ENVIRONMENT AND DEVELOPMENT

(An Integrated Approach)

Editors

Dr. Debabrata Das

Dr. Pampi Ghosh

Dr. G. Maheswari

Dr. J. K. De

Kripa Drishti Publications, Pune.

ENVIRONMENT
AND
DEVELOPMENT
(AN INTEGRATED APPROACH)

Editors:

Dr. Debabrata Das

Dr. Pampi Ghosh

Dr. G. Maheswari

Dr. J. K. De

Kripa-Drishti Publications, Pune

Book Title: **Environment and Development (An Integrated Approach)**

Editors: **Dr. Debabrata Das, Dr. Pampi Ghosh, Dr. G. Maheswari, Dr. J. K. De**

Authored by: **Tanmay Ghosh, Madhumonti Naskar, Sidhu Murmu, Kanu Murmu, Dr. Goutam Ghosh, S. K. Tripathi, Radha Singh, V. Mala, I. Muthuvel, V. Usha, G. Thirunarayanan, Parthasarathi Rengasamy, Elango Rasavel, Harini Sundaresan, Akash Krishnamoorthy, Kavinilavu Narayanasamy, Elango Rasavel, Dr. Debabrata Das, Atmaja Avirupa Das, Rajkumar Muth, Lenin Rajendran, Dr. Rajabhuvaneswari Ariyamuthu, Dipu Samanta, Samadrita Deb, Chayan Munshi, Koushiki Bhattacharya, Dr. Manoj Kumar, Santhanambika M. S., G. Maheswari, Layana Nelson, Valsala P., Gunavathi V., Santhy, K. S., Zeenath**

1st Edition

ISBN: **978-93-90847-17-4**

9 789390 847174

Published: **December 2021**

Publisher:

KRIPA DRISHTI PUBLICATIONS

Kripa-Drishti Publications

A/ 503, Poorva Height, SNO 148/1A/1/1A,
Sus Road, Pashan- 411021, Pune, Maharashtra, India.
Mob: +91-8007068686
Email: editor@kdpublications.in
Web: https://www.kdpublications.in

About the Editors:

Dr. Debabrata Das

Debabrata Das (b.1969) Ph.D. in Botany (Plant Ecology) from Vidyasagar University, Midnapore, West Bengal is presently working as Associate Professor of Botany and Head, Department of Botany, Government General Degree College, Lalgarh at Binpur-I, Lalgarh, Jhargram, W.B. He acted as IQAC Co-ordinator of the same College and acted as Govt. officer since 2002 under West Bengal Educational Service (W.B.E.S). Before that he served at Jhargram Raj College, Jhargram, West Bengal as lecturer and Assistant Professor from 2002 to 2012. Again he acted as Assistant professor and Associate Professor at P.G. Dept. of Botany, Darjeeling Govt. College, Darjeeling, W.B. up to 2016. He is a pioneer researcher in the College on restoration ecology and also in this lateritic Southwest Bengal zone. He was a research fellow (JRF and SRF) of forest productivity project funded by ICFRE, Dehradun and done his work at southwest Bengal forests from 'Centre for Natural Studies (CNS)' at Raja N.L.Khan Women's College, Midnapore, W.B. Later on he worked as JRF and SRF at Central National Herbarium (CNH), Botanical Survey of India (BSI), Shibpore, Howrah, W.B. under 'Flora India Project'. He has worked in various Medicinal Plants Conservation Areas (MPCAs) as expert with his team at Eastern Himalayan part, Dooars and in South Bengal (Susunia Hills) of W.B. He authored more than 100 scientific research papers and 4 books in Environmental studies and in Botany. He has worked as technical advisors to many scientific national and international journals. Now he is a coordinator of a series of lectures (online) and conferences of many national and international kinds. He also acted as co-ordinators of National and International conferences conducted by various organizations during Covid-19 and during new normal.

Dr. Pampi Ghosh

Dr. Pampi Ghosh (b.1974) is an Assistant Professor of Botany, Seva Bharati Mahavidyalaya, Kapgari, Jhargarm, West Bengal. She was a headmistress at Pasang Girls' High School, Paschim Medinipur 10th December, 2008. Before that she was an Assistant Teacher and served two Govt. aided schools in West Bengal. In the Year 1999, she joined at Jahangirpur High School at Dakshin Dinajpur, W.B. and served there up to August, 2002 and acted as Teacher in Botany. After that she joined at Baidara Janakalyan High School, Uttar Dinajpur in West Bengal as Assistant teacher in Botany up to October 2007. She again transferred to a school and acted as Head Mistress at Pasang Girl's High School in 'Debera Thana of Paschim Medinipur, W.B., in the year 2007. She was actively engaged in various school programmes including Eco-club programme funded by 'Paschim Banga Vigyan Mancha' run by Govt. of West Bengal. She has joined at Seva Bharati Mahavidyalaya, Kapgari, Jhargram, West Bengal, the department of Botany through West Bengal College Service Commission and acted as Lecturer in Botany. After

that, she served as Assistant Professor and actively participated in various programmes like NSS, Environmental field study, research Laboratory visit with students, medicinal plant Garden visit, Institutional Garden like BSI, and NGOs garden visit with many students and other people associated with it. She has completed 2 minor research projects funded by UGC-ERO, Kolkata on Ethno-botany. She also did work on various aspects like soil AM fungi with the supervision of Professor (Dr.) N K Verma, Department of Botany & Forestry, Vidyasagar University, Midnapore, W.B. Many of the works of Dr. Ghosh have been published in reputed scientific journals. She was also co-author of text book in Botany, Soil plants and microbial interactions and other book chapters and acted as co-author since 2008. Her interest on ethno-botany, plant taxonomy, soil AM fungi, experimental plant physiology with bio-fertilizers, medicinal plants, soil borne fungi, socio cultural aspects of marginalized people of West Bengal, Odisha and Jharkhand including ecology.

She also attended many national and international conferences (online) during Covid-19, and also conducting webinar series on "biodiversity' and Environment & development'. Now she is engaged in social activities and posted many scientific events in Flora and Fauna Facebook group as co-admin. Dr. Ghosh is not only actively participated in science research activities but she is doing work in Social Science Research (SSR) particularly on marginalised people. She actively participated in Social science research aimed to develop organic farming, to develop better environment in future and to reduce the house hold waste in a managed way.

Dr. G. Maheswari

Dr. G. Maheswari (b.1975), Assistant Professor (SS), Department of Zoology, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamil Nadu is having teaching and research experience of more than 15 years. Her field of specialization is Stored Product Entomology and working in the management of stored product insects using physical, mechanical methods and botanicals. She presented papers in national and international conferences, published papers in national and international peer reviewed journals. She organized workshops, training programs, webinars and conferences at regional, national and international levels. She has written a book on safety and disaster management education in schools. She also completed one UGC funded in house Project and currently doing a minor project in artificial intelligence. She awarded best NSS program officer by the Ministry of Information and Broadcasting, Field Outreach Bureau, Government of India.

Dr. Joy Krishna De (b.1952)

Ph.D. in Zoology from the University of Calcutta in 1984, M.Sc. in Zoology from the University of Calcutta in 1975, B.Sc. (Hons.) in Zoology from the University of Calcutta in 1973. Superannuated on 31.07.2012 from the Zoological Survey of India, Ministry of Environment & Forests, Climate Change Govt. of India in the

capacity of Scientist-D (Dy. Director) after 33 years of services. Engaged as Consultant in the Zoological Survey of India, Ministry of Environment & Forests, Climate Change, Govt. of India for 6 months. Engaged as Project Scientist under Integrated Coastal Zone Management (ICZM) Project sponsored by the World Bank for 6 months at Marine Aquarium and Research Centre, Digha, Zoological Survey of India, Ministry of Environment & Forests, Climate Change, GOI. Engaged as Scientific Officer at the West Bengal Zoo Authority, Kolkata, Directorate of Forests, Govt. of West Bengal for more than 3 years. Attached with the Indira Gandhi National Open University, Kolkata, Ministry of Human Research Development, Govt. of India as an Academic Counselor for teaching under graduate students. Recently he is attached with a number of NGOs involved for the conservation of biodiversity.

In his research field he has undertaken a number of research projects on Morpho-taxonomy, Tricho-taxonomy, Status survey, Ecological study, Animal Census of different mammalian fauna. Already published a total number of 96 research publications including 21 publications in International Journal and three books. He conducted 55 Faunistic Surveys with special reference to mammalian fauna in different states of India.

Participated at the 22nd Indian Scientific Expedition to Antarctica for conducting moss- inhabiting Invertebrate and logging of mammal and bird fauna encountered during to and fro Voyage and also population dynamics of Avian Fauna at Schirmacher Oasis.

PREFACE

Our mother earth contains enormous resources in forests, mountain, plains, wetlands, deserts and marine habitats etc. India is blessed with rich variety of fauna and flora in a diversity of ecological habitats from tropical, sub-tropical rainforests to alpine vegetation, temperate forests to coastal wetlands. Tropical rain forests endowed with habitat heterogeneity and high level of biological resources and the destruction of which due to industrialisation & various anthropogenic activities causes severe climate change. Scientists and Government and Non-government agencies are engaged to reduce the pollution and to protect the natural world.

Now- a- days the most important environmental issue are Deforestation, Air Pollution, Global Warming, Water Pollution, and Natural Resource Depletion. To mitigate all these environmental issues, an integrated approaches are to be taken up as per Bruntland Commission Report1987 of the United Nations, which says "**development that meets the needs of the present without compromising the ability of future generations to meet their own needs**." Before implementing any environmental integration programme, main difference between development and sustainable development are to be taken into consideration. It says that development aims at raising the quality of life of only present generation whereas sustainable development aims at raising the quality of life of both present and future generations without threatening natural endowment and environment. Conservationist has to develop comprehensive strategies to protect our natural resources including biodiversity in and outside of the protected areas.

A total of 8 nos. of articles written by a group of researchers, academicians and experts of different fields of biodiversity. We are in the hope that this book will be the source of information to those who are engaged in biodiversity research, conservation and sustainable utilisation of nature and natural resources. It may also help to the decision makers for implementing different environmental laws and acts.

We record our sincere thanks to the contributors of this book for timely submission of their articles. We will be grateful for constructive criticism and suggestions for further improvements in the book.

CONTENT

ISBN: 978-93-90847-17-4

1. Biofertilizer Including Bacterial, Fungal AM/ VAM, Ectomycorrhizae, Cyanobacteria for Sustainable Agriculture

Tanmay Ghosh

Assistant Professor,
Department of Microbiology,
Dinabandhu Andrews College, Baishnabghata,
South 24 Parganas, Kolkata,
West Bengal, India.

Summary:

Modern agriculture involves usage of pesticides and chemical fertilizers with an essence of increasing the world's food production. Thus, these serve as a fast food for plants, causing them to grow more rapidly and efficiently. Fertilizers, though they are vital as a nutrient supplement to plants and comprised mainly nitrogen (N), potassium (K) and phosphorous (P), they also cause several health hazards. Researchers have found "Bio fertilizer" as an excellent alternative to chemical fertilizers which provide nutrients through the action of nitrogen fixation, solubilising phosphorus, and trigger plant growth through the synthesis of growth promoting essence.

Keywords: Biofertilizers, Microbiology, Soil, Cyanobacteria.

1.1 Introduction:

Biofertilizer can be defined as biological products containing living microorganisms that, when applied to seed, plant surfaces, or soil, promote growth by several mechanisms such as increasing the supply of nutrients, increasing root biomass or root area and increasing nutrient uptake capacity of the plant .Continuous application of chemical fertilization Leads to the decay of soil quality and fertility and might Lead to the collection of heavy metals in plant tissues, Affecting the fruit nutritional value and edibility (Farnia And Hasanpoor, 2015). In the recent years, many organic fertilizers have been introduced that act as natural stimulators for plant growth.

A particular group of organic fertilizers includes outcomes based on plant growth-promoting microorganisms identified as 'Biofertilizers'. These biofertilizers comprised efficient strains of nitrogen fixing or phosphate solubilizing microorganism.

Organic farming has appeared as a prime concern area globally in aspect of the growing demand for safe and healthy food, durable sustainability and issue on environmental pollution associated with random use of agrochemicals (Ghany et al.,2013).

Biological fertilization is based on the supply of organic inputs including fertilizers, organic wastes, domestic sewage, animal manure, and microorganisms, such as fungi and bacteria. The bio-fertilizers supply also enhance the productivity per area in a comparatively short time, consume smaller amounts of energy, reduce contamination of soil and water, increase soil fertility, and encourage antagonism and biological control of phytopathogenic organisms. Biofertilizers approach pose lots of such benefits from an economic, social, and environmental point of view (-Muñoz and Carmona-Garcia, 2012). From long-ago, the chemical pesticides and fertilizers have Played a vital role in improving agricultural production.

Although they have a short history in modern agriculture, their instant action and low cost managed to bring them quickly into the center of attention. Thus, their adverse effects on environment, plant, animal and human life have diverted the priority on ecofriendly plant protection (Patel et al., 2014). The term biofertilizer, depict everything from manures to plant extract (Aggani, 2013). Biofertilizer is a material which contains living microorganisms. When applied to plant surfaces, they promote plant growth by increasing the supply of primary nutrients to the host plant. Bio-fertilizers add nutrients through natural processes such as nitrogen fixation, solubilizing phosphorus, and stimulating plant growth along with the synthesis of growth-promoting substances.

The practice of organic manure does not only include the management of crop yields, but also plays a vital role towards exhibiting both direct, as well as indirect influence on the nutrient accessibility in soil by improving the physical, chemical and biological properties of soil and likewise enhances the utilization effectiveness of applied fertilizers (Kapoor and Pandit, 2015). Biofertilizer is an organic by-product containing living microorganisms arrested from plant roots or soil.

Choice of bio-fertilizer is becoming increasingly popular for the replacement of chemical fertilizer in order to lower the cost of crop production, enhance the growth and crop yield by increasing the nitrogen availability and by producing certain substances, such as auxin, cytokinin and gibberellins, which are helpful in the growth of plants. Microbial activity plays a key role in agriculture because they are very significant in the movement and availability of minerals required for plant growth and ultimately lower the use of chemical fertilizers (Verma et al., 2017).

Further, the use of bio-fertilizers can raise productivity per unit area in a short time, use smaller amounts of energy, reduce contamination of soil and water, increase soil fertility, and encourage antagonism and biological control of phytopathogenic organisms (Yasin et al., 2012). Biofertilizers are significant, not only for the decrease in quantity of chemical fertilizers, but also for better yield in sustainable agriculture. Bio fertilizer production is cheap and does not create pollution in the natural system (Farnia and Hasanpoor, 2015). In India, systematic study on biofertilizers was started by N. V. Joshi in 1920. Rhizobium was the first isolated from various cultivated legumes, and this was followed by vast research by Gangulee, Sarkaria and Madhok on the physiology of the nodule bacteria besides its inoculation for better crop production. Rhizobium and Blue Green Algae (BGA) are considered as the traditional biofertilizers, while Azolla, Azospirillum and Azotobacter are at the middle stage (Rahimi et al.,2014).

1.2 Biofertilizer:

A biofertilizer is a substance which contains living microorganism, when applied to seed, plant surface or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers add nutrients through the natural process of nitrogen fixers, solubilizing phosphorus and stimulating plant growth through the synthesis of growth promoting substance. Some features of thebiofertilizer which improve the soil fertility are described below:

a. Biofertilizers are natural fertilizers that are microbial inoculants of bacteria, algae and fungi (separately or in combination).
b. Which may help biological Nitrogen fixation for the benefit of plants.
c. They help build up the soil microflora and there by the soil health.
d. Biofertilizer also include organic fertilizers (like manure).
e. The use of biofertilizer is recommended for improving the soil fertility in organic farming.

The biofertilizer (bio-manure) is a substance which contains living miniature life forms which, when applied to seeds, plant surfaces, or soil, colonize the rhizosphere or the inside of the plant and advances development by expanding the inventory or accessibility of essential supplements to the host plant. Biofertilizers add supplements through the regular cycles of nitrogen obsession, solubilizing phosphorus, and invigorating plant development through the union of development advancing substances. The microorganisms in biofertilizers reestablish the dirt's regular supplement cycle and fabricate soil natural matter. Using biofertilizers, solid plants can be developed, while upgrading the maintainability and the strength of the dirt. Biofertilizers can be required to decrease the utilization of engineered manures and pesticides, however they are not yet ready to supplant their utilization. Since they assume a few parts, a favored logical term for such gainful microbes is "plant-development advancing rhizobacteria".

1.2.1 Biofertilizers in Today:

Biofertilizers give "eco-accommodating" natural agro-input. Biofertilizers like Rhizobium, Azotobacter, Azospirilium and blue green growth have been being used quite a while.

Rhizobium inoculant is utilized for leguminous harvests. Azotobacter can be utilized with crops like wheat, maize, mustard, cotton, potato and other vegetable yields. Azospirillum immunizations are suggested primarily for sorghum, millets, maize, sugarcane and wheat.

Blue green growth having a place with an overall cyanobacteria class, Nostoc or Anabaena or Tolypothrix or Aulosira, fix air nitrogen and are utilized as vaccinations for paddy crop developed both under upland and swamp conditions.

Anabaena in relationship with water greenery Azolla contributes nitrogen up to 65 kg/ha/season and furthermore improves soils with natural matter. Kelp is plentiful in different kinds of mineral components (potassium, calcium, phosphorus, minor components and so forth) thus they are widely utilized as excrement by individuals of waterfront areas. Ocean growth - compost likewise helps in separating muds. Fucus is utilized by Irish individuals as fertilizer for an enormous scope.

In tropical nations base mud of evaporated lakes which contain bountiful blue green growth is consistently utilized as compost in fields. The combination of ocean growth and blue green growth may fill in as optimal compost.

Figure 1.a: Blue green algae used in biofertilizer

1.2.2 Parts of Biofertilizers:

The parts of biofertilizers include:

a. Bio Compost: It is one of the eco-accommodating items made out of waste material delivered from sugar enterprises which are deteriorated. It is amplified with human-accommodating microorganisms, organisms, and different plants.

b. Tricho-Card: It is an eco-accommodating and nonpathogenic item utilized in an assortment of harvests just as in green and elaborate plants, like paddy apple, sugar stick, brinjal, corn, cotton, vegetables, citrus, and so forth It goes about as a useful destroyer and opposing hyper parasitic against eggs of a few bores, shoot, natural product, leaves, bloom eaters and different microorganisms in the field.

c. Azotobacter: It shields the roots from microbes present in the dirt and assumes an essential part in fixing the barometrical nitrogen. Nitrogen is a vital supplement for the plant and about 78% of the absolute climate involves nitrogen.

d. Phosphorus: Phosphorus is one of the fundamental supplements for plants development and advancement. Phosphate solubilizing microorganisms, hydrolyze insoluble phosphorus mixtures to the solvent structure for take-up by plants. Numerous parasites and microbes are utilized for the reason like *Penicillium, Aspergillus, Bacillus, Pseudomonas,* and so forth.

e. Vermicompost: It is an Eco-accommodating natural manure involves nutrients, chemicals, natural carbon, sulfur, anti-toxins that assistance to build the amount and nature of yield. Vermicompost is one of the handy solutions to work on the ripeness of the dirt.

1.2.3 Benefits of Biofertilizers:

- Biofertilizers are method for fixing the supplement accessibility in the dirt. For the most part Nitrogen insufficiencies.
- Since a bio-manure is actually living, it can cooperatively connect with plant roots. Included microorganisms could promptly and securely convert complex natural material into basic mixtures, so they are handily taken up by the plants. Microorganism work is in long length, causing improvement of the dirt fruitfulness. It keeps up with the regular living space of the dirt.
- It builds crop yield by 15 to 25%, replaces substance nitrogen and phosphorus by 28%, and invigorates plant development. It can likewise give security against dry spell and some dirt borne infections.
- It has additionally been shown that to create a bigger amount of yields, biofertilizers with the capacity of nitrogen obsession and phosphorus solubilizing would prompt the best conceivable impact.
- They advance shoot and root development of numerous harvests versus control groups. This can be significant while carrying out new seed development.
- Biofertilizers additionally advance solid soil, prompting more noteworthy cultivating maintainability.

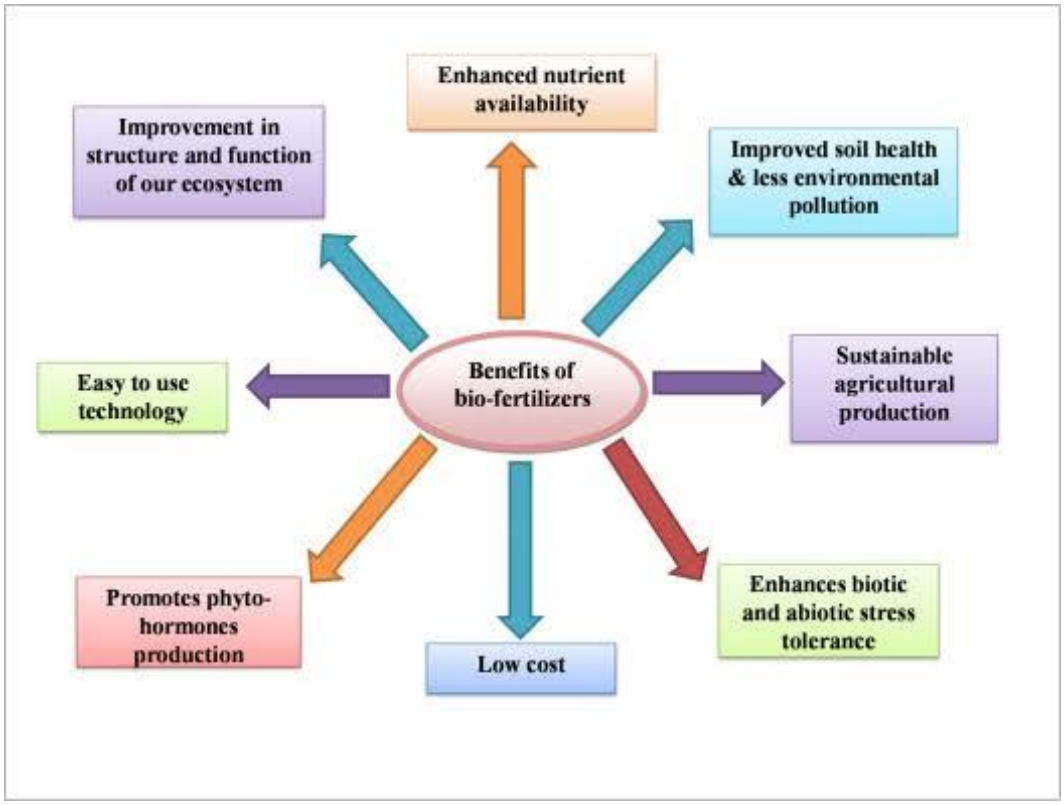


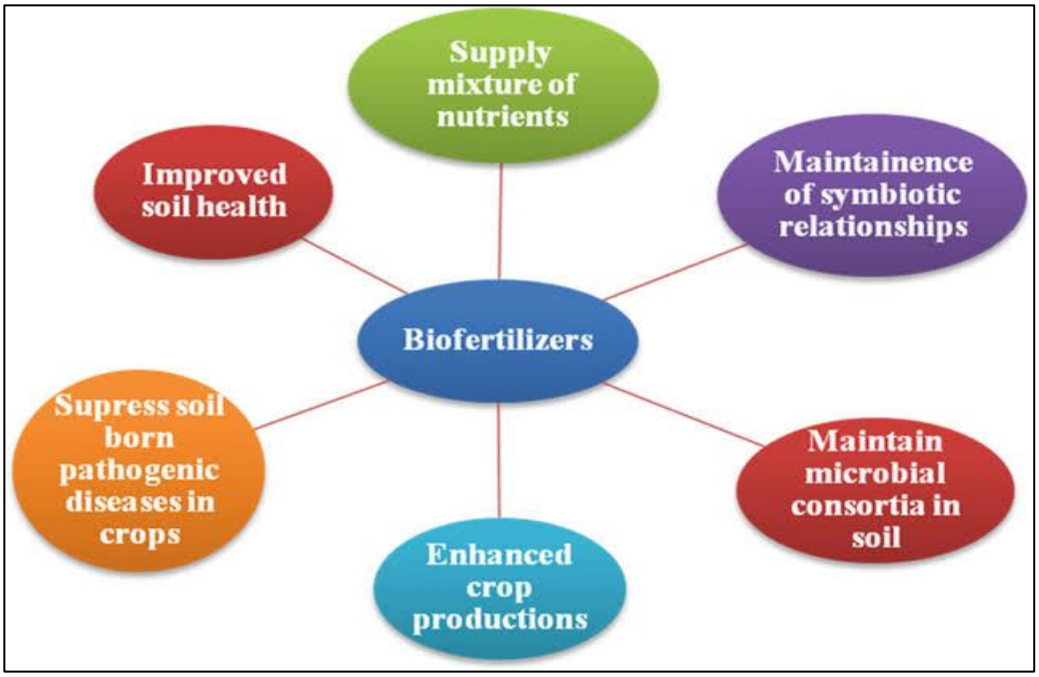
Figure 1.b: Benefits of bio-fertilizer

1.2.4 Application of Biofertilizer:

a. Seed Treatment: Every parcel (200g) of inoculant is blended in with 200 ml of rice slop arrangement. The seeds needed for one hectre are blended in the slurry to have uniform covering of the inoculants over the seeds and afterward conceal dried for 30 minutes. The treated seeds ought to be utilized inside 24 hous. One parcel of inoculant is adequate to treat to 10 kg seeds. *Rhizobium, Azospirillum, Azotobacter*and Phosphobacteria are applied as seed treatment.

b. Seedling Root Plunge: This technique is utilized for relocated harvests. Five bundles (1.0 kg) of the inoculants are needed for one ha and blended in with 40 liters of water. The root part of the seedlings is plunged in the answers for 5 to 10 minutes and afterward relocated. *Azospirillum* is utilized for seedling pull plunge especially for rice.

c. Soil Treatment: 4 kg every one of the suggested biofertilizers are blended in 200 kg of manure and kept for the time being. This blend is joined in the dirt at the hour of planting or planting.



1.3 Cyanobacteria:

These are blue-green microorganisms found in water and ashore. They additionally assist with fixing environmental nitrogen. Models are *Oscillatoria*, *Nostoc*, *Anabaena* and so on the advantageous relationship between the amphibian greenery

Azolla and Anabaena is vital for rice fields. In this affiliation, Anabaena gets carbon and nitrogen from the plant in return for fixed nitrogen. This adds natural make a difference to the dirt upgrading the fruitfulness of rice fields.

1.3.1 Blue Green Algae:

Blue green growth is alluded to as rice life forms as a result of their wealth in the rice field. Numerous species having a place with the genera, Tolypothrix, Nostic, Schizothrix, Calothrix, Anoboenosois and Plectonema are bountiful in tropical conditions. The majority of the nitrogen obsession BGA are filamenters, comprising of chain of vegetative cell including particular cells called heterocyst what work as a micronodule for blend and N fixing apparatus.

1.3.2 Utilization of Blue Green Algae:

- Algal culture is applied as dried chips at 10 kg/ha over the standing water in field rice.
- This is done two days subsequent to relocating in loamy soils and six days in the wake of planting in clayey soils.
- The field is kept water logged for not many days following algal application.
- The biofertilizer is to be applied for 3-4 sequential seasons in a similar field.

Figure 1.c: Blue green algae

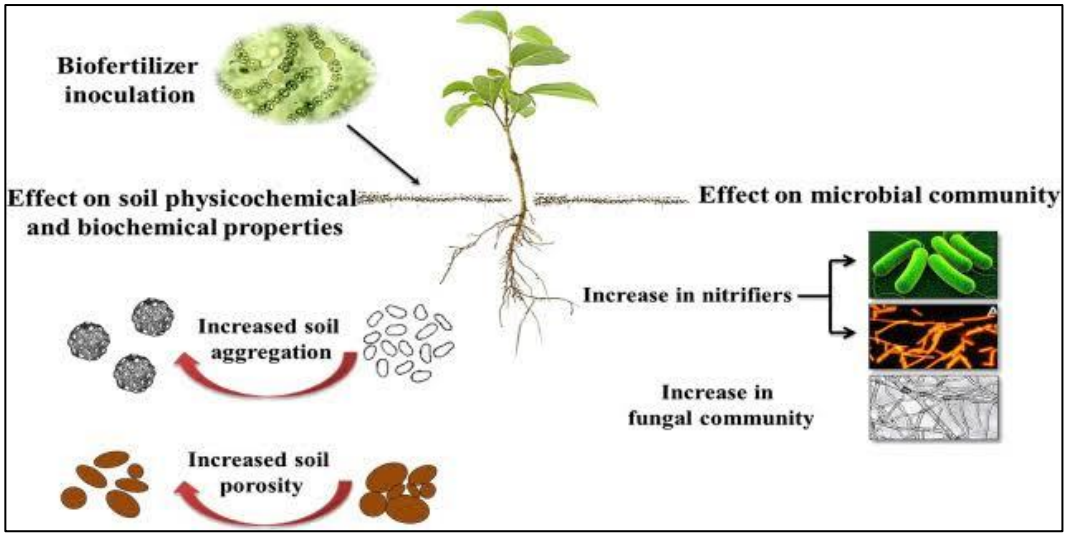


Figure 1.d: Role of green algae in plant

1.4 Azolla:

Azolla is a sort of seven types of oceanic plants in the family Salviniaceae. They are incredibly diminished in structure and specific, looking not at all like other commonplace plants however seriously taking after duckweed or a few greeneries.

Azollafiliculoides is one of only two plant species for which a reference genome has been distributed.

1.4.1 Utilization of Azolla:

a. Green Compost:

Azolla is applied @ 0.6-1.0 kg/m2 (6.25-10.0 t/ha) and fused prior to relocating of rice.

b. Double Yield:

Azolla is applied @ of 100 g/m2 (1.25t/ha), one to three days in the wake of relocating of rice and permitted to increase for 25-30 days. Azolla fronds can be joined into the dirt at the hour of first weeding.

Figure 1.e: Azolla

1.4.2 Fungi:

Advantageous affiliations exist among plants and growths as well. These affiliations are called ‘Mycorrhizae’.

The parasite in this affiliation retains phosphorus from the dirt and gives it to the plant. Plants that develop with these affiliations likewise show other worthwhile qualities, for example,

- Resistance to dry spell conditions and saltiness.
- Protection from root-borne microbes.
- A general expansion in plant development and advancement.

1.5 VAM:

Vesicular - arbascular mycorrhizas whose hyphae penetrate plant calls, producing structures that are either ballon- like (vehicles) or branching invagination as a means of nutrient exchange.

Arbascularmycorrhizal are found in 85% of all plant families and occur in many crop species.

The hyphae of arbascularmycorrhizal fungi produce the glyco - protein glomalin, which may be one of the major stores of carbon in the soil.

1.5.1 VAM Fungi (Vesicular Arbascular Mycorrhizae):

- Fungi formed VAM association with plants may belongs to ascomycetes, basidiomycetes and zygomycetes.
- All VAM fungi are obligate biotrophic, as they are completely dependent on plants for their survival.

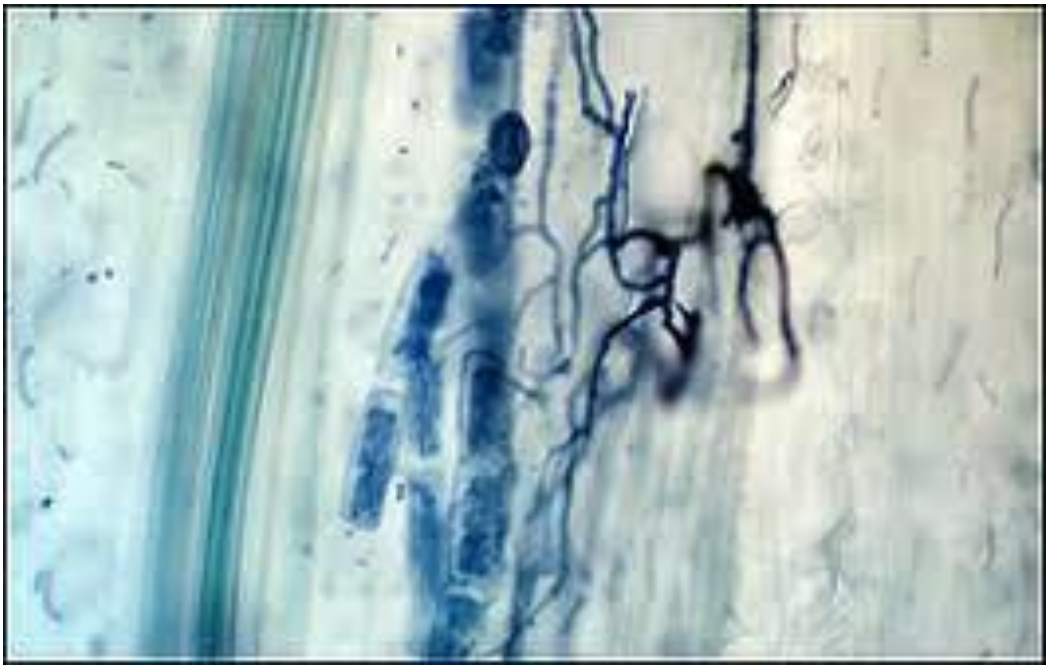


Figure 1.f: VAM fungi (vesicular Arbascular mycorrhizae)

1.6 Ectomycorrhizae:

- Ectomycorrhizal fungi from exchange mechanism outside of the root cells, extracellularly.
- Ectomycorrhizae (ECM) are association, where fungi form a mantle around roots. There is no hyphae penetration of cells. Fungi hypha is generally separate. A distinct Hartig's net is present between the cells.
- Xylem, epidermis, cortex and fungi sheath is present.
- Ectomycorrhizae or abbreviated EcM is a form of symbiotic relationship that occurs between a fungal symbiont, or mycobiont, and the roots of various plant species.

