterophyllus* Lam

    Local name: Kathal

    Family: Moraceae; Growth form: Tree

    Parts used: Fruit, seeds, wood, leaves

    Uses: The health advantages of several parts of the *Artocarpus heterophyllus* are utilized in ethnomedicine. Because of its rich fibre and vitamin content, the ripe fruit is eaten to aid digestion and give you energy. The seeds are believed to have antibacterial and anti-inflammatory qualities and have long been used to treat digestive disorders. Jackfruit bark is occasionally used to promote wound healing, while the leaves treat diabetes and skin issues. All things considered, the plant is prized in traditional medicine for its capacity to promote digestive, skin, and immunological health.

    Conservation status: N/A

35. Botanical name: *Michelia champaca* L.
    Local name: Champa
    Family: Magnoliaceae; Growth form: Tree
    Parts used: Flower, roots, and barks
    Uses: Because of its aromatic flower, bark, and leaves, *Michelia champaca* is prized in traditional medicine. Anxiety, fever, and inflammation are frequently treated with the flowers. Since leaf extracts have antibacterial qualities, they treat wounds and skin conditions. It is also thought that *Michelia champaca* has mild sedative qualities that reduce anxiety and tension. Conservation status: Least Concern (LC)
36. Botanical name: *Moringa oleifera* Lam
    Local name: Sajna
    Family: Moringaceae; Growth form: Tree
    Parts used: Bark, leafs, and pods
    Uses: Because of its high nutritional profile, the moringa tree is utilized extensively in traditional medicine. Its seeds and roots are utilized for their anti-inflammatory and antibacterial qualities, and its leaves aid digestion, control diabetes, and strengthen immunity. Moringa is highly prized for its ability to lower blood pressure, improve skin health, and nourish the body in general.
    Conservation status: Least Concern (LC)
37. Botanical name: *Terminalia arjuna* (Roxb.) Wight &Arn
    Local name: Arjun
    Family: Combretaceae; Growth form: Tree
    Parts used: Bark
    Uses: *Terminalia arjuna* is utilized extensively because of its potent cardio-protective qualities. Its bark has long been utilized to strengthen the heart, increase blood flow, and cure cardiac diseases, including hypertension and angina. It is also used to treat wounds, respiratory conditions, and digestive problems because of its antibacterial and anti-inflammatory properties.
    Conservation status: N/A
38. Botanical name: *Rauvolfia serpentina* (L.)
    Local name: Sarpagandha
    Family: Apocyanaceae; Growth form: Herb
    Parts used: Roots
    Uses: Because of its relaxing and blood pressure-lowering properties, sarpagandha has long been employed in ethnomedicine. Its root is used to alleviate anxiety, sleeplessness, and hypertension. It is also used in traditional medicine to treat snake bites, epilepsy, and mental illnesses. Because of its calming qualities, Sarpagandha is useful for easing anxiety and encouraging sound sleep.
    Conservation status: N/A
39. Botanical name: *Dioscorea bulbifera* L.
    Local name: JangliAlo
    Family: Dioscoreaceae; Growth form: Climber
    Parts used: Tuber
    Uses*: Dioscorea bulbifera* is utilized in traditional medicine due to its anti-inflammatory, analgesic, and antibacterial qualities. It is frequently used to treat skin disorders, ulcers, and wounds because of

its healing properties. It is also used in certain cultures to treat joint pain, digestive problems, and respiratory health.

Conservation status:

40. Botanical name: *Tamarindus indica* L.
    Local name: Tetul
    Family: Caesalpiniaceae; Growth form: Tree
    Parts used: Bark, flower, fruit and seed
    Uses*:* *Tamarindus indica* is commonly used in traditional medicine due to its numerous health benefits. The pulp of the tamarind fruit is recognized for its laxative effects and is commonly used to treat constipation and digestive issues. The leaves and bark are used in poultices to treat wounds and skin diseases, and tamarind extract is thought to promote liver function and act as an antioxidant. Its nutritional value makes it popular in various herbal medicines and gourmet recipes.
    Conservation status: Least Concern (LC
41. Botanical name: *Heliotropium indicum* L.
    Local name: Hatishoor
    Family: Boraginaceae; Growth form: Herb
    Parts used: Whole plant
    Uses: *Heliotropium indicum*, commonly known as 'Indian heliotrope'has several medicinal uses in traditional medicine. Its antibacterial and anti-inflammatory properties make its leaves and roots useful for treating eczema, wounds, and ulcers. Together with digestive problems like diarrhoea, the herb is also used to treat respiratory conditions like bronchitis and coughing.
    Conservation status: N/A
42. Botanical name: *Schima wallichii* (DC.) Korth
    Local name: Kanak
    Family: Theaceae; Growth form: Tree
    Parts used: Bark and flower
    Uses: *Schima wallichii* is highly appreciated in traditional medicine due to its numerous medicinal applications. The expectorant characteristics of the leaves and bark make them useful in folk treatments for respiratory diseases such as coughs and bronchitis. It is also used for its anti-inflammatory properties to treat illnesses such as arthritis and muscle discomfort. In some cultures, it is used in herbal preparations to aid digestion and overall health.
    Conservation status: Least Concern (LC)
43. Botanical name: *Terminalia chebula* Retz.
    Local name: Haritaki
    Family: Combretaceae; Growth form: Tree
    Parts used: Fruit
    Uses: A strong laxative, it is mainly used to ease constipation and support digestive health. It is also said that the fruit helps to cleanse the gastrointestinal tract and is well-known for its detoxifying qualities. It is frequently used as a general rejuvenator to promote general well-being, improve oral health, and boost cognitive function.
    Conservation status: Least Concern (LC)

44. Botanical name: *Ziziphus mauritiana* Lamk.
    Local name: Boroi
    Family: Rhamnaceae; Growth form: Tree
    Parts used: Fruit, leaves
    Uses: Traditional medicine extensively uses *Ziziphus mauritiana* because of its health-promoting qualities. The fruit, valued for its high vitamin C content, is used to ease constipation, enhance digestion, and strengthen immunity. Because of its antibacterial qualities, its leaves cure skin ailments, including boil, wounds, and inflammation.
    Conservation status: Least Concern (LC)
45. Botanical name: *Buteamono sperma* (Lamk.)
    Local name: Palash
    Family: Fabaceae; Growth form: Tree
    Parts used: Bark, seed, flower
    Uses: Its flowers are traditionally used to heal skin conditions and, because of its astringent qualities, to purify blood. The gum from the tree is used to treat diabetes, dysentery, and diarrhoea. While the bark is utilized for its anti-inflammatory properties in situations like arthritis, the seeds are applied in herbal medicines to treat intestinal parasites.
    Conservation status: Least Concern (LC)
46. Botanical name: *Tectona grandis*L.f.
    Local name: Segun
    Family: Lamiaceae; Growth form: Tree
    Parts used: Leaves, bark and wood
    Uses: Teak is considered valuable in traditional medicine due to the healing characteristics of its leaves, bark, and wood. Because of their anti-inflammatory and antibacterial properties, the leaves are frequently used to treat headaches, fever, and skin conditions. Teak bark is used to cure illnesses such as diarrhoea, dysentery, and even bronchitis due to its astringent and cooling characteristics. Teak wood is prized for its durability, strength, and natural resistance to pests.
    Conservation status: Endangered (EN)
47. Botanical name: *Mallotus philipinensis* (Lam.)
    Local name: Shinduri
    Family: Euphorbiaceae; Growth for: Tree
    Parts used: Fruits and leaves
    Uses: Because of its medicinal qualities, *Mallotus philippensis* is frequently utilized in traditional medicine. The fruit powder known as Kamala dye is used as a natural anthelmintic to eliminate intestinal worms.
    Conservation status: Least Concern (LC)
48. Botanical name: *Schima wallichii* (DC.) Korth
    Local name: Banakh
    Family: Theaceae; Growth for: Tree
    Parts used: Bark, leaves, and roots
    Uses: Its bark, leaves, and roots are used by indigenous populations for various purposes, including pain alleviation, wound healing, and inflammation reduction. It is also used to treat fevers and

gastrointestinal illnesses, including dysentery and diarrhoea, as well as for its antibacterial qualities, which are especially useful for skin and digestive infections.

Conservation status: Least Concern (LC)

Conclusion:

Several species of plants essential to ecological balance and human well-being can be found in tropical forests, renowned for their vast biodiversity. These areas' diverse flora, which includes everything from tall trees to fragile understory plants, creates a special and intricate ecosystem that sustains a wide variety of fauna and controls the processes that affect the climate globally. Since Indigenous people have long used different species to treat illnesses and promote health, many plants have substantial ethnomedicinalsignificance. This kind of therapeutic plant knowledge has been handed down through the years, demonstrating a deep awareness of the forest's resources.

Tropical forests have a wealth of possibilities for modern medicine, as seen by the ethnomedical use of their plants. Innumerable plants still have undiscovered compounds, while many have already produced compounds that have created life-saving medications. However, this rich diversity and the associated cultural legacy are in danger due to the unrelenting forces of habitat degradation, deforestation, and climate change. Thus, protecting tropical forests and encouraging sustainable practices are crucial for maintaining biodiversity, knowledge systems, and possible medical advances they offer. The preservation of plant diversity and the sustainable usage of ethnomedicinal plants must be prioritized as we continue to investigate and comprehend the vast botanical world. By doing this, we pay attention to the past's knowledge and the future's promise.

Warnings:

The powerful bioactive compounds found in ethnomedicinal plants can be very dangerous if taken improperly. Key precautions include the following:

- ✓ **Consult a Professional Therapist:** Because improper use of ethnomedicinal plants might result in toxicity or negative effects, it is best to take them under the supervision of a skilled folk medicine practitioner or Ayurveda practitioner.
- ✓ **Be Aware of Dosage:** Self- dosing is risky because the toxic and therapeutic levels of many ethnomedicinal plants can sometimes be extremely near.
- ✓ **Examine Possible Interactions:** Prescription drugs and certain plants may interact negatively. Forinstance; St. John’s wort can reduce the functionality of anti-depressant drug Xanan (NCBI, 2011).
- ✓ **Monitor Allergic Reactions:** Some people may experience allergic reactions to wild plants, which can range from skin irritation to serious respiratory problems.
- ✓ **Avoid during Pregnancy and Breastfeeding:** A number of plants contain substances that could be dangerous for breastfeeding mother and their infants. Before using ethnomedicinal plants in certain situations, always get professional assistance.

These safety measures can assist avoid unforeseen health hazards and guarantee that the therapeutic potential of plants used in ethnomedicine is used in a safe and efficient manner.

Some photographs of Ethnomedicinal plants of Unakoti Hills are shown in following figure.

Calotropis gigantea

Leucas aspera

Cassia fistula

Cinnamomum zeylanicum

Microcos paniculata

Butea monosperma

Tectona grandis

Sesbania grandiflora

Eclipta prostrata

Lagerstroemia speciosa

Alstonia scholaris

Holarrhena antidysenterica

Elaeocarpus serratus

Michelia champaca

Neolamarckia cadamba

Heliotropium indicum

Artocarpus heterophyllus

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FIELD OF ECOLOGY, SCOPES AND CAREER ACCEPTANCE IN INDIA: A PREVIEW

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Abstract:

Ecology is one of the vital fields of life sciences that is enlightening on interactions between organisms and their environment. In India, Ecology plays an adamant role in addressing environmental challenges, managing natural resources and facilitating sustainable development. The Ecology field offers diverse career opportunities in various sectors including academic research, biodiversity conservation and management. Notwithstanding its importance, the field of ecology faces various challenges in India including limited awareness i.e lack of understanding and proper recognition and funding. This preview aims to explore the scope and acceptance of ecology as a career in India. This chapter discusses how to create the future in the ecology field, scopes of ecology, major topics that are taught during graduation and post graduation, research funding agencies, NGOs & institutions, academic programs & research initiatives, job prospects and required skills for ecologists in India. Overall, this preview provides an overview of the ecology field, feasible scopes and its career prospects in India. By promoting ecology and its applications, current and future generations can conserve natural resources and would make more sustainable future for all.

Keywords: Ecology, Conservation, Future Prediction, Sustainable Development, Scopes, Climate Change, India

Introduction:

Learning has no end and when it is about making questions, it becomes a most curious matter. Gathering knowledge in various disciplines including science is essential for various aspects i.e to understand the natural world, its laws and principles, mechanisms, our daily life strategies, environmental sustainability, socio-economic conditions etc. Such knowledge helps us to build up for future careers in various fields of science branches like Physics, Chemistry and various fields of life sciences including Ecology, Environmental Science, Biotechnology, Microbiology, Molecular Biology, Zoology, Botany and various medical research.