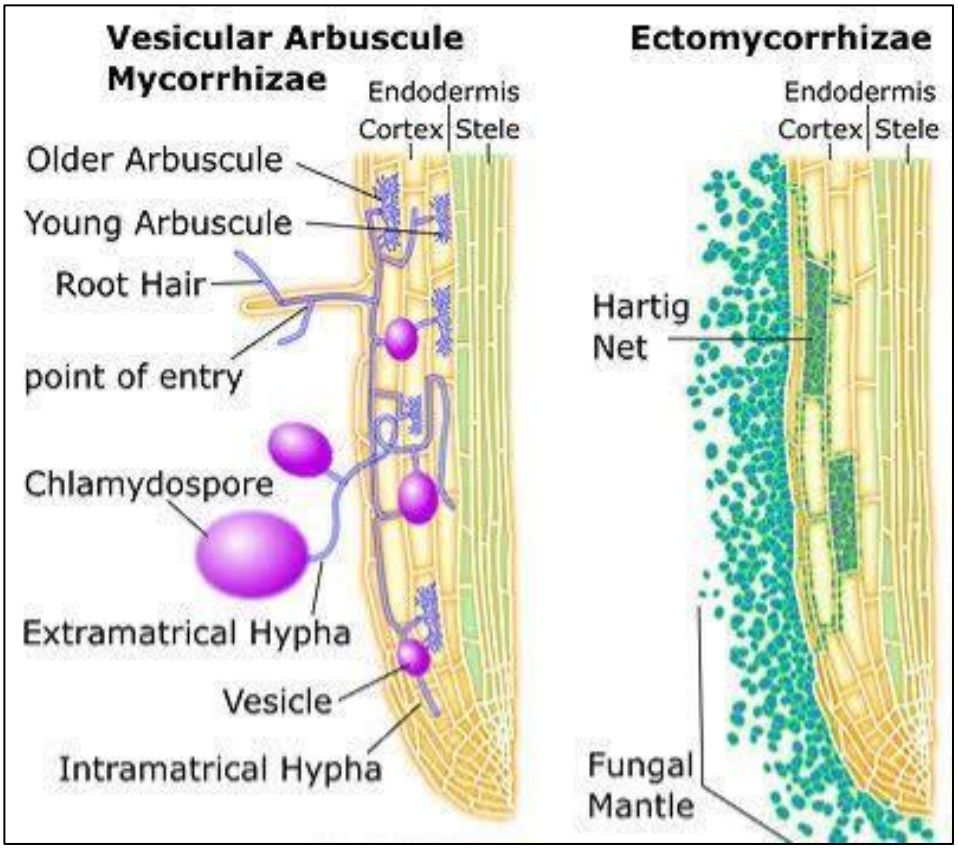


Figure 1.g: Ectomycorrhizae

1.6.1 Application:

- Increase nutrient uptake of plant from soil Nutrition and other elements: N, K, Ca, Mg, Zn, Cu, S, Fe.
- Significant role in nutrient recycling.
- Increase plant resistant to disease and drought.
- Stimulate the growth of beneficial microorganism.
- Increases uptake of water and sulphur from the soil
- Increase the concentration of cytokines and chloroplast in plants and protect plant during stress condition.

1.6.2 Bacteria:

The nitrogen-fixing knobs on the foundations of vegetables. This an extraordinary illustration of biofertilizers.

The knobs are shaped by the relationship of the bacterium 'Rhizobium' with the underlying foundations of these plants. This affiliation is gainful and is, consequently, called 'cooperative'.

The knobs help in fixing environmental nitrogen into natural structures which would then be able to be utilized as sustenance by the plants.

Adding Rhizobium societies to fields has become a typical practice to guarantee a sufficient measure of nitrogen in the dirt.

Different instances of microorganisms that go about as biofertilizers incorporate Azospirillum and Azotobacter. These microbes are free-living in the dirt. Azotobacter is normally utilized with crops like cotton, wheat, mustard, maize, and so on

1.7 Rhizobium:

Rhizobium is somewhat more successful and broadly utilized biofertilizer. Rhizobium, in affiliation mind vegetables, fixes climatic N.

The vegetables and their harmonious relationship with the rhizobium bacterium bring about the arrangement of root knobs that fix environmental N.

Fruitful nodulation of leguminous harvest by rhizobium to a great extent relies upon the accessibility of a viable mess for a specific vegetable.

Rhizobium populace in the dirt is subject to the presence of vegetables crops in field. Without vegetables the number of inhabitants in rhizobium in the dirt reduces.

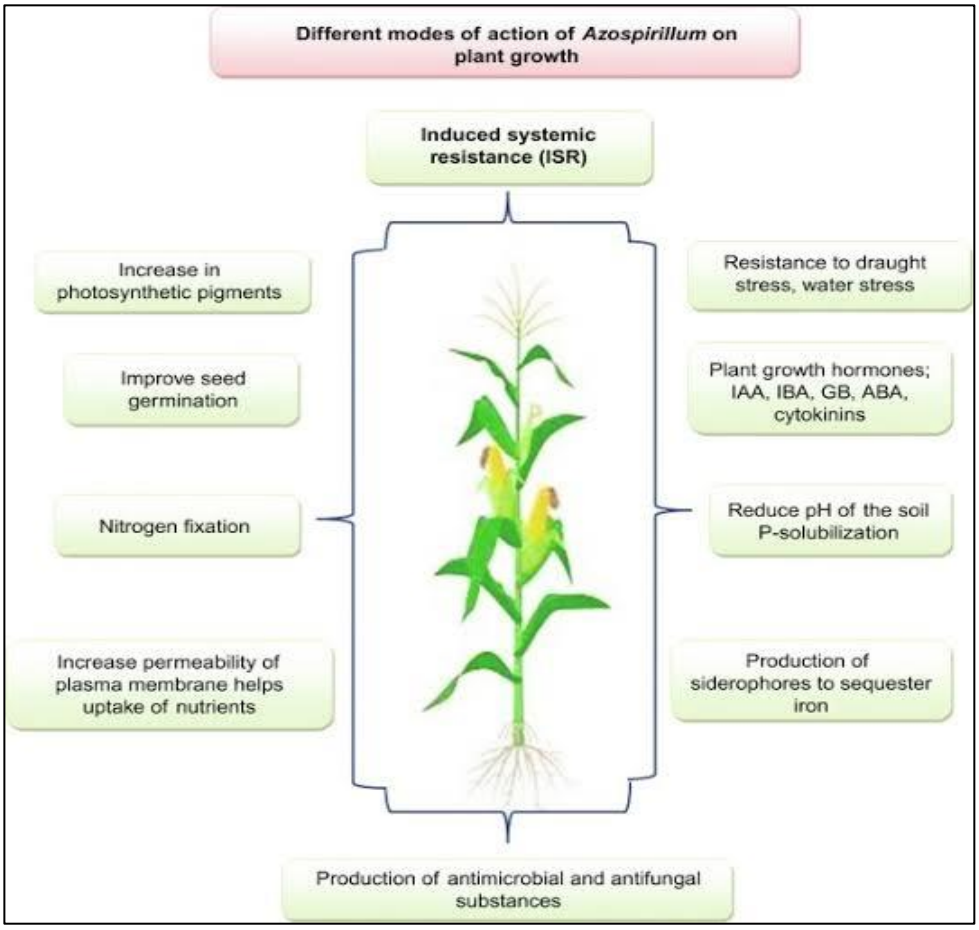
Figure 1.h: Rhizobium

Figure 1.i: Azospirillum

1.8 Azospirillum:

Azospirillum is known to have a nearby cooperative beneficial interaction with the higher plant framework.

These microorganisms have relationship with oats like, sorghum, maize, pearl millet, finger millet, foxtail millet and other minor millets and furthermore grain grasses.



1.9 Azotobacter:

It is a typical soil bacterium. A. chrococcum is available generally in Indian soil. Soil natural matter is the significant factor that chooses the development of this microorganisms.

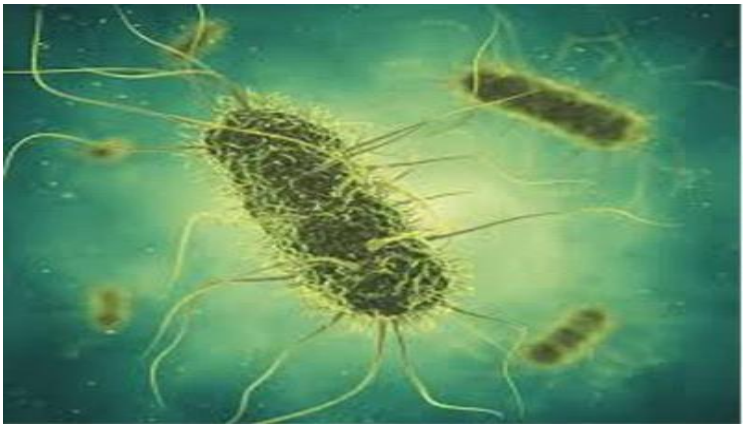


Figure 1.j: Azotobacter

1.10 Phosphate Solubilizing Bacteria:

Different sorts of microbes, purported phosphate-solubilizing microorganisms, for example, *Pantoeaagglomerans* strain or *Pseudomonas putida* strain, can solubilize the insoluble phosphate from natural and inorganic phosphate sources. Indeed, because of immobilization of phosphate by mineral particles like Fe, Al and Ca or natural acids, the pace of accessible phosphate (Pi) in soil is well beneath plant needs. What's more, synthetic Pi composts are additionally immobilized in the dirt, quickly, so that under 20% of added manure is consumed by plants. Along these lines, decrease in Pi assets, on one hand, and natural contaminations coming about because of both creation and utilizations of compound Pi compost, then again, have effectively requested the utilization of phosphate-solubilizing microbes or phosphate biofertilizers.

Figure 1.k: Phosphate solubilizing bacteria

1.10.1 Role of Phosphate Solubilizing Bacteria:

- Increasing the accessibility of other trace elements Fe, Cu, Zn and Mg
- Biocontrol of plant pathogen and production of plant growth hormones.
- Support resistance to abiotic stress and soil aggregation.

1.11 Conclusion:

The Biofertilizer have a significant role in agriculture. The microorganisms play an important role in Biofertilizer. They not only help in the growth of the plant but also the antagonistic effect of the other pathogens on the plant. The algae, fungi, Bacteria have major action in the microbial Biofertilizer. In comparison of chemical fertilizers, the biological fertilizers have major benefits upon the nature. They don't even prevent the pollution of chemical fertilizers but also increase the connection between the ecosystems. The fertilizers also help the plant growth and the soil fertility.

1.12 References:

1. Farnia A, Hasanpoor K (2015). Comparison between effect of chemical and biological fertilizers on yield and yield components in wheat (Triticumaestivum L.). Indian J. Nat. Sci. 5 (30): 7792-7800.
2. Ghany TMA et al (2013). Role of biofertilizers in agriculture: a brief review. Mycopath. 11 (2): 95-101.
3. Carvajal-Muñoz JS, Carmona-Garcia CE (2012). Benefits and limitations of biofertilization in agricultural practices. Livestock Research for Rural Development. 24(3).
4. Patel N (2014). Bio fertilizer: A promising tool for sustainable farming. Int. J. Innov. Res. Sci. Eng. Techno. 3 (9): 15838-15842.
5. Aggani SL (2013). Development of bio-fertilizers and its future perspective. Schol. Acad. J. Pharm. 2(4): 327-332.
6. Ajmal M et al (2018). Biofertilizer as an Alternative for Chemical Fertilizers. J. Agri. Sci. 7(1): 1-7.
7. Bhattacharjee R, Dey U (2014). Biofertilizer, a way towards organic agriculture: A Review. Afr. J. Microbiol. Res. 8(24): 2332-2343.
8. Kapoor A, et al (2015). Organic agriculture: biofertilizer– A review. Int. J. Pharmaceut. Biol. Arch. 6 (5): 1-5.
9. Verma S (2017). Bio-efficacy of organic formulations on crop production-A review. Int. J. Curr. Microbiol. App. Sci. 6(5): 648-665.
10. Yasin M (2012). Bio-fertilizers, substitution of synthetic fertilizers in cereals for leveraging agriculture. Crop Environ. 3 (1-2): 62-66.
11. Yasin M (2012). Review article: bio-fertilizers, substitution of synthetic fertilizers in cereals for leveraging agriculture. Crop Environ. 3 (1-2): 62-66.

ISBN: 978-93-90847-17-4

2. Classification and Importance of Biofertilizers in Agriculture

Madhumonti Naskar, Sidhu Murmu, Kanu Murmu

Department of Agricultural Chemistry and Soil Science,
Faculty of Agriculture,
BCKV, Mohanpur, Nadia, West Bengal.

2.1 Introduction:

With the ever-increasing population to feed, the sustainability in the food production and security can surely be achieved through the maintenance of soil health. Soil is the holder and carrier of every terrestrial organism. Intensive cultivation with the goal to achieve maximum productivity inorganic fertigation, application of insecticides and heavy tillage procedures have been taken into account since the past century.

This slowly degraded soil physical, chemical and biological properties, collectively known as “Soil Health”. Many fertile lands become barren due to intensive cultivation processes.

To restore such lands and decrease the pace of destruction, scientists from every corner of the world contributed their wholesome effort. Introduction of organic farming, conservation agriculture, integrated pest management are some of the important visionary steps inculcated by the scientist community.

The biological health of the soil is the worst affected sector by this type of intensive cultivation. Introduction of biofertilizers is one of the boons to boost the soil health organically. Commercial journey of biofertilizers began with the launch of “Nitragin” by Nobbe and Hiltner in 1895. Inoculation of beneficial fungal and bacterial species with the inert base material are introduced to the field to create a symbiosis between the microorganism and the plant.

Biofertilizers are the natural booster for the nutrient supply, the organisms act as an agent that provides essential nutrients like nitrogen, phosphorus, carbon for the host. In return they rely on the host for energy and growth substances. The species may be facultative or obligatory in nature.

They are responsible for symbiotic or freely fixing atmospheric nitrogen in the soil, solubilization of phosphorus and decomposition of organic substances. They are capable of infecting the roots called rhizobium where the N-N triple bond is broken, and nitrogen is fixed.

Phosphorus solubilizing bacteria or fungi develop structures that are able to store phospholipids and break the phosphate organic compounds or dissolve the inorganic compounds as rock phosphate, slag etc.

According to 2014-16 report of Soil Biodiversity-Biofertilizer research progress more than 2000 isolations of rhizobia of 20 major legumes made all over India including 700 from hyper-arid and arid regions of Rajasthan and Haryana, acidic soil of jharkhand, "taal" lands of bihar and soils of Uttarakhand.

The urge to develop more effective biofertilizer species for bacteria and fungi through biotechnological advancement has clearly paved the way for sustainable crop production. More awareness regarding the effectiveness of biofertilizers as well as the dark side of chemical fertilizer application needs to be focused. In this arena of hunger, the complete reliability of alternative nutrient management is very hard. Identification of regions with gradually degrading soil health and the applicability of suitable biofertilizers are the prime objectives to be focused on.

2.1.1 What are Biofertilizers?

Biofertilizers are the products containing one or more viable microorganisms which have ability to increase the soil fertility by increasing availability of plant nutrients through several biological processes such as nitrogen fixation, phosphorus solubilization, excretion of plant growth promoting substances or cellulose and lignin degradation etc. Use of biofertilizers is one of the important constituents of integrated nutrient management as they are the cost effective and adequate renewable sources of plant nutrients in supplement of chemical fertilizers for sustainable development in agriculture.

2.1.2 Classification of Biofertilizers:

a. Nitrogen Fixing Biofertilizers:

Nitrogen is the most limiting nutrient to plant growth although the atmosphere contains about 80% nitrogen because plants cannot take the nitrogen from air. Some microorganisms are capable of fixing atmospheric nitrogen for plant uptake. Nitrogen fixing biofertilizers are bacteria and blue green algae. Bacteria are both symbiotic and non-symbiotic. Bacteria become associated with different plant parts and fix the nitrogen and make the nitrogen able to plant uptake.

i. Symbiotic Nitrogen Fixing Bacteria:

The best known and effective symbiotic nitrogen fixing bacteria are belonged to the family Rhizobiacieae (Rhizobia) and the following families are included into this family: Rhizobium, Bradyrhizobium, Sinorhizobium, Azorhizobium, Mesorhizobium, and Allorhizobium (Vance, 1998; Graham and Vance, 2000).

The N2-fixing capability of rhizobia varies greatly up to 450 Kg N·ha–1 depending on host plant species and bacterial strains (Stamford et al., 1997; Unkovich et al., 1997; Unkovich and Pate, 2000).

Inoculation is very important because local and resident soil rhizobia population are absent or very low in some particular soil conditions like acidic soils generally contain no or low

population densities of the alfalfa rhizobial symbiont *Sinorhizobium meliloti*, whereas basic soils contain a low inoculum potential of *Bradyrhizobium sp.*, a rhizobial symbiont of *Lupinus spp.* (Amager, 1980, Catroux et al., 2001).

Rhizobia inoculant is very effective and cost-effective in terms of proper use, as if the rhizobia are present in high quantities in the soil, then the application of inoculation becomes unnecessary and loss of investment. Catroux et al. (2001) suggested that when rhizobial population density is lower than 100 rhizobia per gram of soil, inoculation is likely to be beneficial for crop productivity. Rhizobia inoculants are prepared and applied in several forms like powder, liquid, and granular formulations. The granular formulations are very favourable and convenient because the application rate and placement can be easily controlled (Stephens and Rask, 2000).

Table 2.a: A list of Common legumes and the Rhizobium strains by which they are inoculated

Rhizobium spp.	Legumes inoculated
1. Rhizobium meliloti	a. a) Melilotus (Sweet clover) b. b) Medicago (Alfalfa) c. c)Trigonella (Fenugreek)
2. R. trifoli	Trifolium (Clover)
3. R. leguminosarum	a. Pisum (Pea) b. Vicia (Vetch) c. Lathyrus (Sweet peas) d. Lens (Lentil)
4. R. phaseoli	Phaseolus (Beans)
5. R. lupini	a. Lupinus (Lupine)
6. R. japonicum	a. Glycine (Soybean) b. Vigba (Cowpea) c. Arachis (Groundnut) d. Crotalaria

ii. Free living Nitrogen Fixing Bacteria:

Many free-living bacteria also fix atmospheric nitrogen such as free-living bacteria such as Azotobacter, Beijerinckia, and Clostridium. The estimation of the N2 fixation by free-living bacteria is quite difficult. In an alfalfa (*Medicago sativa*) stand, the contribution of free-living N2-fixing bacteria was estimated to range from 3 to 10 kg N·ha–1 (Roper et al., 1995). In a greenhouse experiment using different types of bacterial inoculation methods (leaf spray, seed soaking, side dressing), *Beijerinckia mobilis* and *Clostridium spp.* stimulated growth in cucumber and barley plants (Polyanskaya et al., 2002).

But the inoculation of these free-living bacteria help in the plant growth especially in non-legumes fixing atmospheric nitrogen without forming nodules. Azotobacter act in temperate zone with the pH range 6.5-8.0 whereas in tropical zone Beijerinckia act with wide pH range 5.0-9.0. Clostridia are tolerant in anaerobic conditions with pH range 5.0-9.0.

iii. Nitrogen fixing associated Bacteria:

Besides symbiotic and free-living nitrogen fixation, some bacteria are capable of nitrogen fixing with association living within the roots of several crop plants like sorghum, pearl millet, rice, maize, wheat and sugarcane.

Examples of such bacteria include *Acetobacter diazotrophicus* and *Herbaspirillum spp.* associated with sugarcane, sorghum, and maize (Triplett, 1996; James et al., 1997; Boddey et al., 2000), *Azoarcus spp*. associated with kallar grass (*Leptochloa fusca*) (Malik et al., 1997), and *Alcaligenes, Azospirillum, Bacillus, Enterobacter, Herbaspirillum, Klebsiella, Pseudomonas,* and *Rhizobium* associated with rice and maize (James, 2000).

The genus Azospirillum makes an association by colonizing plant roots more than other bacteria mentioned earlier. They possess not only as a great root colonizer but also can increase the growth of plants. These include sunflower, carrot, oak, sugarbeet, tomato, eggplant, pepper, and cotton in addition to wheat and rice (Bashan et al., 1989; Bashan and Holguin, 1997). The yield increases can be substantial, up to 30 percent, but generally range from 5 to 30 percent.

These yield increases by Azospirillum are possibly a result of the production of growth-promoting substances rather than N2 fixation (Okon, 1985). They can fix atmospheric nitrogen upto 15-30 kg/ha.

iv. Blue Green Algae or Cyanobacteria:

Soil algae are microscopic, chlorophyll containing organisms which can fix atmospheric nitrogen by obtaining energy from sunlight. Blue green algae are also known as Cyanobacteria. The first agronomic potential of blue green algae in rice was recognised by P. K. Dey (1939). The rice field ecosystem provides a favourable environment for development of blue green algae with respect to their requirements like light, water, temperature, air, nutrient requirements etc.

They contribute about 20-30 kg N/ha, and they can also add organic matter, excrete several growth promoting substances and also amend the physical and chemical properties of the soil. Nostoc, Anabaena, Calothrix, Tolypothrix, Aulosira etc.are considered as dominant nitrogen fixers and can be used as soil based mixed algal cultures for growth of rice plants.

v. Azolla:

Azollae are the free floating water which fix the atmospheric nitrogen in symbiotic association with blue green algae in rice fields. They fix nitrogen by using energy through sunlight through photosynthesis contributing about 40-60 kg N/ha/year.

There are several species of Azolla present in the environment, among them Azolla pinnata is most widely distributed in India. Azolla can be used both as green manure before transplanting and as a dual crop after transplanting of rice.

b. Phosphorus Solubilizing Biofertilizers:

The total phosphorus determines the amount of phosphorus availability to the plants. The solubility of phosphate compounds is of great concern. Most of the soils are deficient to soluble forms of phosphorus thus causing deficiency syndromes. It is the second most limiting nutrient after N2 that consists of 0.2% of the total plant dry weight (Schachtman et al., 1998). Phosphorus is mainly available in inorganic form as rock phosphate (RP) and slag.

Bone meal, fish meal and other plant residue consists of organic phosphate compounds.

Microorganisms such as bacteria and fungi play a vital role converting them into plant available form. They are able to solubilize and mineralize the inorganic and organic forms respectively.

Pseudomonas, Bacillus, Penicillium, Aspergillus etc are some of the important fungi and bacterial species that act as PSM. Stalstron (1903) and Sacket et al. (1908) first showed the capability of bacterial species to solubilize the rock phosphate into plant uptake form.

They are even capable of breaking the organic phosphate bonds and converting them to orthophosphates. PSM consists of 0.5 - 1% of the total soil microbial population mainly from the bacterial species. Though the aerobic bacterial species are more effective they are highly disturebed through the tillage process. While the fungi population and efficiency regarding phosphate solubilizing in the tilled soil is undisturbed.

The symbiosis between the plant and the root colonizing mycorrhizal fungi may be a facultative or an obligatory relationship.

Fungus is mostly dependent on the host for the carbon, photosynthates and energy. In return they provide several benefits to the host plant. The extended surface area of the hyphal structure of the mycorrhiza is capable of extracting nutrients from a larger volume of soil matrix.

Thus, this type of symbiosis increases the crop yield demonstrated by many scientists. They are also heavy metal accumulators and moisture absorbers and help them avoid toxicity and drought. Mycorrhizal growth on plant roots also increases the soil aggregation and provides better soil health. The mycorrhizal growth formed due to fungal association may be classified into two major categories, as follows

i. Vesicular Arbuscular Mycorrhizal Fungi:

This type of inoculation can be made through the application of spores, fragments or roots along with some carrier substances like pumice or clay, sand, vermiculite. The hyphal

system creates vascular (vesicles and arbuscules) structure inside the host body, this is also known as "endomycorrhiza". This obligate symbiont plays a key role in efficient use of Phosphate fertilizers and enhancing nitrogen fixation. They also enhance the uptake of K, S, Cu and Zn. The arbuscules help in nutrient transfer and vesicles store phospholipids. Application of excess P-fertilizers ceases their further growth and mostly proliferates in agroforestry. Sorghum, barley, wheat, upland rice, tobacco, citrus, cotton, guava, apple showed beneficial effects of VAM inoculation.

ii. Ectomycorrhizal Fungi:

Ectomycorrhizal symbiosis of the fungi are the externally infected fungi species that connect with the hosts through infectious peg. The fungi suck root sap through the infectious peg and also provides nutritional elements to the host plant. Frank (1885) hypothesized the presence of ectomycorrhizal fungi and their benefits. *Pisolithus tinctorius* is one of the widespread ectomycorrhizal species in the plantation orchards. Inoculum for the ectomycorrhizal fungi can be developed through vegetative mycelium in a peat of vermiculite carrier. Alternative techniques as application of liquid and spore based mycelial inoculum were lately introduced. But their proliferation time may vary due to delayed establishment and fragmentation.

c. Organic Matter Decomposer:

Composting is a fruitful technology to use a wide variety of organic wastes including rural and urban wastes. This process takes a long time about 4-6 months for maturity, but it is very rich in plant nutrients. In order to increase the decomposition of the organic wastes, there are some microorganisms present in the composting mass. They are mainly two types: cellulolytic and ligninolytic microorganisms. These microorganisms decompose the organic matter at a much faster rate and make the compost ready within 2-3 months for application. The efficient microorganisms for rapid decomposition used as biofertilizers are *Trichoderma viride, Trichurus spiralis, Aspergillus niger, Phaenerocheate crysosporium, Paecilomyces fusisporus* etc.

d. Plant Growth Promoting Rhizobacteria (PGPR):

Bacteria which are capable in promoting the plant growth present in the rhizosphere, collectively they are called plant growth promoting rhizobacteria (PGPR). These group of bacteria help in stimulate the plant growth by colonizing in the root rhizosphere. They promote the growth through the suppression of several diseases, by improving nutrient acquisition or by producing phytohormones to stimulate the growth. These PGPR generally produce different kind of phytohormones like indole-acetic acid, cytokinins, gibberellin and inhibitors of ethylene production. Species of *Pseudomonas* and *Bacillus* can produce phytohormones or growth regulators that helps crops to have greater amounts of fine roots and ultimately increasing the absorptive surface of plant roots for uptake of water and nutrients. Bertrand et al. (2000) showed that a rhizobacteria belonging to the genus *Achromobacter* could enhance root hair number and length in oilseed rape (*Brassica napus*). *Achromobacter* increased NO3 and K uptake and, consequently, shoot and root dry weights by 22 to 33 percent and 6 to 21 percent respectively (Bertrand et al., 2000).

Table 2.b: Biofetilizers and their mode of action, host crops, methods of application and rate of inoculants used

Name of the organisms	Mode of action	Host crops which used	Method of application	Rate of application	Remarks
Rhizobium strain	Symbiotic nitrogen fixation	Legumes (pulses, soybean, groundnut)	Seed treatment	200 g/ 10 kg seed	Leaves residual nitrogen in soil for next crop
Azotobacter	Non-symbiotic nitrogen fixation	Cereals, millets, cotton, vegetables	Seed treatment	200 g/10 kg seed	Also control certain diseases
Azospirillum	Associated nitrogen fixation	Non-legumes (maize, barley, oats, sorghum, millets, sugarcane etc.)	Seed treatment	200 g/ 10 kg seed	Produces growth promoting substances
Phosphate solubilizes	Phosphate solubilization	Soil application for all crops	Seed treatment	200 g/ 10 kg seed	Can be mixed with rock phosphate
Blue green algae (BGA)	Non-symbiotic nitrogen fixation	Rice	Soil application	10 kg/ha	Reduces soil alkalinity; has growth promoting effects
Azolla	Symbiotic nitrogen fixation	Rice	Soil application	1 t/ha (dried material)	Increases organic carbon, soil physico-chemical properties
Mycorrhiza (VAM/AM)	Symbiotic association	Many trees and crops, wheat, sorghum	Soil application	varied	Usually, seedlings are inoculated

2.1.3 Methods of Application of Biofertilizers:

There are three types of application of microbial inoculum for application as biofertilizers: a) seed treatment, b) seedling root tip, and c) soil treatment.

a. Seed Treatment: In the case of seed treatment, 200g of biofertilizers is suspended in 300-400ml of water and mixed gently with about 10kg seeds by using an adhesive like gum acacia, jaggery solution etc. Due to these processes, the bioinoculants may get energy for their prolonged survival. But care must be taken for the seed coat that the seed coat should keep intact. The seeds are then spread over a clean sheet under shade for drying and used for sowing immediately.

b. Seedling Root Dip: Seedling root dipping is generally used for transplanted crops. In the case of rice, a seedbed is prepared in the field and filled with water. Recommended biofertilizers are mixed with the water and then the roots of rice seedlings are dipped into the water for 8-10 hr. And then transplanted into the field.

c. Soil Treatment: Biofertilizers are applied as basal application; About 4 kg each of recommended biofertilizers is mixed with 200 kg of compost and kept overnight. Then the mixture is applied in the soil at the time of sowing the crops.

2.1.4 Advantages of Biofertilizers:

There are some advantages in the application of biofertilizers:

- They are eco- friendly as well as cost effective
- Their use leads to soil enrichment and the quality of the soil improves with time.
- Though they do not show immediate results, but the results shown over time are spectacular.
- These fertilizers harness atmospheric nitrogen and make it directly available to the plants.
- They increase the phosphorous content of the soil by solubilising and releasing unavailable phosphorous.
- Biofertilizers improve root proliferation due to the release of growth promoting hormones.
- Microorganism converts complex nutrients into simple nutrients for the availability of the plants.
- Biofertilizers contains microorganisms which promote the adequate supply of nutrients to the host plants and ensure their proper development of growth and regulation in their physiology.
- They help in increasing the crop yield by 10-25%.
- Biofertilizers can also protect plants from soil borne diseases to a certain degree.

2.2 Conclusion:

To meet the demand of food security the sustainable development in agriculture is very necessary now-a-days. To achieve the goal the better agronomic practices in sustainable way will be our main moto. But high application of chemical fertilizers and pesticides cause the harmful impact on the soil and plant growth and ultimately in our food security. To mitigate the problems, application of biofertilizers combined with the chemical fertilizers can help the development of plant growth and increase the yield. Biofertilizers are the very good option for the farmers to increase the productivity per unit area. More future research should increase the biofertilizers application in the field and help in the crop production in sustainable manner to mitigate the problems and achieve our goals.

2.3 References:

1. Amarger, N. (1980). Aspect microbiologique de la culture des légumineuses. Le Selectionneur Francais 28: 61-66.
2. Bashan, Y. (1998). Inoculants of plant growth-promoting bacteria for use in agriculture. Biotechnology Advances 16: 729-770.
3. Bashan, Y. and Holguin, G. (1997). Azospirillum-plant relationships: Environmental and physiological advances (1990-1996). Canadian Journal of Microbiology 43: 103-121.
4. Bertrand, H., Plassard, C., Pinochet, X., Touraine, B., Normand, P., and Cleyet- Marel, J.C. (2000). Stimulation of the ionic transport system in Brassica napus by a plant growth-promoting rhizobacterium (Achromobacter sp.). Canadian Journal of Microbiology 46: 229-236.
5. Boddey, R.M., Da Silva, L.G., Reis, V., Alves, B.J.R., and Urquiaga, S. (2000). Assessment of bacterial nitrogen fixation in grass species. In E.W. Triplett (ed.), Prokaryotic nitrogen fixation: A model system for analysis of a biological process (pp. 705-726). Wymondham, UK: Horizon Scientific Press.
6. Catroux, G., Hartmann, A., and Revellin, C. (2001). Trends in rhizobial inoculant production and use. Plant and Soil 230: 21-30.
7. Frank, A.B. (1885). Über die auf Wurzelsymbiose beruhende Ernährung gewisser Bäume durch unterirdische Pilze. Berichte der Deutchen Botanischen Gesellschaft 3: 128-145.
8. Graham, P.H. and Vance, C.P. (2000). Nitrogen fixation in perspective: An overview of research and extension needs. Field Crops Research 65: 93-106.
9. James, E.K. (2000). Nitrogen fixation in endophytic and associative symbiosis. Field Crops Research 65: 197-209.
10. James, E.K., Olivares, F.L., Baldani, J.I., and Döbereiner, J. (1997). Herbaspirillum, an endophytic diazotroph colonizing vascular tissue in leaves of Sorghum bicolor L. Moench. Journal of Experimental Botany 48: 785-797.
11. Malik, K.A., Bilal, R., Mehnaz, S., Rasul, G., Mirza, M.S., and Ali, S. (1997). Association of nitrogen-fixing, plant growth-promoting rhizobacteria (PGPR) with kallar grass and rice. Plant and Soil 194: 37-44.
12. Okon, Y. (1985). Azospirillum as a potential inoculant for agriculture. Trends in Biotechnology 3: 223-228.

13. Polyanskaya, L.M., Vedina, O.T., Lysak, L.V., and Zvyagintsev, D.G. (2002). The growth-promoting effects of Beijerinckia mobilis and Clostridium sp. cultures on some agricultural crops. Microbiology 71: 109-115.
14. Roper, M.M., Gault, R.R., and Smith, N.A. (1995). Contribution to the N status of soil by free-living N2-fixing bacteria in a Lucerne stand. Soil Biology and Biochemistry 27: 467-471.
15. Sackett, W. G., Patten, A. J., & Brown, C. W. (1908). The solvent action of soil bacteria upon the insoluble phosphates of raw bone meal and natural raw rock phosphate. Centralbl Bakteriol, 202, 688-703.
16. Schachtman, D.P., Reid, R.J., and Ayling, S.M. (1998). Phosphorus uptake by plants: From soil to cell. Plant Physiology 116: 447-453.
17. Stamford, N.P., Ortega, A.D., Temprano, F., and Santos, D.R. (1997). Effects of phosphorus fertilization and inoculation of Bradyrhizobium and mycorrhizal fungi on growth of Mimosa caesalpiniaefolia in an acid soil. Soil Biology and Biochemistry 29: 959-964.
18. Stephens, J.H.G. and Rask, H.M. (2000). Inoculant production and formulation. Field Crops Research 65: 249-258.
19. Triplett, E. (1996). Diazotrophic endophytes: Progress and prospects for nitrogen fixation in monocots. Plant and Soil 186: 29-38.
20. Unkovich, M.J. and Pate, J.S. (2000). An appraisal of recent field measurements of symbiotic N2 fixation by annual legumes. Field Crops Research 65: 211-228.
21. Unkovich, M.J., Pate, J.S., and Sanford, P. (1997). Nitrogen fixation by annual legumes in Australian Mediterranean agriculture. Australian Journal of Agricultural Research 48: 267-293.
22. Vance, C.P. (1998). Legume symbiotic nitrogen fixation: agronomic aspects, In H.P. Spaink, A. Kondorosi, and P.J.J. Hooykaas (eds.), The Rhizobiaceae (pp. 509- 530). Dordrecht, the Netherlands: Kluwer Academic Publishers.

ISBN: 978-93-90847-17-4

3. Traditional Shifting Agricultural Systems Practiced by the Idus in Upper Dibang Valley District of Arunachal Pradesh, India

Dr. Goutam Ghosh

Department of Botany,
Bejoy Narayan Mahavidyalaya,
Itachuna, Hooghly, West Bengal, India.