Ecology, the study of interactions between organisms and their environment, plays a vital role in addressing global environmental challenges (Odum, 1971; Begon *et al.*, 2006). According to the Indian Ecological Society report (2020), India has a vast scope, encompassing various trending themes, issues and opportunities. Major areas of this field are conservation biology, ecosystem services, climate change research, statistical analysis, environmental policy makings, governance and sustainable development. As the world grapples with biodiversity loss, climate change and environmental degradation, the demand for ecologists is rising. WHO (2016) report says, future careers in ecology hold promise in research, academia, conservation, environmental consulting, policy, and advocacy. In an article, Ecological Society of America (2020) mentioned that Ecology offers a rewarding and challenging career path for those passionate about understanding and protecting the natural world with its interdisciplinary approach and global relevance.

Importance of studying Ecology:

Ecology study is important for Understanding Ecosystems and Ecological Balance (Odum, 1971). Millennium Ecosystem Assessment (2005) report mentioned that Ecology helps us in interconnectedness i.e understand the relationships between living organisms and their environments. Studying ecology reveals the importance of ecosystem services, such as air and water purification, soil formation, and climate regulation (Daily, 1997). World Wildlife Fund (2020) mentioned that ecology helps preserve ecosystems, species, and genetic diversity.

According to Ecological Society of America (2020), Ecology promotes critical thinking and problem-solving skills, essential for addressing complex environmental challenges and Indian Ecological Society (2020) specified that by studying ecology, we can gain a deeper understanding of the natural world, address environmental challenges, improve human health and well-being, and inform sustainable development and resource management.

Apart from studying living organisms, ecologists are also responsible for investigating the footprints humans have on nature (Odum, 1971). This study, known as human ecology, examines the interactions between human populations and the environment (Bennett & McGoldrick, 2012).

Duties of an Ecologist:

Followings are vital duties of an Ecologist:

1. Ecologists Classify organisms including animals, plants and microorganisms and do field visits to know about organisms, their behavior, roles and their habitat preferences.
2. They visit local areas for surveys, collect data, study the environmental impact and find its solution and spread it among local people through discussion and seminar programs.
3. They recommend environmental legislation to government bodies and prepare geographic information systems like software programmes.
4. They generate ideas for ecological projects and for sustainable development.
5. They do work with Government bodies, local organizations and Environmental groups, in research laboratories, in College and Universities.

Thrust Areas of Ecological studies in India:

Followings are probable core zones for studying Ecology:

1. Western Ghats, Eastern Himalayan biodiversity hotspots and Indo-Burma hotspot region.
2. Coastal and marine ecosystem conservation.
3. Desert ecology and arid zone management.
4. Island ecosystems (Andaman & Nicobar, Lakshadweep).
5. Urban ecology and sustainability.

Few recognised Indian Universities for pursuing MSc as well as BSc in Ecology and relevant courses:

Following Institutions/ Colleges/ Universities offers various courses regarding Ecology and relevant courses:

a) Assam University, Silchar, Assam

b) Eastern Institute for Integrated Learning in Management (EIILM) University., Sikkim.

c) Nalanda University, Bihar.

d) Indian Institute of Ecology and Environment, New Delhi (offers MSc in Ecology and Environmental Science, Sustainable Development, and Disaster Mitigation)

e) Pondicherry University, Puducherry. (Ecology and Environmental Science)

f) Pragyan International University, Jharkhand (offers MSc in Ecology and Environmental Science)

Some more top colleges and universities in India that offer BSc in Ecology or relevant courses: Miranda House (college for women at the University of Delhi), Indian Institute of Ecology and Environment, Lady Shri Ram College for Women, Hindu College, St. Stephens College, Asutosh College, Anugrah Narayan College, Netaji Mahavidyalaya, The Global Open University etc Institutions offer a range of courses and specializations in ecology, and can provide students with a strong foundation in the field.

Major topics taught in BSc and MSc Ecology programs:

Following topics are taught during graduation program(s) in different Institutions:

BSc Ecology Courses:

1. Introduction to Ecology: Principles of ecology, ecosystem dynamics, and conservation biology.
2. Ecological Theories: Study of ecological concepts, including population ecology, community ecology, and ecosystem ecology.
3. Biodiversity and Conservation: Exploration of biodiversity, conservation biology, and wildlife management.
4. Ecological Research Methods: Introduction to research design, data collection, and statistical analysis in ecology.
5. Environmental Science: Study of environmental systems, including climate, water, and soil.
6. Ecological Restoration: Principles and practices of restoring degraded ecosystems.
7. Wildlife Management: Management of wildlife populations, habitats, and ecosystems.
8. Ecological Modeling: Introduction to mathematical modeling in ecology, including population dynamics and ecosystem modeling.
9. Field Ecology: Hands-on experience with ecological field methods, including sampling, data collection, and species identification.
10. Ecology and Society: Exploration of the relationships between ecology, society, and human well-being.

MSc Ecology Courses:

Following possible topics are taught during M.Sc in different Universities:

1. Advanced Ecological Theories: In-depth study of ecological concepts, including meta-population dynamics, landscape ecology, and ecosystem services.
2. Conservation Biology: Advanced study of conservation biology, including species conservation, habitat restoration, and ecosystem management.
3. Ecological Research Design: Advanced training in research design, data analysis, and statistical modeling in ecology.
4. Ecological Modeling and Simulation: Advanced study of mathematical modeling and simulation in ecology, including individual-based modeling and ecosystem modeling.
5. Environmental Policy and Management: Study of environmental policy, management, and governance, including climate change policy and sustainable development.
6. Ecological Restoration and Rehabilitation: Advanced study of ecological restoration and rehabilitation, including restoration ecology and ecosystem engineering.

7. Wildlife Ecology and Management: Advanced study of wildlife ecology and management, including population ecology, habitat management, and human-wildlife conflict.
8. Ecology and Human Health: Exploration of the relationships between ecology, human health, and well-being, including ecosystem services and environmental health.
9. Ecological Economics: Study of ecological economics, including environmental valuation, cost-benefit analysis, and sustainable development.
10. Research Project: Original research project under the supervision of a faculty member, culminating in a thesis or dissertation.

N.B: Syllabus is primary root of any content. So here, for generating basic ideas regarding UG and PG level syllabus, author just highlighted on syllabus topics or themes. It may vary from institution to institution. Author did not collect it from any particular or targeted source. Just arranged from an idea and open source, so no references regarding syllabus or relevant parts are mentioned here.

What possibilities have that Ecologists could do for maintaining future Climate change:

Ecologists will play a crucial role in addressing climate change in the future. By playing the following roles, ecologists will be essential in helping societies adapt to climate change, mitigate its impacts, and preserve ecosystem services for future generations.

Followings are some possible key ways ecologists can contribute-

Research and Monitoring: a) Tracking climate change impacts: Ecologists will study how climate change affects ecosystems, biodiversity, and ecosystem services. b) Monitoring ecosystem health: They will monitor ecosystem health, identifying early warning signs of climate change impacts.

Conservation and Management: a) Developing conservation strategies: Ecologists will develop conservation strategies to protect vulnerable ecosystems and species. b) Ecosystem-based adaptation: They will design ecosystem-based adaptation plans to help ecosystems adapt to climate change. c) Sustainable land-use planning: Ecologists will work on sustainable land-use planning, balancing human needs with ecosystem conservation.

Policy and Decision-Making: a) Informing climate policy: Ecologists will provide scientific advice to policymakers, informing climate change mitigation and adaptation strategies. b) Ecosystem services valuation: They will help value ecosystem services, enabling policymakers to make informed decisions about ecosystem conservation.

Education and Outreach: a) Climate change education: Ecologists will educate the public, policymakers, and other stakeholders about climate change impacts on ecosystems. b)Promoting ecosystem stewardship: They will promote ecosystem stewardship, encouraging individuals and communities to take action to protect ecosystems.

Collaboration and Interdisciplinary Research: a) Interdisciplinary research: Ecologists will collaborate with researchers from other disciplines, such as climate science, economics, and social sciences. b) International collaborations: They will work with international partners to address global climate change challenges.

Few notable Government Institutions in India regarding Ecology and Environmental Science:

Following are notable institutions:

1. Ministry of Environment, Forest and Climate Change (MoEFCC)
2. Indian Institute of Ecology and Environment (IIEE)
3. Wildlife Institute of India (WII)

4. Centre for Environmental Education (CEE)
5. National Centre for Sustainable Aquaculture (NaCSA)
6. Indian National Science Academy (INSA) - Ecology and Environmental Sciences section

Possible major Government research funding agencies for continuing Ecological research in India:

1. Department of Science and Technology (DST)
2. Ministry of Environment, Forest and Climate Change (MoEFCC)
3. Indian Council of Forestry Research and Education (ICFRE)
4. Council of Scientific and Industrial Research (CSIR)

Scope and possible Carrier acceptance in Ecology field in India:

Studying ecology in India can lead to a wide range of career opportunities in India which are as follows-

Government Sector:

1. Indian Forest Service (IFS): Manage and conserve India's forests and wildlife.
2. Wildlife Institute of India (WII): Work on wildlife conservation, research, and management.
3. Ministry of Environment, Forest and Climate Change (MoEFCC): Contribute to environmental policy-making and implementation.

Research and Academia:

1. Research Institutes: Work in institutes like the National Centre for Biological Sciences (NCBS), Indian Institute of Science (IISc), or the Wildlife Institute of India (WII).
2. Universities and Colleges: Teach and conduct research in ecology and related fields.
3. Ph.D. Programs: Pursue advanced research in ecology and related fields.

Non-Governmental Organizations (NGOs):

1. Wildlife Conservation Society (WCS): Work on wildlife conservation and community development.
2. World Wildlife Fund (WWF): Contribute to conservation efforts and sustainable development.
3. The Energy and Resources Institute (TERI): Focus on environmental research, policy, and sustainable development.

Private Sector:

1. Environmental Consulting: Work with companies on environmental impact assessments, sustainability, and eco-friendly practices.
2. Sustainable Development: Contribute to sustainable development projects, such as eco-tourism, organic farming, or renewable energy.
3. Ecological Restoration: Work on restoring degraded ecosystems, such as forests, wetlands, or wildlife habitats.

Other Career Paths:

As an Ecologist, anyone can select following such paths:

1. Science Writing and Communication: Share ecological knowledge with the public through writing, editing, or broadcasting.
2. Ecotourism and Wildlife Tourism: Promote responsible tourism practices and support conservation efforts.
3. Policy and Advocacy: Work with governments, NGOs, or private companies to develop and implement environmental policies.

These are just few examples of the many career paths available to ecology students in India. Remember to consider your interests, skills, and values when exploring these options.

The future of ecology in India is directly linked to the country's economic growth, human health, and sustainability.

Figure 1: Above chart showing key areas of possible growth in Ecology field, career opportunities of an ecologist and their possible contributions.

Conclusions:

We currently face significant, anthropogenic, global environmental challenges and the role of ecologists in mitigating these challenges is arguably more important than ever. Consequently there is an urgent need to recruit and train future generations of ecolo-gists, both those whose main area is ecology, but also those involved in the geological, biological and environmental sciences (Cooke *et al.*, 2021). Understanding the effects of climate change on species diversity is critical for developing long-term conservation strategies (Jones *et al.*, 2013; Range *et al.*, 2019). Ecological niche modelling (ENM) aid us in determining the connection between species occurrence and environmental variables (Jose and Nameer, 2020).

By following Ecological principles, Ecologists inform strategies for environmental sustainability, conservation of bioresources, wildlife conservation and management. They are able to recognise the intricate relationships between human health and the environment. So, for making better version of country i.e for sustainable development, for making good socio-economics, reduce climate change issues and to understand eco-friendly human activities we always need good Ecologists in India even in other countries.

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ARBUSCULAR MYCORRHIZAL FUNGI: A POTENTIAL MYCORHIZOSPHERIC FUNGI FOR SUSTAINABLE AGRICULTURE

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Abstract:

Plant roots are colonized by the diverse group of mycorhizospheric fungi and are considered as a critical component of terrestrial ecosystem. Mycorrhiza, the obligate symbionts considered as one of the most primeval known symbionts on the earth participating in mutualistic approaches of nutrient acquisition by plants. In this type of symbiotic association, myco partner facilitates phyto partners to absorb the requisite minerals, predominantly phosphorus from the nutrient deficient rhizosphere and in returns plant furnishes the photosynthates to the fungus. The non-nutritional assistance of mycorrhizal association is resistance to phytopathogens and pest, alleviation of drought and salinity stress, amplified reproductive capability, enhancement of foliar biomolecules and plant productivity and diversity.AM fungi beneficially interact with other rhizosphere microorganisms and above-ground organisms and thus impart synergistic effect on plant performance. However, to unknot the exact role of AM fungi as indispensible bioinoculant for sustainable agriculture, agricularists should scale up the exploration of this group of fungi in agricultural field followed by the proper management strategies, easy accessibility and cost effectiveness.

Keywords: Obligate Symbiont, Bio Inoculant, Rhizosphere

Introduction:

The term sustainability has become familiar since 1994 which has the basic goal of percieving better future requirements for the inhabitants preserving resources that will flourish and gain acceptancy. At present scenario sustainable agriculture is addressed by agricultural communities in significant ways for satisfying the need of food for human, enhancing natural resources and increases the economic demands. Sustainable farming practices like intercropping Brooker *et al.* (2015) help to conserve ground biodiversity, detoxification, water storaging and nutrient retention Bardgett and Van der Putten (2014); Cavagnaro *et al.* (2015).

Mycorrhizal symbiosis is widespread in natural environments Hodge *et al.* (2009) as approximately 95% of vascular plants encompass mycorrhizal association Brundrett (1991). This symbiosis is the integral part of the natural ecosystem Chakraborty *et al. (*2019). Mycorrhizal habit has a long evolutionary history Nicolson (1975), possibly associated with the evolution of land plants Pirozynski and Malloch (1975). The evolution towards biotrophic nutrition has occurred in all the fungi capable of forming mycorrhizal associations Lewis (1973). The mycorrhization process can be divided into distinct steps *viz.*, germination of spores, hyphae differentiation, appressorium formation, host root penetration, intraradical hyphae formation, intercellular growth along with developed extraradical hyphae, and arbuscule formation, subsequently exchanging nutrients and carbohydrates between the host and fungus Goltapeh *et al. (*2008). This symbiotic relation occurred in a variety of ecosystems ranging from terrestrial ecosystems from tropical to temperate forests, deserts, grasslands and as well as in agro-ecosystem Brundrett (1991). Plant species belonging to Brassicaceae, Chenopodiaceae, Cyperaceaa, Juncaceae, Urticaceae and Caryophyllaceae lack mycorrhizal associations (Newman and Reddell (1987).

Morphologically, AM fungi are classified into two types based on the structures they form after invasion into roots and they are commonly known as *Arum* type and *Paris* type Gallaud (1905). *Arum* type of morphology is characterized by the formation of intercellular longitudinal hyphal growth appearing at right angles to the main root axis Smith and Read (1997) whereas in *Paris* type the coils forms branched arbuscule from one or more loci resulting in cell to cell connection Gallaud (1905); Smith and Smith (1997). The host plant species and the AM fungal identity specify the morphology of mycorrhiza Cavagnaro *et al.* (2001). Despite of no significant functional differences between both the types of AM morphology *Paris* type exhibited slower rate of spreading of colonization compared to *Arum* type Brundrett and Kendrick (1990). The importance of slower rate of colonization is pointed out by Brundrett and Kendrick (1990) as slower rate of colonization significantly helping the host plant to restore its energy supply to AM fungi in a moderate level so as to sustain the rate of growth of plants in their actual form. *Arum* type of morphological structures is mostly observed in field crops Smith and Smith (1997) where as *Paris* type is observed in plants of natural ecosystems such as temperate broad leaf forests Brundrett and Kendrick (1990).

Improvement of plant productivity and diversity

AM fungal symbiosis has imperative role in the maintenance and support of the productivity of and thus improve biodiversity Allen *et al.* (1995). In terrestrial ecosystems this symbiosis is considered as a primary determinant of plant health and soil fertility Jeffries *et al.* (2003). AM fungal inoculation in corn, millet, soybean, rice, trifoliate orange and seventeen tropical legumes has demonstrated an improved economic impact on agriculture and horticulture (Vinayak and Bagyaraj (1990); Tewari *et al.* (1993); Khalil *et al.* (1994); Duponnois *et al.* (2001). AM symbiosis contributes significantly to global phosphate and carbon cycling and thus, influences primary productivity in terrestrial ecosystems Fitter (2005). The biodiversity of fungal and plant communities are positively correlated with each other Maherali and Klironomos (2007) and host preference seems to play a key role in natural ecosystems Vandenkoornhuyse *et al. (*2003).

Improvement of soil fertility

The maintenance of soil health is crucial for the sustainable development but its health is detoriated with various anthropogenic disturbances resulting in the detoriation of agricultural soil fertility. The quality of the soil not solely depends on the chemical and physical properties but also depends on the availability of the microbiota and their influential activity Doran and Linn (1994). AM fungi, the indispensible components of soil mycobiota are dominant in all ecological situations particularly in those plant communities with high species diversity and also in normal cropping procedure, with special reference to sustainable practices Gianinazzi and Schepp, (1994). Being obligate in nature AM fungi, the life cycle of AM fungi depends on plant roots and prevents the plants from attack of micro-organisms in soil, especially where there is limiting supply of phosphorus Linderman (1992). Glomalin, a hypothetical glycoprotein produced by AM fungi deposited in the neighbouring walls of mycorrhizal extraradical hyphae and soil particles is best known for its soil adhering attributes Wright and Upadhyaya (1998, 1999). The mycorrhizal mycelium plays an inimitable role in the production of this water stable macroaggregates in relation to the health of soil Andrade *et al.* (1998); Bethlenfalvay *et al.* (1999) as this water stability is a crucial factor for maintaining the fertility of soil. There are also some affirmations that modified agricultural practices are associated with the beneficiary activity of AM fungi on the crop field and different crop rotations in the similar soil and climatic conditions induce large and drastic change in the populations of AM fungi linked with that crop Hendrix *et al.* (1995) which reveals that plant dominancy are also a key factor for affecting AM fungal communities. For establishment of AM fungi as a useful tool in the field of agriculture, accurate crop rotation is the foremost criteria and if mycorrhizal dependent plant species are used prior to the crop rotation, then there is increase in the indigenous growth of beneficial AM fungal populations Dodd *et al.* (1990).There is a progressive activity of AM fungi in the toxic soil Weissenhorn *et al.* (1993); Gucwa-Przepiora and Turnau (2001).Reports are also available on soil restoration by AM fungi Orłowska *et al.* (2002). AM fungi also function as an effective tool for monitoring changes in soil pattern and soil quality Lovera and Cuenca (1996); Jacquot *et al.* (2000).

Resistance against drought stress

Drought stress (DS) is considered as one of the most hazardous factors that are pierced with the declining of crop productivity by inhibiting the both vegetative and reproductive growth of plants Shukla *et al.* (2012). During drought stress plants cannot make up their requisite nutrient amount and as a consequence leads to stunted growth, limited CO_2 diffusion and increased abscisic acid stress Heidaiy and Moaveni, (2009). From existing literature survey, it is evident that AM fungal symbiosis is effective in overcoming DS by altering certain hormonal balance, enhancing hydro-mechanical conductivity through increased absorption of water by the hyphal networks (Augé *et al.*, 2007) and osmotic adjustment Porcel and Ruiz-Lozano (2004).AM fungi mitigated the DS through combination of cellular and nutritional variation Augé *et al.* (2001). The main perceptive process that is affected by DS in plant is photosynthesis which further destructs the Photo system I and Photo system II Teskey *et al.* (2015). AM fungal colonization helps in maintaining the uptake of required water for deplete the DS effect in plant is photosynthesis which further destructs the Photo system I and Photo system II Teskey *et al.* (2015). AM fungal symbiosis also known to increases anti-oxidant enzymatic activity in host plant that relieves the DS Huang *et al.* (2017). Thus AM fungi has a great influence in suppression of DS.

AM fungi in improvement of salt tolerance

AM fungi, the critical component in stressed soils root system Ruiz Lozano *et al.* (2012).The occurrence of AM fungi has been reported even under severe saline conditions Yamato *et al.* (2008) and in salt marshes Wilde *et al.* (2009).AM fungi have been found to improve salt tolerance in different plant species such as tomato, cucumber, maize, lettuce, clover, fenugreek, sesbania, and acacia Giri *et al.* (2007); Giri and Mukerji (2004); Evelin *et al.* (2013). Improved nutrient acquisition, particularly P by AM fungi, could ascribe to be the primary mechanism by which mycorrhizal fungi mitigate the adverse effects of salinity stress on plant growth Giri *et al.*, (2007). Increased photosynthetic rates and stomatal conductance in AM fungal compared to non-AM fungal plants under salinity stress Wu *et al.* (2010). The increased rate of photosynthesis in AM fungi-colonized plants under salinity stress has been correlated with the lower intercellular CO_2 concentration in mycorrhizal plants, since the higher photosynthetic capacity increases water use efficiency for the assimilation of more carbon per unit water transpiration Sheng *et al.* (2008).

Role of AM fungi on phytoremediation

Phytoremediation denotes the application of plants to free up the soil contaminants. Plants are applied to degrade or stabilize or remove heavy accumulated metals or metalloid Kling (1997); Kumar *et al.* (1995).AM fungi enhance phytoremediation Hildebrandt *et al.* (1999). Extra radical mycelium of AM fungi produces some compounds which directly takes part in removal of heavy metals and metalloid by means of bio-accumulation and bio-absorption Gadd (1993). The hyphal network can invade deep to the soil and able to uptake the metals that contaminate the soil and this indicates that there is a heavy metal tolerance activity in these fungi and they play a vital role in phytoremediation Chaudhry *et al.* (1998). There are also some reports suggesting the significant role of AM fungi in plant root protection from heavy metals Gali *et al.* (1994). Establishment of sustainable native grass community is a reclaimative goal where tactonite iron ore tailing areas are prevalent and infectivity by means of AM fungi on these prairie grasses increases their durability against those heavy metals Noyd *et al.* (1996).

AM fungi in plant defence

The use of chemicals for eradicating predators which are mainly soil microbes is substantially affecting both soil and plant Dehne (1982). It has been proclaimed that the use of AM fungi colonised plant assist protection against root pathogens and thus assuring defence to the plant Dehne (1982). AM fungi helps in improving the defence mechanism of plant through changing the chemical orientation of plant tissue and alleviating the stress condition Hooker *et al.* (1994). AM fungi and their associated interactions with plants reduce the damage caused by plant pathogens Harrier and Watson (2004). These fungi are major constituent of the rhizosphere of plants and may affect the incidence and severity of root diseases Linderman (1992). The AM inoculated plants possess a strong vascular system, which imparts greater mechanical strength to diminish the effects of pathogens Schonbeck (1979). Phenolic compounds have been shown to be formed after mycorrhizal colonization Sylvia and Sinclair (1983) and are thought to play a role in disease resistance Goodman *et al.* (1967). Improvement of phosphorus nutrition following AM colonization of phosphorus-deficient roots results in a decrease in membrane permeability and reduction in root exudation Graham *et al.* (1981). AM inoculation increased the quantities of sugars and amino acids in plant tissue which may be responsible for the reduction of nematode infestation Suresh and Bagyaraj (1984).

AM fungi in weed management

Weed can be described as the plants that grow or reproduce forcefully and invasively outside its native habitat Janick *et al.* (1979). Weeds are conscientious for about 10% loss of crop of the world per year and could potentially affect 34% more damage if not controlled Oerke (2006). Moreover it has the potentiality to survive in diverse condition and reproduce quickly Quammen (1998). The interaction between agricultural weeds and AM fungi is not a mutualistic one and it is reported that AM fungi imparted negative impact on ruderal species colonization such as weeds occupying in such areas Francis and Read (1994); Francis and Read (1995).

AM fungi in reduction of soil erosion and nutrient leaching

The rate of soil erosion has been accelerated through various human activities at a global scale Grimm *et al.* (2002) that imparted negative effects including loss of topsoil, decrease in soil organic matter and pollution of surface water Lal (2001). It is postulated that soil biota indirectly decrease soil erosion through the formation and stabilization of soil aggregates Rillig and Mummey (2006). The root inhabiting AM fungi are known for their rule in increasing the soil aggregation Leifheit *et al.* (2014). AM fungi promote soil aggregation processes by various mechanisms on different hierarchical levels Rillig and Mummey (2006). Two key mechanisms are the physical stabilisation through entanglement of soil particles by fungal hyphae and chemical stabilisation by glue-like fungal exudates Wright and Upadhyaya (1998). The AM fungal hyphal network endorsed plant growth and root system development Gutjahr and

Paszkowski (2013) that protects the soil from erosion by wind and water. AM fungi also increase the surface roughness led to decrease in near-ground wind velocities Chepil (1951) which in turns reduce soil erosion. Glomalin, a soil glycoprotein produced by AM fungi was identified as an additional important agent in the stabilization of soil aggregates Singh *et al.* (2013). Existing literature survey revealed the fact that inoculation of mycorrhizal propagules associated with the improvement of soil physical, chemical and biological properties resulting in the enhancement of the establishment of vegetation in degraded environments Requena *et al.* (2001). Studies under experimental condition have shown that mycorrhizal fungi improve the soil resistance to water erosion and the fraction of water stable aggregates Bearden and Peterson (2000).