Abstract:

Upper Dibang Valley district of Arunachal Pradesh shows two types of *jhums* as bamboo forest derived and grassland-derived *jhums* were prevalent. The agronomic yield was higher in bamboo forest-derived *jhum* rather than the grassland-derived *jhum*. The yield of different crops declined markedly over the cropping years under different types of jhums particularly in bamboo forest derived *jhum*. The yield increased in the second year of cropping compared to that of the first year in grassland-derived *jhum* due to better crop management practices followed in second year. The use *Fagopyrum cymosum* in the first year cropping mainly for the improvement of grassland-derived *jhum* was commonly practiced facilitating growth of other crops in this soil in the subsequent years. Due to abundance of grasses in this area the tribes particularly the Idus adopted the grassland-derived *jhum.* The adoption of grassland derived *jhum* decreased the percentage of forest destruction, increased the sustainable use of local natural resources efficiently and indirectly saves the ecology, environment and nature of this region.

Keywords: Shifting agriculture, bamboo forest-derived *jhum*, grassland – derived *jhum*, mixed cropping, soil fertility

3.1 Introduction:

The state of Arunachal Pradesh is characterized by 8 forest types like subtropical broad leaved, subtropical pine, temperate broad leaved, temperate conifer, sub alpine scrubs, alpine pastures, bamboo brakes and grassland. It has spare population of approximately 10, 91,200 due to location disadvantages, like the difficult terrain and lack of communication means. The Upper Dibang Valley district is one which is very far away and poorly communicated with state capital Itanagar. The main inhabitants in this district are the *Idus* tribe who belong to the Mongoloid race. Great altitudinal variation with temperature, relative humidity, and high annual rainfall represents distinct types of forest vegetation in the lower parts as sub-tropical to temperate pine, bamboo forests and grass land where as in the upper part leads to snow clad peaks, glacial lakes and traditionally have two types of subsistence agricultural systems, slash and burn agriculture, locally known as *jhum* and rice cultivation in the valley.

Recently, Scientists have started looking at subsistence agriculture or traditional agriculture as a one with high productive efficiency.

The high yields for subsistence agriculture that are often over looked by scientists are now receiving more study (Mitchell, 1979; Gliessman et al., 1981; Ramakrishnan, 1981; Altieri, 1983). *Jhum* cultivation, though with some subtle vitiation (Toky and Ramakrishnan, 1981a; Mishra and Ramakrishnan, 1981; Ramakrishnan, 1983; 84 a), basically involves slashing the forest often by clearing, felling, burning the dried slash and raising crops for one or two years on the temporarily nutrient enriched soil. The plot is abandoned for natural regrowth during the fallow phase before returning to the same plot after a few years. This is referred to as a '*Jhum* cycle'. There is some confusion regarding the yield of crops from *jhum* cultivation with *jhum* cycles. Slaats et al. (1998) compared fallow period, weeding regime and yield and concluded that the longer the land laid fallow, the higher was the maize yield obtained during the first year after clearing. Another study from Laos also corroborated to this conclusion that yield and fallow period did not provide any significant relationship (Pravongviengkham 1998). The study of Roder et al. (1995) and Wadley (1997) with large sample size showed no correlation between fallow period and yield. The model by Rasmussen and Moller Jensen (1999), however, only assumes that a minimum fallow period is needed to build up required nutrients for crop production. Therefore, in this study an effort has been made to study the *jhum* types based on management practices and previous vegetation of the fields.

3.2 Materials and Methods:

Survey works were conducted during 2001 to 2003 at the Upper Dibang valley district of Arunachal Pradesh. Among the two Circles, biggest one and mostly *jhum* cultivated Anini Circle was selected for the study of *jhum* types. In this study the *jhum* systems were evaluated in terms of productivity. The jhum systems in this area consist of two main types such as bamboo forest derived *jhum* (7–10-year cycle) and grassland-derived *jhum* (5–7-year cycle). The bamboo forest-derived jhum is characterized by bamboo species dominated forest and grasses, where herbs and shrubs dominate the grassland-derived *jhum*. The bamboo forest-derived *jhum* and grassland-derived *jhum* were evaluated in the villages of Angrivalley, Dumbin, Gipuling and Anini under Anini Circle. The evaluation of the different *jhum* systems were made on the basis of crop data collected randomly from 15 families of each village. The cultural practices and economic yield (edible or useful products) of crops in the study area were recorded by personal presence at the time of cultural operations, harvesting and processing or on the basis of interview the farmers. Several village headmen and old farmers were interviewed about the various ethnic knowledge of *jhum* cultivation practiced by them in the area. Various data on site selection, cropping systems, soil fertility maintenance and method of cultivation were recorded.

3.3 Observations and Discussion:

3.3.1 Site Selection:

The site selection for *jhum* cultivation was mainly based on the indigenous knowledge of the tribal community. For bamboo forest-derived jhum, they select a landslide free area near water sources. The sites should get plenty of available solar radiation '*Manu*' land that have greater than nine hours sunshine per day. They judge the fertility status of the soil through the growth of bamboos and other trees.

When these trees showed vigorous growth with dark green leaves and forest floor became comparatively clean and free from creepers, they use the land for *jhum* cultivation. In selecting sites, they gave priority to the sites dominated by *Alnus nepalensis*, *Castanopsis* spp. and bamboos and always tried to avoid any existent of pine tree in their *jhum* land. For the grassland-derived *jhum*, the site that was dominated by grasses and more or less in a topography receiving abundant sunlight and nearer to the water sources were generally preferred.

3.3.2 Field Preparation:

The sites are usually selected during winter. They slash the forest vegetation in the month of November to December. During slashing a few small sized trees and bamboos were left in the field to provide support to the climbing crops. Large sized trees were cut above the ground and the stumps were left undisturbed.

After slashing each bamboo was piled and dried during the ensuing winter. Such technique was also followed for other shrubs and small trees. Before burning, a fire line was cleared around the field to protect the forest around the field. They start burning the dried, slashed plants against the direction of wind that helped in slow burning and checked the spreading of fire to the adjacent areas.

Burning was often repeated to destroy any unburned material. A bamboo hut was built for temporary living and protecting the field crops from the wild animals.

3.3.3 Cultivation Practices:

Cultivation methods were more or less similar in both grassland-derived *jhum* and bamboo forest-derived *jhum* systems. First year cropping in the grassland-derived *jhum* started late in the month of August, whereas in bamboo forest-derived *jhum* it started from May. But in the subsequent years, sowing time (Table1), cultural practices and harvesting time did not vary much between the two types of *jhuming* practices.

The seeds of *Zea mays* (maize), *Oryza sativa* (paddy), *pulses like Phaseolus mungo*, *Glycine max*, (Soybean), *Vinga umbellata* (rice bean), cucurbits like *Cucurbita maxima* (pumpkin) and *Cucumis sativus* (cucumber) were dibbled in order to ensure their optimum germination immediately after burning and cleaning of the field. *Zea mays* was dibbled at regular intervals and mixed with other crops at random with the help of bamboo made pointed stick known as *'Amboliathaba'*.

Two local varieties of *Eleusine coracana* (finger millet)- '*Ambo*' (early variety) and '*Apu*' (late variety) were sown during May-June through broadcasting method and mixed properly with soil with the help of a tool made of local bamboo '*Tabu*' in the middle of August.

Coix lachryma was sown along the periphery of the field, whereas Zea *mays* and *Eleusine coracana* were uniformly distributed in the whole field, *Cucurbita* sp., *Sechium* sp., *Chenopodium album* were sown at random and *Colocasia* sp. and *Dioscorea* sp. were also dibbled at random.

Solanum tuberosum and *Glycine max* were dibbled in patches and *Phaseolus mungo* and *Vigna umbellata* were grows around the small tree or bamboo plants were inter-cropping with *Zea mays* or *Eleusine coracana* or *Solanum tuberosum* or *Oryza sativa*.

Apart from raising food crops, trees like *Alnus nepanensis* and *Castonopsis* spp. were also planted in the field for enriching the soil fertility.

Table 3.a Sowing and harvesting period of different crops in jhum systems.

Crops	Sowing period	Harvesting period
Solanum tuberosum	February-March	July-August
Oryza sativa	April-May	October–November
Cucurbita maxima	April-May	August-October
Colocasia esculenta	April-May	November-December
Pogostemon sp.	May	November
Vigna umbellata	May	November-December
Phaseolus mungo	-do-	-do-
Cucumis sativus	-do-	-do-
Sechium edule	May-June	August-November
Glycine max	May-June	November-December
Zea mays	May-June	August-September
Eleusine coracana	-do-	-do-
Dioscorea sp.	-do-	December
Chenopodium album	May-June	November-December
Coix lachryma	June	November-December
Fagopyrum cymosum	1st.week of August	December last

Weeds caused a major problem during monsoon. Frequent slashing by '*Dao*' (Sickle), free hand–hoeing and with U-shaped bamboo made '*Tabu*' was used for weeding. Usually, two times weeding was done by the women-folk during the cropping period. The intensity of weed infestation increased gradually in the subsequent years.

3.3.4 Cropping Systems:

The *Idus* people choose different crop composition for bamboo forest-derived and grass land-derived *jhum* systems. In case of bamboo forest-derived *jhum*, they generally practice maize-based cropping followed by millet-based cropping and paddy-based cropping in the subsequent years.

In case of grassland-derived jhum, the common cropping system was buckwheat-based: *Fagopyrum cymosum, Glycine max and Phaseolus mungo* in the first year, followed by potatobased cropping:

Solanum tuberosum, Colocasia esculenta, Pogostemon sp., *Glycine max, Phaseolus mungo, Coix lachryma* and *Cucumis sativus*, or maize-based and millet-based cropping: *Eleusine coracana, Colocasia esculenta, Glycine max, Phaseolus mungo, Chenopodium* sp., Cucurbita maxima and Cucumis sativus in the second and third year, respectively.

3.3.5 Harvesting and Storage:

The local people generally follow staggered method of harvesting of crops (Table 3.a) in their *jhum* fields. Only the panicles of *Oryza sativa and Eleusine coracana* and economic parts of other plants are harvested, and the remaining parts of the plants are left in the field to allow decomposition.

They store panicles in the granary (*Akka*) for 2-3 months after harvesting and drying in sunlight properly without threshing. Later they thresh, clean and carry it manually to their home.

3.3.6 Soil Fertility Management:

Special care was taken for maintaining the soil fertility in the grassland-derived *jhum*. Buckwheat was cultivated during the first year. The crop quickly covered the ground and thus prevented germination, sprouting and growth of weeds in the field. The crop (buckwheat) being very leafy, succulent and tender in nature, decomposed very quickly after maturity and thus the soil not only became enriched with nutrients, but also became soft. This helps in weeding the field in the subsequent years.

They also took some common measures for maintaining or enriching soil fertility of both bamboo forest-derived and grassland–derived *jhum* systems. The dried leaves and small twigs were burnt *in situ* and large logs and bamboos were piled and fired two to three times to ensure complete burning, which helped in producing better crops in their *jhum* lands. In the subsequent years, all the weeds after removing were kept in heaps in different areas of the *jhum* land, except the thorny plants.

These weeds decomposed naturally by microbial activity and added nutrients to the soil.

The tribals also cultivate legumes like *Glycine max, Phaseolus mungo* and *Vigna umbellata* not only for grain production but also for maintaining soil fertility in the croplands. Further they also plant *Alnus nepalensis* and *Castonopsis* spp. for enriching and maintaining soil fertility status on a long-term basis. Besides, they did not cut their crops at the base of the plant, instead they took only the mature fruits or panicles (economic organ), and the remaining parts of the crops were left in the field and this after decomposition release the nutrient helping the ensuring production.

3.4 Crop Yield:

The yield of various crops grown in different *jhum* types have been presented in the table 3.b. Oryza sativa produced 750 kg ha^{-1} grain yield during third year cropping in bamboo forestderived *jhum*.

It was very close to the rice yield data studied by Wadley (1997) for the period 1979-1993 in West Kalimantan from 14 households in an Iban community on interview and classified fallow vegetation in very broad categories based on vegetation morphology rather than fallow age and thus a 20- year fallow on very poor sandy soil came in the same category as a 4-year fallow on a clay soil (Young fallow of 3 to 20 years old gave average yield of 1042 kg ha^{-1}, young secondary of 10-45 years old gave an average yield of 923 kg ha^{-1}, and old secondary/ mature forest of 20-70 years old gave 1187 kg ha^{-1}).

The yield of different crops declined markedly over the cropping years under different types of *jhums*. This was particularly evident in the case of *Zea mays* in all types of *jhums* in these areas (Table 3.b). This is in conformity with the findings of Arnason et al. (1982) who noticed decline in maize yield in Belize. The yield of *Zea mays* in bamboo forest-derived *jhum* was declined from 1280 kg ha-1to 381 kg ha-1in the second year and 126kg ha-1in third year.

Similarly yield reduction over years in *Phaseolus vulgaris* was recorded from 34 to 14 kg ha^{-1}in bamboo forest-derived *jhum*. Glycine max recorded yield reduction from 71 to 24 in bamboo forest-derived *jhum* and 169 to 19kg ha-1in grassland derived *jhum* respectively. Similarly, vegetables like *Benincasa cerifera, Cucumis sativus, Cucurbita maxima, Sechium edule, Colocasia* and *Dioscorea* also recorded yield reduction over the year to a considerable extent under different *jhums*. There was also evidence of yield increase in grassland-derived *jhum* under this study. The yield increased markedly in the second and third year of cropping compared to that of the first year in grassland-derived *jhum* due to better crop management practices followed in second and third year under this system. The low yield of grassland-derived *jhum* during the first year was mainly due to use of the field for *Fagopyrum* and pulse crops for enriching the soil rather than getting high yield and prepared it for next year cropping of cereals and other crops.

The *Idus* use nitrogen-fixing non-legumes like *Alnus nepalensis* and *Castanopsis* sp. to improve the nitrogen economy of their *jhum* systems during cropping and fallow phases. Ramakrishnan and Toky (1983) and Ramakrishnan (1999) noticed that bamboo sprouts of the species like *Bambusa tulda, B. khasiana, Dendrocalamus hamiltonii and Neohouzeaua dulloa,* in the bamboo forest derived *jhum* increased potassium content in soil when *jhum* cycles decline up to 5 years.One of the major causes for the low yields after first year cropping and onwards was the poor fertility builds up. This became more obvious during the third year cropping in any type of *jhum* systems (Ahlgren and Ahlgren, 1965; Ramakrishnan and Toky, 1981).

Weeds were recognized to be another important cause of declining yield under slash and burn agriculture in many parts of the world. *Epatorium* spp. and *Imperata cylindrical* were found as predominant weeds in the study sites. Freeman (1955), Zinke et al. (1978) and Ramakrishnan et al. (1978) also noticed sever yield loss caused by *Imperata cylindrica* in Sarawak, *Eupatorium odoratum* in Thiland and these along with other weed species in North-Eastern India in different *jhum* systems. Therefore, it is concluded that the yields of different crops in jhum cultivation depends not only for the *jhum* cycle but also on crop management practice and vegetation of the *jhum* field types.

Table 3.b: Yield of crops (kg ha 1) in different jhum systems

Jhum types	**Bamboo forest-derived**			**Grassland-derived**		
Crops	Iyr	IIyr	IIIyr	Iyr	IIyr	IIIyr
Cereals						
Chenopodium album	-	35	25	-	41	28
Coix lachryma	-	117	77	-	53	25
Eleusine coracana	-	767	-	-	-	412
Fagopyrum cymosum	-	-	-	180	-	-
Oryza sativa	-	-	750	-	-	-
Zea mays	1280	381	126	-	230	112
Sub-total	1280	1300	978	180	324	577
SD	±107.8	±111.3	±93.9	±17.2	±30.1	±56.2
Pulses						
Glycine max	55	71	24	169	74	19
Phaseolus vulgaris	34	14		16	38	32
Phaseolus vulgaris	73	25	45	65	50	67
Sub-total	162	110	69	250	162	118
SD	±13.3	±10.4	±5.4	±16.4	14.3±	±9.8
Fruit vegetables						
Cucumis sativus	122	76	26		70	43
Cucurbita maxima	158	224	108		224	124
Sechium edule	75	37			54	-
Sub-total	654	337	134	-	348	117
SD	±51.2	±27.5	±12.1	-	±27.5	±8.8
Oil seeds						
Perilla ocimodes	-	21	45	-	23	42
SD	-	±1.8	±3.7	-	±2.1	±3.6

Jhum types	**Bamboo forest-derived**			**Grassland-derived**		
Tubers and Rhizome						
Colocasia esculenta	-	185	63	-	226	28
Dioscorea sp.	117	-	-	-	70	47
Solanum tuberosum	-	-	-	-	860	-
Sub-total	177	185	63	-	1156	75
SD	±10.7	±15.0	±5.0	-	±66.3	±7.1
Total	2213	1953	1289	1289	2013	979

3.5 Conservation and Conclusion:

Yield of staple crops are often quite low, but many other plants are intercropped in this *jhum* field and collected from secondary forest making overall productivity much higher. Precise quantification of total productivity in shifting cultivation is very difficult.

However (Mertz 2001) Multiple cropping provides an "insurance" policy to the cultivators because some crops are likely to give a good return even if there is partial or complete failure of other crops. The incidence of pest diseases is also minimized under mixed cropping. The pre-planting burn contributes to controlling harmful ants and other insect pests. After harvesting of early crops, late crops get more space at their peak growth period.

In mixed cropping under *jhum* several crop species with diverse growth habits developed a multistoried canopy with crops would help in efficient capture of light energy and a multi layered root mass distribution below the soil would help in optimal use of nutrients from the soil profile.

They use nitrogen-fixing non-legumes like *Alnus nepalensis* and *Castanopsis* sp. to improve the nitrogen economy of their *jhum* systems during cropping and fallow phases.

Ramakrishnan and Toky (1983) and Ramakrishnan (1999) noticed that bamboo sprouts of the species like *Bambusa tulda, B. khasiana, Dendrocalamus hamiltonii* and *Neohouzeaua dulloa,* in the *jhum* increased potassium content in soil when *jhum* cycles decline up to 5 years.

Land clearing in traditional shifting cultivation had the lowest amount of erosion and sediment loss from the system compared to any other form of land clearing and tillage system (Lal 1987). The reasons for low erosion despite farming on steep slopes are very short periods with exposed soil (after burning, before plant establishment), limited or no tillage, and traditional measures such as placing unburned logs horizontally on the slope.

The canopy also protects the land from excessive soil erosion and leaching once the crop cover is established.

Most of the orthodox tribal cultivators do not adopt new improved crop varieties in their *jhum*, on the contrary, they continue to grow the traditional crop varieties or wild relatives (even less productive) there by maintaining the germplasm. Biodiversity is higher in shifting cultivation systems than in permanent farming system due to fallow and mixed cropping. Compared to climax forest, biodiversity increases in long fallow systems where natural forest patches are maintained along with secondary forest. Some species endemics to climax forests may disappear in shifting cultivation areas, but the small patches of climax forest ensure natural forest biodiversity (Jessup 1981).

3.6 Acknowledgements:

The Author is grateful to his Ph D guide Professor Dr. D. C. Ghosh of Visva Bharati and Dr. Uma Melkinia, ex-Associate Professor of NERIST and Professor of G.B.Pant University of Agriculture and Technology for encouragement and critical suggestions. The study was supported by the Department of Environment and Forests, GOI, New Delhi through research grant and was completed at Forestry Department, NERIST, Nirjuli (Itanagar), Arunachal Pradesh. Special thanks are due to Mr. Bijit Basumatari, village Headman's and local tribal people for their cooperation and help during the field survey.

3.7 Reference:

1. Ahlgren, I. F. and Ahlgren, C. E. 1965. Effects on prescribed burning on soil microorganisms in a Minneesota Jack pine forest. *Ecology* **46:** 306-310.
2. Altieri, M. A., Letourneau, D.K. and Davis, J. R. 1983. Developing sustainable Agro ecosystems. *Bio. Science* **33:** 45-49.
3. Arnason, T., Lambert, J. D. H., Gale J., Cal, J. and Vernon, H. 1982. Decline of soil fertility due to intensification of land use by shifting agriculturists in Belize, Central America. *Agro Ecosystems* **8:** 27-37.
4. Freeman, J. D. 1955. *Iban Agriculture*. A report on the shifting cultivation of hill rice by the Iban of Sarawak. H.M.S.O., London.
5. Ghosh G, Studies on Plant Diversity, Ethnobotany and Ethnoagriculture in Dehang-Debang Biosphere Reserve of India, Ph.D. Thesis submitted to Visva Bharati, Santiniketan, 2005.
6. Gliessman, S. R., Garcia, S. R. and Amador, A. M. 1981. The ecological basis for the application of traditional agricultural technology in the management of tropical agroecosystems. *Agro-Ecosystems* **7:** 173-185.
7. Jessup, T.C. (1981) *Why do Apo Kayan Shifting cultivators move*? Borneo Research Bulletin **13:**16-32.
8. Lal, R. (1987) *Need for, approaches to and consequences of Iand clearing and development in the tropics.* In Tropical Land Clearing for Sustainable Agriculture. Proceedings of an IBSRAM Inaugural Workshop held in Jakarta and Bukittingi, Indonesia 27.8-3.9 1985, pp. 15-27. *Ed IBSRAM. Bangkok: IBSRAM.*
9. Mertz, O. (2001) *Rethinking the fallow-yield relationship in shifting cultivation*? Agroforestry Systems.
10. Mishra, B. K. and Ramakrishnan, P. S. 1981. The economic yield and energy efficiency of hill agro-ecosystems at higher elevations of Meghalaya in north-eastern India. *Acta Oecologica: Oecol. Applic.* **2:** 369-389.

11. Mitchell, R. 1979. The analysis of Indian agroecosystems. *Interprint,* New Delhi, pp.180.
12. *Pravongvienkham, P. P. 1998. The Role of Animal Husbandry and Aquaculture in Improvements of Swidden-Based Livelihood Systems in the Lao PDR. Thesis submitted to School of Environment, Resources and Development, Asian Institute of Technology.
13. Ramakrishnan, P. S. 1978. Observations on biological aspects of Productivity of forest ecosystems. **In** *Glimpses of Ecology* (Ed. Singh, J.S. and Gopal, B.). Internat. Scientific Publ., Jaipur, India. pp. 194-999.
14. Ramakrishnan, P. S. 1981. Jhum- an ecological assessment. In Souvenir, Silver Jubilee Symp. *Internat.* Soc. Trop. *Ecol.*, Bhopal, India. pp.41-49.
15. Ramakrishnan, P. S. 1981. Jhum- an ecological assessment. In Souvenir, Silver Jubilee Symp. *Internat. Soc. Trop. Ecol.*, Bhopal, India. pp.41-49.
16. Ramakrishnan, P. S. 1983. Socio-economic and cultural aspects in the north-east and options for eco-development of tribal areas. **In** *Tribal Techniques, Social Organisation and Development: Disruption and Alternates* (Ed. Chaubey, N.P.). Indian Acad. Social Sci. pp.12-30.
17. Ramakrishnan, P. S. 1984. The science behind rotational bush fallow agriculture systems (jhum). **Proc.** *Indian Acad. Sci.* (Plant Sci.) 93:379-400.
18. Ramakrishnan, P. S. 1984a. The Science behind rotational bush fallow agriculture systems (Jhum). **Proc.** *Indian Acad. Sci. (Plant Sci.)* 93: 397-400.
19. Ramakrishnan, P. S. 1999. The Impact of Globalisation on Agricultural systems of Traditional Societies. Sustainable Agriculture and Environment: globalization and the impact of trade liberalization (Ed. Andrew, K., Dragun and Clem Tisdell). Edward Elgar Publishing. Inc. USA. Pp-185-200.
20. Ramakrishnan, P. S. and Toky, O. P. 1981. Soil nutrient status of hill agroecosystems and recovery pattern after slash and burn agriculture (Jhum) in north-eastern India. *Plant* and *Soil* **60:**41-64.
21. Ramakrishnan, P. S. and Toky, O. P. 1983. Some Aspects of Environmental Degradation in North-Eastern Hill Areas of India. *Studies in Eco-Development Himalayas Mountains and Men* (Ed. Tejvir Singh and Jagdish Kaur). Print House (India), Lucknow. Pp 149-156.
22. Rasmussen, K. and Moller-Jensen, L. 1999. A generic model of shifting cultivation. *Danish Journal of Geography Special Issue* 1: 157-164.
23. Roder, W., Phengchanh, S. and Keoboulapha, B. 1995. Relationships between soil, fallow period, weeds and rice yield in slash-and–burn systems of Laos. *Plant and Soil* **176:** 27-36.
24. Slaats, J. J. P., Janssen, B. H. and Wessel, M. 1998. Crop production in relation to cultural practices in the *Chromolaena odorata* fallow system in South-West Cote d'Ivoire. *Netherlands Journal of Agricultural Science* **46:** 305-317.
25. Toky, O. P. and Ramakrishnan, P. S. 1981a. Cropping and yields in agricultural systems of the north-eastern hill region of India. *Agro-Ecosystems* **7:** 11-25.
26. Uhl, C. and Murphy, P. 1981. A comparison of productivities and energy value between slash and burn agriculture and secondary succession in the Upper Rio Negro region of the Amazon Basin. *Agro-Ecosystems* **7:** 63-83.USA. Pp-185-200.
27. Wadley, R. L. 1997. Circular Labor Migration and Subsistence Agriculture- A case of the Iban in West Kalimantan, Indonesia. Arizona State University.

28. Zinke, P. J., Sabhasri, S. and Kunstadter, P. 1978. Soil fertility aspects of the 'Luas' Forest fallow system of shifting cultivation. **In** *Farmers of the Forest* (Ed. Kunstadter, P., Chapman, E.C. and Sabhasri, S.). East West Centre, Honolulu, Hawaii.

ISBN: 978-93-90847-17-4

4. Bio-Control Approaches for Plant Disease Management

S. K. Tripathi

Professor and Head,
Department of Plant pathology,
JNKVV, College of Agriculture Rewa,
M.P., India.

Radha Singh

Assistant Professor,
Department of Plant Physiology,
JNKVV, College of Agriculture Rewa,
M.P., India.

4.1 Introduction:

Biotic stress is a major cause of limiting the agricultural productivity. It is caused by living organisms such as viruses, bacteria, fungi, nematodes, insects, arachnids, and weeds. Biotic stress agents directly take up their host of its nutrients leading to reduced plant survival rate and, in extreme cases, death of the host plant.

The term "bio-control" is abbreviated form of "biological control" mostly used in field of entomology and plant pathology. In entomology, it has been used to describe the use of live predatory insects, entomopathogenic nematodes, or microbial pathogens to suppress populations of different pest insects. In plant pathology, the term applies to the use of microbial antagonists to suppress diseases as well as the use of host specific pathogens to control weed populations. In both fields, the organism that suppresses the pest or pathogen is referred to as the biological control agent (BCA). More broadly, biological control refers to the purposeful utilization of introduced or resident living organisms, other than disease resistant host plants, to suppress the activities and populations of one or more plant pathogens.

Biological control is basically natural control, as system by which nature maintains the biological equilibrium and during the process checks the populations of plant pathogenic organisms also in this system, nature employs interactions between microorganisms and environment.

Biological control is defined as the reduction of inoculums density or disease-producing activities of a pathogen or parasite in its active or dormant state, by one or more organisms, accomplished naturally or through manipulation of the environment, host, or antagonists, or by mass introduction of one or more antagonists. Biological control is the reduction of the amount of inoculums or disease producing activity of a pathogen accomplished by one or more organisms other than man".

The bio control agents produce antibiotics or toxic compounds also and act through antibiosis. In addition, most of them have been found to induce systemic resistance in the plant against one or more pathogens of the same plant species. Even in treatment of fruits for prevention of post- harvest decay they have been found to induce resistance by triggering defense reactions.

4.1.1 Types of Bio-Control Agents

Nematodes (phylum Nematoda) -- There are over 300 species of nematodes (in 19 families) that are known to attack insects. Most of the research in biological control, however, has focused on only two genera, *Steinernema* and *Heterorhabditis*. These nematodes are unique because they harbor symbiotic bacteria that are pathogenic to the nematode's insect host.

4.2 Pathogens:

4.2.1 Fungi:

Although natural populations of insects are commonly attacked by fungal pathogens, there has been only limited success in using these organisms as biocontrol agents. In general, fungi are slow to kill their hosts.

The fungal mycelium usually invades all body tissues and may eventually cause suffocation by blocking the tracheal system. Some fungal pathogens have a relatively broad host range (e.g., *Beauveria bassiana, Metarhizium anisopliae,* and *Cordyceps* spp.) while others are more narrowly adapted to specific hosts like aphids (e.g., *Erynia radicans* and *Aschersonia* spp.), muscoid flies (e.g., *Entomophthora muscae*), mosquito larvae (e.g., *Lagenidium giganteum, Coelomomyces* spp. and *Tolypocladium* spp.), or Lepidoptera (e.g., *Nomuraea rileyi* and *Paecilomyces* spp.).

4.2.2 Protozoa:

Most species of entomopathic protozoa cause chronic infections that weaken, but do not kill their host. For this reason, there is little interest in these organisms as biocontrol agents. One notable exception is *Nosema locustae*, a microsporidian that has been mass-produced and marketed for control of grasshoppers under the trade name "Hopper Stopper".

4.2.3 Bacteria:

Most of the bacteria that are pathogenic to insects belong to the coccobacilli group. Members of the genus *Bacillus* are especially important as biological control agents. Some of these bacteria cause turbidity of body fluids (e.g., *Bacillus popillae*) and the diseases they cause have, therefore, come to be known as "milky" diseases. Other species form toxic protein crystals in conjunction with spore formation (e.g., *Bacillus thuringiensis*). Several strains of *B. thuringiensis* have been isolated and are now mass-produced and sold as pest control agents. Each strain has slightly different host specificity:

B. thuringiensis kurstaki -- lepidopterous larvae

B. thuringiensis israelensis-- mosquitoes and black flies

B. thuringiensis san diego-- some coleopteran larvae

4.2.4 Viruses:

The use of entomopathic viruses for insect control is still in its infancy. Many of these pathogens appear to have good potential as biocontrol agents because they are relatively host specific. Viral-induced mortality is usually caused by toxic proteins that accumulate during the reproductive cycle of the virus. After death, the integument and the internal tissues typically "melt away" into a liquified blob. Most entomopathic viruses are grouped according to the type of "inclusions" found within infected cells:

a. NPV or CPV (Nuclear or Cytoplasmic Polyhedrosis Virus): Clusters of virus particles are embedded within polyhedral inclusion bodies (crystals) that develop inside the nucleus or cytoplasm of infected cells. These are the most common viruses. They usually attack larvae of Lepidoptera or Hymenoptera (sawflies). The U.S. Forest Service has used NPVs as biocontrol agents for pine sawflies, tussock moths, and gypsy moths. There is also commercial interest in developing NPVs for use against corn earworms, cotton bollworms, cabbage loopers, and alfalfa butterflies.

b. Granulosis Virus: Each virus particle is enclosed in its own protein coat, giving infected cells a "granular" appearance under high magnification. These pathogens typically infect the fat body in Lepidopteran larvae and pupae. A granulosis virus has been developed for use in apple orchards against larvae of the codling moth (*Cydia pomonella*).

c. Non-inclusion Viruses: These pathogens (entomopox virus, for example) do not produce granules or polyhedral bodies. The cause of their toxicity is not well understood, but they are usually less virulent than other types of viruses.

Table 4.a: Inhomogeneous fungi as biocontrol agent.

(Biocontrol agent)	Target Insect Pests	Name of Production
Aschersonia aleyrodis	Glass House white fly	
Beauvenia bassfianae	Green leaf hopper, Rice blackbug, Potato beetle Pinc Catterpiller	Boverin
Entompphthora	Lucern aphid	
Sphaerosperma		
Hirsutella thompsonil	Citrus rustmite	Mycar

(Biocontrol agent)	Target Insect Pests	Name of Production
Metarhizium anisopliae	Spittle bug of sugaracane blackwine weevil,	Metaquino metabiol
	Coconut pests	
Nomuraea vileyi	Soybean catter piller & Lapidoptera insect	
Verticillium lecanii	Aphids, whitefly lgreen scale	Mycotal vertelea
Bacillus thuringiensis	Mosquito, mite	Thyricde, Biocontrol

Table 4.b: Nematogeneous fungi as biocontrol agent.

Nematogeneous fungi (Biocontrol agent)	Target Nematoda
Arthrobotrys musiformis	Rotylenchus similis
A. Oligospora	Meloidogyne haple
Glomus fasciculatus	Meloidogyne haple
A. oligospora	Neoplectana sp.
A. arthobotryoides, Dactyfaria thaumasis, Dactylella oviparasitica, Gliocladium roseum, Paecilornyces lilacinus	Meloidogyne incognita
Clomus mosseae	Rotylenchus reniformis
Verticillium chalmydosporium	Heterodera sp.
Cylindrocarpon destuctains, Entomphthora etc.	
Nemtatophythora, gynophila, Catenara auxilliaris	Heterodera avenae
Catenaria auxillaris and Paecilomyces lilacinus	Globodera rostochinensis

4.2.5 Biological Control of Inoculum:

Biological control of inoculums includes (i) destruction of inoculums by parasites and predators, (ii) prevention of formation of inoculums, (iii) weakening or displacement of the pathogen from the food base (infected residue), and (iv) reduction of vigor or virulence of the pathogen by such agents as mycoviruses (ds RNA).

a. Destruction of Dormant Propagules: Natural destruction of fungal propagules in soil is common and Sclerotia are destroyed by parasitism of *Sporodesmium sclerotivorum*, *Trichoderma harzianum* and *Coniothyrium minitans* and other fungi. Oospores of P*hytophthora, Pythium and Aphanomyces* are parasitized by many chytridiales, hyphomycetes, actinomycetes and Pseudomonas.

Nematode trapping fungi abound in soil and are known to feed on plant parasitic nematodes including cysts by parasitization and predation.

The objective of biological control of plant pathogens is to hasten the death of pathogenic or parasitic propagules with the help of such organisms and for this several methods have been suggested to strengthen their numbers.

The incorporation of decomposable organic matter such as farm yard manure, green manures, oilcakes, sawdust etc. During the decomposition of organic matter dormant propagules of many pathogens, viz., sclerotia of *Sclerotium*, are induced to germinate (germ tubes, hyphae) and then killed by lysis through soil microbial action.

b. Prevention of Inoculum Formation: This approach to biological control can be more efficient than mass action of biocontrol agents on biomass of the pathogens. The logic behind this approach is to incapacitate the inoculum producing organs, such as females and cysts of nematodes, to prevent a pathogenic fungus from colonizing plant residue in soil where it could multiply inoculum, encouraging development of antagonists on aerial parts of the plant where they could destroy the inoculum.