A considerable amount of N and P fertilizers is lost from agro-ecosystems via leaching, causing serious groundwater pollution and eutrophication Galloway *et al.* (2003).This losses can be regained by the application of AM fungi as they have decisive role in nutrient cycling Smith and Smith (2011).Works from different groups of workers suggest that AM fungi are capable of reducing P losses via leaching Asghari and Cavagnaro, (2011); Bender *et al.* (2014). In addition, AM fungi have the ability to assimilate N in different forms (Veresoglou *et al.* (2012) and reduce the losses of ammonium (NH_4^+) and nitrate (NO_3^-) from the ecosystem Cavagnaro *et al., (*2015) although their impact on decreasing mineral N losses is variable Cavagnaro *et al.* (2015). AM fungi enhance the nutrient interception ability of soils and decreases the nutrient leaching risk by enhancing nutrient uptake and immobilizing nutrients Bender *et al.* (2016). AM fungal hyphae improving soil structure by stabilizing soil micro- and macro-aggregates Rillig and Mummey (2006) and this is another way that can affect soil water relations and leaching volume. The effect of AM fungi on P losses is especially relevant for sandy soils where P loss can be substantial Sims *et al.* (1998). Auge (2004) proclaimed that AM fungi improve soil moisture retention in a sandy soil.

AM fungi enhance plant growth regulator and foliar biomolecules content

AM fungi residing at soil rhizosphere are the most promising soil mycobiota associated with the betterment of plant growth and yield. Numerous studies have shown that AM fungi can increase plant health and yield Rouphael *et al.* (2015); Hijri (2016). AM fungi interfere with the phytohormone balance of host plants, thereby influencing plant development (bioregulators) and inducing tolerance to soil and environmental stresses Rouphael *et al.* (2015).

AM fungi also stimulate the photosynthetic activity through the enhancement of photosynthetic pigment levels and by the drain of carbon resulting in a higher export of triose phosphate to the cytoplasm; there is a larger activation of the Calvin cycle which results in a higher production of primary metabolites, which are precursors of secondary metabolism pathways Kaschuk *et al.* (2009). Increase in photosynthetic rates is coupled with the storage and export of photosynthates at the same period Auge (2001). The higher content of foliar carbohydrate in AM fungal inoculated plants may be due to the increase in quantity and size of chloroplasts as reported earlier Krishna and Bagyaraj, (1981); Arumugam *et al.* (2011). The increased leaf protein content in the AM fungi inoculated plants may be due to the increased nitrogen and phosphorus content Rabie and Humiany, (2004); Azcon-Aguilar and Barea (2015) which is attributable with the potentiality of AM fungal hyphae for supplying N to mycorrhizal plants through atmospheric N fixation Rabie and Humiany (2004) and increasing in the percentages of N, P in plant, organic acids added to soils increased the plant uptake of P from a water soluble P Bolan *et al.* (1994). The plants with higher extent of mycorrhizal colonization have the higher phenolic contents which may be due to the reaction of the plant against mycorrhizal colonization Lu *et al.*

(2015).Accumulation of phenolic compounds is associated with plant defense response against microorganisms Vierheilig, (2004).Carotenoids originated from primary carbon metabolism Taiz and Zeiger, (2006), include lycopene and βcarotene found in the species that tend to be the most effective naturally existing radical sequesters for oxygen DiMascio *et al. (*1989).The enhancement in the carotenoid pigments content in AM fungi inoculated plants is associated with improvement of photosynthetic performance through enhancement of water and soil nutrient uptake Schopfer and Brennicke (2006).

Role of AM fungi on leaf litter decomposition

Litter decomposition is a process of conversion of leaf litter to simple compounds like CO_2, H_2O and inorganic ions that are absorbed by plant roots and other organisms inhabiting in the soil Brun (2005). It is a fundamental process for terrestrial ecosystems and an indispensible component of nutrition and carbon cycles Lavelle *et al.* (1993). It is well established that AM fungi have a positive impact in decomposition process Herman *et al. (*2012). Host plant's N acquisition is enhanced significantly from the litter patch due to the presence of AM fungi in it and increases the carbon from the litter Hodge *et al.* (2015). AM fungi have an indirect impact through regulation of free-living group act as decomposers in the soil and decompose the leaf litter Hodge *et al.* (2001). It is reported that alternation arises in about 10% bacterial community during litter decomposition the presence of AM fungi Nuccio *et al. (*2012).

Conclusion:

The use of synthetic chemical fertilizers and unscientific anthropological practices over a longer period of time lead to the destruction of native soil micro-biota resulting in reduction of soil fertility. To tide over with such difficulties plant and soil scientists are in search of potential alternative and soil microbiota can serve as indispensible bio resources capable of increasing the plant growth and yield. AM fungi belonging to monophyletic group Glomeromycota has the potent activity on the improvement of soil nutrient status and help in the nutrient acquisition of the native plant communities in available form from nutrient deficient sites through mutualistic symbiotic association. AM fungi also help in various physiological processes of associated plants and act as potential biocontrol agent by improving the plant resistant capability against certain plant pathogens.

Acknowledgements:

The authors are thankful to Head, Department of Botany, Tripura University for assisting the laboratory facilities. KC is grateful to Department of Science and Technology, Government of India for the INSPIRE fellowship.

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BIO-DIVERSITY AND DISTRIBUTION PATTERN OF *ANABAENA*, *TRICHORMUS*, *NOSTOC*, *CALOTHRIX* AND *SCYTONEMA* (HETEROCYSTOUS, CYANOPROKARYOTES) FROM TRIPURA, INDIA

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Abstract:

The present communication deals with the biodiversity and distribution of *Anabaena*, *Trichormus*, *Nostoc*, *Calothrix* and *Scytonema* from eight districts of Tripura. From the present communication we are reporting 64 species of which 12 species belonging to the genus *Anabaena*, 6 species belonging to genus *Trichormus*, 17 species belonging to the genus *Nostoc*, 19 species of the genus *Calothrix* and 10 species of genus *Scytonema* from different habitats including rice field, uncultivated land, moist soil, roof top, tree bark and sub-aerial habitats of Tripura. From the present communication, it was observed that all the eight districts of Tripura, India harbour a large number of the members of *Anabaena*, *Trichormus*, *Nostoc*, *Calothrix* and *Scytonema*. Maximum number of species was observed in Unakoti Tripura while minimum number of species was observed in South Tripura.

Introduction:

Cyanoprokaryotes (Blue green algae/Cyanobacteria) are the first photosynthetic simple microorganisms and some of them particularly heterocystous forms are bestowed with unique potential of diazotrophic nitrogen fixation along with carbon fixation (Anand, 1989). Because of these unique combinations of two entirely opposed physiological processes i.e. oxygen evolution as a by-product of carbon fixation via photosynthesis and diazotrophic nitrogen fixation they contribute significantly in the ecosystem as well as nitrogen economy Bharadwaja, (1963). They help in increasing the soil fertility and carbon sequestration. They gained a lot of attention in recent years because of their potential applications in biology, biotechnology and agriculture. The biomass of heterocystous blue-green algae is considered as one of the valuable natural sources of bio-fertilizer to increase the fertility of the soil and improve physico-chemical characteristics of soils such as water-holding capacity and mineral nutrient status of the soil (Aishampayan, 2001).

The cyanoprokaryotes are classified conventionally on the basis of morphological parameters (Bhattacharya and Gupta, 2011) or following polyphasic approach (Castenholz, 1998). Later, Komárek *et al*. (2014) revised the system of classification of cyanoprokaryota based on molecular characterization, cellular ultra structure and thylakoid arrangement. Cyanobacteria represent a major component of the photosynthetic microorganism community of most of the aquatic and terrestrial ecosystems (De, 1939), but may grow in a wide range of habitats including rice fields. As the North Eastern part of India is considered as one of the mega hotspots for its diversity richness including cyanobacteria. Cyanobacteria are found in diverse habitats of Tripura, a north eastern state of the country India.

The main aim of the study is to explore the diversity of Nostocalean members from different habitats of Tripura, India. From the present study, we are reporting total 314 strains of which 12 species belonging to the genus *Anabaena* viz. *A. constricta*; *A. duployae; A. ghosei, A. hieronymii; A. minuta; A. oblonga; A. orientalis; A. papillosa; A. schauderi; A. sedovii; A. spinosa, A. torulosa*; 6 species belonging to the genus *Trichormus* viz. *T. azollae; T. ellipsosporus; T. gelatinicola; T. minor; T. naviculoides; T. subtropicus*; 17 species belonging to the genus *Nostoc viz. N. calcicola*, *N. commune*, *N. ellipsosporum*, *N. foliaceum*, *N. gelatinosum*, *N. halophilum*, *N. kihlmanii*, *N. letestui*, *N. linckia*, *N. minutissimum*, *N. minutum*, *N. muscorum*, *N. paludosum*, *N. passerinianum*, *N. pruniforme*, *N. punctiforme* and *N. verrucosum* while 19 species of the genus *Calothrix* including one forma and one var. viz. *C. aeruginosa*, *C. breviarticulata*, *C. clavata*, *C. clavatoides*, *C. columbiana*, *C. conica*, *C. cylindrica*, *C. fusca* f. *durabilis*, *C. fusca*, *C. geitleri*, *C. geitonos*, *C. gloeocola*, *C. gracilis*, *C. javanica*, *C. linearis*, *C. marchica* v. *intermedia*, *C. parva*, *C. scopulorum* and *C. subsimplex* and 10 species of genus *Scytonema* including *S. bivaginatum*, *S. chengii*, *S. coactile*, *S. hormocystum*, *S. millei*, *S. ocellatum*, *S. praegnans*, *S. pseudohofmannii*, *S. twymanianum* and *S. zellerianum* from different habitats of Tripura.

Material and Methods:

The sites of present study were different biotopes of Tripura state of India. The Tripura lies between 22°56'-24°32' N latitude and 91°09- 92°20'E longitude (Figure 1A-B). Total 1150 algal samples were collected randomly from different habitats of Tripura. All the collected samples were mixed thoroughly by homogenizer (Remi-RQT-127AD) and transferred into sterilized petridishes (Borosil) filled with nitrogenous and nitrogen deficient liquid and solid BG- 11 culture medium Kant *et al.*, (2005). Total 314 strains were raised containing 110 strains of *Anabaena*; 39 strains of *Trichormus*; 85 strains of *Nostoc*, 80 strains of *Calothrix* and 55 strains of *Scytonema* from Tripura. All the isolated strains of *Anabaena*, *Trichormus*, *Nostoc*, *Calothrix* and *Scytonema* were identified up to the species level with the help of available literatures and monographs (Komárek, 2013).

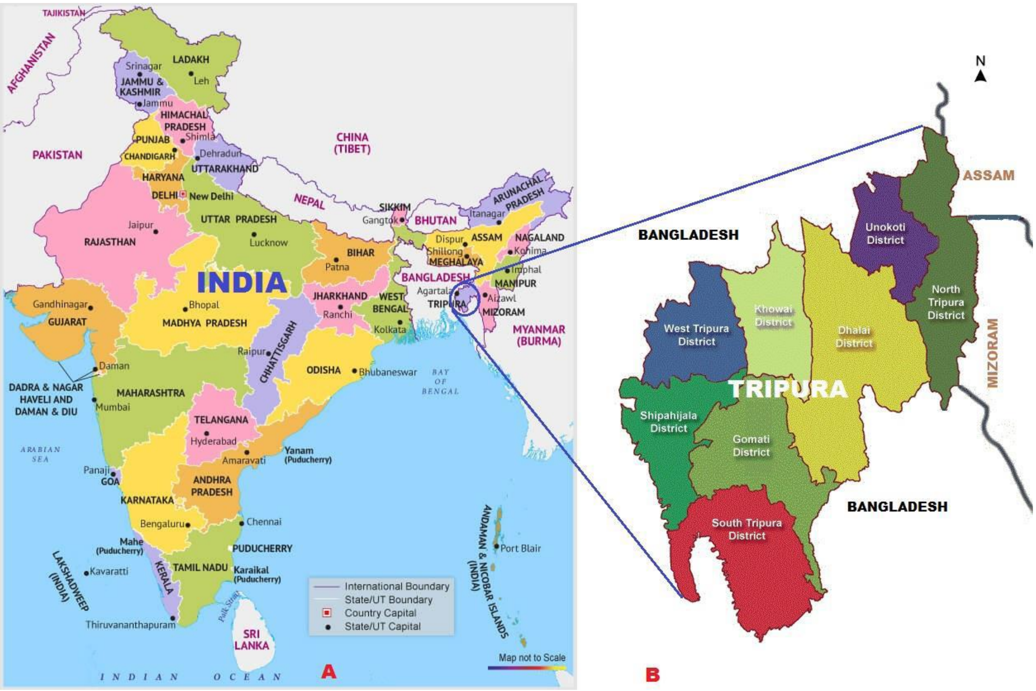

Figure-1 (A-B): (A) Google map of India (B) Map of Tripura showing study area.

Results:

Total 314 strains belonging to five genera including *Anabaena*, *Trichormus*, *Nostoc*, *Calothrix* and *Scytonema* were isolated from different biotopes of eight districts of Tripura and identified up to species level. Of 314 strains, 12 species belonging to the genus *Anabaena* including *A. constricta*; *A. duployae; A. ghosei, A. hieronymii; A. minuta; A. oblonga; A. orientalis; A. papillosa; A. schauderi; A. sedovii; A. spinosa, A. torulosa*; 6 species belonging to the genus *Trichormus* including *T. azollae; T. ellipsosporus; T. gelatinicola; T. minor; T. naviculoides; T. subtropicus*; 17 species belonging to the genus *Nostoc* including *N. calcicola, N. commune, N. ellipsosporum, N. foliaceum, N. gelatinosum, N. halophilum, N. kihlmanii, N. letestui, N. linckia, N. minutissimum, N. minutum, N. muscorum, N. paludosum, N. passerinianum, N. pruniforme, N. punctiforme* and *N. verrucosum* while 19 species belonging to genus *Calothrix* including one forma and one variety *viz. C. aeruginosa, C. breviarticulata, C. clavata, C. clavatoides, C. columbiana, C. conica, C. cylindrica, C. fusca* f. *durabilis, C. fusca, C. geitleri, C. geitonos, C. gloeocola, C. gracilis, C. javanica, C. linearis, C. marchica* v. *intermedia, C. parva, C. scopulorum* and *C. subsimplex* and 10 species of genus *Scytonema* including *S. bivaginatum, S. chengii, S. coactile, S. hormocystum, S. millei, S. ocellatum, S. praegnans, S. pseudohofmannii, S. twymanianum* and *S. zellerianum* from rice field, uncultivated land, moist soil, roof top, tree bark and sub-aerial habitats of eight different districts of Tripura. Detailed list on occurrence and distribution pattern of five different blue-green algal genera is given in Table-1.

Table 1: Showing occurrence and distribution pattern of *Anabaena, Trichormus, Nostoc, Calothrix* and *Scytonema* species and their habitats in Tripura

Species	**Biotopes**	**Occurrence of *Anabaena* species**							
		DL	**GM**	**KW**	**NT**	**SJ**	**ST**	**UK**	**WT**
Anabaena constricta	RF/UL	-	+	+	+	+	+	+	-
A. duployae	RF	+	+	-	+	+	+	+	-
A. ghosei	RF	+	-	+	+	+	+	+	+
A. hieronymii	RF/UL	+	+	+	+	-	+	+	+
A. minuta	RF/UL	-	-	+	+	-	+	+	-
A. oblonga	RF	+	+	+	-	+	+	+	+
A. orientalis	RF/UL	+	-	+	+	+	-	+	+
A. papillosa	RF	+	+	+	+	+	-	+	+
A. schauderi	RF	+	+	+	-	-	-	+	+
A. sedovii	RF	-	+	-	-	-	+	+	-
A. spinosa	RF/UL	-	+	+	-	+	-	+	-
A. torulosa	RF/UL	+	+	+	-	+	-	+	-
		Occurrence of *Trichormus* species							
Trichormus azollae	RF/MS	-	-	+	+	+	+	+	-
T. ellipsosporus	UL	+	-	+	-	-	+	+	+
T. gelatinicola	RF/UL	-	+	+	-	-	+	+	+
T. minor	UL	-	-	+	+	-	-	+	+
T. naviculoides	UL	+	-	+	+	-	-	+	-
T. subtropicus	RF/MS	+	-	-	+	-		+	-
		Occurrence of *Nostoc* species							
Nostoc calcicola	SA/MS/UL	+	+	+	+	+	+	+	+
N. commune	UL/MS	+	+	+	+	+	+	+	+

N. ellipsosporum	UL/ MS	+	-	+	+	-	+	+	+
N. foliaceum	SA/ UL	-	+	-	-	-	+	+	-
N. gelatinosum	UL/MS	+	+	+	+	+	-	+	-
N. halophylum	RF/MS	+	-	-	+	+	-	+	+
N. kihlmanii	UL/MS	-	+	+	+	-	-	+	-
N. letestui	UL/MS	+	+	-	-	+	+	+	-
N. linckia	UL/MS	+	-	+	+	+	+	+	+
N. minutissimum	RF/MS	-	-	+	+	+	-	+	+
N. minutum	RF/MS	-	+	+	+	-	-	+	-
N. muscorum	UL/MS	+	+	+	+	+	+	+	+
N. paludosum	RF/MS	+	+	+	+	+	+	+	+
N. prasserinianum	UL/MS	-	-	-	+	-	-	-	-
N. pruniforme	TB/SA	-	+	+	+	+	+	+	+
N. punctiforme	UL/MS	+	+	+	+	+	+	+	+
N. verrucosum	UL/MS	-	-	-	-	-	-	+	-
		Occurrence of *Calothrix* species							
Calothrix aeruginosa	RF/TB	+	-	+	-	-	+	+	-
C. breviarticulata	UL/RT/BW/TB	-	+	-	+	+	-	+	+
C. clavata	UL	-	+	+	-	+	-	+	+
C. clavatoides	RF/BW/TB	+	+	-	-	-	-	+	+
C. columbiana	UL/BW	+	-	+	-	-	-	-	-
C. conica	RF/UL	-	-	+	-	-	+	+	-
C. cylindrica	BW/TB			+		+	+	+	
C. fusca f. *durabilis*	RT	-	+	-	-	-	-	-	+
C. fusca	RF/UL	-	+	-	+	-	-	+	+
C. geitleri	RF/UL	-	+	-	+	-	-	-	+
C. gelatinosa	RF/UL	+	-	-	-	-	-	+	+
C. gloeocola	UL/BW	+	-	-	-	-	-	+	-
C. gracilis	RF/UL	-	-	-	-	-	-	+	+
C. javanica	RF/UL/TB	-	-	+	+	-	-	+	+
C. linearis	RF/TB	-	-	+	+	-	-	+	-
C. marchica v. *intermedia*	RF/UL/RT/TB	-	-	+	-	+	+	+	-
C. parva	RF/UL/TB	+	-	-	-	+	+	+	-
C. scopulorum	RF/UL/RT/TB	+	-	+	-	-	-	+	+
C. subsimplex	RF/BW	-	-	+	-	-	-	+	+
		Occurrence of *Scytonema* species							
Scytonema hormocystum	RF	-	-	-	-	+	-	+	-
S. millei	RF	+	-	-	-	+	-	+	-
S. zellerianum	TB/SA	+	-	+	-	-	-	+	-
S. coactile	RF	-	-	+	-	-	-	+	+
S. pseudohofmannii	TB/SA	-	+	-	-	-	-	+	+
S. chengii	RF	-	+	-	-	-	-	+	-
S. praegnans	RF	-	-	-	+	-	-	+	-

S. twymanianum	TB/SA	-	-	-	-	+	-	+	-
S. bivaginatum	TB/SA	-	-	-	-	+	-	+	-
S. ocellatum	UL	-	+	-	-	-	-	+	-
		30	30	39	31	29	25	60	32

District wise occurrence of *Anabaena*, Trichormus, *Nostoc*, *Calothrix* and *Scytonema* species in Tripura (DL=Dhalai, GM=Gomati, KW=Khowai, NT= North Tripura, SJ=Sepahijala, ST=South Tripura, UK=Unakoti, WT=West Tripura), RF= Rice Field, UL= Uncultivated Land, MS= Moist Soil, RF=Roof Top, TB=Tree Bark, SA=Sub-aerial

Discussion:

Cyanobacteria (Blue-green Algae) have been most fascinating group of microorganisms since long decade because of their contribution as primary colonizer in the ecosystem and nitrogen fixation (Komárek and Anagnostidis, 1989; Mishra and Pabbi, 2004; Mishra, Srivastava, 2005; Komárek, *et al.*, 2014; Maurya and Paliwal, 2019). The taxonomy of the filamentous heterocystous Blue-green algal genera has been very much disputed due to their many morphotypes and genotypes (Rippka *et al.*, 1979). As the taxonomic entry totally depend on trichome and characteristics of the vegetative cell, heterocyst and akinetes (Komárek, 2013).

In India, the blue-green algae have been explored by numerous phycologists from different states and some of important contribution include Desikachary (1959), Bharadwaja (1963), Pandey and Mitra (1965), Tiwari (1972), Sinha and Mukharjee (1975), Tiwari and Pandey (1976), Prasad and Mehrotra (1980), Anand (1989), Santra (1993), Prasanna *et al.* (2006); Tiwari *et al.* (2007), Roy *et al.* (2015), Singh *et al.* (2016), Snehee and Verma (2018), Maurya and Paliwal (2019) but most of the North Eastern region of India still remains less explored. The rice fields of Tripura have been explored by a few researchers in search for the cyanobacterial diversity Das *et al.*, (2010); Kant (2012); Ghosh *et al.* (2019); Kant *et al.* (2020a,b, 2021a,b, 2022); Sarma *et al.* (2020, 2022a,b) and Bharati *et al.* (2020) worked on the algal flora of major districts of Tripura but information on growth, occurrence and distribution pattern of heterocystous forms including *Anabaena*, *Trichormus*, *Nostoc Calothrix* and *Scytonema* from all the eight districts of Tripura is still unavailable.

From the present communication we are reporting 64 species of five different Nostocalean genera including *Anabaena*, *Trichormus*, *Nostoc*, *Calothrix* and *Scytonema* from eight districts of Tripura. From the present communication on bio-diversity of Nostocalean genera, it was observed that all the eight districts of Tripura, India contains a large number of the members of *Anabaena*, *Trichormus*, *Nostoc*, *Calothrix* and *Scytonema*. Maximum number of species was observed in Unakoti Tripura while minimum number of species was observed in South Tripura.

Conclusion:

On the basis of field's survey and collection of blue-green algal growth samples, and culturing and their morphological observations, it is concluded that, Tripura harbor a good number of heterocystous cyanobacteria. Further, it is also concluded that occurrence of *Anabaena*, *Trichormus*, *Nostoc*, *Calothrix* and *Scytonema* are comparatively more in numbers, which may be used as bioinoculants in the rice fields of Tripura and but needs more thorough study before using them as biofertilizers.

Acknowledgement:

The authors are thankful to Dr. G.L. Tiwari, Ex. Professor and Head, Botany Department, Allahabad University, Prayagraj, India for identification of *Anabaena*, *Trichormus*, *Nostoc*, *Calothrix* and *Scytonema* species.

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ICT TOOLS USED TO PROTECT WILDLIFE IN INDIA: APPLICATIONS AND EXAMPLES

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Abstract:

The use of Information and Communication Technology (ICT) in wildlife conservation has revolutionized how we monitor, protect, and manage biodiversity. India, with its diverse ecosystems and vast wildlife populations, faces significant challenges in conservation due to habitat loss, human-wildlife conflict, and poaching. ICT tools such as camera traps, GPS tracking, drones, geospatial technology, and artificial intelligence provide innovative solutions to these issues. This chapter explores various ICT tools used in India, their specific applications, and examples of their successful implementation, highlighting their role in safeguarding the country's unique biodiversity.

Introduction:

India is home to some of the most biodiverse ecosystems in the world, ranging from the Himalayan mountains to tropical rainforests and mangrove swamps. However, threats such as habitat destruction, illegal wildlife trade, and climate change pose significant challenges to conservation efforts. ICT tools have emerged as indispensable resources in addressing these challenges. These technologies enable more efficient data collection, real-time monitoring, and improved enforcement of conservation policies.

ICT tools and their applications in wildlife conservation

1. Camera traps

Application: Camera traps are widely used to monitor wildlife populations, capture behavioral data, and identify species in remote areas without human interference.

Example: In Panna Tiger Reserve, Madhya Pradesh, camera traps were used to monitor tiger reintroduction efforts. These devices captured images of tigers to track their population recovery and understand their behavior post-reintroduction.

Impact: They provide non-invasive methods to gather critical data for species conservation, especially for elusive and nocturnal animals.

2. GPS and satellite tracking

Application: GPS collars and satellite tracking help monitor animal movements, migration routes, and habitat utilization, which is crucial for managing species prone to human-wildlife conflict.

Example: GPS collars on Indian elephants in Kerala have been instrumental in tracking their migration paths, helping authorities mitigate conflicts with local communities.

Impact: These tools facilitate the creation of wildlife corridors, ensuring the safe movement of species across fragmented habitats.

3. Drones

Application: Drones provide aerial views for monitoring wildlife in inaccessible areas and detecting poaching or deforestation activities.

Example: In Kaziranga National Park, Assam, drones are used to monitor rhino populations and deter poachers in real-time.

Impact: Drones enable rapid responses to illegal activities and reduce the need for extensive ground patrols in challenging terrains.