The nematophagous fungus *Nematophthora gynophila* parasitizes females and cysts of *Heterodera avenae* (cereal cyst nematode), the nematode trapping fungus *Dactylella oviparasiticus* parasitizes females and eggs of Meloidogyne species and the bacterium *Bacillus penetrans* parasitizes root knot nematodes preventing production of larvae as inoculums *Verticillium chlamydosprum* parasitizes eggs, larvae and cysts of the cereal cyst nematode (Heterodera *avenae*). Many fungal pathogens such as Pythium, Phtophtora and Armillaria are unlikely to colonize host plant residues in soil and suppress the growth of nematode and other pathogens.

c. Weakening or Displacement of the Pathogen in Crop Residue: Many root pathogens (Helminthosporium, *Gaeumannomyces graminis, Fusarium* species that cause vascular wilt, and *Armillaria mellea*) use crop debris for short or long duration perpetuation. They are primary colonizers (pioneers) of the host residue and are difficult to displace by secondary invaders or saprophytes.

d. Reduction of Vigor or Virulence of the Pathogen: this approach involves the reduction of vigor, aggressiveness, fitness, pathogenicity, virulence or other attributes of the pathogen essential to its saprophytic or parasitic activities accomplished through factors inherent (or carried) in the pathogen itself.

4.2.6 Biological Protection Against Infection:

The approach involves establishment of an antagonist in or around the site of infection so as to provide protection of the area against attack of a pathogen. The host is not involved in the interaction between the pathogen and the antagonist. The resident antagonists on the host surface providing control of a disease, effective blological control achieved by organic treatments and the phenomenon of suppressive soils characterized by lack of propagule germination for penetration and growth in the rhizosphere fall in this category.

a. Protection of Planting Material:

There are numerous examples of biological control achieved by protective covering of seed, rhizomes, tubers, etc. with propagules of an antagonist *Bacillus subtilis*, some species of Pseudomonas, *Penicillium, Chaetomium and Trichodrma* are often as effective as seed protectant chemicals such as thiram and captan. In per-emergence seed rot of pea caused by *Pythium ultimum*, the pathogen derives nutrients for colonization of seed and subsequent invasion from seed exudates released during swelling of the seed in soil. Species of *Trichodrma* have also been used similarly to provide protection to seeds during germination against seed rot fungi. *Trichodrma hamatum and T. harzianum* are effective seeds protectants against *Pythium* spp. and *Rhizoctonia solani*. Seedling roots, corms, bulbs, tubers, etc. can also be treated with spore or cell – suspension of such antagonists. Bacillus subtilis has been used against *Fusarium* species that cause rot of cuttings and bulbs. This bacterium has been used to control plant pathogens and increase plant growth. Seed treatments with this *bacterium have been shown to control various diseases caused by R.* solani, Helminthosporium in rice and tomato damping off. It forms endospores hence can be formulated in dusts, wettable powders, etc. without losing efficacy. Similarly, control of wilt of chickpea caused by *Fusarium oxysporum f.sp ciceris* by *Pseudomons fluorescence* is effective.

b. Protection of Foliage and Flowers. Existence of epiphytic microflora on plant surfaces including leaves and flowers is a natural phenomenon. These organisms do not harm the plant. There are many studies where their presence has been cited to explain reduction of disease incidence Brown leaf spot rice (Helminthosporium *oryzea*), leaf spot of rye (Helminthosporium *sativum*), fire blight of apple and pear (Erwinia *amylovora*), *Alternaria s*pot of tobacco, and many other foliage diseases are less severe when the normal epiphytic microflora is allowed as spray of broad-spectrum fungicides.

c. Prevention of Post-Harvest decay of Fruits: Attempts to check various types of fruit rots after harvest had been mostly through heat and chemical treatment. In recent years there have been successful demonstrations of biological control of post-harvest fruit rots by using bacteria and fungi including yeasts. Application of *Penicillium capacia* to lemon fruits after harvest gives 80% control of green mold caused by *Penicilium* without any visible injury to the fruits, *Bacillus subtills* gives control of peach brown rot (*Monilinia fructicola*), *Enterobacter cloacae* reduces peach Rhizopus rot (Rhizopus *stolonifer*).

d. Inoculation of Pruning Wounds with Antagonists: This method has been successfully demonstrated in case of certain wood and stump rot causing fungi.

Table 4.c: Weed Control by Fungi as Biocontrol Agent.

Biocontrol agent	**Target Weeds**
Puccinla chondrillina	*Chondrilla juncea (Rush skeleton weed)*
Phragmidium violaceum	*Rubus fruticosus*
Cercosporella ageretina	*Ageratina riparia*

Biocontrol agent	Target Weeds
Colletotrichum gloeosporides (COLLEGEO)	*Aeschynomene virginicia*
Phytophthora palmivora (DEVINE)	*Monenia adoreta (Milk weed vine)*
Colletotrichum cocodes (VELGO)	*Abutilon theophrasti (Velvet leaf)*
C. gleosporiodes f. sp cuscutae f. sp malvae (BIOMOL)	*Cuscuta (Dodder)*
Alternaria cassia	*Cassia obtusifolla (Sickcepod)*
Ascochyta cypericota	*Cyperus rotundus*
Cercospora rodmani	*Water hyacinth (Eichornia Crass I pes)*
Alternaria macrospora	*Anoda cristata*

4.3 Biocontrol Agents and their Mechanism of Action:

Plant diseases are the result of interactions of the three components i.e., host, pathogen and environment. Biological control agents are the organisms that interact with three components and manage the diverse group of plant diseases. Bio control agents involve a bewildering array of mechanisms in achieving disease control. Understanding the mechanisms of biological control of plant diseases through the interactions between biocontrol agent and pathogen may allow us to manipulate the soil environment to create conditions conducive for successful biocontrol or to improve biocontrol strategies (Fravel, 1988). Bio control can result from many different types of interactions between organisms. In all cases of bio control, pathogens are antagonized by the presence and activities of other organisms that they encounter. Different mechanisms of antagonism occur across a spectrum of directionality related to the amount of interspecies contact and specificity of the interactions.

Direct antagonism results from physical contact and/or a high degree of selectivity for the pathogen by the mechanism(s) expressed by the BCA(s). In such a system, hyperparasitism by obligate parasites of a plant pathogen would be considered the most direct type of antagonism because the activities of no other organism would be required to exert a suppressive effect. In contrast, indirect antagonisms result from activities that do not involve sensing or targeting a pathogen by the BCA(s). Stimulation of plant host defense pathways by non-pathogenic BCAs is

Table 4.d: Types of interspecies antagonisms leading to biological control of plant pathogens.

Type	Mechanism	Examples
Direct antagonism	Hyper parasitism /predation	Lytic/some nonlytic mycoviruses *Ampelomyces quisqualis Lysobacter enzymogenes Pasteuria penetrans Trichoderma virens*
	Antibiotics	2,4-diacetylphloroglucinol

Type	Mechanism	Examples
Mixed-path antagonism		Phenazines Cyclic lipopeptides
	Lytic enzymes	Chitinases Glucanases Proteases
	Unregulated waste products	Ammonia Carbon dioxide Hydrogen cyanide
	Physical/chemical interference	Blockage of soil pores Germination signals consumption Molecular crosstalk confused
Indirect antagonism	Competition	Exudates/ leachates consumption Siderophore scavenging Physical niche occupation
	Induction of host resistance	Contact with fungal cell walls Detection of pathogen-associated, molecular patterns Phytohormone-mediated induction

the most indirect form of antagonism. However, the most effective BCAs studied to date appear to antagonize pathogens using multiple mechanisms.

For instance, Pseudomonas known to produce the antibiotic 2,4-diacetylphloroglucinol (DAPG) may also induce host defenses (Iavicoli et al. 2003).

Additionally, DAPG-producers can aggressively colonize roots, a trait that might further contribute to their ability to suppress pathogen activity in the rhizosphere of wheat through competition for organic nutrients (Raaijmakers and Weller 2001).

4.4 Antibiotic Mediated Suppression:

Antibiotics are microbial toxins that can, at low concentrations, poison or kill other microorganisms. Antibiotics produced by bacteria include volatile antibiotics (hydrogen cyanide, aldehydes, alcohols, ketones, and sulphides) and nonvolatile antibiotics: polyketides (diacetylphloroglucinol; DAPG and mupirocin), heterocyclic nitrogenous compounds (phenazine derivatives: pyocyanin, phenazine-1-carboxylic acid; PCA, PCN, and hydroxyphenazines) (de Souza et al. 2003), and phenylpyrrole antibiotic (pyrrolnitrin) (Ahmad et al. 2008). Bacillus strains produce a variety of lipopeptide antibiotics (Iturins, bacillomycin, surfactin, and Zwittermicin A).

Methods have been developed to ascertain when and where biocontrol agents may produce antibiotics (Notz et al. 2001) but detecting expression in the infection court is difficult because of the heterogenous distribution of plant-associated microbes and the potential sites of infection.

In a few cases, the relative importance of antibiotic production by biocontrol bacteria has been demonstrated, where one or more genes responsible for biosynthesis of the antibiotics have been manipulated. For example, mutant strains incapable of producing phenazines (Thomashow and Weller 1988) or phloroglucinols (Keel et al. 1992) have been shown to be equally capable of colonizing the rhizosphere but much less capable of suppressing soil borne root diseases than the corresponding wildtype and complemented mutant strains. The role of antibiotics in biocontrol has been studied by genetic analysis, e.g., mutants that do not produce antibiotics to demonstrate a correlation between antibiotic productivity and biocontrol

Table 4.e: Antibiotics Produced by Biocontrol Agents.

Antibiotic	**Source**	**Target pathogen**	**Disease**	**Reference**
2,4 diacetyl phloroglucinol	*Pseudomonas fluorescens* F113	*Pythium spp.*	Damping off	Shanahan et al. (1992),
Agrocin 84	*Agrobacterium radiobacter*	*Agrobacterium Tumefaciens*	Crown gall	Kerr (1980)
Bacillomycin D	*Bacillus subtilis* AU195	*Aspergillus flavus*	Aflatoxin contamination	Moyne et al. -2001
Bacillomycin, fengycin	*Bacillus amyloliquefaciens* FZB42	*Fusarium Oxysporum*	Wilt	Koumoutsi et al. -2004
Xanthobaccin A	*Lysobacter* sp. strain SB-K88	*Aphanomyces Cochlioides*	Damping off	Islam et al. -2005
Gliotoxin	*Trichoderma Virens*	*Rhizoctonia solani*	Root rots	Wilhite et al. -2001
Herbicolin	*Pantoea Agglomerans* C9-1	*Erwinia amylovora*	Fire blight	Sandra et al. -2001
Iturin A	*B. subtilis* QST713	*Botrytis cinerea* and *R. solani*	Damping off	Paulitz and Belanger (2001),

Antibiotic	Source	Target pathogen	Disease	Reference
				Kloepper et al.
				-2004
Mycosubtilin	*B. subtilis*	*Pythium*	Damping off	Leclere et al.
	BBG100	*Aphanidermatum*		-2005
Phenazines	*P. fluorescens*	*Gaeumannomyces*	Take-all	Thomashow et
	2-79 and 30-84	*graminis* var. *tritici*		al. (1990)
Pyoluteorin,	*P. fluorescens*	*Pythium ultimum*	Damping off Howell and	Howell and
pyrrolnitrin	Pf-5	and *R. solani*	Stipanovic	Stipanovic
			-1980	-1980
Pyrrolnitrin,	*Burkholderia*	*R. solani* and	Damping off	Homma et al.
pseudane	*Cepacia*	*Pyricularia oryzae*	and rice blast	-1989
Zwittermicin A	*Bacillus cereus*	*Phytophthora*	Damping off	Smith et al.
	UW85	*medicaginis*		-1993

activity. For example, a phenazine antibiotic (Phz) produced by *Pseudomonas fluorescens* strain 2-79 has been implicated in control of take all disease of wheat caused by *Gaeumannomyces graminis* var tritici (Handelsman and Parke, 1989). Among other bacteria, antibiotic agrocin 84 produced by *Agrobacterium radiobacter* strain K84 is one of best described examples of biocontrol to control crown gall caused by virulent *A. tumefaciens* strains (Kerr, 1989). Several studies have implicated agrocin K84 in the disease control process produced by *Trichoderma virens* in the suppression of Pythium damping-off of cotton seedlings has also been confirmed recently by mutational analysis (Di Pietroet al., 1993)

4.5 Competition:

This process is considered to be an indirect interaction whereby pathogens are excluded by Biocontrol agents and their mechanism in plant disease management 51 depletion of a food base or by physical occupation of site (Lorito et al., 1993). Biocontrol by nutrient competition can occur when the biocontrol agent decreases the availability of a particular substance thereby limiting the growth of the pathogen. Particularly, the biocontrol agents have a more efficient uptake or utilizing system for the substance than do the pathogens (Handelsman and Parke, 1989). For example, iron competition in alkaline soils may be a

limiting factor for microbial growth in such soils (Leongand Expert 1989). Some bacteria, especially fluorescent Pseudomonas produce siderophores that have very high affinities for iron and can sequester this limited resource from other microflora thereby preventing their growth (Loper and Buyer 1991. Some studies have found siderophores to play little or no role in disease control, particularly with Pythium species (Hamdan, *et al*., 1991). More recently, Leeman *et al*., 1996 have reported that iron-chelating salicylic acid produced by selected *P. fluorescens* strains at low iron availability may be involved in the induction of systemic resistance to Fusarium wilt of radish. Competition for specific substances or stimulants for germination of microorganisms may also occur in soil since most resting structures of microbes cannot germinate without specific stimulants due to soil fungistasis (Ko, and Lockwood 1970). Infection of plants by pathogens occurs only after dormancy is broken in the presence of stimulants from plant hosts. Consequently, microbes including pathogens may compete for specific stimulants of germination that may come from germinating seeds or growing roots. These factors may include fatty acids, or their peroxidation products (Harman and Nelson 1994), or volatile components such as ethanol and acetaldehyde (Gorecki *et al*., 1985).

4.6 Hyperparasites and Predation:

In hyperparasitism, the pathogen is directly attacked by a specific BCA that kills it or its propagules. Usually, there are four major classes of hyperparasites: obligate bacterial pathogens, hypoviruses, facultative parasites, and predators. *Pasteuria penetrans* is an obligate bacterial pathogen of root-knot nematodes that has been used as a BCA. Hypoviruses are hyperparasites. A classic example is the virus that infects *Cryphonectria parasitica*, a fungus causing chestnut blight, which causes hypovirulence, a reduction in disease-producing capacity of the pathogen. The phenomenon has controlled the chestnut blight in many places (Milgroom and Cortesi 2004).

However, the interaction of virus, fungus, tree, and environment determines the success or failure of hypovirulence. There are several fungal parasites of plant pathogens, including those that attack sclerotia (e.g., *Coniothyrium minitans*) while others attack living hyphae (e.g. *Pythium oligandrum*). And a single fungal pathogen can be attacked by multiple hyperparasites. For example, *Acremonium alternatum*, *Acrodontium crateriforme*, *Ampelomyces quisqualis*, *Cladosporium oxysporum*, and *Gliocladium virens* are just a few of the fungi that have the capacity to parasitize powdery mildew pathogens (Kiss 2003). Other hyperparasites attack plant-pathogenic nematodes during different stages of their life cycles (e.g., *Paecilomyces lilacinus* and *Dactylella oviparasitica*). In contrast to hyperparasitism, microbial predation is more general and pathogen non-specific and generally provides less predictable levels of disease control. Some BCAs exhibit predatory behavior under nutrient-limited conditions. However, such activity generally is not expressed under typical growing conditions. For example, some species of *Trichoderma* produce a range of enzymes that are directed against cell walls of fungi. However, when fresh bark is used in composts, *Trichoderma* spp. do not directly attack the plant pathogen, *Rhizoctonia solani*.

But in decomposing bark, the concentration of readily available cellulose decreases and this activates the chitinase genes of *Trichoderma* spp., which in turn produce chitinase to

parasitize *R. solani* (Benhamou and Chet 1997). This process involves the direct utilization of one organism as food by another (Handelsman and Parke 1989). Fungi that are parasitic on other fungi are usually referred to as mycoparasites (Baker and Cook 1974.). Many mycoparasites occur on a wide range of fungi and some of them have been proposed to play an important role in disease control (Adams, 1990). For example, Darlucafilum (now *Sphaerellopsis filum*) was described by Saccardo as a parasite of some rust fungi, especially *Puccinia* and *Uromyces* (Sundheim and Tronsmo 1988). *Trichoderma lignorum (T. viride)* parasitizing hyphae of *Rhizoctonia solani* and suggestion of inoculating soil with *Trichoderma* spores to control damping-off of citrus seedling was reported by Weindling and Fawcett in 1936. This and other *Trichoderma species* were observed to parasitize *Rhizoctonia bataticola* and *Armillaria mellea* (Baker and Cook. 1974). Generally, mycoparasitism can be described as a four-step process (Chet, 1987): The first stage is chemotropic growth. The biocontrol fungi grow tropistically toward the target fungi that produce chemical stimuli. For example, a volatile or water- soluble substance produced by the host fungus serves as a chemo attractant for parasites. The next step is recognition. Lectins of hosts (pathogens) and carbohydrate receptors on the surface of the biocontrol fungus may be involved in this specific interaction (Inbar and Chet 1994). The third step is attachment and cell wall degradation. Mycoparasites can usually either coil around host hyphae or grow alongside it and produce cell wall degrading enzymes to attack the target fungus (Chet, 1987). These enzymes such as chitinases and b-1,3-glucanase may be involved in degradation of host cell walls and may be components of complex mixtures of synergistic proteins that act together against pathogenic fungi (Di Pietro, et al, 1992). The final step is penetration. The biocontrol agent produces appresoria-like structures to penetrate the target fungus cell wall (Chet, 1987).

Table 4.f: List of Hyper Parasites.

Sr. No.	Hyperparasite (S)	Target Pathogens
1.	*Laetisaria arvolis (Corticum species)*	*Rhizoctnia, Pythium*
2.	*Pythium spp.*	*Phytophthora sp.*
3.	*Talaromycs flavus*	*Verticillium sp.*
4	*Coniothyrium virens (Gliogard)*	*Solerotium*
5	*Gliocladium virens (Gliogard)*	*Solerotium*
6	*Sporidesmium selerotivorum*	*Solerotinia, Sclerotium*
7	*Bacillus subtilis (Kodiak)*	*Solerotium, Phytophthora, Pythium etc.*
8	*Aphelencheus avenae (Nematode)*	*Rhizoctonia, Fusarium*
9	*Pseudomonas fluorescens (Dagger-G)*	*Pythuim, Rhizoctonia sp.*
10	*Tuberculina maxima*	*Cronartium ribicola*
11	*Verticillium lecanii*	*Rust fungi*
12	*Ampelomyces quisqualis*	*Powdery mildews*
13	*Telletiopsis sp.*	*Sphaerotheca sp.*

Sr. No.	Hyperparasite (S)	Target Pathogens
14	*Nectria inventa*	*Alternaria sp.*
15	*Trichoderma harzianum (Vinab-T), (F-stop)*	*Damping off (Rhizoctonia, Sclerotium)*
16	*Sseudomonas syrinage (Biosae)*	

4.7 Induction of Systemic Resistance

The inducible resistance in plants to a variety of pathogens is known as systemic acquired resistance (SAR). SAR may be induced by inoculating plants either with a necrogenic pathogen or nonpathogen or with certain natural or synthetic chemical compounds (Lam and Gaffney 1993). These defense responses may include the physical thickening of cell walls by lignification, deposition of callose, accumulation of antimicrobial low-molecular-weight substances (e.g., phytoalexins), and synthesis of various proteins (e.g., chitinases, glucanases, peroxidases, and other pathogenesis related (PR) proteins) (Hammerschmidt, et al, 1984). This defense system is also triggered when plants are colonized by plant growth-promoting rhizobacteria (Sticher, et al., 1997). Recently, many strains of PGPR have been shown to be effective in controlling plant diseases by inducing plant systemic resistance (Liu, et al., 1995). The chemical Biocontrol agents and their mechanism in plant disease management 53 compounds that induce resistance of plants to pathogens may include polyacrylic acid, ethylene, salicylic acid and acetyl salicylic acid, various amino acid derivatives, the herbicide phosphinotricin, and harpin produced by *Erwinia amylovora* (Sequeira, 1983). It is known that stress can induce defense mechanisms against pathogens (Maurhofer, et al., 1994). However, the hypothesis should be proved by genetic analysis such as heterologous expression, which shows that inducing ability may be transferred to other potent strains as an additional complementary mode of action, and gene mutation, which knocks out the ability and leads to less disease control.

Various classes of compounds are released by the *Trichoderma* sp. into the zone of interaction and induce resistance in plants. The first class is proteins with enzymztic or other activity. Fungal proteins such as xylanase, cellulases and swollenins are secreted by T*richoderma* species (Martinez *et al.*, 2001). Lots of findings indicated that *Trichoderma* endochitinase can also enhance defense, probably through induction of plant defense related proteins.

Number of proteins and peptides that is active in inducing terpenoid phytoalexin biosynthesis and peroxidase activity in cotton, e.g., the small protein, SM1, which has hydrophobin-like properties, were found to be produced by strains of *T. virens* (Dreuge *et al.,* 2007. Another group of proteins that induce defense mechanisms in plants are the products of avirulence-like (Avr) genes (woo *et al.,* 2006). They usually function as race- or pathovar-specific elicitors of hypersensitive and other defense-related responses in plant species that hold the corresponding resistance (R) gene. Saksirirat *et al.,* 2009, proposed the efficacy of *Trichoderma* strains in inducing resistance in tomato and findings indicated that *Trichoderma* was effective in inducing systemic resistance in tomato plant.

4.8 Plant Growth Promotion and Competition for Nutrients

Biocontrol agents also capable to produce growth hormones like, Auxins, Cytokinin, Gibberellins etc. These hormones play vital role in suppression of deleterious pathogens and promote the growth of plants and increase in their yield. The research on mechanism of growth promotion indicated that PGPR promotes plant growth directly by production of plant growth regulators or indirectly by stimulating nutrient uptake, by producing siderophores or antibiotics to protect plant from soil borne pathogens or harmful rhizosphere organisms. Plant growth promotion and productivity stimulated by microbial endophytic communities are often associated with increased plant health, achieved by direct and/or plant-mediated control of plant pests and pathogens. Some research reported that root-associated microbes, particularly mycorrhizae and/or rhizobacteria, might influence and change plant physiology such that the aboveground parts are less prone to attack by phytophagous insects (Pangesti *et al.,* 2013). Plant defense is then achieved by priming for enhanced expression of sequences regulated by the production of jasmonic acid, ethylene, or salicylic acid. In other cases, beneficial microbes, such as root-colonizing pseudomonads, may directly act against plant-feeding insects by producing volatile organic compounds (VOCs) that have insecticidal properties (Kupferschmied *et al., 2013*). In diverse studies, most of the antagonistic relationships between beneficial microbes and pathogens have been successful in elucidating efficient biocontrol activity against various fungal diseases (Baker, R. 1991). Various studies, researchers have found that endophytic microorganisms may have a symbiotic association with their host plants. The endophytic Bacillus pumilus efficiently protected pea plants from *Fusarium oxysporum* f. sp. pisi, the causal agent of Fusarium root rot (Benhamou *et al*., 1996). in the same way, The growth-promoting activity in various plants elicited by the endophytic fungus Piriformospora indica (Varma *et al*., 1999). These endophytic microorganisms offer actual advantages to the host plants, for example, by enhancing the physiological activity of the plant or facilitating the uptake of nutrients from the soil. Thus, they may serve as biocontrol agents or plant growth promoters (Shimizu *et al*., 2009). Among other microorganisms, a variety of actinomycetes inhabits a wide range of plants as endophytes (Tian *et al*., 2004); therefore, such actinobacteria may have both the potential to serve as effective biocontrol agents and to be considered as efficient plant growth promoters (Kunoh, H. 2002). The genus Streptomyces has been extensively used for biocontrol of soil borne fungal pathogens due to its intense antagonistic activity through the production of various antifungal metabolites (El-Tarabily *et al*., 2006). In soil, most of the known actinomycetes belong to genus Streptomyces and have been used for various agricultural purposes, mainly due to their production of antifungal and antibacterial metabolites and a number of plant growth-promoting (PGP) traits (Suzuki *et al*., 2000). *Trichoderma* spp. are rapidly growing fungi that have persistent conidia and a broad spectrum of substrate utilization. They are very efficient competitors for nutrition and living space (Hjeljord *et al.,* 2000). In addition, *Trichoderma* spp., are naturally resistant to many toxic compounds, including herbicides, fungicides, and phenolic compounds. Therefore, they can grow rapidly and impact pathogens by producing metabolic compounds that hamper spore germination (fungistasis), kill the cells (antibiosis), or alter the rhizosphere, (e.g., by acidifying the soil so that the pathogens cannot grow) and starvation is the most common cause of death for microorganisms, so competition for limited nutrients is mainly important in the biocontrol of phytopathogens. Iron uptake is essential for filamentous fungi and under iron starvation; fungi excrete low-molecular weight ferriciron-specific chelators, termed siderophores.

Trichoderma spp. produce highly efficient siderophores that chelate iron and stop the growth of other fungi (Benitez et al., 2004). Therefore, soil characteristics influence Trichoderma as a biocontrol agent.

4.9 References:

1. Adams, P.B. (1990). The potential of mycoparasites for biological control of plant diseases. Annu. Rev. Phytopathol. **28**:59-72.
2. Ahmad, F., Ahmad, I. and Khan, M.S. (2008). Screening of free-living rhizospheric bacteria for their multiple plant growth promoting activities. Microbiol. Res. **163**:173–181.
3. Baker, K.F., and Cook, R. J. (1974). Biological Control of Plant Pathogens. Am. Phytopathol. Soc., St. Paul. MN.433.
4. Baker, R. (1991). Diversity in biological control. Crop Prot.**10**: 85–94.
5. Benhamou, N. and Chet, I. (1997). Cellular and molecular mechanisms involved in the intersection between *Trichoderma harzianum* and *Pythium ultimum*. Appl. Environ. Microbiol. **63**:2095–2099.
6. Benhamou, N., Kloepper, J.W., Quadt-Hallman, A. and Tuzun, S. (1996). Induction of defense-related ultrastructural modifications in pea root tissues inoculated with endophytic bacteria. Plant Physiol.**112**: 919–929.
7. Benitez, T., Rincon, A.M., Limon, M.C. and Codon, A.C. (2004). Biocontrol mechanism of Trichoderma strains. Int. Microbiol. **7**: 249-260.
8. Chet, I. (1987). *Trichoderma* application, mode of action, and potential as biocontrol agent of soil-borne pathogenic fungi. in: Innovative Appro. Plant Disease Control. I. Chet,ed., John Wiley, New York. 137-160.
9. De Souza, J.T.A., Arnould, C., Deulvo,t C., Lemanceau, P., Gianinazzi-Pearson, V. and Raaijmakers, J.M. (2003). Effect of 2,4-diacetylphloroglucinol on Pythium: cellular responses and variation in sensitivity among propagules and species. *Phytopatholol*. **93** :966–975.
10. Di Pietro, A. (1993). Chitinolytic enzymes produced by Trichoderma harzianum antifungal activity of purified endochitinase and chitobiosidase. *Phytopathol*. **83**: 302-307.
11. Druege, U., Baltruschat, H. and Franken, P. (2007). *Piriformospora indica* promotes adventitious root formation in cuttings. *Scientia Horticulturae.* **112:** 422–26.
12. Fravel, D.R. (1988). Role of antibiosis in the biocontrol of plant diseases. Annu. Rev. Phytopathol. **26**: 75-91.
13. Gorecki, R.J., Harman, G.E., and Mattick, L.R. (1985). The volatile exudates from germinating pea seeds of different viability and vigor. Can. J. Botany.**63**:1035- 1039.
14. Hamdan, H., Weller, D.M., and Thomashow, L.S. (1991). Relative importance of fluorescent sensitivity among propagules and species. Phytopatholol. **93**:966–975.
15. Handelsman Jo. and Parke, J.L. (1989). Mechanisms in biocontrol of soil borne plant pathogens. in: Plant-Microbe Interactions, Molecular and Genetic Perspectives T. Kosuge, and E. W. Nester, eds., McGraw-Hill, New York. **3**:27-61.
16. Harman, G.E. and Nelson, E.B. (1994). Mechanisms of protection of seed and seedlings by biological control treatments: Implications for practical disease control. Seed Treatment: Progress and Prospects. T. Martin, ed., BCPC, Farnham, UK. 283-292.

17. Homma, Y., Kato, Z., Hirayama, F., Konno, K., Shirahama, H., and Suzui, T. (1989). Production of antibiotics by *Pseudomonas cepacia* as an agent for biological control of soil borne plant pathogens. *Soil Biol. Biochem*. **21**:723-728.
18. Howell, C. R., Beier, R.C. and Stipanovi, R.D. (1980). Production of ammonia by Enterobacter caloacae and its possible role in the biological control of phythium pre-emergence damping off by the bacterium. *Phytopathology.* **78:** 105-1078.
19. Inbar, J. and Chet, I. (1994). A newly isolated lectin from the plant pathogenic fungus *Sclerotium rolfsii*: purification, characterization and role in mycoparasitism. J. Microbiol. **140**: 651-657.
20. Islam, T.M., Hashidoko, Y., Deora, A, Ito, T. and Tahara, S. (2005). Suppression of damping-off disease in host plants by the rhizoplane bacterium *Lysobacter* sp. strain SB-K88 is linked to plant colonization and antibiosis against soilborne peronosporomycetes. *Applied Environmental Microbiology.* **71:** 3786-3796.
21. Kerr, A. (1980). Biological control of crown gall through production of agrocin 84. *Plant Disease.* **64:** 25-30.
22. Kerr, A. (1989). Commercial release of a genetically engineered bacterium for the control of crown gall. *Agric. Sci*. **2**:41-48.
23. Kiss, L. (2003). A review of fungal antagonists of powdery mildews and their potential as biocontrol agents. *Pest Management Science.* **59**: 475–83.
24. Kloepper, J.W., Ryu, C.M. and Zhang, S. (2004). Induce systemic resistance and promotion plant growth by *Bacillus* spp. *Phytopathology.* **94:** 1259-1266.
25. Ko, W. H. and Lockwood, J. L. (1970). Mechanism of lysis of fungal mycelia in soil. *Phytopathol.* **60**:148-154.
26. Koumoutsi, A., Chen, X.H., Henne, A., Liesegang, H., Gabriele, H., Franke, P., Vater, J. and Borris, R. (2004). Structural and functional characterization of gene clusters directing nonribosomal synthesis of bioactive lipopeptides in *Bacillus amyloliquefaciens* strain FZB42. *Journal of Bacteriology.* **86:** 1084-1096.
27. Kunoh, H. (2002). Endophytic actinomycetes: Attractive biocontrol agents. *J. Gen. Plant Pathol*. **68**, 249–252.
28. Kupferschmied, P., Maurhofer, M. and Keel, C. (2013). Promise for plant pest control: Root-associated pseudomonads with insecticidal activities. *Front. Plant Sci*. **4**: 287.
29. Lam, S.T. and Gaffney, T.D. (1993). Biological activities of bacteria used in plant pathogen control. in: Biotechnology in Plant Disease Control.I. Chet,ed., *John Wiley*, New York . 291-320.
30. Lavicoli, A., Boutet, E., Buchala, A. and Métraux, J.P. (2003). Induced systemic resistance in *Arabidopsis thaliana* in response to root inoculation with *Pseudomonas fluorescens* CHA0. *Mol. Plant-Microbe Interact.* **16**:851-858.
31. Leclere, V., Bechet, M., Adam, A., Guez, J.S., Wathelet, B., Ongena, M., Thonart, P., Gancel, F., Chollet-Imbert, M. and Jacques, P. (2005). Mycosubtilin overproduction by *Bacillus subtilis* BBG100 enhances the organism's antagonistic and biocontrol activities. *Appl. Environ. Microbiol*. **71**:4577-4584.
32. Leeman, M., Den Ouden, F.M., Van Pelt, J.A., Dirkx, F.P.M., Steijl, H., PAHM, B. and Schippers, B. (1996). Iron availability affects induction of systemic resistance to *Fusarium* wilt of radish by *Pseudomonas fluorescens*. *Phytopathology*.**86**:149–155.
33. Leong, S.A. and Expert, D. (1989). Siderophores in plant pathogen interactions. in: Plant-Microbe Interactions, Molecular and Genetic Perspectives, T. Kosuge, and E. W. Nester, eds., McGraw-Hill, New York. **3**: 62-83.