4. Acoustic sensors

Application: Acoustic sensors record sounds to monitor species presence and detect environmental threats such as illegal logging.

Example: In the Western Ghats, acoustic sensors monitor bird and amphibian populations, providing valuable data on ecosystem health.

Impact: These devices help detect changes in biodiversity and alert authorities to potential threats to habitats.

5. Geospatial Technology (GIS)

Application: Geographic Information Systems (GIS) map and analyze habitats, monitor land-use changes, and assess the impact of human activities on wildlife.

Example: GIS mapping in the Sundarbans helps track habitat loss and plan conservation strategies for the Bengal tiger.

Impact: GIS supports targeted interventions by visualizing critical wildlife corridors and areas under threat.

6. Mobile apps and citizen science platforms

Application: Mobile applications and platforms engage citizens in reporting wildlife sightings, contributing to data collection and conservation awareness.

Example: The "HawkEye" app in Karnataka enables citizens to document animal movements and report illegal activities, involving the public in wildlife conservation.

Impact: These tools empower communities and create large-scale databases for biodiversity monitoring.

7. Artificial Intelligence (ai) and machine learning

Application: AI algorithms analyze large datasets such as camera trap images or sound recordings to identify species and estimate populations.

Example: AI models used in Gir National Park help track Asiatic lions by identifying individuals based on images.

Impact: AI reduces the time and labor required for data analysis, allowing conservationists to focus on implementing strategies.

8. RFID and biometric tools

Application: RFID tags and biometric tools track individual animals, monitor population health, and prevent poaching.

Example: RFID tags on sea turtles in Odisha provide data on their migration and nesting behaviors.

Impact: These tools are crucial for studying endangered species and managing breeding programs.

9. Anti-poaching technologies

Application: Advanced technologies like ShotSpotter detect poaching activities and alert authorities in real-time.

Example: ShotSpotter is used in Tadoba-Andhari Tiger Reserve, Maharashtra, to detect gunshots and prevent poaching incidents.

Impact: These systems strengthen anti-poaching measures, ensuring the safety of endangered species.

10. Remote sensing

Application: Satellite imagery is used to monitor deforestation, habitat loss, and climate impact on ecosystems.

Example: Remote sensing data in the Himalayas is used to track snow leopard habitats and assess the impact of environmental changes.

Impact: Remote sensing provides large-scale insights into environmental trends, guiding conservation policies.

11. Blockchain for wildlife trade monitoring

Application: Blockchain technology ensures traceability and transparency in wildlife trade, reducing illegal trafficking.

Example: India has begun exploring blockchain solutions to track ivory and other wildlife products, ensuring legal compliance.

Impact: Blockchain creates an accountable system, deterring illegal trade and supporting conservation laws.

Challenges and Limitations

Despite their advantages, ICT tools face several challenges in implementation:

- High costs and maintenance requirements.
- Limited access to remote areas due to connectivity issues.
- Need for training and capacity-building for forest officials and local communities.
- Ethical concerns over invasive tracking methods and data privacy.

Conclusion and Future directions

ICT tools have transformed wildlife conservation efforts in India, offering innovative solutions to long-standing challenges. By improving data collection, enabling real-time monitoring, and fostering community involvement, these tools enhance conservation outcomes. Future advancements in AI, machine learning, and blockchain technology promise to address current limitations and further strengthen wildlife protection initiatives. Increased investment, training, and collaboration will be essential to fully leverage the potential of ICT in conservation.

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AN ETHNOBOTANICAL STUDY OF TRADITIONAL MEDICINAL PLANTS USED TO TREAT HELMINTHIC DISEASES IN TRIPURA

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Abstract:

Tripura owns diverse group of indigenous people, including the Tripuri, Reang, Noatia, Jamatia, Halam, Kuki, Chaimal, Uchai, Khasia, Garo, Chakma, Lushai, Bhutia, Mog, Lepcha, Bhill, Munda, Oraon, and Santhal. They have comprehensive folk medicine knowledge for treating various ailmentswhich they have acquired through practice and experience in their protracted scuffle with disease and the inconsiderate natural environment. Medicinal plants are an integral part of health care systems and proper documentation of these plants with utmost care is the key step for the preservation of indigenous knowledge, identification of bioactive compounds, and the eventual discovery of novel medicinal plant species. A variety of traditional medicinal plants has been widely used by different indigenous people in Tripura for the treatment of helminthic disease. Data were collected using semi-structured questionnaires, group discussions, and field observation. In general, the study area is rich in medicinal plants that have a significant role in the management ofhelminthic disease. This is reflected in the high diversity of the recorded species used for medicinal purposes. Pharmacological studies on the plants with high percentage use values and fidelity levels are needed to validate for therapeutic applications. Further research should be carried out in aiming isolation and characterization of the plant's active compounds which may be helpful for the discovery of new potential antihelminthic drugs.

Keyword: Medicinal Plants, Fidelity Level, Therapeutic Application

Introduction:

Ethnobotany is the study of medicinal plants and their practical uses by local communities based on the traditional knowledge of local culture and people Alam *et al.* (2019). Indigenous people have the knowledge regarding the mode of preparation of medicinal preparation by using the native plants from the wild or home gardens which have enormous values in present pharmaceutical medicine Pandey and Tripathi (2017). Most of the modern society and lifestyle diseases such as vitality, diabetes, memory loss, etc, which are generally not cured through allopathic medicine, can be overcome by using herbal medicine Kanta *et al.* (2018). The indigenous knowledge of medicinal plants came into existence when humans started to learn how to use the traditional knowledge of medicinal plants Birhane *et al.* (2011). India harbors around 17,000 plant species, of which 7500 are known aspharmaceutical plants Ray *et al.* (2010).

In indigenous knowledge, it is quite common to use many medicinal plants having antihelminthic properties, generally in tropical developing countries, including India. It is in this context that people consume several plants or plant-derived preparations to cure helminthes infectionsTemjenmongla and Yadav (2005). Intestinal helminthes are one of the most common causes of infection in human, especially in tropical and subtropical countries. The cost of harbouring this parasite in terms of human misery and economic loss is inestimableSavioli *et al.* (1992). Parasite helminthes count as the major globally important pathogen with a significant reduction in protein production and malnutrition, causing prominent economic losses and intimidating food security in developing and tropical countries Jazani *et al.* (2018). Globally, over 3.5 billion people are infected with intestinal worms, of which children betw.een 5-15 years account for the highest infection rate of about 400 million cases of worm burden that are mainly attributed to poor sanitation and hygiene Yadav and Tangpu (2011). Several plants have been screened against parasitic diseases particularly helminthiasis. Helminths infections are generally chronic and debilitating in nature in humans. In animals, the disease manifests clinically as in appetence, lethargy, dullness, loss of generalbody condition, rough hair coat, pallor of mucous membrane, depression and anemia. The disease results in loss of behavior, reduced growth rates, low enrichment, low birth weight, waned animal products such as milk, wool, meat, hide, and skinEnejoh*et al.* (2015). The scarcity of pharmaceutical plants is not a big issue in countries like India, which is having wealthy agroclimatic zones, ethnic knowledge, and ethnical biodiversity Milind *et al.* (2012).

In Tripura, there has been no report on ethnomedicinal plants having antihelminthic property prompted us to carry out this present study aiming to document the potential phytoresources available and their mode of preparation for treating the patients suffering from helminthic disease.

Materials and Methods:

Study area

Tripura is the third smallest state of India, located in the Biogeographic zone of 9B- North East Hills between 22º56 and 24º56′ N latitude and between 90º09 and 92º20′ E longitude. The total area of the state is 10,497.69 sq. km. In Tripura, 19 tribal communities *viz.*, Tripuri, Reang, Noatia, Jamatia, Halam, Kuki, Chaimal, Uchai, Khasia, Garo, Chakma, Lushai, Bhutia, Mog, Lepcha, Bhill, Munda, Oraon, and Santhalare residing. Each community has their unique socio-cultural heritage, language and food habits. Most importantly they have their own traditional knowledge for treating various ailments as they are largely dependent on their own medicinal system rather than modern health care system.

Ethnobotanical survey

The ethnobotanical investigation was conducted in the different districts of Tripura during the period from August 2019 to March 2020. Frequent field surveys were conducted to the selected study area to build up an understanding with the head of the forest dwellers and traditional healer as they are enriched with the traditional knowledge. The information concerning antihelminthic activity of plantswas noted down by a discussion with them. Repeated queries were made for confirmation of data gathered on each plant and cross-checked for reaffirmation. The information was collected from 80 indigenous peoples including traditional healers, family head and other experience person. Questionnaires' were used to collect local name, parts of plant used, mode of preparation and application. We have also recorded the recommended dose and timing for consumption of the preparation and other ingredients (if any) used for preparation. Each of the selected plant material was collected during its flowering and fruiting stage from their natural habitat and taken into the laboratory of Department of the Forestry and Biodiversity, Tripura University for identification and further processing of the samples. Each plant species were identified using flora of Tripura Deb (1983, 1985).

Fidelity Level (FL) value

The fidelity level (FL), the percentage of informants claiming the use of a certain plants for the same major purpose was calculated according to the following formula Tumoroand Maryo (2016)

$$\text{FL} = \frac{I_p}{I_u} \times 100$$

Where, I_p is the number of informants who independently suggested the use of a plant species for a particular disease and I_u is the total number of informants who mentioned the same plant for any disease.

Results and Discussion:

Table 1: Demographic data of informants

Category	Age group	n	Percentage
Age	Under 50	10	12.5
	50-60	29	36.25
	60-70	24	30
	Above 70	17	21.25
Sex	Male	62	77.5
	Female	18	22.5
Ethnic tribe	Debbarma	10	12.5
	Chakma	14	17.5
	Reang	12	15
	Halam	6	7.5
	Tripura	8	10
	Darlong	5	6.25
	Jamatia	9	11.25
	Mog	6	7.5
	Kalai	4	5
	Mizo	3	3.75
	Garo	3	3.75

n=number of informants

Table 2: List of antihelminthicplants, mode of preparation and established pharmacological evidences

Botanical Name	Local Name	Part Using	Tribe Using	Other Ingredient Used	F%	Dosages and Mode of Preparation	Pharmacological Evidences
Azadirachta indica (L.) Benth.	Neem	Leaves	Debbarma Reang Halam Jamatia Kalai Chakma Darlong Mog	No	47.5	Grind the leaves and take the juice and take one cup of these juice in empty stomach in early morning.	Neem leaf powder at 500mg/kg body weight showed significant decrease eggs per gram (EPG) after 7 days of treatment Jamra *et al.* (2014) Aqueous and ethanol extracts of the bark significantly exhibited paralysis inworms in lower dose 50 mg/ml and also caused death of worms especially at higher concentration of 100 mg/ml Hogade *et al.* (2014).
Ananas comosus (L.) Merr.	Pineapple	Leaves	Debbarma Reang Halam Chakma Darlong	No	56.25	Paste the lower part of the leaves and take the juice and take one cup of these juice in empty stomach in early morning.	Ethanolic extracts significantly decreased larval counts of *Haemonchuscontortus* Ahmed *et al.* (2013).
Parkia timoriana (DC.) Merr.	Tree bean	Fruit	Debbarma Halam	No	8.75	Dishes for food	-
Andrographis paniculata (Burm.f.) Wall. ex Nees	Chireta	Leaves	Debbarma Kalai Reang Jamatia Halam Darlong Chakma	Warm water	26.25	Grind the leaves to extract juice and mix it with warm water and take one cup of these juice in empty stomach in early morning.	The aqueous and methanolic extractsexhibited significant antihelminthic activity against adultearth worms (*Phertimaprosthuma*) at different concentrations (25, 50, 75mg/ml) Venkata *et al.* (2011)
Solanum indicum	Nightshade	Fruit	Debbarma	Dry fish,	3.75	Boil the fruit, with	Ethylacetate extract showed significant

L.	plant			Potato, green chilli		potato, dry fish green chilli and mix salt in water, after 15-20 minute later grind the whole ingredients and it is used for food dishes.	antihelminthic effect with high death rate of worms at hourly interval at a concentration of 0.05 mg/mlagainst sheep intestinal worms *Haemonchuscontortus* Zeb *et al.* (2013)
Oroxylum indicum (L.) Kurz	Broken bones tree, Oroxylum	Fruit, Flower	DebbarmaTripura Halam Chakma	Dry fish, Green chilli, salt	7.5	Boil the Fruit and flower, with dry fish, green chilli and mix with salt in water after 15-20 minute later the entire ingredient it is used for dishes.	Methanolic extract of bark at 1000 mg/kg caused 79.3 % reduction in EPG counts and 70.8 % of reduction in worm counts. Deoriand Yadav (2016).
Leucas aspera (Willd.) Link	Leucas	Whole plant	Debbarma Reang	No	11.25	Dishes for food	Aqueous extract at 250 mg/ml concentration showed efficient antihelminthic activity against *Pherithemaposthuma* Agarwal *et al.* (2011)
Centella asiatica (L.) Urb.	Centella	Whole plant	Debbarma Reang Jamatia Chakma	No	2.5	Grind the leaves take the juice and take one cup of this juice in empty stomach in early morning.	Petroleum ether leaf extracts showed strongest activity. The worms stay alive in this extract only for the period of 2 hours Aftab *et al.* (2017)
Nyctanthes arbor-tristis L.	Sepalika	Leaves	Debbarma Halam	No	28.75	Grind the leaves to the extract juice and take one cup of this juice in empty stomach in early morning.	The ethanolic extracts seeds andflowers exhibited to cause lethal effect at the concentration of 2 and 5 mg/ml, whereas the leaves and barks showed lethal effect on the worms at 5mg/ml only Sanjita *et al.* (2010)