34. Liu, L., Kloepper, J.W. and Tuzun, S. (1995). Induction of systemic resistance in cucumber against bacterial angular leaf spot by plant growth-promoting rhizobacteria. *Phytopathol***. 85**: 843-847.
35. Lo, C.T. (1997). Biological control of turfgrass diseases using *Trichoderma harzianum.* Plant Prot. Bull. **39**: 207-225.
36. Lo, C.T., Nelson, E.B., Hayes, C.K. and Harman, G.E. (1998). Ecological studies of transformed *Trichoderma harzianum* strain 1295-22 in the rhizosphere and on thephylloplane of creeping bent grass. *Phytopathology* **88** :129 - 136.
37. Loper, J.E. and Buyer, J.S. (1991). Siderophores in microbial interactions on plant surfaces. Molec. Plant Microbe Interact. **4**:5-13.
38. Lorito, M., Harman, G.E., Hayes, C.K., Broadway, R., Tronsmo, A, Woo, S.L. and Di Pietro, A. (1993). Chitinolytic enzymes produced by *Tricboderma barxianurn*: antifungal activity of purified endochitinase and chitobiosidase. *Plytopathology*.**83**: 302-307.
39. Martinez, C.,Blanc, F., Le, C.E., Besnard, O., Nicole, M. and Baccou, J.C. (2001). Salicylic acid and ethylene pathways are differentially activated in melon cotyledons by active or heat-denatured cellulase from *Trichoderma longibrachiatum*. *Plant Physiology.* **127:** 334–44.
40. Maurhofer, M., Keel, C., Schnider, U., Voisard, C., Haas, D. and Defago, G. (1992). Influence of enhanced antibiotic production in *Pseudomonas fluorescens* CHA0 on its disease suppressive capacity. Phytopathol. **82**:190-195.
41. Meguro, A., Ohmura, Y., Hasegawa, S., Shimizu, M., Nishimura, T. and Kunoh, H. (2006). An endophytic actinomycete, Streptomyces sp. MBR-52, that accelerates emergence and elongation of plant adventitious roots. *Actinomycetologica*. **20**: 1–9.
42. Moyne, A.L., Shelby, R., Cleveland, T.E. and Tuzun, S. (2001). Bacillomycin D: an Iiturin with antifungal activity against *Aspergillus flavus. J. Applied Microbiol*. **90:** 622-629.
43. Notz, R., Maurhofer, M., Schnider-Keel, U., Duffy, B., Haas, D., and Defago, G. (2001). Biotic factors affecting expression of the 2,4-diacetylphloroglucinol biosynthesis gene phlA in Pseudomonas fluorescens biocontrol strain CHA0 in the rhizosphere. *Phytopathol.* **91**:873-881.
44. Paulitz, T C. (1991). Effect of *Pseudomonas putida* on the stimulation of *Pythium ultimum* by seed volatiles of pea and soybean. *Phytopathology.* **81:** 1282- 1287.
45. Raaijmakers, J.M., Vlami, M. and De Souza, J.T. (2002). Antibiotic production by bacterial biocontrol agents. *Anton. van Leeuw*. **81**:537-547.
46. Saksirirat, W., Chareerak, P. and Bunyatrachata, W. (2009). Induced systemic resistance of bio control fungus, *Trichoderma* sp. against bacterial and gray leaf spot in tomatoes. *Asian Journal of Food and Agro industry*. 99-104.
47. Sandra, A. I., Wright, C. H., Zumoff, L.S.and Steven, V. B. (2001). *Pantoea agglomerans* strain EH318 produces two antibiotics that inhibit *Erwinia amylovora in vitro*. *Appied Environmental Microbiology.* **67:** 282-292.
48. Shimizu, M., Yazawa, S. and Ushijima, Y.A. (2009). Promising strain of endophytic Streptomyces sp. for biological control of cucumber anthracnose. *J. Gen. Plant. Pathol*. **75**: 27–36.
49. Smith, K.P., Havey, M.J. and Handelsman, J. (1993). Suppression of cottony leak of cucumber with *Bacillus cereus* strain UW85. *Plant Disease.* **77:** 139-142.
50. Sticher, L., Mauch-Mani and Metraux, J.P. (1997). Systemic acquired resistance. *Annu. Rev. phytopathol*. **35**: 235 - 270.

51. Sundheim, L. and Tronsmo, A. (1988). Hyperparasites in biological control. in: Biocontrol of Plant Diseases. K. G. Mukerji, and K. L. Garg, eds., CRC Press, Boca Raton, FL. 53-69.
52. Thomashow, L.S., Weller, D.M., Bonsall, R.F., and Pierson, L.S. III. (1990). Production of the antibiotic phenazine-1-carboxylic acid by fluorescent pseudomonas in the rhizosphere of wheat. *Appl. Environ*. Microbiol. **56**: 908-912.
53. Varma, A. Verma, S., Sahay, N., Bütehorn, B. and Franken, P. (1999). *Piriformospora indica*, a cultivable plant-growth-promoting root endophyte. *Appl. Environ. Microbiol***. 65**: 2741–2744.
54. Woo S L, Scala F, Ruocco M, Lorito M. (2006). The molecular biology of the interaction between *Trichoderma* spp., phytopathogenic fungi, and plants, *Phytopathology,* **6**:181–185.

ISBN: 978-93-90847-17-4

5. Insect Antifeedant Active Aryl Enones

V. Mala

Department of Chemistry,
Annai College of Arts and Science,
Kovilacheri, Kumbakonam, India.

I. Muthuvel

Department of Chemistry,
Annamalai University, Annamalainagar.
MR Government Arts College,
Mannargudi, India.

V. Usha

Department of Chemistry,
University College of Engineering,
Panruti, India.

G. Thirunarayanan

Department of Chemistry,
Annamalai University,
Annamalainagar, India.

Abstract:

About four series of halogen substituted aryl 2E-enones were synthesized using Ultrasonicated Crossed Aldol condensation of various substituted aryl ketones and aldehydes. The yields of the enones are more than 92%. The synthesized enones were analyzed using their Physico-chemical properties and spectroscopic data. The insect antifeedant activities of synthesized compounds were evaluated using castor *semilooper Achoea Janata L.* The chlorinated enones showed better insect antifeedant activity.

Keywords: Aryl *2E*-enones, Ultrasonication, Aldol condensation, Insect antifeedant activity.

5.1 Introduction:

Aryl enones possess an unsaturation and keto moieties in their structure [1]. Based on the orientation of alkene moiety with respect to keto group, they are classified as *s-cis* and *s-trans* conformers and are confirmed by infrared spectroscopy [2]. The *E* or *Z* configuration of the chalcones were confirmed by the orientation of protons in alkene moiety and are confirmed with their 1H NMR coupling constant 'J' values. If the J value is more than 15 Hz, then the chalcone possess *E* configuration. Suppose the J values is less than 15 Hz, then the chalcone possess Z configuration [3].

In general, *E* configured chalcones are more stable than Z configuration. Chalcones are important intermediates for carbon building blocks [4]. They are the key intermediates for synthesis of flavanones [5], Pyrazolines [6], pyrimidine [7], thiopyrimidine [8] and oxazine [9] derivatives.

Various methods were employed for synthesis of chalcones such as conventional heating, microwave assisted, ground chemistry and Ultrasonications [10-12]. Similarly, numerous catalysts were employed for the aldol condensation leads to synthesis of chalcones [13, 14].

Chalcones possess many biological activities such as antimicrobial [15], antiviral [16], anticancer [17], anti-HIV [18], anticordivascular [19], antioxidant [20], antiplasmodial [21]. Halogenated chalcones showed insect antifeedant activities [22].

Nalwar et. al., have studied and observed the good insect antifeedant activity of some chalcones against the mealy bug of cotton (*Phenacoccus solanopsis*) [23]. Chen and his co-workers [24] reported the antifeedant activity of some enones derived from natural Genus Tephrosia against the legume pod-borer *Maruca testulalis*, with an important pest of cowpea (*Vigna*). An appreciable insecticidal activity of some pyrazolyl enones were evaluated using third instar nymph of *P. solenopsis* was reported by Rani et. al., [25].

The first instar larvae of *Nomophila indistinctalis* was employed for assessing the insect antifeedant activity of enones from natural *Polygonum persicaria* extracts by Romero [26] group of researchers. V′asquez et. al., [27] used the insect *Spodoptera litoralis* and *Myzus persicae* for measuring the insect antifeedant activity of some enone and flavonoids isolated from *Senecio adenotrichius* DC plant. Jackowski et. al., [28] used three coleopteran stored product pests namely *Sitophilus granarius* L., *Tribolium confusum* Duv. and Trogoderma granarium Everts for evaluated the insect antifeedant activity of some flavonoids.

Three insect pests: *lesser mealworm, Alphitobius diaperinus (Panzer); Colorado potato beetle, Leptinotarsa decemlineata (Say); and peach-potato aphid, Myzus persicae (Sulz.)* were incorporated for evaluation of antifeedant activity of some hydroxy lactones and racemic piperitones by Grudniewska and his co-workers [29]. Hidalgo et. al., have studied and reported the insect antifeedant activity of some mono- and bis- chalcones on *Spodoptera frugiperda* (Lepidoptera: Noctuidae) [30]. Morimoto co- workers used the insect Spodoptera litura Larvae for evaluation of insect antifeedants of some aurones [31]. Within the above view the authors also interested to evaluate the insect antifeedant activities of some halogenated enones using Dethler's [32] castor *semilooper Achoea Janata L.*

5.2 Experimental and Results:

5.2.1 General:

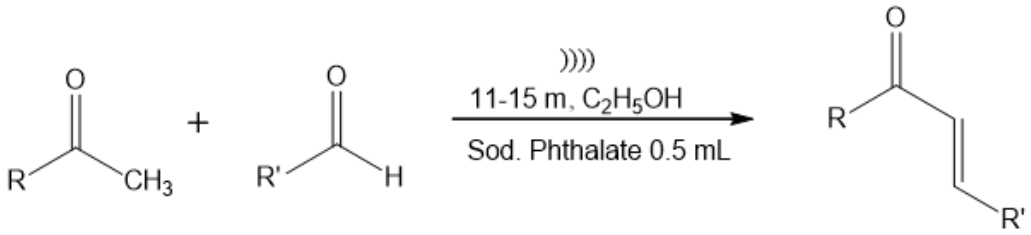
IR spectra of all α, β-unsaturated ketones under investigation were recorded using SHIMADZU 8400 FT-IR spectrophotometer with KBr discs. he ^{1}H and ^{13}C NMR Spectra of all α, β-unsaturated ketones under investigation were recorded using the BRUKER AV 400 NMR spectrometer applying 400MHz for ^{1}H NMR, 125.46 MHz for ^{13}C NMR spectra and TMS as a standard.

5.2.2 Preparation of Enone Compounds (1-40):

a. Synthesis of (E)-1-(Substituted Phenyl)-3-Phenylprop-2-En-1-Ones (1-36):

A mixture of equimolar quantities of substituted acetophenone (1mmol) and substituted benzaldehydes (1mmol), sodium phthalate (1N, 0.5mL) and 10 mL of ethanol were Ultrasonicated at 40 Hz for 10-15 minutes (Citizen Ultra Sonicator, 40 Hz, 120W, 240V, AC) as shown in **Scheme-5.1.**

After the completion of the reaction, as monitored by TLC, the resulted precipitate was filtered and washed with cold water. The products appeared as crude yellow solid. Then these are



Scheme 5.1: Synthesis of (E)-1-(substituted phenyl)-3-phenylprop-2-en-1-ones

Entry	R	R′	Entry	R	R′
1	4-BrPh	H	19	2,4-F_2Ph	3-NO_2
2	4-BrPh	2-Cl	20	2,4-F_2Ph	4-NO_2
3	4-BrPh	3-Cl	21	3,4-$(OCH_3)_2$Ph	4-Br
4	4-BrPh	4-Cl	22	3,4-$(OCH_3)_2$Ph	3-Cl
5	4-BrPh	4-F	23	3,4-$(OCH_3)_2$Ph	2-F
6	4-BrPh	2-OH	24	3,4-$(OCH_3)_2$Ph	4-F
7	4-BrPh	2-OCH_3	25	2,6-$(OCH_3)_2$Ph	4-Br
8	4-BrPh	4-OCH_3	26	2,6-$(OCH_3)_2$Ph	2-Cl
9	4-BrPh	4-CH_3	27	2,6-$(OCH_3)_2$Ph	4-Cl
10	4-BrPh	3-NO_2	28	2,6-$(OCH_3)_2$Ph	4-F
11	4-BrPh	4-NO_2	29	4-OCH_3Ph	4-Br
12	2,4-F_2Ph	H	30	4-OCH_3Ph	3-Cl
13	2,4-F_2Ph	3-Br	31	4-OCH_3Ph	4-Cl
14	2,4-F_2Ph	4-Br	32	4-OCH_3Ph	4-F
15	2,4-F_2Ph	4-Cl	33	2-CH_3Ph	4-Br
16	2,4-F_2Ph	2-OCH_3	34	2-CH_3Ph	2-Cl
17	2,4-F_2Ph	4-OCH_3	35	2-CH_3Ph	4-Cl
18	2,4-F_2Ph	4-CH_3	36	2-CH_3Ph	4-F

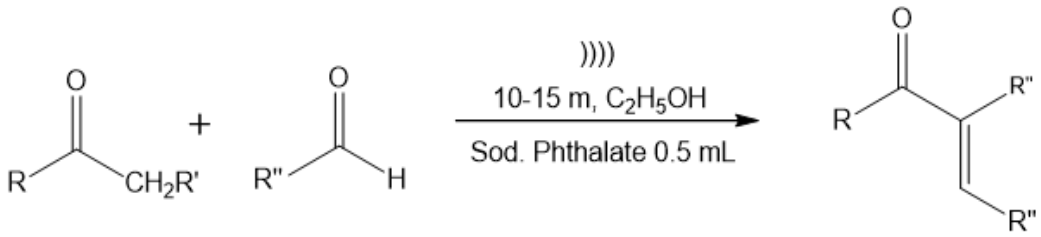
b. Synthesis of (*E*)-1,2,3-triphenylprop-2-en-1-ones (37-40):

A mixture of equimolar quantities of 1,2-diphenylmethanone (1mmol) and substituted benzaldehydes (1mmol), sodium phthalate (1N, 0.5mL) and 10 mL of ethanol were Ultrasonicated at 40 Hz for 10-15 minutes (Citizen Ultra Sonicator, 40 Hz, 120W, 240V, AC) as shown in **Scheme-5.2**.

After the completion of the reaction, as monitored by TLC, the resulted precipitate was filtered and washed with cold water.

The products appeared as crude yellow solid.

Then this was recrystallized using ethanol to afforded pale yellow glittering solids.



Scheme 5.2: Synthesis of (E)-1,2,3-triphenylprop-2-en-1-ones

Entry	R	R′	R′′	Entry	R	R′	R′′
37	Ph	Ph	2-Br	**39**	Ph	Ph	4-Cl
38	Ph	Ph	2-Cl	**40**	Ph	Ph	4-F

The enones 1-32 and 37-40 were characterized by their physical constants and they are well agreed with literature data [13a, 33-37].

The enones 33-36 were characterized by their yield, physical constants and analytical parameters of these synthesized chalcones were presented in Table 5.a.

The spectroscopic data of these chalcones were given in Table 5.a.

Table 5.a: Analytical parameters of the synthesized enones 33-36.

Entry	R	R′	MF	MW	Yield (%)	Time (m)	m. p. (°C)
33	2-CH_3Ph	4-Br	$C_{16}H_{13}BrO$	301	92	12	58-59
34	2-CH_3Ph	3-Cl	$C_{16}H_{13}ClO$	257	93	11	106-107
35	2-CH_3Ph	4-Cl	$C_{16}H_{13}ClO$	257	94	10	62-63
36	2-CH_3Ph	4-F	$C_{16}H_{13}FO$	240	90	13	60-61

Table 5.b: IR vibrational frequencies (v, cm 1), NMR chemical shifts (δ, ppm) and Mass spectral fragments (m/z) data of enones 33-36.

Entry	IR frequencies (v, cm ^{1})						
	$CO_{s\text{-}cis}$	$CO_{s\text{-}trans}$	CH_{ip}	CH_{op}	$CH{=}CH_{op}$	$C{=}C_{op}$	
33	1670.35	1597.06	1066.64	761.88	1008.77	489.92	
34	1618.28	1523.76	1091.71	754.17	1091.71	526.51	
35	1668.43	1597.06	1089.78	761.88	1008.77	495.71	
36	1664.57	1595.13	1118.71	754.17	1001.06	543.93	
	^{1}H NMR chemical shifts (δ, ppm)			**^{13}C NMR chemical shifts (δ, ppm)**			
	H_α	H_β	Ar-H	CO	C_α	C_β	Ar-C
33	7.273	7.813	7.234-7.764	179.08	119.71	142.08	124.97-141.45
34	7.281	7.796	7.290-7.783	177.98	123.34	140.42	125.23-139.09
35	7.244	7.761	7.257-7.753	190.00	123.48	142.91	124.01-141.37
36	7.336	7.572	7.340-7.487	189.68	123.49	142.83	124.87-141.73
	Mass (m/z)						
33	301[M^{+}], 303[M^{2+}], 221, 209, 168, 155, 145, 136, 91, 79, 77, 15						
34	257[M^{+}], 259[M^{2+}], 256, 221, 145, 132, 124, 111, 91, 77, 35, 15						
35	257[M^{+}], 259[M^{2+}], 256, 221, 165, 145, 137, 132, 124, 119, 111, 91, 77, 35, 15						
36	240[M^{+}], 242[M^{2+}], 149, 145, 132, 121, 119, 108, 95, 91, 77, 19, 15						

5.2.3 Measurement of Insect Antifeedant Activities

a. Measurement of Insect Antifeedant Activities:

The insect antifeedant activity of all enones measured using Dethler's method [32]. Insect antifeedant measurement test was done with a 4th instar larva *Achoea janata* L against castor *semilooper*, were tended as pronounced on the leaves of castor, *Ricinus communis* in the laboratory at the temperature range of 26 °C ±1 °C and a comparative humidity of 75-85 %.

The leaf – disc bioassay technique was employed with the 4th instar larvae to measure the antifeedant activity. The 4th instar larvae were chosen for conducting the experiment, since the larvae at this level feeded very hungrily. Castor leaf diskettes of a diameter of 1.85 cm were perforated and complete with the dish-petioles.

All synthesized enones were dissolved in acetone with in the diluted concentration of 200 ppm immersed for 5 minutes. The leaf diskettes were air-dried and positioned in one litre beaker having slight water in order to smooth translocation of water.

Therefore, the leaf diskettes persist fresh up to completion of the experiment, 4th instar larvae of the test insect, which was conserved on the leaf diskettes of all enones and allowed to feed on them for 24 h. The zones of the leaf diskettes spent were measured are presented in Table 5.c.

Table 5.c: The insect antifeedant activities of enones.

Entry	4-6 pm	6-8 pm	8-0 pm	10-2 pm	12-6 am	6-8 am	8am 12Nn	12Nn-2pm	2-4 pm	Total leaf disc consumed in 24 h
1	1	1	1	0.5	0.5	1	1	2	2	10
2	1	1	0.5	0.5	1	1	1	1	1	8
3	1	2	1	2	0	0	1	1	1	9
4	0.5	1	1	0.25	0.5	0.5	0.5	0.5	0.5	5
5	1	1	1	1	0.5	0.5	0.5	1	0.5	7
6	1	1	1	1	0	0.5	0.5	1	0.5	6.5
7	1	0.5	1	1	1	1	0.5	0.5	0.5	7
8	1	1	1	0.25	0.25	1	0.5	1	0.5	7
9	1	1	2	0.5	0.5	2	1	1	1	10
10	1	1	0.5	0.5	1	1	0.5	1	0.5	7
11	1	1	1	1	1	1	1	1	1	9
12	1	1	0.5	0.5	1	1	1	1	1	8
13	1	1	0.5	0.5	1	1	1	2	2	10
14	1	1	2	1	1	0	1	1	1	9
15	0.5	1	1.5	0.25	0.5	0.5	0.5	0.5	0.5	5.5
16	1	1	1	1	1	1	1	1	1	9
17	1	1	0.5	0.5	1	1	1	1	1	8
18	1	1	0.5	0.5	1	1	0.5	1	0.5	7
19	1	1	1	1	1	1	1	2	2	11
20	1	1	1	1	1	1	1	2	2	11
21	1	1	1	0.5	0.5	1	1	1	1	8
22	1	1	1	0.5	0.5	1	0.5	1	0.5	7
23	0	1	2	1	1	1	1	1	1	9
24	1	1	1	0	1	1	1	1	1	8
25	1	1	1	1	1	1	1	1	1	9
26	2	1	1	0.5	0	0.5	0.5	1	0.5	7
27	0.5	1	1.5	0	0	0.5	0.5	0.5	0.5	5
28	2	1	1	1	1	1	1	0	0	10
29	2	1	1	0.5	0	0	0	1	0.5	6

Entry	4-6 pm	6-8 pm	8-0 pm	10-2 pm	12-6 am	6-8 am	8am 12Nn	12Nn-2pm	2-4 pm	Total leaf disc consumed in 24 h
30	1	0.5	1.5	0	0	0.5	0.5	0.5	0.5	5
31	1	1	1	1	1	1	1	1	1	9
32	1	1	1	0	1	1	1	1	1	8
33	1	1	1	0	1	1	1	1	1	8
34	2	1	0.5	0.5	0	0.5	0.5	1	0.5	6.5
35	0.5	1	1.5	0.5	0	0.5	0.5	0.5	0.5	5.5
36	1	2	1	1	1	1	1	1	1	10
37	1	1	1	0	1	1	1	1	1	8
38	1	0	1	0	1	1	1	1	1	7
39	0	1	1.5	0.5	0	0.5	0.5	1	1.5	6.5
40	1.5	1	1.5	1.5	0	0.5	0.5	0.5	0.5	8.5

5.3 Discussion:

The results of the obtained insect antifeedant activity of enones are presented in Table 3 and it reveals that all halogenated compounds were found to reflect satisfactory insect antifeedant activities. This test was performed with the insects which ate only two-leaf disc soaked under the solution of this compound. All compounds are active for insect antifeedant activities. The enones **1-11,** the chloro substituted compound **4** good antifeedant activity. The substituents H, $_2$-OH, 4-F, $_2$-OCH_3, 4-OCH_3, and NO_2 were shown least activities. This is due to electronegativity; inductive and hyper conjugative effects of the substituents lack the activity by unfeeding of the insects. In substituted styryl 2,4-difluorophenyl ketones **12-20**, the 4-Cl substituted compound **15** shows good antifeedant activity comparatively other substituents. The electron withdrawing nature of inductive effects enhanced the antifeedant activity by unfeeding the insect. The enones **21-24,** the above said same trend was observed. Here the 4-Cl substituted compound **22** shows good antifeedant activity. Here -I effect of methoxy groups reduced the insect activity. In the chalcone series **25-28 and 29-32**, the chloro substituted compounds **26, 27, 30** and **31** shows good activity. Remaining compounds shows least activity leads by -I effect of methoxy groups. Enones from 2-methyl phenyl ketones **33-36**, the chloro substituted compounds **34** and **35** shows good antifeedant activity. Remaining compounds have less activity. This is due to +I effect of methyl group and electronegativity of fluorine atoms are tend to attract the insect for high feeding.

Chalcones **37-40**, the chloro substituted compounds **38 and 39** shows good antifeedant activities than other. Here the less effect was due to the +I effect of aryl group and electronegativity of fluorine atom enhances the feeding interest of insects. In all the series of enones the chloro substituted compounds shows good activity. Further this test was carried out with the different 50, 100, 150 ppm concentrations and the observation reveal that, the insect antifeedant activity was increased as the concentrations decreased. In this test, the 4-chloro substituted enones shows better insect feedant activity. These are shown in Table 5.d.

Table 5.d: insect antifeedant activity of chloro substituted enones with various dilutions.

Entry	ppm	4-6 pm	6-8 pm	8-10 pm	10-2 pm	12-am	6-8 am	8am 12Nn	12Nn 2pm	2-4 pm	Total leaf disc consumed in 24h
4, 15, 22, 27, 31, 35, 39	**50**	0.25	0	0.25	0.25	0	0	0	0	0	0.75
	100	0.25	0.25	0	0	0	0	0	0	0	0.5
	150	0.25	0	0	0	0	0	0	0	0	0.25

5.4 Conclusions:

About forty halogenated aryl enones were synthesized by ultrasonication method. The antifeedant activities of these enones were tested using Dethler's semilooper method with *Achoea Janata* L insect larvae. All chalcones exhibits antifeedant activities. Among these the chloro substituted enones showed better antifeedant activity with various concentrations. The variation in antifeedant of the enones were due to the electronic effects of substituents such as, electronegativity, Inductive effect, hyper conjugation and electron with-drawing nature.

5.5 Acknowledgement:

Authors thank to DST-NMR Facility, Department of Chemistry, Annamalai University, Annamalianagr-608 002, India for Recording NMR spectra of enones.

5.6 References:

1. G. Thirunarayanan and G. Vanangamudi, *Arkivoc*, **12**, 2006, 58.
2. G. Thirunarayanan, *J. Korean Chem. Soc*., **51(2),** 2007, 115.
3. G. Thirunarayanan and G. Vanangamudi, *Spectrochim Acta*, **81A**, 2011, 390.
4. G. Thirunarayanan and K. G. Sekar, *Der Pharma Chemica*, **5(6),** 2013, 142.
5. U. H. shah and S. G. Patel, Asian J. Pharm. Clin. Res., **10(2),** 2016, 403.
6. G. Thirunarayanan and K. G. Sekar, *J. Taibah Univ*. Sci. **8**, 2014, 124.
7. M. M. Adilmat, M. Khairuddean, M. N. Norman, A. N. M. Asri, M. H. M. Shuaimi and G. Sharma, *Arabian J. Chem*., **14**, 103304, 2021.
8. S. S. Panda and P. V. R. Chowdary, Indian J. Pharam. Sci., **70,** 2008, 208.
9. G. Thirunarayanan and V. Renuka, *J. Chil. Chem. Soc*., **59(3)** 2014, 2574.
10. G. Thirunarayanan and P. Ananthakrishna nadar, *A. J. Chem*., **14(3-4),** 2002, 1518.
11. I. Muthuvel, G. Thirunarayanan, V. Thangaraj, N. Sundaramurthy, S. Rajalakshmi and V. Usha, *Mat. Today, Proc.*, **43,** 2021, 2203.
12. (a). G. Thirunarayanan, *J. Indian Chem. Soc.*, **85(4),** 2008, 447. (b). V. Mala, I. Muthuvel, G. Thirunarayanan, S. P. Sakthinathan, R. Arulkumaran, V. Manikandan, R. Sundararajan, D. Kamalakkannan, R. Suresh and V. Usha, *Ovidus Univ. Annal. Chem*., **31**, 2020,152.

13. (a). V. Mala, I. Muthuvel, G. Thirunarayanan, V. Usha, *Mat. Today, Proc.*, **43**, 2021, 2117 (b). K. G. Sekar, P. Janaki, I. Muthuvel, V. Usha, K. Thirumurthy and G. Thirunarayanan, *Mat. Today, Proc.*, **43,** 2021, 2208. (c). K. Ranganathan, D. Kamalakkannan, R Suresh, SP. Sakthinathan, R. Arulkumaran, R. Sundararajan, V. Manikandan, P. Venkatachalam, S. Rajalakshmi, I. Muthuvel and G. Thirunarayanan, *Mat. Today Proc*. **22,** 2020, 1196. (d). S. Balaji, V. Manikandan, M. Rajarajan, V. Usha, S. Rajalakshmi, P. Venkatachalam, I. Muthuvel and G. Thirunarayanan, *Mat. Today Proc*. **22,** 2020, 931.
14. (a). S. John Joseph, K. Ranganathan, R. Suresh, R. Arulkumaran, R. Sundararajan, D. Kamalakkannan, S. P. Sakthinathan, G. Vanangamudi, S. Dineshkumar, K. Thirumurthy, I. Muthuvel, G. Thirunarayanan, K. Viveksarathi, *Mat. Sci and Appl. Chem.*, **34,** 2017, 12. (b). R. Arulkumaran, S. Vijayakumar, R. Sundararajan, S. P. Sakthinathan, D. Kamalakkannan, R. Suresh, K. Ranganathan, G. Vanangamudi and G. Thirunarayanan, *Int. Lett. Chem. Phys. Astro*., **4**, 2012, 17.
15. M. Subramanian, G. Vanangamudi and G. Thirunarayanan, *Spectrochim Acta*, **110A**, 116, 2013.
16. D. Elkhalifa, I. A. Hashimi, D. D. A. Moustafa and A. Khalil, *J. Drug Target*., **29**, 403, 2021.
17. Y. Ouyang, J. Li, X. Chen, X. Fu, S. Sun and Q. Wu, *Biomolecules*, **11**, 2021, 894.
18. J. H. Wu, X. H. Wang, Y. H. Yi and K. H. Lee, *Bioorg. Med. Chem. Lett*., **13**, 2003, 1813.
19. D. K. Mahapatra and S. K. Bharti, *Life Sci*., **148,** 2016, 154.
20. G. Vanangamudi, M. Subramanian and G. Thirunarayanan, *Arabian J. Chem*., **10**, 2017, S1254.
21. R. Arulkumaran, R. Sundararajan, G. Vanangamudi, M. Subramanian, K. Ravi, V. Sathiyendiran, S. Srinivasan, and G. Thirunarayanan, *IUP. J. Chem*., **3(1),** 2010, 82.
22. G. Thirunarayanan, *J. Saudi Chem. Soc*., **18**, 2014, 854.
23. Y. S. Nalwar, M. A. Sayyed, S. S. Mokle, P. R. Zanwar and Y. B. Vibhute, *World J. Chem*., **4(2),** 2009, 123.
24. Y. Chen, T. Yan, C. Gao, W. Cao and R. Huang, *Molecules*, **19**, 2014, 1432.
25. A. Rani, S. Jaina and R. D. Gautam, *J. Plant Pro. Res*., **52**, 2012, 146.
26. L. Q. Romero, C. F. Galleguillos, J. Bergmann, M. A. Bravo, and E. F. Contreras, *J. Pharm. Pharm. Res.*, **5(3),** 2017, 167.
27. L. R. V′asquez, A. S. Olmeda, G. Zuniga, L Villarroel, L F. Echeverri, A. G. Coloma and M. Reina, *Chem. Biodiversity*, **14**, 2017, e1600155.
28. J. Jackowski, J. Popłoński, K. Twardowska, J. Magiera-Dulewicz, M. Hurej and E. Huszcza, *Bull. Entomol. Res*., **107**, 2017, 592.
29. A. Grudniewska, M. Kłobucki, K. Dancewicz, M. Szczepanik, B. Gabryś and C. Wawrzeńczyk, *PLoS ONE*, **10(7),** 2015, e0131028.
30. J. R. Hidalgo, M. Santillán, E. A. Parellada, P. Khyaliya, A. Neske and K. L. Ameta, Int. *J. Pest Mangement*, **66**, 2020, 116.
31. M. Morimoto, H. Fukumoto, T. Nozoe, A. Hagiwara and K. Komai, *J. Agric. Food Chem*., **55,** 2007, 700.
32. V. G. Dethler, Chemical Insect Attractants and Repellents, Blackistan, Philadeciphia, 1947, p. 210.
33. S. Vijayakumar, G. Vanangamudi and G. Thirunarayanan, *World Scientific News*, **54**, 2016, 132.

34. S. Vijayakumar, R. Arulkumaran, R. Sundararajan, S. P. Sakthinathan, R. Suresh, D. Kamalakkannan, K. Ranganathan, K. Sathiyamoorthy, V. Mala, G. Vanangamudi, and G. Thirunarayanan, *Int. Lett. Chem. Phys. Astro*. **14**, 2013, 68.
35. S. Vijayakumar, G. Vanangamudi and G. Thirunarayanan, *J. Pharm. Appl. Chem*., 2(3), 2016, 153.
36. S. Vijayakumar, V. Manikandan, R. Arulkumaran, P. Christuraj, R. Sundararajan and G. Thirunarayanan, *World Scientific News*, **115**, 2019, 52.
37. V. Mala, K. Sathiyamoorthy, SP. Sakthinathan, D. Kamalakkannan, R. Suresh,
38. G. Vanangamudi and G. Thirunarayanan, *Q-Science Connect*, 2013:7; DOI http://dx.DOI.org/10.5339,2013.7.

ISBN: 978-93-90847-17-4

6. Biosurfactants Based Biocontrol in Agriculture

Parthasarathi Rengasamy, Elango Rasavel, Harini Sundaresan,

Akash Krishnamoorthy, Kavinilavu Narayana samy

Department of Agricultural Microbiology,
Faculty of Agriculture, Annamalai University,
Annamalai Nagar, Tamilnadu, India.

6.1 Introduction:

Biosurfactants, widely known as surface-active agents of biological origin. First biosurfactant "surfactin" was purified and characterized by Arima *et al*. (1968). Data reveals there are more than 250 patents obtained on these wonder biodegradable molecules so far (Shete *et al.,* 2006; Rahman and Gakpe, 2008). There are five major categories of biosurfactants viz. glycolipids, phospholipids and fatty acids, lipopeptides and lipoproteins, polymeric biosurfactants and particulate biosurfactants that have found applications in agricultural, pharmaceutical, food, cosmetics, and detergent industries.

Among the various categories of biosurfactants the glycolipid biosurfactants "rhamnolipids" stand apart. Rhamnolipid, primarily a crystalline acid, is composed of β-hydroxy fatty acid connected by the carboxyl end to a rhamnose sugar molecule.

Rhamnolipids are predominantly produced by *Pseudomonas aeruginosa* and classified as: mono and di-rhamnolipids. *Pseudomonas* species that have been reported to produce rhamnolipids are *P. chlororaphis, P. plantarii, P. putida, and P. fluorescens.*

In 1984, the first patent for the production of rhamnolipids was filed by Kaeppeli and Guerra-Santos (US 4628030) and obtained in 1986 for their work on Pseudomonas aeruginosa DSM 2659, Kaeppeli and Guerra-Santos, 1986.

Subsequently, Wagner et al. filed a patent (US 4814272) in 1985 for the biotechnical production of rhamnolipids from Pseudomonas sp. DSM 2874 and obtained the same in 1989 (Wagner et al., 1989). The reason behind the current global interest in rhamnolipid production in various industries was, "eco-friendly" properties.

6.1.1 Inimitable Applications of Rhamnolipids:

Over the years rhamnolipids are becoming broadly pertinent in various industries and are posing a serious threat to the synthetic surfactants. Increasing the demand for the biosurfactant.

Five major applications of rhamnolipids that cater to the wide range of industrial demands includes:

a. Bioremediation and enhanced oil recovery (EOR): Rhamnolipids show excellent emulsification properties, efficiently remove crude oil from contaminated soil and facilitate bioremediation of oil spills (Rahman et al., 2003; Costa et al., 2010).

b. Pharmaceuticals and therapeutics: Rhamnolipids show low toxicity, surface active properties and antimicrobial activities against several microbes (*Bacillus cereus, Micrococcus luteus, Staphylococcus aureus, Listeria monocytogenes*) thereby showing promising applications in pharmaceuticals and therapeutics (Magalhaes and Nitschke, 2013).

c. Cosmetics: Rhamnolipid as an active ingredient is found to be effective for several skin treatments i.e., wound healing with reduced fibrosis, cure of burn shock, treatment of wrinkles hence are in demand in the health and beauty industry (Piljac and Piljac, 2007).

d. Detergents and cleaners: Rhamnolipids are natural emulsifiers and surface active agents leading to their wide spread usage in detergent compositions, laundry products, shampoos and soaps (Parry *et al*., 2013).

e. Agriculture: Rhamnolipids are already used for soil remediation for improving soil quality and are now further getting explored for plant pathogen elimination, for aiding the absorption of fertilizers and nutrients through roots and as biopesticides (Sachdev and Cameotra, 2013).

6.1.2 Leading Producers of Biosurfactants:

Rhamnolipids are highly applicable in various activities with some researchers advancing the technology from laboratory to higher scale. However, there still are very limited companies in the field which are producing biosurfactants at a marketable scale. Leading producers of biosurfactant in India includes Evonik India Pvt. Ltd., Mitsubishi India, Vetline (Unit of Simfa Labs Pvt. Ltd.,) They focus on producing Cleaners, Food processing, Agricultural chemicals, Detergents, Oil field chemicals and the products used are; Glycolipids, Alkyl Polyglucosides, Methyl Ethyl sulfonates, Sucrose Esters, Sorbitan Ester, etc.,

Table 6.a: Biosurfactant Producing Companies Globally.