Syzygium cumini (L.) Skeels	Java Plum (Indian blackberry)	Leaves/Fruit	Debbarma	No	23.75	Grind the leaves/Fruit and take the juice take one cup of this juice in empty stomach in early morning.	Methanolic extract of leaves required 8 minutes for paralysis and 15 minutes for death at dose of 100 mg/mL against Tape worms and Red worms Aqsa *et al.* (2020).
Carica papaya L.	Papaya	Seeds/Fruit	Debbarma Chakma Reang Darlong	Honey	46.25	Mix one tablespoon each of fresh raw papaya juice and honey with three or four tablespoon of hot water. Drink it in the morning on an empty stomach.	Ethanolicextracts of the leaves expressed a demonstrated paralysis significantly, and alsoliable for the death of *P. cervi* and *H. contortus* specially at the upper concentration (100%) Rabiul *et al.* (2019)
Momordica charantia L.	Bitter guard	Leaves/Fruit	Debbarma	No	5	Grind the root and take the juice one cup in empty stomach in early morning.	Aqueous,Petroleum ether, chloroform and ethanol extracts at concentration of 20 mg/mL showed significant antihelminthic activity. Ethanol extract exhibited paralysis within 3 min and death within 8 min against *Pheretimaposthuma*Vedamurthy *et al.* (2015)
Zingiber officinale Roscoe	Ginger	Rhizome	Debbarma Darlong Halam Chakma	Warm water	1.25	Grind the seeds and take the powder mix with warm water take the juice in empty stomach in early morning	Crude powder and crude aqueous extract exhibited a dose- and a time-dependent antihelminthic effect with respective maximum reduction of 25.6% and 66.6% in eggs per gram (EPG) of faeces on day 10 of post-treatmentIqbal *et al.* (2006).
Citrus medica L.	Citron	Seeds	Debbarma Halam	Water	1.25	Grind the seeds take the powder mix with water take the juice in empty stomach in early	Various concentrations (20-80 mg/ml) of the petroleum ether extract exhibit potentiate to paralyze earthworm and also caused its death after some time. The

						morning.	shortest time of paralysis and time of death was observed at higher dose (80 mg/ml) of petroleum ether extract was found to 30.86 min. Bairagi *et al.* (2011)
Citrus maxima (Burm.) Merr.	Pomelo	Seeds	Chakma Tripura	No	1.25	Grind the leaves and take the juice take one cup of these juice in empty stomach in early morning	-
Mentha piperita L.	Mint	Leaves	Reang Jamatia Halam	No	1.25	Grind the leaves and takes the juice take one cup of these juice in empty stomach in early morning.	Methanol extracts of leaves, stems and roots exhibited considerable antihelminthic activities. Stem extract showed more active than other parts Girme *et al.* (2006)
Psidium guajava L.	Guava	Leaves	Debbarma Reang Jamatia Chakma Halam	Warm water	12.5	Takes the leaves boiling in warm water takes the juice and take one glass of this juice in empty stomach in early morning.	Butanolicextract at the concentration of 12.5mg/ml exhibitedboth paralysis and death in 17.85 & 38.50 minute respectively against *Pherithimaposthuma*. Ismail *et al.* (2012)
Adhatoda zeylanica Medik. (Synonym: *Justicia adhatoda* L.)	Basak	Leaves	Chakma Reang Darlong	No	20	Takes the leaves and climbers take the juice and take one cup of this juice in empty stomach in early morning.	Various doses of ethanolic extractswere able to show antihelminthic activity at 10mg/mL concentration against *Pheretimaposthuma* Alam *et al. (*2010).
Tinospora cordifolia (Willd.) Hook.f. & Thomson	Heart leaved moonseed	Leaves	Debbarma Mog Chakma	No	7.5	Grind the bark and take the juice and take one cup of this juice in empty stomach in early morning.	Ethanolic and aqueous extracts of stem exhibited very significant activities at 100 mg/ml concentration Tiwari *et al.* (2011)

Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Arjuna	Seeds	Debbarma	No	1.25	Used for food	LC50 values of methanolic extract in egg hatch and larval development of *Haemonchuscontortus* found to be 645.65 and 467.74 µg mL-1, respectively Bachaya *et al.* (2009)
Curcuma longa L.	Turmeric	Rhizome	Halam Debbarma	No	2.5	Dishes for food.	Methanolic and aqueous extract of rhizome exhibited paralysis as well as the death of the worms within 12 h at 10 mg/mL concentration (Pandey *et al.* 2018)
Moringa oleifera Lam.	Drum stick	Fruit/seeds/ Flower/Lea ves	Debbarma Chakma Jamatia Reang Darlong	No	1.25	Grind the leaves take the juice andtake one cup of these juice in empty stomach in early morning.	Ethanolic and aqueous extracts of seeds against *H. contortus* eggs showed 95.89% and 81.72% egg hatch inhibition at 15.6 mg/mL, respectively. In case of larvae, the ethanolic and aqueous extracts showed 56.94% and 92.50% efficacy at 7.8 mg/mL, respectively Cabardo *et al.* (2017)
Aloe vera (L.) Burm.f.	Alovera	Leaves	Debbarma Halam Mog	Warm water	1.25	Takes the leaves and boiling in water and take one cup of these juices in empty stomach in early morning.	Aqueous and ethanolic extract showed potent antihelminthic activity against gastrointestinal nematodes of sheep. 50%egg hatch inhibition was found to be 0.57mg/ml concentration Meenakshisundaram *et al.* (2017)
Ocimum tenuiflorum L.	Tulsi	Leaves	Halam Darlong Debbarma	No	1.25	Takes the leaves and grind the leaves and takes of these paste juice in empty stomach in early morning.	Aqueous extractexhibit potent antihelminthic activity against intestinal round worm parasites of humans. Extract took 145±14 minutes to paralyze and 223+11 minutes to death of the worm Madhavulu *et al.* (2015)
Capsicum annuum L.	Chilli	Fruit	Chakma Reang	No	1.25	Dishes for food.	-

Neptunia oleracea Lour.	Water mimosa	Whole plant	Debbarma	No	2.5	Dishes for food.	-
Acmella paniculata (Wall. ex DC.) R.K. Jansen	Marsh para cress	Whole plant	Debbarma Halam Tripura Chakma	Warm water	1.25	Grind the seeds and take the powder with warm water and take the juice in empty stomach in early morning.	Different concentration of (15mg/ml, 7.5mg/ml and 22.5mg/ml)pet ether, chloroform, methanoland ethyl acetate extracts of the whole plant exhibited potent antihelminthic activity Rajeshwar andLalitha (2013)
Artocarpus chaplasha Roxb.	Chamal	Seeds	Mog, Chakma	No	3.75	Dishes for food	-
Corchorus olitorius L.	Jute	Leaves	Jamatia kalai	Warm water	2.5	Grind the garlic take the juice mix with some warm water and take the juice one cup in empty stomach in early morning.	-
Allium sativum L.	Garlic	Rhizome	Halam Debbarma	No	2.5	Grind the onion & take the juice & drink the one cup in empty stomach in early morning.	Ethanolic extract affected the survival of 100% of *Ancylostomacaninum* larvae at 156 µg/ml concentration Orengo *et al.* (2016)
Allium cepa L.	Onion	Rhizome	Debbarma Reang	No	1.25	Grind the whole plant take the juice one cup in empty stomach in early morning	Ethanolic extract affected the survival of 100% of *Ancylostomacaninum* larvae at 156 µg/ml concentration Orengo *et al.* (2016)
Scoparia dulcis L.	Goat weed	Whole plant	Chakma	No	5	Paste the whole plant and take juice of these paste one cup in empty stomach in early morning.	Chloroform and ethanol leaf extract showed potent antihelminthicactivity against the Indian earthworm *Pheretimaposthuma* Kumar and Kumari (2017).

Cucurbita maxima Duchesne	Pumpkin	Seeds	Debbarma Tripura	No	2.5	Used for food.	Seed has high antihelminthic activity against Erol *et al*. (2015)
Physalis minima L.	Native goose berry	Fruit	TripuraHal am	No	3.75	Dishes for food	-
Portulaca oleracea L.	Common purslane	Whole plant	Debbarma Reang	No	2.5	Dishes for food	Ethanol extract showed potent activity at 100mglml concentration against *Pheretimaposthuma*. Extract required time to paralysis 1.96 minute and 4.96 death Mutha *et al*. (2012)
Bauhinia variegata L.	Mountain ebony	Bark	Reang	Honey	5	Grind the bark and take the juice and mix with honey and drink the juice in empty stomach in early morning.	The methanolic extract of leaf showing 80% mortality at 1000µg/ml concentration of 5 hour incubation against mature*Haemonchuscontortus* Anita *et al*. (2005)
Borassus flabellifer L.	Palmyra palm	Root	Debbarma Reang	No	1.25	Paste the root and take the juice and drink it in the morning on an empty stomach.	Leaves showed potent antihelminthic activity against*Pheretimaposthuma*at 50 mg/mL concentration Jamkhande *et al*. (2014)
Clerodendrum infortunatum L.	Glory bower	Root/ Leaves	Jamatia Halam	No	10	Grind the root and leaves to extract juice take the	The ethanolic and aqueous extracts of leaves and roots showed potential antihelminthic activity against *Pheretimaposthuma* and *Ascardiagalli*. Ethanolic extract of root exhibited good antihelminthic activity at 200 mg/ml concentration Das *et al*. (2011)
Careya arborea Roxb.	Slow match tree	Bark	Chakma Mog	No	1.25	Paste the bark and take one cup of this paste in empty stomach in early morning.	-

Cleome viscosa L.	Wild Mustard	Seeds	Debbarma Reang	Warm water	2.5	Grind the seeds take the powder and mix it with warm water and drink it in empty stomach in morning.	The methanol extract exhibited significant antihelminthic activity at a concentration of 2000 µg/ml Pillai and Nair (2011)
Coccinia grandis (L.) Voigt	Ivy gourd	Whole Plant	Darlong Halam Chakma	No	5	Dishes for food.	Methanolic extract showed potent activity at 10mg/ml concentration Dewanjee *et al.* (2007)
Vernonia cinerea (L.) Less.	Purple fleabane	Root	Reang Chakma	No	1.25	Paste the root and take the juice and drink it one cup of these juice in empty stomach in early morning.	-
Enhydra fluctuans Lour.	Water cress	Whole Plant	Tripura Chakma	No	1.25	Dishes for food	-
Averrhoa carambola L.	Star fruit	Leaves	Debbarma	No	5	Grind the leaves take the juice of these paste drink it in empty stomach.	Aqueous acetone extract (100mg/ml) took 40.60 and 57.30 minutes for paralysis and death respectively Jyoti *et al.* (2015)
Annona squamosa L.	Sugar apple	Fruit	Debbarma, Tripura	No	13.75	Dishes for fruit	The aqueous extract of the leaves (400, 800, 1200 µg/mL) showed significant antihelminthic activityChoudhary (2007)
Annona reticulata L.	Wild sweetstop	Fruit	Tripura Reang	No	1.25	Dishes for fruit	Ethanol extract showed significant antihelminthic activity at 20 mg/ml concentrations Nirmal *et al.* (2010)
Alstonia scholaris (L.) R. Br.	Blackboard tree	Bark	Chakma Reang	Honey	3.75	Paste the bark take the juice and mix with one spoon of honey and drink it.	Petroleum ether,chloroform, ethanol and aqueous extracts at 20 mg/ml exhibited significant antihelminthic activity Kumar *et al.* (2013)

Amaranthus spinosus L.	Spiny amaranth	Whole plant	Reang Tripura	No	1.25	Dishes for food	Water extracts of whole plant showed dose-dependent antihelminthic activity and very effective at 50 mg/ml concentration against *Tubifextubifex* Baral *et al.* (2010)
Anacardium occidentale L.	Cashew	Fruit	Debbarma Chakma	No	2.5	Dishes for fruit	The LC_{50} values of acetone extract was 0.311 and 1.72mg/ml for egg hatch and larval viability test, respectively Ademola (2011)
Oxalis corniculata L.	Yellow sorrel	Whole plant	Reang Chakma	No	3.75	Dishes for food	*Oxalis corniculata* has potent antihelminthic activity Badwaik *et al.* (2011)
Phyllanthus acidus (L.) Skeels	Malay gooseberry	Root	Tripura Halam	No	8.75	Grind the root take the juice of these paste and drink it in empty stomach in early moring	-
Sesamum indicum L.	Benne	Leaves	Debbarma Reang Chakma	No	2.5	Paste the leaves take the juice and drink it in empty stomach	Ethanolic and petroleum ether extract of seeds exhibited potent antihelminthic activity against *Pheretimaposthuma*at 200 mg/ml Bhandare (2018)
Syzygium jambos (L.) Alston	Rose apple	Laves/Fruit /Bark	Chakma Tripura Mog	No	1.25	Young leaves and fruit used for food, bark water extract is taken	-

Table 3: Percentage contribution of plant families

Name of the families	No. of species	% of species	Name of the families	No. of species	% of species
Acanthaceae	2	3.77	Caricaceae	**1**	1.89
Amaranthaceae	1	1.89	Combretaceae	**1**	1.89
Amaryllidaceae	2	3.77	Cucurbitaceae	**3**	5.66
Anacardiaceae	1	1.89	Labiatae	**1**	1.89
Annonaceae	2	3.77	Lamiaceae	**2**	3.77
Apiaceae	1	1.89	Lecythidaceae	**1**	1.89
Apocynaceae	1	1.89	Meliaceae	**1**	1.89
Arecaceae	1	1.89	Menispermaceae	**1**	1.89
Asphodelaceae	1	1.89	Mimosaceae	**2**	3.77
Asteraceae	3	5.66	Moraceae	**1**	1.89
Bignoniaceae	1	1.89	Moringaceae	**1**	1.89
Bromeliaceae	1	1.89	Myrtaceae	**3**	5.66
Caesalpiniaceae	1	1.89	Nyctanthaceae	**1**	1.89
Capparaceae	1	1.89	Scrophulariaceae	**1**	1.89
Oxalidaceae	2	3.77	Solanaceae	**3**	5.66
Pedaliacea	1	1.89	Verbenaceae	**1**	1.89
Phyllanthaceae	1	1.89	Zingiberaceae	**2**	3.77
Portulaceae	1	1.89			
Rutaceae	2	3.77			

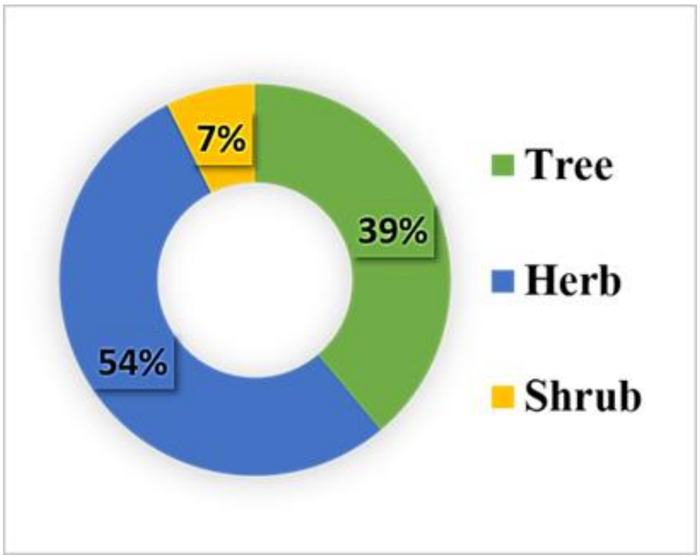

Figure 1: Habitat wise contribution of plant

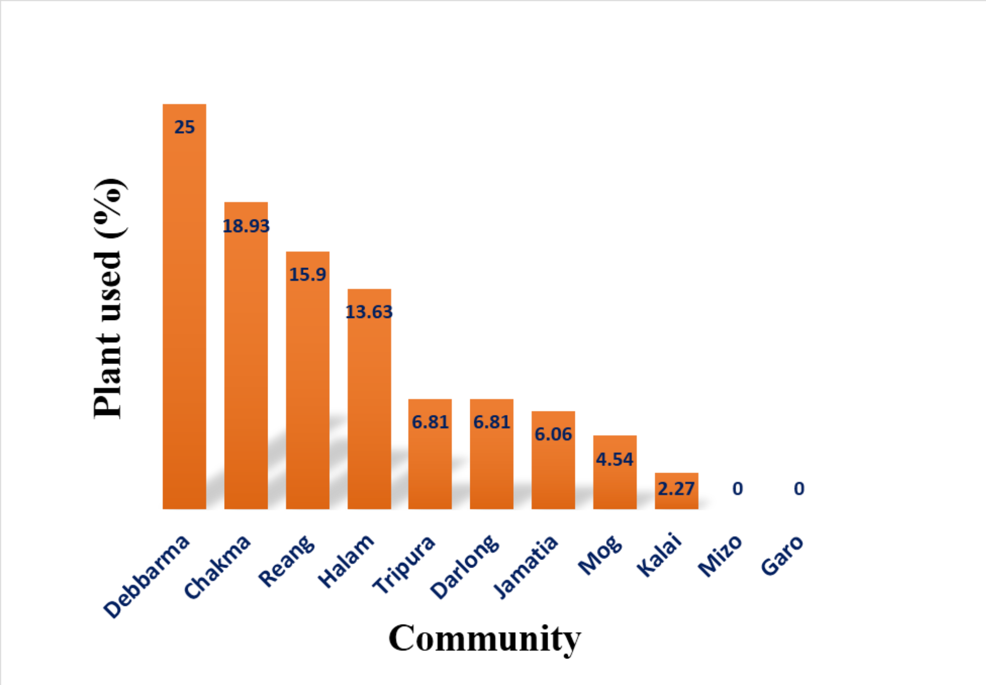

Figure 2: Percentage of plant used by different ethnic communities

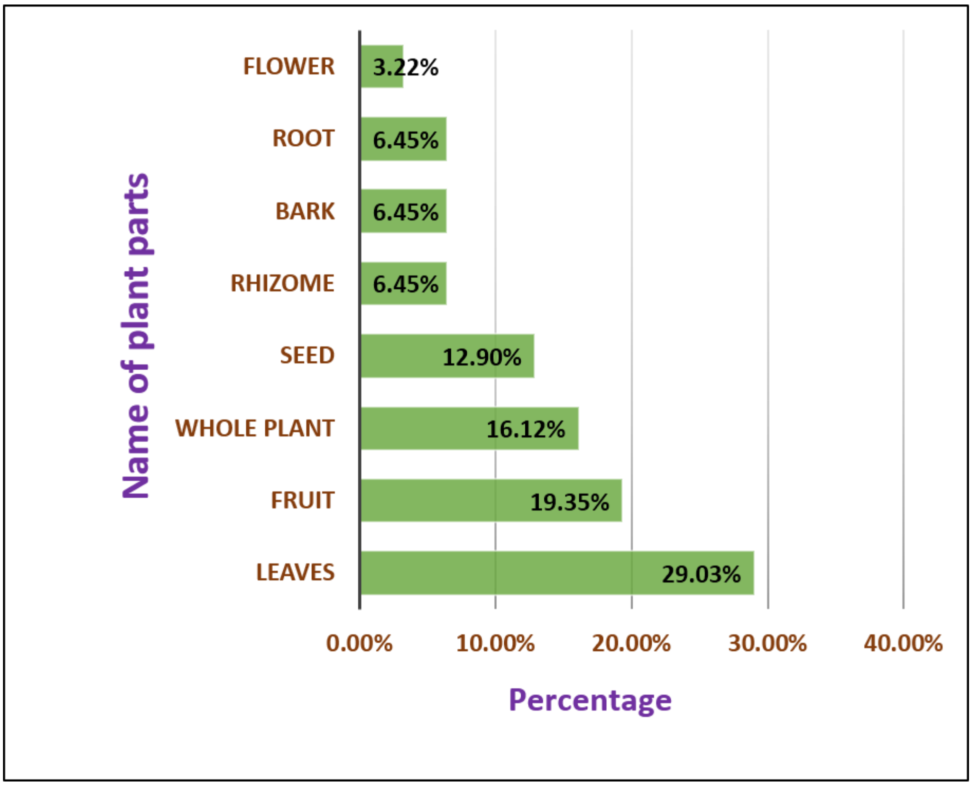

Figure 3: Percentage contribution of different plant parts used in the medicine preparation

Discussion:

In the present investigation, a total number of 53 plant species (29 Herbs, Tree 21, Shrubs 3), belonging to 37 families, and 45 genera were discovered used by the tribal people of Tripura. Based on the family dominance, Cucurbitaceae (3), and Solanaceae (3) is found to be most widely used family followed by family Zingiberaceae (3), and Acanthaceae (2), and Apocynaceae (1), Scrophulariaceae (1), Labiate (1), Combretaceae (1), Verbanaceae (1), and Malvaceae (1). However many families such as

Asteraceae and Myrtaceae (3), and Rutaceae, Lamiaceae, Oxalidaceae, Amaryllidaceae and Annonaeae (2), and such as Apiaceae, Nyctanthacae, Caricaceae, Menispermaceae, Moringaceae, Liliaceae, moraceae, portulaceae, Casalpiniaceae, Arecaceae, Lecythidaceae, Capparacae, Amaranthaceae, Anacardiaceae, Phylanthaceae, and Pedaliaceae are represented by one species each. They used various parts of the plant such as Leaves, Fruit, whole plant, seed, rhizome, bark, root, flower. Were most frequently used followed by Leaves (29.03%), fruit (19.35%), whole plant (16.12%), seed (12.90%), rhizome, bark and root (6.45%) and Flower (3.22%). women are so active more than men in the field of usage antihelminthic plants. In most rural areas, indigenous women know how to use the antihelminthic plants compared to the indigenous men. Also, the usage of antihelminthic plants is more among the Debbarma (25%), Chakma (18.93%), Reang (15.93%), Halam (13.63%) tribes, and usage of antihelminthic plants is less among the Tripura and Darlong (6.83%), Jamatia (6.06%), Mog (4.54%), Kalai (2.27%). No information regarding the usage of antihelminthic plants could be found fromthe Mizo and Garo tribes.The factors responsible for this may be due to urbanization and better health facilities of medical science.The present survey similar to the other survey done on antihelminthic plants used for treatment of worm infections in Nagaland, North-east Temjenmongla and Yadav (2005), Gujarat india Mali and Mehta (2008), Manipur, North-east Jiribam sub-division Imphal East Yumnam and Tripathi (2012), Uttar Pradesh, India Bauri *et al.* (2015), Lucknow, India Prakash and Mehrotra (1987), Vellore, India Rajeswari (2014), Kolkata, India Bora *et al.* (2017), Where similar uses of 5 species was found were also reported in the study of anticestodal efficacy of folklore medicinal plants of naga tribes in north-east, India Temjenmongla and Yadav (2005), where similar use of 6 was found, similar finding were also observed in the study conducted in Gujarat india Mali and Mehta (2008), where 5 similar species were found, another similar research on traditional knowledge of eating raw plants by the Meitei of Manipur as medicine/ nutrient supplement in their diet Manipur, North-east India Yumnam and Tripathi (2012), where 7 similar species were found, similar finding were also indicated in the study worked on a review on use of medicinal plants to control parasites in Uttar Pradesh, Bauri *et al.* (2015), where 8 similar species were found on antihelminthic plants in traditional remedies in Lucknow, India Prakash and Mehrotra (1987), where 5 similar species found on antihelminthic activity of plants review in Vellore, India Devi (2014). Also similarity usage of 5 plants species were found on a comprehensive review on *in vitro*antihelminthic activities of some ayurvedic plants Kolkata, India Bora *et al.* (2017). The present study also revealed the present scenario and status of antihelminthic plants and their importance in the ethnic peoples of Tripura.

Conclusion:

The ethnobotanical research conducted on antihelminthic plants found in Tripura is an attempt to update our knowledge on therapeutic applications of different medicinal plants, which are clearly of great importance in the lives of the local inhabitant. The knowledge of the medicinal properties of the plants and how they are used by the indigenous people is a result of the specific geographical location of the study area, high biodiversity, ethnic and cultural differences, and folk traditions that have evolved over the centuries. This study has documented traditional knowledge on treating the helminthes causing ailment to the people of Tripura,which should be preserved to prevent it from being lost and elapsed. The importance of medicinal plants used as foodstuffs and their significance for the local market and exports as well as ecotourism should not be overlooked either.

Acknowledgements:

The authors are thankful to Head, Department of Forestry and Biodiversity for providing the laboratory facilities tocarry out the work.

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Ecology and Biodiversity

ISBN: 978-93-48620-69-9

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