Company	Location	Products	Focus On
TeeGene Biotech	UK	Rhamnolipids and Lipopeptides	Pharmaceuticals, cosmetics, antimicrobials and anti-cancer ingredients
AGAE Technologies LLC	USA	Rhamnolipids (R95, an HPLC/MS grade rhamnolipid)	Pharmaceutical, cosmeceutical, cosmetics, personal care, bioremediation (*in*

Company	Location	Products	Focus On
			situ & *ex situ*), Enhanced oil recovery (EOR)
Jeneil Biosurfactant Co. LLC	USA	Rhamnolipids (ZONIX, a bio-fungicide and RECO, a rhamnolipid used in cleaning and recovering oil from storage tanks)	Cleaning products, EOR
Ecover Belgium	Belgium	Sophorolipids	Cleaning products, cosmetics, bioremediation, pest control, pharmaceuticals
Rhamnolipid Companies, Inc.	USA	Rhamnolipids	Agriculture, cosmetics, EOR, bioremediation, food products, pharmaceutical
Synthezyme LLC	USA	Sophorolipids	Cleaning products, cosmetics, food products, fungicides, crude oil emulsification
Allied Carbon Solutions (ACS) Ltd	Japan	Sophorolipids (ACS-Sophor—first bio-based surfactant from Indian mahua oil)	Agricultural products, ecological research
Lion Corporation	Japan	Methyl ester sulfonates (MES)	Detergent's formulations, cleaning products

6.2 Biosurfactant:

Surfactants are amphiphilic molecules with both hydrophilic and hydrophobic regions attributing towards decrease in surface tension by the formation of aggregates at interfaces between fluids of different polarities. Biosurfactants are the surface-active biomolecules produced by microorganism. Basically, these microorganisms produce different biosurfactants for various purposes like detergency, emulsification, adhesion, coatings, wetting, foaming, soil and water remediation, paints, chromatographic separation, medicine, agriculture, cosmetics etc,

For instance, Rhamnolipids increases the solubility of hydrophobic hydrocarbon, cause changes in microbial surface properties, and enhance the bioavailability of potential hydrophobic carbon sources.

6.3 Biosurfactants Supposedly Act Through Three Distinct Activities:

- Modification of surface properties,
- Alteration of compound bioavailability,
- Interaction with membranes.

6.4 Properties:

- Surface and interface activity,
- Low toxicity,
- Emulsion forming and emulsion breaking,
- Antiadhesive agents,
- Temperature and pH tolerance,
- High degree of biodegradability,
- High foaming capacity.
- Optimal activity at extreme environmental conditions.

6.5 Classification of Biosurfactants:

6.5.1 Glycolipid:

They are carbohydrates linked to long-chain aliphatic acids or hydroxyaliphatic acids by an ester group. Biosurfactants are majorly glycolipids. Among the glycolipids, the best known are.

- Rhamnolipids
- Trehalolipids
- Sophorolipids

6.5.2 Rhamnolipids:

One or two molecules of rhamnose are linked to one or two molecules of hydroxydecanoic acid. The principal glycolipids produced by *P. aeruginosa*.

6.5.3 Trehalolipids:

Trehaloselipids from *Rhodococcus erythropolis* and *Arthrobacter* spp. Lowered the surface and interfacial tension in culture broth from 25-40 and 1-5 mNm, respectively. Enhance the bioavailability of hydrocarbons.

6.5.4 Sophorolipids:

Produced by yeast like *Torulopsis bombicola, T. apicola* and *Wickerhamiella domericqiae,* consist of a dimeric carbohydrate sophorose linked to a long-chain hydroxyl fatty acid by glycosidic linkage. Sophorolipids, generally a mixture of at least six to nine different

hydrophobic sophorolipids and lactone form of the sophorolipid is preferable for many applications. Sophorolipids have the capacity to lower the surface tension of water, Recovery of hydrocarbons from dregs and muds and Removal of heavy metals from sediments, enhancement of oil recovery.

6.5.5 Lipopeptides and Lipoproteins:

These consist of a lipid attached to a polypeptide chain. Several biosurfactants have shown antimicrobial action against various bacteria, algae, fungi and viruses. The antifungal property and the antibacterial property of the lipopeptide, iturin which was produced by ***Bacillus subtilis.*** Iturin from *B. subtilis* was found to be active even after autoclaving, pH 5-11 and with a shelf life of 6 months at -18°C.

6.5.6 Surfactin:

A cyclic lipopeptide which contain a -hydroxy fatty acid in its side chain., one of the most effective biosurfactants known so far, which was first reported in ***B. subtilisATCC-21332***. Recent studies indicate that surfactin shows potent antiviral, antimycoplasma, antitumoral, anticoagulant activities as well as inhibitors of enzymes. Potential applications in medicine or biotechnology but have not been exploited extensively till date.

6.5.7 Lichenysin:

Bacillus licheniformis produces several biosurfactants which exhibit excellent stability under extreme temperature, pH and salt conditions which are similar to surfactin. Lichenysin from *B. licheniformis* are able to reduce the surface tension and interfacial tension of water to 27 and 0.36 mN m^{-1}, respectively. Lichenysin is a more efficient cation chelator compared with surfactin.

6.5.8 Iturin:

The iturin group of compounds are cyclic lipoheptapeptides which contain α - amino fatty acid in its side chain. Iturin-A was isolated from a *Bacillus subtilis* strain taken from the soil in Iturin (Zaire). They are potent antifungal agents which can also be used as biopesticides for plant protection.

6.5.9 Polymeric Biosurfactants:

a. Emulsan: Effective emulsifying agent for hydrocarbons in water, even at a concentration as low as 0.001-0.01%

b. Liposan: Extracellular water-soluble emulsifier synthesized by *Candida lipolytica* and is composed of 83% carbohydrate and17% protein and used as emulsifier in food and cosmetic industries.

c. **Alasan**: Produced by *A. radioresistensKA-53* was reported to solubilise and degrade polyaromatic hydrocarbons.

d. **Biodispersan:** Produced by *Acinetobacter calcoaceticu* A2 used in dispersion of limestone in water.

e. **Mannoprotein**: Produced by *Saccharomyces cerevisiae used in* Stabilization of hydrocarbon-in-water emulsions.

6.5.10 Biosurfactant as an Antiadhesive Agent:

Implementing the biosurfactant to the solid surface may prevent the adsorption of pathogenic or spoilage-causing microorganisms in food surface, equipment, pipeline and other food processing materials, thereby preventing the contamination in food industries to a great extent. In reference to the report of (McL and sborough *et al*. (2006), a surface-active agent interferes with the biofilm matrix and reduces the interfacial tension among solid surface and biofilm, thereby eliminating the biofilm.

6.6 Application in Agriculture:

6.6.1 Improvement of Soil Quality:

The productivity of agriculture land is affected by presence of organic and inorganic pollutants that impart abiotic stress on the cultivated crop plant. To increase the quality of such soil contaminated by hydrocarbon and heavy metals, process of bioremediation is required. Biosurfactant can be effectively used for removal of hydrocarbons as well as heavy metals and known to enhance bioavailability and carry out biodegradation of hydrophobic compounds, different technologies such as soil washing technology and clean up combined technology employ biosurfactant for effective removal of hydrocarbons. Example: *Pseudomonas* sp, *Bacillus* sp., and *Acinetobacter* sp.

Probiotic biosurfactant is preferred in many applications in recent years owing to the property of the probiotic strain than other pathogenic ones (Sharma et al. 2016). Their antimicrobial and antiadhesive property makes them more effective in the biomedical application aspect. The antiadhesive property of *Lactobacillus plantarum* and *Lactococcus lactis* preventing the microbial colonization has been demonstrated in the study of Fatena *et al.* (2016) and Rodrigues *et al.* (2004).

There are certain factors that determine the efficacy of the biosurfactant- producing probiotic strain, which include acid and bile tolerance, proteolytic resistance, and antagonist properties against pathogenic microbes, providing a better environment for the beneficial microbes. Typically, lactic acid bacteria (probiotic strain) have established a substantial interest for their potential use in establishing the competitive environment towards pathogenic microbiota. However, *Lactobacillus species* shows evidence of antioxidative activity, thereby decreasing the risk of accruing reactive oxygen species on food products (Kullisaar *et al.* 2002).

6.6.2 Biosurfactant Extending the Shelf Life of Food Products:

In recent times, biosurfactant has been established in numerous food products for extending its shelf life, thereby accounting for profitability in the food industries and better health of consumers The rhamnolipids are currently approved for use in the food industry by the US Environment Protection Agency (EPA). The rhamnolipids in synergistic action with niacin

extends the shelf life of UHT (ultrahigh temperature) soymilk by inhibiting hemophilic spores. Furthermore, the similar combinations of niacin with rhamnolipids have also been implemented in salads as well as cottage cheese to increase its shelf life and to inhibit the growth of mold, bacteria and spore formers as stated by Haesendonck et al. (2004).

6.6.3 Potential of Biosurfactants in Pesticide Industries:

Surfactants act as adjuvant with fungicides, insecticides, and herbicides. The synthetic surfactant presently used in pesticides industries act as emulsifying, dispersing, spreading and wetting agent and enhance the efficiency of pesticides. The synthetic surfactants are considered as potent organic pollutants in soil, bacteria belonging to *Pseudomona* sp. And *Burkholderia* sp. from paddy field to degrade surfactants. Pesticides formed with the assistance of biosurfactant can be widely used on agricultural fields.

6.6.4 Microbes from Soil Environment as Producers of Biosurfactants:

Many rhizospheres and plant associated microbes are known to produce biosurfactant indicating the potential role of biosurfactant in plant-microbe interaction and further application of biosurfactant in agriculture. The prevalence of biosurfactant producing bacteria in environment and applications in agriculture and related industries as they play vital role in soil remediation, plant pathogen elimination and by increasing the bioavailability of nutrient for beneficial plant associated microbes.

6.6.5 Plant Pathogen Elimination:

Biosurfactants facilitates biocontrol mechanism of plant growth promoting microbes such as parasitism, antibiosis, competition, induced systemic resistance, and hypovirulence. Surfactants producing *Pseudomonas putid* promotes growth that can cause lysis off zoospores of the oomycete pathogen *Phytophthora capsici*, causative agent of root rot of capsicum. The lipopeptide biosurfactant produced by strains of *Bacillus* exhibits growth inhibition of phytopathogenic fungi like *Fusarium* spp., *Aspergillus* spp., and *Biopolaris sorokiniana.*

6.6.6 Plant–Microbes Interactions and their Importance to Biocontrol:

Fluorescent *Pseudomonas spp*. are well-studied plant-associated bacteria, which include several plants– pathogen strains as well as a range of isolates with biocontrol abilities. *Bacillus* comes second after *Pseudomonas,* with bio-control abilities. *Pseudomonads* and *Bacilli* mainly produce cyclic lipopeptide (CLP) type biosurfactants, which are made up of a cyclized oligopeptide lactone ring coupled to a fatty acid tail.

6.6.7 Plant–Pseudomonas Interactions:

Pseudomonas aeruginosa, an opportunistic pathogen, cause serious infections in susceptible individuals also exhibit plant growth promoting effects. Most strains of this species produce rhamnolipid type biosurfactants. 60% of fluorescent *Pseudomonas* isolates

from the sugar-beet rhizosphere in a sandy soil produced biosurfactants, whereas only 6% of sugar beet rhizosphere isolates from a loamy soil were able to produce biosurfactants.

Table 6.b: Anti-Phytopathogenic Properties of Rhamnolipids.

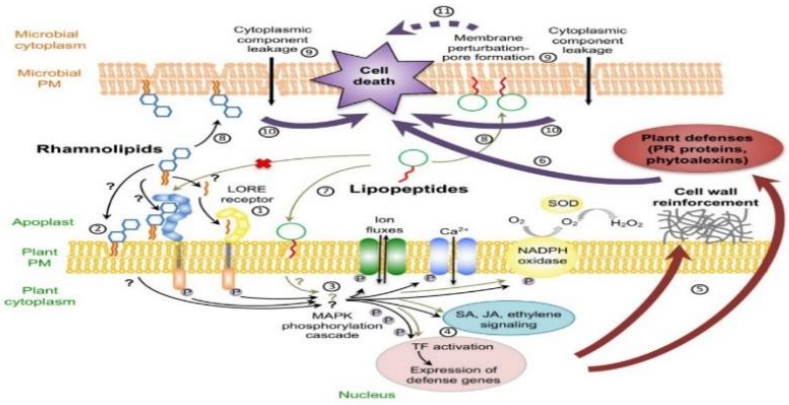
Compositions	**Source organisms**	**Sensitive hytopathogens**	**Effect**
Rhamnolipids	*Pseudomonas spec.DSM 2874*	*Glomerella cingulata*	Conidial germination inhibition, Growth inhibition (MIC) Lang *et al*., 1989
Rha-Rha-C_{10}-$C_1$0, Rha-C_{10}-C_{10}	*Pseudomonas aeruginosa*	*Phytophthora capsici, Pythium aphanidermatum, Plasmopara lactucae-radicis*	Zoospore lysis (Stanghellini and Miller, 1997)
Rha-Rha-C_{10}-C_{10}	*Pseudomonas aeruginosa B5*	*Cercospora kikuchii, Cladosporium cucumerinum, Colletotrichum orbiculare, Cylindrocarpon destructans, Magnaporthe grisea, Phytophthora capsici*	Zoospore lysis, spore germination and hyphal growth inhibition (Kim *et a*l., 2000)
Rha-Rha-C_{10}-C_{10}, Rha-C_{10}-C_{10}, Rha-Rha-C_{10}-C_{12}, Rha-C_{10}-C_{12}, Rha-$C_{12:1}$-C_{10}, Rha-$C_{12:2}$, Rha-$C_{8:2}$	*Pseudomonas aeruginosa AT10*	*Botrytis cinerea, Rhizoctonia solani, Colletotrichum gloeosporioides, Fusarium solani, Penicillium funiculosum*	Growth- inhibition (MIC) Abalos *et al.*, 2003
Rha-Rha-C_8-C_{10}, Rha-C_{10}-C_8/Rha-C_8-$C_1$0, Rha-Rha-C_8-$C_{12:1}$, Rha-Rha-C_{10}-$C_{10,}$ Rha-Rha-C_{10}-$C_{12:1}$, Rha-C_{10}-C_{10}, Rha-Rha-$C_{10}C_{12}$/Rha-Rha-C_{12}-C_{10} , Rha-C_{10}-$C_{12:1}$/Rha-$C_{12:1}$-C_{10},	*Pseudomonas aeruginosa 47T2*	*Penicillium funiculosum, Fusarium solani, Botrytis cinerea, Rhizoctonia solani*	Growth inhibition (MIC) (Benincasa *et al.*, 2004)

Compositions	**Source organisms**	**Sensitive hytopathogens**	**Effect**
Rha-Rha-$C_{12:1}$-C_{12}, Rha-Rha-C_{10}-$C_{14:1}$, Rha-C_{10}-C_{12}/Rha-C_{12}-C_{10}			
Rha-Rha-C_{10}-C_{10}, Rha-C_{10}-C_{10}, Rha-Rha-C_{10}-$C_{12:1}$, Rha-C_{10}-$C_{12:1}$, Rha-Rha-C_{10}-C_{12}, Rha-C_{10}-C_{12}	*Pseudomonas aeruginosa LBI*	*Penicillium funiculosum, Alternaria alternata*	Growth inhibition (MIC) (De Jonghe *et al*., 2005)
Biosurfactant PRO1 (formulation of 25% RLs) Plant support (the Netherlands)	*Pseudomonas aeruginosa*	*Phytophthora cryptogea*	Zoospore lysis, reduction of sporangia formation (Yoo *et al.*, 2005)
Mono- and di-rhamnolipids	*Pseudomonas aeruginosa IGB 83*	*Phytophthora capsici, Phytophthora nicotianae, Phytophthora cactorum, Phytophthora infestans, Pythium aphanidermatum, Pythium ultimum*	Motility inhibition, zoospore lysis, mycelial growth inhibition (Parneel *et al*., 2008)
Rha-Rha-C_{10}-C_{10}, Rha-C_{10}-C_{10} (Jeneil Biosurfactant Company JBR599)	*Pseudomonas aeruginosa*	*Botrytis cinerea*	Spore germination and mycelial growth inhibition (Varnier *et al*., 2009); (Monnier et al., 2018)
Rha-Rha-C_{10}-C_{10}, Rha-C_{10}-C_{10}	*Pseudomonas aeruginosa ZJU211*	*Phytophthora infestans, Phytophthora capsici, Botrytis cinerea, Fusarium graminearum, Fusarium oxysporum*	Mycelial growth Inhibition (sha *et al.*, 2012)

Compositions	**Source organisms**	**Sensitive hytopathogens**	**Effect**
Mono- and di-rhamnolipids	*Pseudomonas aeruginosa ZJU-211*	*Alternaria alternata*	Spore germination and mycelial growth inhibition (Goswami *et al*., 2014)
Rha-C_{10}-C_{10}, Rha-Rha-C_{10}-C_8, Other Rha or Rha-Rha: -C_{10}-C_{10}, -C_8-C_{10}, -C_{10}-C_{12}, -C_{12}-C_{12}, -C_{14}-C_{10}, -C_{10}-C_{16}	*Serratia rubidaea SNAU02*	*Fusarium oxysporum, Colletotrichum gloeosporioides*	Mycelial growth Inhibition (Nalini and Parthasarathi., 2014)
Rha-C_{10}-C_{10}, Rha-Rha-C_{10}-C_{10}	*Pseudomonas aeruginosa KVD-HM52*	*Fusarium oxysporum*	Mycelial growth and fungal biomass accumulation inhibition (Deepika *et al*., 2015)
Rha-$C_{8:2}$, Rha-$C_{8:1}$, Rha-C_{10}, Rha-$C_{12:1}$, Rha-Rha-$C_{10:1}$, Rha-C_{10}-$C_{10:1}$/Rha-$C_{10:1}$-C_{10}	*Pseudomonas aeruginosa DS9*	*Colletotrichum falcatum*	Spore germination and mycelial growth inhibition (Goswami *et al*., 2015)
Rha-C_8, Rha-C_{10}-C_{10}	*Pseudomonas aeruginosa SS14*	*Fusarium verticillioides*	Spore germination and mycelial growth inhibition (Borah *et al*., 2016)
Rha-Rha-C_{10}, Rha-Rha-C_8-C_{10}, Rha-Rha-C_{10}-C_{10}	*Pseudomonas aeruginosa DR1*	*Sclerotium rolfsii, Fusarium oxysporium, Phytophthora nicotianae, Macrophomina phaseolina*	Mycelial growth inhibition (Sathi Reddy *et al*., 2016)
Rha-Rha-C_{10}-C_{10}, Rha-C_{10}-C_{10}	*Pseudomonas aeruginosa ZJU211*	*Verticillium dahliae*	Spore germination and mycelial growth inhibition (Sha and Meng, 2016)
Rha-C_{10}-C_8, Rha-C_{10}-C_{10}, Rha-C_{10}-$C_{12:1}$, Rha-C_{10}-C_{12},	*Pseudomonas aeruginosa #112*	*Aspergillus carbonarius*	Mycelial growth inhibition (Rodrigues *et a*l., 2017)

Compositions	**Source organisms**	**Sensitive hytopathogens**	**Effect**
Rha-Rha-C_8-C_{10}, Rha-Rha-C_{10}-C_{10}, Rha-Rha-C_{10}-$C_{12:1}$, Rha-Rha-C_{10}-C_{12}			
Semipurified rhamnolipid mixture (RL90-A, AGAE Technologies, Corvalis, United States) and RL90-N, NatSurFact, Fairfax, United States)	*Pseudomonas aeruginosa*	*Leptosphaeria maculans*	Mycelial growth inhibition (Monnier *et al.*, 2020)

Dual Effects of Rhamnolipids and Lipopeptides on Antimicrobial Activities and Plant Defense Induction:



Courtesy: Jerome Crouzet et al 2020 Frontiers in Bioengineering and Biotechnology (https:// doi.org/10.3389/fbioe.2020.01014)

1. mc-3-OH-acyl building block of rhamnolipids is perceived by plant through the LORE receptor.
2. Rhamnolipid could be sensed through their direct insertion in plasma membrane.
3. Recognition of rhamnolipids leads to early signaling events like ion fluxes (Ca2+), reactive oxygen species production (H_2O_2) and MAPK phosphorylation cascade.
4. These early responses trigger defense gene expression, probably through activation of transcription factors (TF) and hormonal signaling pathways.
5. This leads to defense mechanisms like cell wall reinforcement and PR protein accumulation.

6. Triggering the resistance to the microbes.
7. Plant immunity due to lipopeptides does not involve a protein receptor and rely on interaction between lipopeptides and the plant membrane.
8. Both rhamnolipids and lipopeptides can also have direct antimicrobial effects through direct insertion into the microbial plasma membrane.
9. These insertions trigger loss of cell morphology leading to pore formation.
10. 10.The pore formation causes cellular component leakage triggering microbial cell death µ. 11. Cell death due to lipopeptides can also be indirectly due to the inhibition or activation of microbial cell functions.

6.7 Application in Agriculture:

Various biosurfactants from microorganisms have antimicrobial activity against phytopathogens and proven to be a promising biocontrol molecule for achieving sustainable agriculture.

The purified mono- and dirhamnolipid were found to highly effective against three zoosporic plant pathogens, *Pythium aphanidermatum, Phytophthora capsici* and Plasmopara lactucae-radicis at a concentration ranging from 5 to 30 mg/L, which caused lysis of the entire zoospore population in less than 1 min (Stanghellini and Miller 1997).

Rhamnolipid mixture obtained from *P. aeruginosa AT10* exhibited inhibitory activity against the bacteria, namely, *Escherichia coli, Micrococcus luteus* and *Alcaligenes faecalis*, at the concentration of 32 mg/ml whereas *Serratia marcescens* and *Mycobacterium phlei* at the concentration of 16 mg/ml.

An excellent antifungal activity was displayed against *Chaetomium globosum, Penicillium chrysogenum* and *Aureobasidium pullulans* at a concentration of 32 mg/ml and *Aspergillus niger* at 16 mg/ml, respectively (Abalos *et al*. 2001). Nielsen and Sorensen (2003)

6.7.1 Biocontrol Activity Against *Phytophthora Infestans:*

All the isolates from Eastern, Northern, Southern part of India, were tested for their biocontrol activity against *P. infestans* using dual culture method. Bacterial cell suspension was prepared and 5 µl aliquots of the bacterial suspension were placed around 5 mm plug of *P. infestans* at four places at equal distance in full grown plates of *P. infestans* on rye A media and kept at 20ºC. Out of 95 bacterial isolates, only five isolates namely *P. aeruginosa-1, P. aeruginosa-2, P. aeruginosa -3, P. aeruginosa-4,* and *P. aeruginosa-5* exhibited best biocontrol activities when tested in dual culture method. These isolates showed 62.22%, 38.33%, 46.22%, 32.66%, and 35.33% inhibition, respectively.

6.7.2 The Biosurfactant Produced by *P. Putida 267:*

The putisolvin-like CLPs, provides excellent biocontrol activity against *Phytophthora* damping-off cucumber (Raaijmaker *et al.*, 2006).

6.7.3 The Biosurfactant Produced by Pseudomonas Koreensis:

The crude extract used against the oomycetes *Pythium ultimum* in hydroponic tomato cultivation (Hultberg *et al.,* 2009). The ability of biosurfactant to bring about a reduction in plant disease caused by *P. infestans* has reported by Tran *et al*. (2007), in a study focusing on tomato late blight.

6.8 Biosurfactant from Pseudomonas as Biocontrol against Fungal Plant Pathogens:

6.8.1 The treatment with Pseudomonas fluorescens SS101:

The biosurfactant induced resistance against *P. infestans* in tomato, both systemically and locally, Tran *et al.* (2007). The biosurfactant used in a grapevine study by Varnier (2009) showed the ability to induce resistance to *Botrytis cinerea* (necrotrophic fungus). Rhamnolipid biosurfactant plays a key role in triggering the plant defense responses.

6.8.2 The treatment with Pseudomonas koreensis 2.74:

Study based on detached leaf assays, shows suppression of late blight, when biosurfactant were applied to potato leaflets *(Hultberg et al. 2010).* The biosurfactant forms the channels in the cell wall and perturbations of the cell surface of the pathogen *(Raaijmakers et al., 2006).* The best-known biosurfactants in biological control are rhamnolipids eg. *P. aeruginosa* PNA1 produces rhamnolipids *(Perneel, 2006).* Malin Hultberg *et al.* (2011) found zoospore-producing oomycetes pathogens of particular in hydroponic systems. They tried three ways of supplying a biosurfactant-producing strain to a recirculating hydroponic cultivation system infected with a zoospore-producing plant pathogen.

The strain *Pseudomonas koreensis* 2.74 was added as washed cells, in a minimal medium adapted from the nutrient solution, and compared with control treatments. A significant reduction in disease with up to 50% was achieved when a high concentration of washed cells was added weekly to the plant cultivation system. The disease suppression obtained through addition of washed cells equaled the effect achieved when the purified biosurfactant was used.

6.8.3 Biosurfactant Producing -Fluorescent Pseudomonads:

Hultberg et al. (2008) Inhibit the growth of fungal pathogens such as *Pythium ultimum* (causative agent of damping off and root rot of plants) *Fusarium oxysporum* (causes wilting in crop plants). *Phytophthora cryptogea* (causes rotting of fruits and flowers).

6.8.4 Pseudomonas Fluorescens Strain Pfg32r:

The antifungal activity against *Fusarium oxysporum f. sp. radicis-lycopersici* and *Fusarium graminearum* was inactivated by mutation in GacS/GacA two-component regulatory system *(Susanta and Takikawa 2006).*

6.8.5 Pseudomonas Sp GR3, Isolated from the Central Himalayan Region.

Pseudomonas sp GR3, could effectively control Damping off (*Phythium aphanidermatum* and *Phytophthora nictotianae)*

6.8.6 Mode of Action:

The disease was spread by propagule of the oomycetes, which is particularly sensitive to interaction with surfactant, as it lacks cell wall.

Disruption of the plasma membrane. As rhamnolipid biosurfactant lysis the plasma membrane of the zoospore fungi (Sharma *et al.* 2007).

6.8.7 Pseudomonas Isolates from Different Crop Plants:

Pseudomonas aeruginosa JS29, control of anthracnose disease, caused by fungal pathogen *Colletotrichum capsica* in Chili. Lankar *et al.* (2018) Ozyilmaz and Benlioglu (2013) isolated *Pseudomonas* from different crop plants were screened for *in vitro* growth inhibition of *Phytophthora capsici* and production of biosurfactant.

6.9 Biosurfactant Against Insects:

6.9.1 P. Aeruginosa Lbi 2a1:

Glycolipid biosurfactant as biopesticides for the insects and control of mosquito invasion. The rhamnolipid exhibited the larvicidal potency against *Aedes aegypti* larvae (Silva *et al.* 2014).

6.9.2 Pseudomonas Sp. EP-3:

Kim *et al.* (2011) reported insecticidal activity of rhamnolipid biosurfactant against *Myzus persicae* (green peach aphid).

The application dose- dependent activity against aphid with. 50% mortality at 40 μg/ml and 100% mortality at 100 μg/ml.

6.9.3 Mode of Action: Damages the cuticle membrane.

6.10 Biosurfactant Against Bacterial Pathogen:

6.10.1 P. Aeruginosa AT10:

Rhamnolipid mixture obtained from *P. aeruginosa AT10* exhibited inhibitory activity against the bacteria, ***Escherichia coli, Micrococcus luteus, Alcaligenes faecalis,*** *A*t the concentration of 32 mg/ml

6.10.2 Mode of Action:

Increase the permeability nature of the membrane present in Gram-positive bacteria, while the lipopeptide type of biosurfactant molecule may penetrate the cellular membrane, resulting in the leakage of cytoplasmic material and leading to cell lysis (Naruse *et al*. 1990; Ocheretina and Scheibe 1997).

6.10.3 Biosurfactant from Bacillus as Biocontrol Against Fungal Pathogens:

The major producers of lipopeptide are *B. subtilis, B. cereus, B. licheniformis, B. amyloliquefaciens*.

6.10.4 Mode of Action:

Due to their amphipathic characteristics, lipopeptides can induce the formation of pore and ion channels in lipid bilayer membranes and cause less pathogen resistance compared with traditional antibiotics or fungicides.

6.10.5 Biosurfactant Produced by Bacillus Licheniformis:

Alkadious *et al.* (2019) reported the antifungal activity of a biosurfactant produced by *Bacillus licheniformis* against *Rhizoctonia solani AG-4* that causes root rot in two cultivars of *Vicia faba* (Nubaria 1 & Sakha 1). Treatment with biosurfactant decreased the disease incidence; Nubaria 1 shows the disease reduction ranging from 20.00 to 62.11%, Sakha 1 shows the disease reduction ranging from 16.51 to 38.93%

6.10.6 Biosurfactant Producing Bacillus Subtilis:

The *Colletotrichum gloeosporioides*, causes anthracnose on papaya leaves is reported to be controlled by biosurfactant producing *Bacillus subtilis* isolated from soil (Kim *et al.,* 2010).

6.11 Bacillus Subtilis SPB1:

Mnif et al. (2015) reported *Bacillus subtilis* SPB1 lipopeptides were evaluated as a natural antifungal agent *against Fusarium solani* infestation. *In vitro* antifungal assay showed a minimal inhibitory concentration of about 3 mg/ml. **Treatment by *SPB1* lipopeptides on** *F. solani* will Generate excessive lyses of the mycelium and cause polynucleation and destruction of the related spores together with a total inhibition of spore production. I*n vivo* antifungal activity was proved against the dry rot potato tubers caused by *F. solani*. After 20 days of fungi inoculation, rot invasion was reduced by almost 78%, in comparison to that of non-treated one. Mnif *et al.* (2016) The crude lipopeptide mixture was tested for its inhibitory activity against phytopathogenic fungi.

6.11.1 Fungistatic Mode of Action for Rhizoctonia Bataticola:

- A minimal inhibitory concentration (MIC)- 0.04mg/ml

- Inhibitory concentration at 50% (IC50%)- 0.012mg/ml
- Inhibitory concentration at 90% (IC90%)- 0.02 mg/ml

6.11.2 Fungistatic Mode of Action for Rhizoctonia Solani:

- A minimal inhibitory concentration (MIC)- 4mg/ml
- Inhibitory concentration at 50% (IC50%)- 0.25mg/ml
- Inhibitory concentration at 90% (IC90%)- 3.3 mg/ml.

6.12 Biosurfactant Against Insects:

6.12.1 Bacillus Subtilis SPB1:

Ghribi *et al.* (2011) evaluated the insecticidal activity of this biosurfactant against the Egyptian cotton leaf worm (*Spodoptera littoralis*) and Displayed toxicity with an LC_{50} of 251 ng/cm^2.

6.12.2 Mode of Action:

The histopathological changes occurred in the larval midgut of *S. littoralis* treated with *SPB1* biosurfactant were formation of vesicle in the apical region, cellular vacuolization, necrosis and damage of epithelial cells.

6.12.3 The Bacterial Strain Bacillus Subtilis V26:

Ben et al. (2020) elucidated antifungal and insecticidal activities, they provide protection against gray mold caused by *Botrytis cinerea*, in grapes and the tomato leaf miner *Tuta absoluta. In vitro* antifungal assay showed a minimal inhibitory concentration of about 2 mg mL$^{1.}$ The biosurfactant V26 also exhibited remarkable insecticidal activity against *Tuta absoluta* larvae (LC_{50} = 278.78 ng cm^2).

6.12.4 Mode of Action:

Act by binding to the receptors located in the brush boarder membrane vesicles of the larvae.

6.12.5 The Lipopeptide Produced by Bacillus Amyloliquefaciens Q-426:

Biocontrol activity against *Curvularia lunata Boed,* exhibits significant inhibitory activity even at extreme temperature, pH and salinity condition and also could grow well in the presence of Fe^{2+} ions below 0.8 ML^{-1} *(Zhao et al. 2013).*

6.12.6 The Bacillus Subtilis Strain NCD-2:

This strain is strongly antagonistic toward phytopathogenic fungi, and functions as an excellent biocontrol agent for cotton soil-borne diseases (Guo *et al.*, 2014).

Strongly inhibited the growth of *Rhizoctonia solani* in vitro. The lipopeptides of strain NCD-2 were separated by Fast Protein Liquid Chromatography (FPLC). The antifungal compound was identified as a cluster of fengycin homologs analyzed by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry. A fengycin-deficient mutant was obtained by in-frame deletion of the fengycin synthetase gene in *B. subtilis* NCD-2. Compared with the wild-type strain, this mutant showed decreased abilities to inhibit the growth of *R. solani* in vitro and to suppress cotton damping-off disease *in vivo*. *R. solani* in the cotton rhizosphere colonized by the fengycin-deficient mutant was twice that in the cotton rhizosphere colonized by the NCD-2 wild-type strain. This study demonstrated that fengycin-type lipopeptides are the main antifungal active compounds produced by *B. subtilis* NCD-2.

6.12.7 Bacillus Sp. CS30 from the Cold Seep in Deep Sea:

Wu et al. (2019) isolated *Bacillus* sp. CS30 from the cold seep in deep sea, exhibited strong growth inhibition against *Magnaporthe grisea*. From mass spectrometry (MS) and tandem MS analysis, two purified antifungal agents were determined to be the member of surfactin family, they are Surfactin CS30-1 and Surfactin CS30-2, The Surfactin CS30-1 shows the higher Antifungal activity. Surfactin CS30-2. Shows lower Antifungal activity.

6.12.8 Mode of Action:

Both of them induce the increased generation of reactive oxygen species (ROS) and caused serious damage to the cell wall and cytoplasm, thus leading to the cell death of *M. grisea*.

6.12.9 Bacillus Mojavensis A21:

Ayed et al. (2019) formulated an economic media for lipopeptides production by *Bacillus mojavensis A21* for application as for plant disease treatment. The inhibitory activity of *A21* lipopeptides against the phytopathogenic *Fusarium sp* was investigated. The *in vitro* test showed a minimal inhibitory concentration of about 0.3 mg/ml.

6.12.10 Mode of Action:

The microscopic examination, of the treated *Fusarium* revealed a natural fungicides excessive lysis of the mycelia ultrastructure with destructed spores. *A21* lipopeptides are effective in decreasing by about 78.26% and 60.68%

6.12.11 Bacillus Cereus BS14:

Bacillus cereus BS14 on fungal growth under in vitro experiments and showed in vivo reduction of disease severity in pulse crop *Vigna mungo* L. They are Plant Growth-Promoting Rhizobacterium (PGPR) based on abilities of production of phytohormone and HCN, phosphate solubilization and biocontrol of *Macrophomina phaseolina*. *B. cereus BS14* proved its efficiency for the growth promotion of *Vigna mungo L* and significantly reduced disease severity index. The purified biosurfactant from *BS14* inhibited the fungal growth by arresting radially growing mycelia.

6.12.12 Serratia Rubidaea SNAU02, A Ramnolipid Producer:

Nalini and Parthasarathi *(2014)* reported *Serratia rubidaea* SNAU02, a rhamnolipid producer, as a biocontrol agent against plant phytopathogens. *Phytophthora sojae* is the main damaging oomycete pathogen of soybean. In pot culture study, application of rhamnolipid biosurfactant from *strain SNAU02* at the concentration of 250 µg/ml was effective against Fusarium wilt of eggplant, which minimize its yield loss and completely inhibit its disease severity. This investigation revealed that application of rhamnolipid biosurfactant from *SNAU02* could be a promising biocontrol agent (Nalini and Parthasarathi 2018).

6.13 Conclusion:

Surfactants have several applications in agriculture and agrochemical industries. However, there is rare use of biosurfactants which are more environmentally friendly. *Pseudomonas* and *Bacillus* as producers of biosurfactants indicating that only limited genera have been studied till date. Most of the disinfectant currently used is synthetic chemicals, which are replaced by biosurfactant in disinfectant formulation for improved cleaning and disinfection of food processing environment. Hence, it can be concluded that a cumulative input by researchers from various fields such as molecular biology, biochemistry, microbiology, computational biology, environmental science is indispensable.

6.14 Important Reference:

1. M. Heyd & A. Kohnert & T.-H. Tan & M. Nusser & F. Kirschhöfer & G. Brenner-Weiss & M. Franzreb & S. Berensmeier. 2008. Development and trends of biosurfactant analysis and purification using rhamnolipids as an example. Springer-Verlag.
2. Srinivasan Nalini, Rengasamy Parthasarathi, and Dhinakarasamy Inbakanadan.2020. Environmental Biotechnology Vol. 2. Chapter 4: Biosurfactant in Food and Agricultural Application.Eric Lichtfouse.,80-89.
3. P. Saminathan & P. Rajendran. 2016. Molecular Identification and Characterization of the Biosurfactant Produced by *Pseudomonas aeruginosa*-PSPA15 from the Oil Contaminated Soil. *International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706* Volume 5 Number 8 (2016) pp. 708-720.
4. R.Parthasarathi and S.Nalini 2021. Antifungal activity of biosurfactants from *Pseudomonas* sp. and *Bacillus* sp. With a potential to control phyto pathogens.
5. Lan Hee Kim., Yongmoon Jung., Sung-Jo Kim., Chang-Min Kim., Hye-Weon Yu., Hee-Deung Park & In S. Kim. 2016. Use of rhamnolipid biosurfactant for membrane biofouling prevention and cleaning. Biofouling; *The Journal of Bio adhesion and Biofilm Research*. Vol. 31, no. 2, 211–220
6. Sonica Tomar., B.P. Singh., Mehi Lal., M.A. Khan., Touseef Hussain., Sanjeev Sharma., S.K. Kaushik and Sathish Kumar. 2013. Screening of Noval microorganisms for biosurfactant and biocontrol activity against *phytophthora infestans. Journal of Environmental biology,* Vol. 35, 893-899.
7. Juan C. Mata-Sandovala., Jeffrey Karnsb., Alba Torrents. 1999. High-performance liquid chromatography method for the characterization of rhamnolipid mixtures

produced by *Pseudomonas aeruginosa* UG2 on corn oil. *Journal of Chromatography A, 864* (1999) 211–220.

8. Jolien D'aes., Katrien De Maeyer., Ellen Pauwelyn and Monica Höfte. 2009. Biosurfactants in plant–*Pseudomonas* Interactions and their importance to biocontrol. Environmental Microbiology Reports (2010) **2(**3), 359–372.
9. Jérôme Crouzet, Anthony Arguelles-Arias, Sandrine Dhondt-Cordelier, Sylvain Cordelier, Jelena Pršić, Gregory Hoff, Florence Mazeyrat-Gourbeyre, Fabienne Baillieul1, Christophe Clément, Marc Ongena and Stéphan Dorey .2020. Biosurfactants in Plant Protection Against Diseases: Rhamnolipids and Lipopeptides Case Study.

ISBN: 978-93-90847-17-4

7. Mitigation of Coir Pith Wastes as Compost and Further Value Addition for Social Benefits

Elango Rasavel, Parthasarathi Rengasamy

Department of Agricultural Microbiology,
Faculty of Agriculture,
Annamalai University, Annamalai nagar,
Tamilnadu, India.

Rajkumar Muth, Lenin Rajendran

Department of Horticulture,
Faculty of Agriculture, Annamalai University,
Annamalai nagar,India.

7.1 Introduction:

Coconut (*Cocos nucifera*) plays a significant role in the economy of India. The coconut husk is the raw material for the coir industry. In India, which produces about one-fourth of the world's 55 billion coconuts each year, only 15% of the husk is actually used for recovery of coir fibers.

The most popular uses for coir are door mats, agricultural twine and geo textiles (blankets that are laid on bare soil to control erosion and promote the growth of protective ground covers) because of its durability, eventual biodegradability, ability to hold water and hairy texture.

7.1.1 Areas of Coconut Cultivation in World:

Although coconut palms grow throughout the tropical regions, the vast majority of the commercially produced coir comes from India and Sri Lanka.

In recent years, India has attained the top position amongst the coconut producing countries i.e., about 26.1%. Indonesia, Sri Lanka and Philippines are the other major countries. In India, coconut is primarily a food crop which produces about one-fourth of the world's 53,598 million coconuts each year, and 15% of the husk fibers are actually recovered for use.

7.1.2 Coir Fibre:

Coir is a 100% organic naturally occurring fiber derived from a renewable resource of coconut husk. Coir fibers resemble the wood fibers in terms of physical properties and chemical composition. Naturally resistant to rot, moulds and moisture, it is not treated with any chemicals during its spinning process for converting it into yarn. Hard and the strongest among all natural fibers, it can be spun and woven into different types of matting and mats.

Coir fibers are categorized in two ways. One distinction is based on whether they are recovered from ripe or immature coconut husks. The husks of fully ripened coconuts yield brown coir. Strong and highly resistant to abrasion, its method of processing also protects it from the damaging ultraviolet component of sunlight. Dark brown in color, it is used primarily in brushes, floor mats and upholstery padding. On the other hand, white coir comes from the husks of coconuts harvested shortly before they ripen.

Actually, SEM Structure of coir fibre light brown or white in color, this fiber is softer and less strong than brown coir. It is usually spun into yarn, which may be woven into mats or twisted into twine or rope.

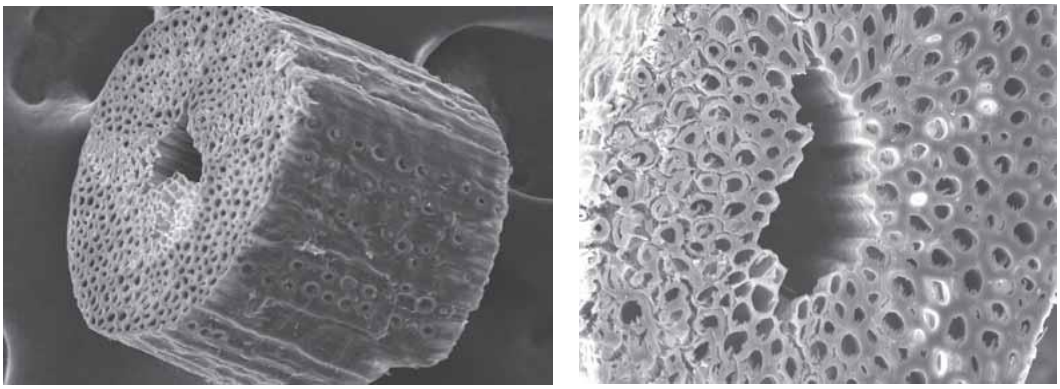


Figure 7.a: SEM Structure of coir fibre

7.1.3 Coir Pith:

Once harvested the whole coconut is separated into kernel and husk, where the kernel is used either directly as food or processed further into food products or oil. The husk goes to fibre mills where the coir fibre is extracted. In the process of extraction of coir fiber from husk generally about one third of it is obtained as fiber and two third of it is obtained as coir waste. Coir pith is a by-product of the coir fibre processing industry.

In the husk, coconut fibers are seen tightly packed along with non-fibrous, fluffy and light weight corky material known as coir pith or coir dust, which constitutes about 50-70 percent of the husk. The spongy material that binds the coir fiber in the husk is the coir pith or coir pith.

The composition and properties of coir pith vary depending on maturity of coconut, method of extraction and disposal, period between extraction and use and environmental factors.

Wide variations in C: N ratio of coir pith from 58:1 to 112:1 has been reported. Coir pith or dust is a biomass residue that decomposes very slowly due to its lignocellulosic nature. It is one of the largest agro wastes in tropical countries. Coir pith obtained from fully mature nuts has higher amounts of lignin and cellulose and lesser amount of water-soluble salts compared to younger nuts.

Coir pith has got many enviable characteristics, making it a highly potential resource if used after proper composting. Coir pith has very high moisture retention capacity of 600- 800 per cent and can be as high as 1100 per cent of dry weight. It has high potassium content and low bulk density (0.18g/cc) and particle density (0.8g/cc). High CEC, which varies from 20-30 meq/100 g, enables it to retain large amounts of nutrients and the absorption complex has high contents of exchangeable K, Na, Ca and Mg. Coir pith having a C: N ratio 24:1 or less could be used as a good source of organic matter for agricultural use. Physically, coir pith is a very light and compressible material. It is highly hygroscopic and has good water holding properties.

7.1.4 Properties of Coir Pith:

Coir pith is a recalcitrant agro-residue containing high amount of lignin and cellulose resisting decomposition by microorganisms under natural conditions. The recalcitrant nature of coir pith is due to the presence of lignin.

It contains 8-12% soluble tannin like phenolics. Coir pith has high water holding capacity of 8 times of its weight. It has fixed carbon, low sulphur, fats and ash. Nutrient content of coir pith varies with place, method of retting, rate of decomposition and storage method.

7.1.5 The Major Properties of Coir Pith Are:

- High water holding capacity, i.e., 6-8 times than its weight.
- Excellent moisture retention even after drying.
- Slow degradation due to high ligno cellulosic bonding.
- High porosity, stores and releases nutrients over extended periods of time.
- Greater physical resiliency that withstands compression better.
- Excellent aeration / oxygenation providing enhanced root penetration.
- Acceptable Electrical Conductivity (EC), pH and Cation Exchange Capacity (CEC).
- 100% degradable, organic and a renewable resource.

7.1.6 Composting of Coir Pith:

Coir pith when inoculated with a proprietary bio-formulation, such as PITHPLUS, and enriched with urea shows a definite reduction in lignin and cellulose contents with an increase in total nitrogen and other nutrient elements after a period of 30 days.

PITHPLUS is derived from *Pleurotus sajor caju, which is a fast growing, edible oyster* mushroom, originally found in India and grows naturally on a succulent plant (*Euphorbia royleans) in the foothills of the Himalayas.*

7.1.7 Method of Composting:

Apply one packet of Pithplus (400gm) uniformly over it. Inoculate the compost with compost organism like *Trimendas hirsuta, Cellulomonas fimii, Phanerochytae chrysosporium.*

Spread uniformly 100 kg coir pith in an area 5M x 3M. Cover with100 kg coir pith and apply 1 kg urea uniformly over it. Spread 100 kg coir pith again. Repeat the sandwiching process. Moisten the heap by sprinkling 25 buckets (approx) of water daily. Allow the heap to decompose for 30 days 200 % Moisture.

1 Ton Coir Pith + 2kg Pithplus + 5 kg Urea ----------> C-POM

7.2 Properties of C-POM:

- Excellent medium for plant growth.
- High moisture retention
- Improves physical and biological condition of soil.
- Reduces frequency of irrigation.
- Enhances strong and healthy root system.
- Contains natural enzymes and plant nutrients.
- Stimulates the production of phytohormones.

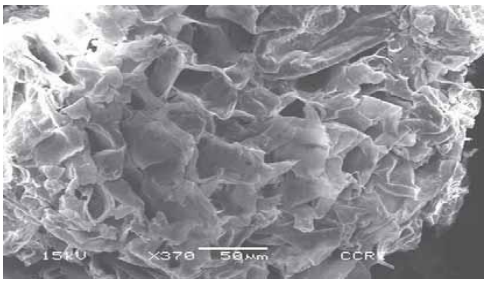


Figure 7.b: SEM view of C-POM

Figure 7.c: Coir pith compost heap

Figure 7.d: Pleurotus

Table 7.a: Nutritive value of raw and composted coir pith compost

Parameters	Raw coir pith (%)	Composted coir pith (%)
Lignin	30.00	4.80
Cellulose	26.52	10.10
Carbon	26.00	24.00
Nitrogen	0.26	1.24
Phosphorous	0.01	0.06
Potassium	0.78	1.20
Calcium	0.40	0.50
Magnesium	0.36	0.48
Iron(ppm)	0.07	0.09
Copper(ppm)	3.10	6.20
C:N ratio	112.1	24:1

7.3 Benefits of composted coir pith:

- The addition of composted coir dust improves soil texture, structure and tilth, sandy soil become more compact and clayey soil become more arable.
- It improves the soil aggregation
- It improves the water holding capacity (more than 5 times its dry weight) contributing towards increased soil moisture.
- The bulk density of both the sub surface (15-30 cm) soil is reduced to considerable extent with the application composted coir pith.
- Composted coir dust contains all plant nutrient elements, and it can provide a supplemental effect along with inorganic fertilizers.
- There is improvement in cation exchange capacity of soils, where composted coir pith is applied.
- Coir pith compost application increased the soil native micro flora because of addition of humic materials.
- Ammonification, nitrification and nitrogen fixation are increased due to improved microbiological activity.
- Application of coir pith compost
- It is recommended that 5 tons of composted coir pith per hectare of land irrespective of the raised.

- It is advised that composted coir pith should be applied basally before taking up the sowing.
- For nursery development in poly bags and in mud pots, while preparing the potting mixture 20 % of composted coir pith can be mixed with the soil and sand before filing it in the poly bag or mud pot
- For applying to the established trees like coconut, mango, banana and other fruit bearing trees, minimum 5 kg composted coir pith is required.

Table 7.b: Specification

Moisture	30- 40%
pH	6.6-6.9
Electrical Conductivity (EC)	< 0.25 Milliohms/cm
Salinity	0-1 ppt
Cation Exchange Capacity (CEC)	40-60 meq/100 gm
Porosity	65-70%

7.4 Coir Pith Grow Bags:

Coir pith grow bags are manufactured by blending coir pith with adequate quantity of short Coir fibre. This is then compressed and packed loosely in a UV stabilized black and white polythene bag and sprayed with. At the user end suitable holes are to be cut for planting as well as for drainage. Coir pith grow bags enable to enjoy delicious crop such as tomatoes, strawberries and cucumbers. The bags are ready to use as planting containers. Simply transplant plants into the coir pith grow bags during the planting season.

7.4.1 Specification:

- Weight 350 g +/- 30g
- Size 100 x 18 x 13 cm
- Compression ratio 5:1
- Moisture content less than 20%

7.5 Physical and Chemical Properties

- Composition: usually, 30% chips and 70% husk but customizable
- Electrical conductivity, E.C.: < 5 mS/cm (24 hours saturated paste method)
- pH: 5.5 – 6.5
- Packaged in white/black or black/black plastic treated against UV rays.
- Bags can be controllable for planting cut holes or pre-cut holes, drip holes, pre-drilled drip holes, drainage cuts, and cut for drip line.
- Grow slab also can be supplied without plastic

Grow Bags are mainly used for hydroponic growing under greenhouse conditions. Grow bags comes in various sizes.

Coco slab usually contains 30% husk chips and 70% coir pith (coco). This ratio can be customized according to grower's requirements.

They are suitable for a wide variety of crops such as:

- Tomato
- English cucumber
- Bell pepper
- Strawberry
- Watermelon
- Egg plant

Continue addting water - Note the expansion of the compressed coco peat inside the grow bag

Fully water absorbed grow bag - ready for plants

7.6 Product Facts:

- Place the grow bag where it is going to be cultivated.
- Center the slab inside the bag to allow an equal expansion.
- To hydrate the slabs, puncture the irrigation drips on the upper part of the slab
- Apply water or nutrient solution in a few irrigation cycles (10 minutes) so the coir will be hydrated slowly, and it will reach all its expected volume. Water required per slab will be approximately 75% of the slab final volume.
- Final expanded volume will be reached in 24 hours.
- After the total expansion, it is necessary to make some cuts in the bottom part of the slab for the drainage.
- The number of cuts will depend on the land's slope.
- Normally three cuts on each side of the slab are done.
- Check out the water drainage electrical conductivity.

7.6.1 Coir Grow Bags are 100% Eco Friendly:

Coir grows bags have proven to be an extremely versatile, biodegradable, 100% eco-friendly, fully renewable material procured from Mother Earth, in addition, these bags have presented a consistent quality along with a high water-retention capacity.

It has been observed that coir grows bags retain water up to eight times its actual weight, besides releasing water over an extended period of time, thereby taking care of frequent watering needs and providing excellent drainage and aeration to the roots. It maintains an optimum air water ratio at all times.

7.6.2 Coir Grow Bags Helps for Root Growth:

Coir grow bags are intrinsically nutrient rich and have the best physical and chemical properties that promote better root growth and healthier plants or crops.

Plants grown in coir grow bags are not just healthier but also have a better root growth compared to other growing mediums. There is never a difficulty with regard to fungus growth in the soil, as coir fundamentally has many anti-fungal properties.

7.6.3 Coir Grow Bags are 100% Eco Friendly:

Coir grows bags have proven to be an extremely versatile, biodegradable, 100% eco-friendly, fully renewable material procured from Mother Earth, in addition, these bags have presented a consistent quality along with a high water-retention capacity.

It has been observed that coir grows bags retain water up to eight times its actual weight, besides releasing water over an extended period of time, thereby taking care of frequent watering needs and providing excellent drainage and aeration to the roots. It maintains an optimum air water ratio at all times.

7.6.4 Coir Grow Bags are Reusable

Many people prefer to cultivate their vegetable garden exclusively in this coir grow bags as they are odorless with very little land preparation needs. The results are a better harvest with plump fruits and vegetables as there is little nutrient wastage in addition to a huge savings with regard to labor cost and reusability factor.

Typically, coir grow bags will nearly have no weed growth, are PH neutral, inexpensive and will never develop crack-ages. Besides, the coir doesn't shrink, so the grow bags maintain their structure and are easy to reprocess for several crop cycles. It is easily disposable without any environmental hazards. The only care to be taken before transplantation of another crop is of careful sterilization of the coir in the grow bag.

- Coir pith block is specially designed for commercial nurseries and greenhouses. This soil conditioner is suitable for all types of garden plants, lawns, flowers, orchids and vegetables in pots or on the ground
- Available Sizes- 5 kg and 650 gm

Weight	Expanded Volume	650gm +/- 30gm
Size	30 x 30 x 13 cm	20 x 10 x 5 cm
Compression ratio	5:1	8:1
Moisture content	< 20%	< 20%
Electrical Conductivity	< 0.5 milliohms/cm	< 0.5 milliohms/cm
Expanded Volume	13 to 14 L/kg	8 to 9 L/kg

7.6.5 Coir Pith Disc Specification:

- Disc & coin Sizes - 20 mm to 100 mm diameter
- Product Weight – 5 gms to 120 gms
- Tonnage Capacity - 200 tons
- Power – 15 kw / 20 hp

7.6.6 Coir Pith Briquette Specifications:

- Weight 650gm +/- 30gm
- Size 20 x 10 x 5 cm
- Compression ratio 8:1
- Moisture content less than 20%
- Electrical Conductivity less than 0.5 mS/cm
- Expanded Volume 8 to 9 Litres
- Packing 2000 briquettes per pallet
- Load ability 20 pallets / 26 MT in one 40 feet HC container

7.6.7 Manufacturing Process:

- The process of manufacturing coir pith blocks involves the following sequence of operations
- The coir pith completely free from seeds, weeds and other foreign particles and brought to the factory.
- The processed coco peat from coconut fibre factory consists of 10 to 20 percent baby fibres
- The incoming material is checked for EC and Ph values to maintain its purity.
- The material is passed to sieving machine. The processed coco peat from coconut fibre factory consists of 10 to 20 percent baby fibres.
- A specially designed rotary sieving machine with a quarter inch mesh is used for effective removal of baby fibre from coconut pith
- The Raw Material is washed with fresh water to reduce the EC level
- Input material EC 3 to ms/cm,Output material EC <0.5 ms/cm V
- The sieved material is sent to squeezing machine to remove excess water
- The sieved material is dried to bring down the moisture to 15%. a specially designed drying plat form is used to dry to 15% moisture which is essential for binding during compaction.
- The dried powder is compressed into blocks or grows bags and sprinkled with EM solution.
- Block size 30X30X10 cm

7.6.8 Preparation of COCOLAWN:

The following materials are used for making a readymade lawn of natural grass comprising:

- A layer of (Coir bhoovastra) netting material made of coir
- A single or plurality of non-woven layers (Coir Needled felt) layer / Coir fibre
- A raw coir pith layer on non-woven layer.
- A layer of fertilizer viz. coir pith organic manure (C-POM) containing inoculated microorganism and natural grass on the coir pith layer.
- Non-woven layers provide thickness to the lawn and allows grass roots to get entangled in the non-woven material. The layer of coir pith gives a support base, coir pith layer can be treated with other nutrients such as mushroom seeds and urea etc. and allowed to mature till the weight is substantially reduced as lignin is consumed by fungi or mushroom seeds.
- After making the coir bed using 'coir bhoovastra' and pith, the grass is planted on it. The lawn will become ready for use within one month. Readymade lawn can be made in the form of rolled like blankets which can be laid on any surface.
- The open weave of the supporting fabric also helps in supporting the roots of the planted grass slips, which form a mat by entangling with the coir fiber and yarn. The coir netting can therefore be laid on any arid surface or even concrete floor to act as a support material as the surface only forms a support for the blanket without contributing to the sustenance of grass.
- The netting also helps to drain the excess water accumulated during irrigation. Coir non-woven [needled] felt has been used as a semi-permeable membrane to retain the coir pith with C-POM, and to give support to the readymade lawn. It helps in creating a microclimate which boosts plant development.
- The non-woven layers impart thickness or bulk properties to the lawn. Another function of the non-woven layers is to allow the grass roots to form a bush and get positively entangled in the non-woven material.
- Grass is planted on the top most layer of Coir Pith Organic Manure, C-POM. Initially, C-POM is required to sustain the grass by providing nutrients like Nitrogen, Phosphorus and Potassium and other micronutrients essential for the growth of grass.

7.7 Advantages:

- Coir based lawns are devoid of pesticides, weeds which are normally associated with grass turfs.
- Further, the composted coir pith provides long term sustainability by slowly releasing the nutrients unlike grass turfs.

- The coir-based lawn is lighter in weight and therefore, easy to handle in comparison to the grass turfs.
- Synthetic lawns are usually treated with ultraviolet radiation resistant chemicals to extend their durability. The disposal of such synthetic lawns becomes a problem.
- Artificial turf tends to be much hotter than natural grass when exposed to the Sun. The abrasions caused by artificial turf have been linked to a higher incidence of infections. Sometimes artificial turf requires infill such as silicon sand and/or granulated rubber made from recycled car tyres.
- This material carries heavy metals which can leach into the water table. Periodic disinfection is required as pathogens are not broken down by natural processes in the same manner as for the coir based natural grass lawn. Recent studies suggest certain microbial life is less active.

Figure 7.e: Potting Media

7.8 As Soil Substitute:

- Mostly the coir pith from India and Sri Lanka are briquettes or compressed into bale or block form. It is done only for loading convenience and to reduce freight cost.
- The importers reprocess the compressed pith by wetting into loose forms and grade according to particle size and mixed in different ratios according to the farmers requirements, either for floriculture or horticulture.

- They also mix fertilizers and micronutrients with it depending on the crop to grow in the pot. EM liquid is sprayed to enhance the growth. It is then transferred to the pot-filling machine where different sizes of pots are filled with this mixed material automatically.

Figure 7.f: Coir baskets

- These are moulded rubberized coir fiber baskets made from sheets of coir fiber, which are mainly available in spherical shape. Used as liners to wire baskets after filled with coir pith or husk chips as growing medium along with effective microorganism for climbers and hanging plants in agri-horti floricultures.
- They are also available in "U" shape and conical shapes. They are used in roof gardens.
- The wall thickness varies from 10 mm to 15 mm. The diameter of ¼ sphere shape is usually of 16 inches, the diameter of ½ sphere shape ranges from 10 inch to 20 inch, "U" shape from 10 inch to 12 inch and conical shape from 9 inch to 20 inch.

7.9 Other Uses of Coir Pith Wastes:

- Preparation of particle board
- Production of bio fuel
- Production of bio-oil
- Production of bio ethanol
- Production of nano cellulose
- Extraction of sodium ligno sulphonate

ISBN: 978-93-90847-17-4

8. Similipal Biosphere Reserve (SBR): A General Discussion

Dr. Debabrata Das

Department of Botany,
Lalgarh Government College,
Lalgarh, Jhargram District, West Bengal, India.

Atmaja Avirupa Das

VSN, Midnapore, Paschim Medinipur,
West Bengal, India.

Abstract:

Biosphere reserve is a big term applied to a large scale system which is ecologically diverse and significant along with many more micro habitats. This amplifies a good governance to protect forest and its components. It is important because of many kinds of ecosystem services which run parallel in way to make the ecosystem meaningful. We can get facilities like water conservation, climate regulation, nutrient flow, soil protection and soil conversion, prevention of water loss from dry land, soil loss, increase organism production, photosynthesis by-product and biomass yield, wind break, minimization of pollutants, carbon-di-oxide influx, oxygen outcome, pest control, and conservation of wildlife and so on. Apart from the above, its main emphasis imposed on tribal people residing inside the biosphere reserve. Not only these above mentioned kinds, it is a habitat that gives us immense pleasure during visit. Botanists, ecologists, foresters, climatologists, horticulturists, zoologists, wildlife specialists, photographers, environmental scientists, scholars, policy maker and students will get benefit from different viewpoints particularly research, extension and management. It is a site laid down by state Govt. and local Forest Protection Committees (FPCs) and eco development committees (EDCs) for eco-tourism development. In this communication, authors are going to represent a general view of Similipal to know about the special eco-climate and wildlife of Similipal.

Key words*:* *Similipal, Eco-climate, Wildlife, tribal people and Management*.

8.1 Introduction:

Similipal biosphere is a biosphere reserve of Odisha and got its name from *simul* (red silk cotton tree). It covers an area of 2750 sq. km though only 303 sq. km is a core area. One sanctuary (Kuldiha bird sanctuary) and one Tiger reserve (STR) is inside the reserve. Due to heavy rain falls and varied microclimatic conditions, it shows a vast green vegetation form satellite image. It harbours wide range of dry deciduous to moist green vegetation

patch. Due to its own geographical features, the biosphere reserve harbours many species of flora and fauna. About 1100 species of plants have been recorded form the forests though the number is not static. Many species of mammals, birds, insects, fungi, molluscs, millipedes, centipedes and reptiles are commonly found in different sites. The high hillocks like khairiburu and meghashini and other peaks attract the tourists for the scenic beauty of land from distance site of the area. The entire land mass allow the rivers like budhabalanga, khairi, salandi, palpala and bhandan to flow and act as water carrying bodies originated from peaks and reverie belts that collect water through rivulets and canals. Many waterfalls attract people in this site. The famous waterfalls are barehipani, joranda and uski attract us and a source of water of foothills.

Government of Odisha has declared the site as Wildlife sanctuary in the year 1979 with an area of 2,200 sq. km and Govt. of India has declared it as Biosphere Reserve in the year 1994. In the year 2009, UNESCO declared it as world heritage site. Medicinal plant species like *Andrographis paniculata, Terminalia bellerica, Terminalia chebula, Phyllanthus emblica, Diospyros embryopteris, Ziziphus jujuba, Michelia champaca, Madhuca indica, Shorea robusta, Holarrhena antidysenterica* are found here. Various colourful mushrooms are available from the floor of the forest during post monsoon. A large number of collectors over the degraded land engage to collect '*Bidi leaf*' (*Diospyros melanoxylon*) so called '*tendu*' for the purpose to rise local economy.

A small herbaceous or shrubby plants get leaves which are marketed but the big trees bear large number of leaves but have no commercial value, as the leaves are thick and not up to the mark as quality leaf. The tract of river side *Eulaliopsis binnata* (Sabai grass/Chinese alpine rush) is common which is economically important. Ethnic people reside inside the forest and cultivate rice, sesame and mustard. Other local vegetables found in their home garden and they depend on the cultivation though forest department involve them to work in various micro-projects. The natural forest, degraded land and plantation sites of the Biosphere reserve cover the entire land mass a unique reserve of man and wildlife. Large number of plants, animals and microbes in the rhizosphere and phyllosphere of this BR is important. Therefore it is essential to know the some of the components of this biosphere reserve. Remembering the theme in mind present article has been placed as a brief overview of Similipal.

8.2 Study Area:

Study areas were podadiha, pithabata, gurguria, joranda, chahala, jamuani, jenabil, bangriposi, udala, karanjia, uski and kuldiha. All study sites are inside the biosphere reserve and nearby and included in the state of Odisha. It is located in the district of Mayurbhanj of Odisha aside the Jhargram district of West Bengal. It lies between 21^0 16' to 22^0 08' N latitude and 86^0 04' to 86^0 37' E longitude. It was declared as BR in June, 1994 by Govt. of India. It comprises tropical moist deciduous, deciduous and dry evergreen and semi evergreen forests. It hosts near about 1100 different plant species along with many diver fungi, algae and diverse animal species. These are under varied microclimatic conditions. Cultivated land and wet paddy field are the characteristic features of this area. So, as a whole, river, hills, dams, forests, home gardens, nursery, medicinal plant garden, fallow land and rice fields are main habitats for Wildlife.

8.3 Material and Methods:

Frequent visits in field was done and plants samples, specimens, soils, photographs and other data like soil temperature, light intensity, micro propagules were recorded to make a study report for annual basis. A compilation of 3 years data was prepared with the help of computer and presented here to locate the present scenario for future study and research. A total 36 (3 in each micro-site) study points were fixed with the help of GPS and recorded points were demarcated with the help of locators and studied for the medicinal plants available there and to study the ecology of them for future study and research. Help of local people was taken to know the common names of the plants and then a few herbarium specimens were prepared with the help of manual available in website along with the knowledge received from Botanical Survey of India, Shibpore, Howrah, West Bengal during the study with valid permission from Govt. office. Sample specimens were housed at herbarium section of Lalgarh Govt. College, Binpur-I, Jhargram and Seva Bharati Mahavidyalaya, Kapgari, Jhargram for preservation and future study. Similarly, soils and rocks including mushrooms were collected and preserved in the Botany Department, Lalgarh Govt. College for further study and research. Used references listed in bibliography [(1-23)] part for further study.

8.4 Results and Discussion:

The data on SBR soil analysis showed that the soil p^H was mainly acidic in nature (6.8) and range varied from 6.5 to 6.8 *i.e.* low variations thereby, indicating a minor variation from one site to another as there were different management for forest and agricultural land use practice. These soils obviously affect the plant growth. Moisture content varied from 11.76-34.12% (Table 8.a) in different types of study soils starting from summer to late summer to early monsoon.

In degraded stand of SBR, sand and silt are higher in value (Table 8.b) in compare to natural sites. Similarly, bulk density value is higher at degrade stand in compare to natural site. Here, clay, soil porosity and soil moisture content at degraded site is lower in compare to natural sites.

The soil of cultivable land at low lying land showed pH value ranged in between 6.4 and 6.6 during summer. Moisture content of the same site showed 14.0 -24.0 %. The same at degraded land (DL) showed mean pH 6.8 and moisture content 12.0-17.0 % in summer. Natural forest land showed the mean pH value 6.5 while the moisture content of soil in between 32 to 34%. This showed a great range due to different land sites from upper part of the degraded site to the lower tract of alluvial land via natural forest. Here we have recorded 200 plant species under 130 genera and 60 families during study. Most of the plants used as medicinal purpose directly or indirectly which are available at the territory of Similipal (Table 8.c). Here the family Euphorbiaceae showed species dominance followed by Fabaceae and Caesalpiniaceae. The site also showed planted species like Eucalyptus that gets flowers and fruits during late winter. Plantation of *Cassia siamea* and *Eucalyptus* makes the degraded land more greenish followed by *Acacia auriculiformis*. Huge medicinal herbs, shrubs and some trees make the land beautiful while ground is covered by medicinal grass. Ground cover of the land in summer showed less to lesser number of plants while

most of the tree species become leafless. The dry deciduous forest floor exhibits gregarious climbers and a few shrubs that show flowers. Potentially the degraded land shows good growth of *bidi* leaf (*Diospyros melanoxylon*) which is used widely by local people to generate income as the plant is commercially important and the demand is high. Similarly, green *sal* (*Shorea robusta*) plates and wide and broad leaves are used widely by local people to generate economy at the rural village. Here *Shorea robusta, Michelia champaca* and *Eucalyptus* sp. are the huge size tree found in the reserve (Table 8.d). The tribal people collect dry leaf litter and fuel wood for their livelihood. Some common medicinal plants are available in the periphery of tribal village inside the biosphere reserve. Diversity of plants in and around the SBR is unique. Here, species diversity is highest in case of tree species (3.12±0.22) and lowest in case of shrubs (1.76±0.16) and concentration of dominance (cd)is highest in case of shrubs (0.38±0.003) followed by herbs (0.30±0.027) and lowest in case of tree species (0.18±0.004) (Table 8.e). Therefore, the site is very interesting and that need more scientific research in a continuous way to know the trend of loss of biodiversity in near future.

Besides, the rich floral and faunal diversity, similipal Biosphere Reserve is also host many tribal populations like khadia, bhatudi, kolha, bhumija and munda people who have rich traditional culture and practice. They totally depend on forest for their livelihood. Village forest protections committees (VFPCs) are conjointly look after the area regarding the problems and even the mitigation process required any time along with the forest department. According to report the entire SBR forest area fall under one of the Schedule-V category (tribal sub-plan area) of the state as a majority of the people are tribal. So, ecologically this area is ecological interactive in which people and wildlife sit together in a common geographical territory. A good management plan is therefore required to make the process of ecosystem holistic that can protect the biodiversity too. Real time planning and management therefore is essential which need more comprehensive research in all fields of allied sciences to get a proper benefit through applications in near future.

Table 8.a: Range of Physico-chemical parameters of soil of some sites at SBR, Odisha, India

Study Parameter	Value (Range)
Soil p^H	6.5-6.8
Soil moisture (%)	11.76-34.12%
Organic carbon (%)	0.88-1.15%
$NO3^-$ - N (Kg ha^-)	12.14-19.05
Total N (%)	0.08-0.14
Available P (Kg ha^-)	21.88-22.66
Available K (Kg ha^-)	167.01-123.84
N.B.: Range of sample value of Degraded to natural via plantation stand basis.	

Table 8.b: Soil composition at depth 0-30cm in different sites under different management regimes at SBR, Odisha, India

Sr. No.	Type	Degraded stand (Range)	Natural site (Range)
1	**Sand (%)**	51.30-54.21	29.10-33.10
2	**Silt (%)**	26.16-30.89	21.41-25.67
3	**Clay (%)**	17.22-21.41	45.40-47.41
4	**Bulk density (g/cm^3)**	1.12-1.23	0.78-0.89
5	**Porosity (%)**	39.1-49.0	58.61-68.12
6	**Soil moisture (%)**	9.69-11.78	30.4-32.14

Table 8.c: Medicinal plants inventory at Similipal, Odisha, India

Sr. No.	Scientific Name / (English Name)	Common Name	Family
1.	**Abutilon indicum (Link) Sweet (INDIAN ABUTILON, INDIAN MALLOW)**	Patari, Atibala	Malvaceae
2.	**Acacia auriculiformis A. Cunn. ex Benth. (TAN WATTLE, EARLEAF ACACIA)**	Akashmoni, Sonajhuri, Minjam	Fabaceae
3.	**Achyranthes aspera L. (CHAFFY FLOWE, PRICKLY CHAFFY FLOWER)**	Apang	Amaranthaceae
4.	**Aegle marmelos (L.) correa (BENGAL QUINCE, GOLDEN APPLE, STONE APPLE, WOOD APPLE, JAPANESE BITTER ORANGE)**	Bael, Bel	Rutaceae
5.	**Ailanthus excelsa Roxb. (TREE OF HEAVEN)**	Simarubi	Simaroubiaceae
6.	**Alstonia scholaris (L.) R. Br. (DEVIL'S TREE)**	Chhatim, Saptaparni	Apocynaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
7.	**Alternanthera sessilis (L.) R. Br. ex DC. (SESSILE JOY WEED)**	Mati Kanduri	Amaranthaceae
8.	**Anacradium occidenatale L. (CASHEW TREE)**	Kaju	Anacardiaceae
9.	**Andrographis paniculata (Burm f.) Wall. ex Nees (KING OF BITTERS, CREAT, GREEN CHIRAYTA)**	Kalmegh	Acanthaceae
10.	**Andropogon aciculatus Retz. (GOLDEN FALSE BEARD GRASS, GREEN STEM GRASS, BROOM SEDGE)**	Chorkanta	Poaceae
11.	**Anisomeles ovate W. T. Aiton (CATMINT)**	Kalobhangra	Lamiaceae
12.	**Anogeissus latifolia (Roxb. ex DC.) Wall ex Bedd. (AXLE WOOD TREE)**	Dhaw	Combretaceae
13.	**Antidesma ghaesembilla Gaertn. (BLACK CURRANT TREE)**	Nonakul	Phyllanthaceae
14.	**Argemone Mexicana L. (MEXICAL PRICKLY POPPY, PRICKLY POPPY OR MEXICAN POPPY)**	Siyal-Kanta	Papaveraceae
15.	**Aristolochia indica L. (SERPENT ROOT PLANT, INDIAN BIRTH WORT)**	Iswarmul	Aristolochiaceae
16.	**Asparagus racemosus Willd. (BUTTERMILK ROOT, WILD CARROT, HUNDRED ROOTS, INDIAN ASPARAGUS)**	Satamuli, Satavari	Asperagaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
17.	**Atylosia scarabeoides (L.) Benth. (Not Available)**	Banur Kalai, Thit Kalai	Fabaceae
18.	**Azadirachta indica A. Juss. (MARGOSA TREE/INDIAN LILAC)**	Neem, Nim	Meliaceae
19.	**Barringtonia acutangula Gaertn. (INDIAN OAK, INDIAN PUTAT)**	Hijal	Lecythidaceae
20.	**Bauhinia variegate (L.) Benth. VARIEGATED BAUHINIA**	Harek Bauhuinia	Fabaceae
21.	**Boerhaavia repens L. (SPREADING HOGWEED, RED HOGWEED)**	Punarnava	Nyctaginaceae
22.	**Borassus flabellifer L. (PALMYRA PALM, TODDY PALM, WINE PALM, TAL PALM)**	Tal	Arecaceae
23.	**Botrychium daucifolium Wall. ex. Hook. & f. (WESTERN GOBLIN, MOUNTAIN MOONWORT)**	Chandni	Lygodiaceae
24.	**Breynia vitis-idaea (Burm. f.) Fisch. (INDIAN SNOWBERRY)**	Kali Sitki	Euphorbiaceae
25.	**Buchanania lanzan Spreng. (CUDDAPAH TREE, ALMONDETTE TREE, CHERONJEE)**	Piyal, Chiranji	Anacardiaceae
26.	**Butea monosperma (Lam.) Taub. (FLAME OF THE FOREST, BUTEA KINO)**	Kingshuk, Palas	Fabaceae
27.	**Butea superb Roxb. (RED KWAO KRUA, CREEPING BUTEA)**	Lat Palas	Fabaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
28.	**Caesalpinia sappan L. (SAPPAN WOOD / INDIAN REDWOOD)**	Nata, Lata	Caesalpiniaceae
29.	**Calotropis gigantean (L.) W. T. Aiton (CROWN FLOWER/GIANT MILKWEED, BOWSTRING HEMP)**	Bara Akanda	Asclepiadaceae
30.	**Calliandra haematocephala Hassk (WHITE POWDER PUFF FLOWER)**	Calliandra	Fabaceae
31.	**Capparis zeylanica L. (CEYLON CAPER)**	Dela	Capparaceae
32.	**Cardiospermum helicacabum L. (BALLOON VINE)**	Sibjhul	Sapindaceae
33.	**Careya arborea Roxb. (WILD GUAVA/CEYLON OAK/PATANA OAK)**	Kumbhi	Lecythidaceae
34.	**Cascabela thevetia (L.) Lippold Syn.-Thevetia peruviana (Pers.) K. Schum. (LUCKY NUT/YELLOW OLEANDER)**	Kolke	Apocynaceae
35.	**Casearia elliptica Willd. (Toothed leaf Chilla)**	Chilla	Salicaceae
36.	**Cassia alata L. (CANDLE BUSH/CHRISTMAS CANDLE)**	Dadmari	Caesalpiniaceae
37.	**Cassia fistula L. (GOLDEN SHOWER TREE)**	Bandar Lathi, Sonali	Caesalpiniaceae
38.	**Cassia occidentalis L. (COFFEE WEED/MOGDAD COFFEE)**	Kalkasunda	Caesalpiniaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
39.	**Cassia siamea Lam. (SIAMESE CASSIA/KASSOD TREE/CASSIA TREE)**	Minziri/Kasunde	Caesalpiniaceae
40.	**Cassia torab L. =Senna tora (L.) Roxb. (SICKLE SENNA)**	Jhunjhuni	Caesalpiniaceae
41.	**Cassytha filiformis L. (LOVE-VINE)**	Akashbel	Cassythaceae
42.	**Catharanthus roseus (L.) G. Don. (MADAGACAR PERIWINKLE/ROSE PERIWINKLE)**	Nayantara	Apocynaceae
43.	**Celastrus paniculatus Willd. (INTELLECT PLANT/CLIMBING STAFF TREE/BLACK OIL PLANT)**	Kijri, Malkagni, Jyotismati	Celastraceae
44.	**Cephalandra indica Naudin (IVY GOURD/SCARLET FRUIT)**	TelaKuncha/Bankundari	Cucurbitaceae
45.	**Cleistanthus collinus (Roxb.) Benth. ex. Hook. f. (GARARI)**	Parasi	Euphorbiaceae
46.	**Clerodendrum indicum (L.) Kuntze (TUBE FLOWER/SKY ROCKET/BOWING LADY/TURK'S TURBIN)**	Bamunhati	Verbenaceae
47.	**Clerodendrum serratum (L.) Moon (BLUE FLOWERED GLORY TREE)**	Bharangi	Verbenaceae
48.	**Clerodendrum viscosusm Vent. (HILL GLORY BOWER)**	Ghentu	Verbenaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
49.	**Cnicus arvensis (L.) Hoffm. (CALIFORNIA THISTLE, CANADA THISTLE, FIELD THISTLE)**	Biral kanta	Asteraceae
50.	**Cocculus hirsutus (L.) Diels (BROOM CREEPER)**	Dadaya/Doipata	Menispermceae
51.	**Cochlospermum religiosum (L.) Alston (Silk Cotton tree, Butter cup tree)**	Silk-cotton tree	Bixaceae
52.	**Combretum decandrum Jacq. (RANGOON CREEPER, BURMA CREEPER)**	Atang/Atur	Combretaceae
53.	**Costus speciosus (J. Koenig.) Sm. (CREPE-GINGER, CANE REED, SPIRAL GINGER)**	Keon, Keo, Keu, Kemuk	Costaceae
54.	**Cretava religiosa G. Forst. (SACRED GARLIC PEAR, TEMPLE TREE)**	Barun	Capparaceae
55.	**Croton bonplandianum Baill. (THREE LEAVES CRAPER)**	Ban tulsi, Banlank, Chrchuri	Euphorbiaceae
56.	**Croton oblongifolus Roxb. (CEYLON AROMATIC CROTON)**	Putli, Chuka, Baragachi	Euphorbiaceae
57.	**Cryptolepis buchanani Roem. & Schult. (INDIAN SARSAPARILLA)**	Shyamlata	Anacardiaceae
58.	**Curculigo orchioides Gaertn. (GOLDEN EYE GRASS)**	Kali musli, Talamuli, Tali)	Hypoxidaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
59.	**Curcuma aromatica Salisb. (WILD TURMERIC)**	Kali Haldu	Zingiberaceae
60.	**Cuscuta reflexa Roxb. (COMMON /GIANTDODDER)**	Swarnalata	Convolvulaceae
61.	**Dalbergia latifolia Roxb. (INDIAN ROSE-WOOD)**	Satisal	Fabaceae
62.	**Dalbergia sissoo Roxb. (NORTH INDIAN ROSE-WOOD)**	Sishu	Fabaceae
63.	**Datura metel L. (DEVIL'S TRUMPET)**	Datura	Solanaceae
64.	**Deeringia amaranthoides (Lam.) Merr. (SHRUBBY DERINGIA)**	Rongoli lata, Gol muhuni, Gol mohani.	Amaranthaceae
65.	**Delonix regia (Hook.) Raf. (ROYAL POINCIANA)**	Gulmohar	Caesalponiaceae
66.	**Dendrobium transpers Wall. (TRANSLUCENT DENDROBIUM)**	Translucent Dendrobium	Orchidaceae
67.	**Dendrophthoe falcate (L. f.) Ettingsh. (HONEY SUCKLE MISTLETOE)**	Bara Manda	Loranthaceae
68.	**Desmodium triflorum (L.) DC. (CREEPING TICK TREFOIL)**	Kudaliya, Kulaliya	Fabaceae
69.	**Dichrostachys cinerea Wight et Am. (Bell Mimosa, Chinese lantern tree, Kalahari Christmas tree)**	Sickle bush	Fabaceae
70.	**Dicliptera bupleuroides Nees (ROXBURGH'S FOLDWING)**	Lal jhnati, Lalsira	Acanthaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
71.	**Diospyros melanoxylon Roxb. (COROMANDEL EBONY, EAST INDIAN EBONY)**	Kend, Tendu	Ebenaceae
72.	**Diospyros sylvatica Roxb. (MOTTLED EBONY, MOUNTAIN PERSSIMON, BOMBAY EBONY)**	Bisgab, bistendu	Ebenaceae
73.	**Eragrostris tenella (L.) P. Beauv. (LOVE GRASS, FEATHER LOVEGRASS, JAPANESE LOVEGRASS)**	Shada fulka	Poaceae
74.	**Eranthemum nervosusm (Vahl) R. Br. ex Roem. & Schult. (BLUE ERANTHEMUM, BLUE SAGE)**	Gulson	Acanthaceae
75.	**Eria meghasaniensis Misra (ENDEMIC ODISHA ORCHID)**	Meghasaniensis orchid	Orchidaceae
76.	**Eucalyptus sp. (TASMANIAN BLUE GUM, BLUE GUM, SOUTHERN BLUE GUM)**	Eucalyptus	Myrtaceae
77.	**Eupatorium odoratum L. (BITTER BUSH, TONKA BEAN)**	Bankarpur, Banmara, Bhutbhairabi	Asteraceae
78.	**Euphorbia hirta L. (ASTHMA WEED)**	Dudhi, Lalkeru, Barokarni	Euphorbiaceae
79.	**Euphorbia trigona Mill. (AFRICAN MILK TREE, CATHEDRAL CACTUS, ABYSSINIAN EUPHORBIA)**	Bajbaran	Euphorbiaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
80.	**Evolvulus alsinoides (L.) L. (DWARF MORNING-GLORY)**	Shanapushpi, Sankhapuspi	Convolvulaceae
81.	**Evolvulus nummularious (L.) L. (ROUND LEAF BINDWEED)**	Bhnui-Akra	Convolvulaceae
82.	**Ficus benghalensis L. (BANYAN, BANYAN FIG, INDIAN BANYAN)**	Bot	Moraceae
83.	**Ficus hispida L. f. (HAIRY FIG, DEVIL FIG)**	Kak damur, Khoksha dumur	Moraceae
84.	**Ficus religiosa L. (PEEPAL TREE, ASWATHA TREE, BODHI TREE)**	Aswatha	Moraceea
85.	**Flacourtia cataphracta Roxb. ex Willd. (SPIKED FLACOUTIA, PUNEALA PLUM)**	Tali	Salicaceae
86.	**Gloriosa superba L. (FLAME LILY, TIGER CLAW)**	Glory lily	Colchicaceae
87.	**Gmelina arborea Roxb. ex Sm. (BEECH WOOD TREE, MALAY BEECHWOOD)**	Gamar	Verbenaceae
88.	**Gnetum ula Brongn. (LIANA GNETUM)**	Long Gnetum	Gnetaceae
89.	**Gomphrena globosa L. (GLOBE AMARANTH)**	Golkamal, Botamphul, Golmakhmal	Amaranthaceae
90.	**Gymnema sylvestre R. Br. (PERIPLOCA OF THE WOODS)**	Gurmar, Merasinghi	Asclepiadaceae
91.	**Haldinia cordifolia (Roxb.) Ridsdale =Adina cordifolia (Roxb.) Brandis (YELLOW TEAK OR HALDU)**	Haldu/Karam	Rubiaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
92.	**Hemidesmus indicus (L.) R. Br. (INDIAN SARSAPARILLA)**	Anantamul	Asclepiadaceae
93.	**Hemigraphis hirta T. Anderson (HAIRY HEMIGRAPHIS)**	Musakani	Acanthaceae
94.	**Hibiscus vitifolius L. (GRAPE LEAVED MALLOW)**	Ban Kapas	Malvaceae
95.	**Holarrhena pubescens Wall. ex G. Don (EASTER TREE)**	Kurchi	Apocynaceae
96.	**Holoptelea integrifolia (Roxb.) Planch. (INDIAN ELM TREE/JUNGLE CORK TREE)**	Challa	Ulmaceae
97.	**Hyptis suaveolens (L.) Poit. (AMERICAN MINT)**	Bilati Tulsi	Lamiaceae
98.	**Ichnocarpus frutescens (L.) W. T. Aiton. (BLACK CREEPER)**	Shama Lata	Apocynaceae
99.	**Impomoea obscura (L.) Ker Gawler (LESSER GLORY)**	Chaggalkuri	Convolvulaceae
100.	**Indigofera cassioides Rottler ex DC. (CASSIS INDIGO)**	-	Fabaceae
101.	**Indigofera linifolia (L. f.) Retz. (MUD INDIGO)**	Bhangra/Motiyari	Fabaceae
102.	**Inga dulcis (Roxb.) (MALINA TAMARIND)**	Ban Tetul, Kich mich, Jilapiphal	Mimosaceae
103.	**Ipomoea aquatic Forsskal (SWAM CABBAGE, WATER MORNING GLORY)**	Jal Kalmi	Convolvulaceae
104.	**Ipomoea carnea Jace. BUSH MORNING GLORY)**	Bera Kalmi	Convolvulaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
105.	**Jatropha gossypiifolia (L.) (BELLYACHE BUSH)**	Lal Bherenda	Euphorbiaceae
106.	**Kalanchoe pinnata (Lam.) Pers. (LIFE PLANT)**	Patharkuchi	Crassulaceae
107.	**Kaempferia rotunda L. (PEACOCK GINGER)**	Mayuri Ada	Zingiberaceae
108.	**Lannea coromandelica (Houtt.) Merr. (GURJON TREE/INDIAN ASH TREE)**	Jiyal	Anacardiaceae
109.	**Lantana camara L. (BIG-SAGE, WHITE-SAGE, RED-SAGE)**	Chotra/Putus/Chatra	Verbenaceae
110.	**Lepisanthes tetraphylla (Vahl) Radlk.**	-	Sapindaceae
111.	**Limonia acidissima L. (WOOD APPLE/ELEPHANT VAPPLE)**	Kot bel	Rutaceae
112.	**Lobelia nicotianifolia L. (WILD TOBACCO)**	Ban tamuk	Campanulaceae
113.	**Luffa aegyptiaca Mill. SPONGE GOURD)**	Purul chal	Cucurbitaceae
114.	**Lygodium japonicum L. (JAPANESE CLIMBING FERN)**	Berajal	Lygodiaceae
115.	**Madhuca longifolia (J. Kong) J.F. Macbr. Syn.: M. indica Benth. (INDIAN BUTTER TREE)**	Mohua/Mohul	Sapotaceae
116.	**Mikania micrantha Kunth. (BITTER VINE, AMERICAN ROPE)**	Taralata, Rabonlata(Ravan lata)	Asteraceae
117.	**Mimosa pudica L. (SENSITIVE PLANT/HUMBLE PLANT)**	Lajjwati	Mimosaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
118.	**Mimosa rubicaulis Lam. IHIMALAYAN MIMOSA)**	Shiakanta, Chirchitkanta	Mimosaceae
119.	**Mitragyna parviflora (Roxb.) Korth. (KAIM, TRUE KADAMB)**	Dharakadamb/Gulikadamb	Rubiaceae
120.	**Momordica charantia L. (BITTER GOURD, BITTER MELON))**	Karela	Cucurbitaceae
121.	**Morinda citrifolia L. (CHEESE FRUIT)**	Nani/Hurdi	Rubiaceae
122.	**Oldenlandia corymbosa L. Syn.-Hedyotis diffusa Willd. (DIAMOND FLOWER)**	Khetpapra	Rubiaceae
123.	**Passiflora foetida L. (STINKING PASSION FLOWER)**	Ban Jhumkolata	Passifloraceae
124.	**Peltophorum pterocarpum (DC.) K. Heyne COPPER POD / YELLOW FLAME)**	Radhachura	Caesalpiniaceae
125.	**Pergularia daemia (Forssk.) Chiov. (TRELLIS-VINE)**	Chagalbati	Asclepiadaceae
126.	**Phyllanthus simplex Retz. (SEED UNDER LEAF)**	Bhuiamla	Euphorbiaceae
127.	**Phyllanthus niruri L. (INDIAN SMALL GOOSEBERRY)**	Choto Bhuiamla	Euphorbiaceae
128.	**Plumbago zeylanica L. (CEYLON LEADWORT/DOCTOR BUSH)**	Sada Chita	Plubaginaceae
129.	**Pongamia pinnata (L.) Pierre (HONGE TREE/PONGAM TREE)**	Karanja	Caesalpiniaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
130.	**Premna latifolia Roxb. (ARARI)**	Agnimantha/Jaya/Gohara	Verbenaceae
131.	**Pterocarpus marsupium Roxb. (MALABAR KINO /INDIAN KINO)**	Bijasal/Piyasal	Sterculiaceae
132.	**Pterospermum acerifolium (L.) Willd. (DINNER PLATE TREE/BAYUR TREE)**	Kanakchampa	Sterculiaceae
133.	**Pterospermum xylocarpum (gaertn.) Santapau & Wagh (TADA)**	Kanakchampa	Sterculiaceae
134.	**Ricinus communis L. (CASTOR BEAN/CASTOR OIL PLANT)**	Reri	Euphorbiaceae
135.	**Rauvolfia serpentine (L.) Benth.ex Kurz. (SNAKE ROOT)**	Sarpagandha	Apocynaceae
136.	**Saraca asoka (Roxb.) Willd. (ASHOKA TREE) State flower of Odisha**	Ashok tree	Fabacveae
137.	**Schleichera oleosa (Lour.) Oken (CEYLON OAK, LAC TREE)**	Kusum	Sapindaceae
138.	**Sebastiania chamaelea (L.) Mull. -Arg. (CREEPING SEBASTIANA)**	Sebastin	Euophorbiaceae
139.	**Semecarpus anacardium L. (MARKING NUT TREE)**	Vela	Anacardiaceae
140.	**Senna didymobotrya (Fresen.) Irwin & Barneby (BLACK SENNA)**	Kali senna	Caesalpiniaceae
141.	**Senna hirsute (L.) H.S. Irwin (HAIRY SENNA)**	Hairy senna	Caesalpiniaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
142.	**Shorea robusta Gaertn. f. (SAL)**	Sal	Dipterocarpaceae
143.	**Smilax macrophylla Roxb. (INDIAN WILD SARSAPARILLA, ROUGH BINDWEED)**	Kumarika	Smilacaceae
144.	**Solanum virginianum L. (YELLOW –FRUIT NIGHT SHADE)**	Kantikari	Solanaceae
145.	**Spermacoce hispida L. (SHAGGY PUTTONWEED)**	Madanbata	Rubiaceae
146.	**Stachytarpheta indica (L.) Vahl (BLUE POTTER WEED/BLUE SNAKE WEED)**	Nilkanthi	Verbenaceae
147.	**Stephania japonica (Thunb.) Miers (SNAKE VINE)**	Tejomala	Menispermaceae
148.	**Sterculia foetida L. (JAVA OLIVE TREE/WILD ALMOND TREE)**	Jangli Badam	Sterculiaceae
149.	**Sterculia villosa Roxb. ex Sm. (HAIRY STERCULIA) (JAVA OLIVE TREE/WILD ALMOND TREE)**	Udal	Sterculiaceae
150.	**Streblus asper Lour. (TOOTH BRUSH TREE)**	Ash seora	Moraceae
151.	**Strychnos nux-vomica L. (NUX VOMICA / POISON NUT TREE)**	Kuchla	Loganiaceae
152.	**Tectona grandis L. f. (TEAK TREE)**	Segun	Verbenaceae
153.	**Tephrosia purpurea (L.) Pers. (WILD INDIGO/PURPLE TEPHROSIA)**	Ban nil	Fabaceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
154.	**Terminalia arjuna (Roxb.) Wight & Arn. (ARJUN)**	Arjun	Combretaceae
155.	**Terminalia bellerica Roxb. (Bastard Myrobolan)**	Bahera	Combretaceae
156.	**Terminalia chebula Retz. (BLACK OR CHEBULIC MYROBOLAN)**	Harituki	Combretaceae
157.	**Terminalia elliptica Willd. (ASAN, SAJ, INDIAN LAUREL, SADAR)**	Asan, Saj	Combretaceae
158.	**Tiliacora racemosa Colebr. (SILVER LIME)**	Telilata	Menispermaceae
159.	**Trewia nudiflora L. (FALSE WHITE TEAK)**	Pitali	Euphorbiaceae
160.	**Tylophora asthmatica (EMETIC SWALLOW-WORT)**	Antamul	Araceae
161.	**Vanda roxburghii R. Br. (VANDA ORCHID)**	Banda, Alokelata	Orchidaceae
162.	**Viscum articulatum Burm.f. (LEAFLESS OR JOINTED MISSTLETOE)**	Mandala	Loranthaceae
163.	**Vitis pedata (Lam.) Wall. ex Wight (SORREL VINE)**	Goalelata	Vitaceae
164.	**Vitis trifoliate (L.) Morales (POSSUM-GRAPE)**	Amal lata, Bundal	Vitaceae
165.	**Wendlandia heynii (Roxb.) DC. (TILAK I)**	Minri, Tilki	Rubiaceae
166.	**Woodfordia fruticosa (L.) Kurz. (FIRE FLAME BUSH)**	Dhatriphul, Dhai	Lythraceae

Sr. No.	Scientific Name / (English Name)	Common Name	Family
167.	**Zanthoxylum armatum DC. (WINGED PRICKLY ASH)**	Tambul, Gaira	Rutaceae
168.	**Ziziphus jujuba Mill. (INDIAN DATE, KOREAN DATE, CHINISE DATE, JUJUBE, RED DATE.)**	Kul	Rhamnaceae
169.	**Ziziphus oenoplia (L.) Mill. (WILD JUJUBE, JACKAL JUJUBE)**	Kan Kul	Rhamnaceae

Table 8.d: Types of plants under various stress in the Biosphere reserve at Similipal, Odisha, India

Sr. No.	Forest tree types	Species
1	Deciduous tree	*Careya arborea, Shorea robusta, Terminalia alata, Albizzia lebbeck, Terminalia bellirica, T. chebula, Phyllanthus emblica, Cassia fistula, Dalbergia sissoo, Bombax ceiba, Madhuca indica.*
2	Evergreen	*Diospyro embryopteris, Mangifera indica*
3	Canopy tolerance	*Diospyro embryopteris*
4	Fire tolerance	*Diospyro embryopteris*
5	Moderate size tree	*Careya arborea, Phyllanthus emblica, Cassia fistula*
6	Light demander	*Careya arborea, Shorea robusta, Terminalia alata, Albizzia lebbeck, Terminalia bellirica, Phyllanthus emblica, Cassia fistula and Dalbergia sissoo*
7	Drought resistance	*Careya arborea, Terminalia bellirica, Phyllanthus emblica*
8	Fire resistant	*Careya arborea, Terminalia bellirica, T. arjuna, Diospyros embryopteris*
9	Coppice	*Eucalyptus sp.*
10	No coppice	*Acacia auriculoformis*
11	Big tree	*Shorea robusta, Michelia champaca, Eucalyptus sp.*
12	Robust Tree	*Madhuca indica, Mangifera indica, Shorea robusta*

Table 8.e: Species diversity of SBR, Odisha, India

Species	Species Diversity	Concentration of dominance
Tree	3.12±0.22	0.18±0.004
Shrub	1.76±0.16	0.38±0.003
Herb	2.15±0.18	0.30±0.027

N.B.: Standard ecological method used for the calculation of plant diversity.

8.5 Photo Plates:

Figure 8.a: Similipal Tiger and Biosphere Reserve

Figure 8.b: Gurguria in Similipal

Figure 8.c: Centipede in forest

Figure 8.d: Orchid in the wild

Figure 8.e: Peacock in Wild

Figure 8.f: White-rumped Shama (Copsychus malabaricus)

Figure 8.g: Indigenous paddy field near Uski water falls (Tribal village)

Figure 8.h: Uski water falls

Figure 8.i: Barehipani waterfalls view point

Figure 8.j: Barehipani water falls from view point

Figure 8.k: Crested serpent eagle in the jungle

Figure 8.l: Emerald Dove on the way at jungle path

Figure 8.m: Spotted Deer in Sal forest

Figure 8.n: Heritage sacred place in SBR

Figure 8.o: Entrance of BR towards uski waterfalls

8.6 Conclusions:

The present study showed 200 plant species found in the Similipal Biosphere reserve as per our study in which 169 are medicinal. Exotic alien species like *Parthenium, Mikania, Mimosa, Eupatorium* and *Lantana* are discontinuously found inside the forest that needs attention which may cause loss of establishment of indigenous species. Here, abnormal activities like huge collection of fuel and leafy materials form forest and degraded land is going on which degrading the ecosystem continuously. The illegal felling and unwanted forest fire loss the forest at a higher rate which ultimately increasing eco-degradation process. This is supported by Dash and Behera, 2012. They found that the rich resource full Similipal Biosphere Reserve (SBR) is under serious threat. They also argued both the Govt. policies and local village level institutions have failed in a large way to conserve biodiversity as well as promote local livelihoods. To postpone the process need local management that might be made or demarcated using scientific means. This includes study on flow of biomass, study on soil loss, forest fire and rate of loss of local flora as well as fauna i.e. insects, butterflies and birds which are main agents for dispersal of propagules even act as pollinating agents. Government departments should take care to make it pristine rather than degraded in near future.

8.7 Acknowledgements:

Authors are grateful to the local people who helped us during field study. Scholars of various Institutes are acknowledged who accompanied us during field at SBR. We are also thankful to the Deputy Librarian of Vidyasagar University, Midnapore for helping us to study at Library particularly in Journal and periodicals sections. Thanks are also to the specialist in field from Odisha their help to consult on the degree of problems raised in field and in laboratory. Last but not least thank goes to local guide, forester who helped us in various ways to make the research complete in all aspect. Principal/OIC of Darjeeling Govt. College, Darjeeling and Lalgarh Govt. College, Lalgarh, W.B. are well acknowledged.

8.8 Bibliography:

1. Das, D. 2016. Ecological Studies on Jhitka Forest under Medinipur Forest Division, *IJSART*, 2 (12): 296-302.
2. Das, D. 2017a. Kansai Basin Flora at Lalgarh of Binpur-I Community Development Block in Jhargram Sub-Divison of Paschim Medinipur District in West Bengal, India, *IJSART*, 3(2): 1-11.
3. Das, D. 2017b. Flora of Kansai basin at Lalgarh of Paschim Medinipur District in West Bengal with special reference to Eco-degradation in India, *IOSR-JPBS*, 12(1): 28-51.
4. Das, D. 2016. Eco-tourism and Eco-degradation in Darjeeling Himalaya, West Bengal, Abstract and full Length Paper in a seminar-Variation and prospects of Eco-Tourism at Darjeeling and Dooars, 20th December, 2016, funded by Higher Education Department, Govt. Of West Bengal, Gorubathan Govt. College, Darjeeling.
5. Das, Debabrata et al. 2017. Presentation of Bio-fertilizer on VAMF: Spores isolated from Jhitka Forest in a Forest Fair (Banabandhab Mela at Lalgarh) on 28/01/2017 and 29/01/2017 at Lalgarh Ramkrishna Vidyalaya, Paschim Medinipur, West Bengal, India to Celebrate District Level Ban-bandhab Utsab-2017, Forest Deptt. Memo: reg., Memo No. 257 dated 16/01/2017- raising of Awareness towards Biodiversity Conservation. Theme: Save Green See Dream.
6. Das, D. 2017. Present day scenario of forest ecosystem in Lalgarh for community development in Paschim Medinipur District of West Bengal, National Conference on Non-linear Dynamics and Its Applications, Organised by Physics Deptt., Durgapur Govt. College, West Bengal, India, Full Length Paper, pp.12, 7-9th February, 2017.
7. Das, D. 2017. Eco-restoration: A General Discussion, Lecture cum workshop at Binod Smriti Agri Horticultural Farm, Panskura, 15-18th April, 2017, Lecture delivered on 16th April, 2017.
8. Das, D and Ghosh, P. 2017. Some Important Medicinal plants used widely in Southwest Bengal, India, *IJESI*, **6**(6): 28-50.
9. Das, D and Ghosh, P. 2017. Some medicinal plants of southwest Bengal used for instant remedy of ailments, *Indian J. Applied & Pure Bio*., **32**(2): 239-244.
10. Das, D; Mondal, S; Acharya, K and Acharya, S. 2017d. Diverse use of some eatable medicinal plants, fruits and flowers of Southwest Bengal with special reference to market demand, *IJIRD*, 6th year, 2(Additional): 44-47.
11. Das, D. 2018. Study of Purnapani Forest Vegetation at Lalgarh of Jhargram District, *IJSART*, **4**(8): 476-482.
12. Das, Debabrata. 2018. *Chromolaena odorata* (*Eupatorium odoratum*) –An exotic weed used in Lalgarh, Jhargram, West Bengal for fuel wood purpose, IJSART, **4**(11): 924-930.
13. Dash, M and Behra, B. 2012. Management of Similipal Biosphere Reserve Forest, *Advancers in Forestry Letter* (AFL), 1(1): 1-15.

14. Ghosh, P. 2014. Vesicular arbuscular mycorrhizal (VAM) status of some important Medicinal Plants from forest of Joypore, Bankura, West Bengal, *IJIRD*, 1:52-57
15. Ghosh, P and Das, D. 2014. Some medicinal plants of Joypore Forest Range of Bankura, West Bengal, India, *Environment & Ecology*, 32 (2): 465-470.
16. Ghosh, P and Verma, N. K. 2015. Vesicular arbuscular mycorrhizal (VAM) status of some medicinal plants of Gar-Panchakot hills in Purulia, West Bengal, India, *Int. J. Pure. App. Biosci.*, 3 (6): 137-149.
17. Ghosh, P. 2017. Vesicular-arbuscular mycorrhizal studies of selected medicinal plants of Southwest Bengal and its impact on yield, Ph. D. Thesis submitted to Vidyasagar University, Midnapore, West Bengal, India (Not yet been Awarded).
18. Ghosh, P and Verma, N. K. 2016. Effect of three AM fungal inocula on widely distributed medicinally important Periwinkle in red lateritic soil of Southwest Bengal, India, *International Journal of Integrated Research and Development*, 5th Year, Dec, II: 21-26, Jour.: Society for Journal of Integrated Research and Development of Nadia, West Bengal.
19. Ghosh, P and Das, D. 2017. VAMF spore diversity of Jhitka Forest floor under proposed Jhargram District in West Bengal, India, *IJSART*, 3(2): 227-232.
20. Ghosh, P. 2017. Mycorrhizal Biofertilizer, Lecture cum workshop at Binod Smriti Agri Horticultural Farm, Panskura, 15-18th April, 2017, Lecture delivered on 16th April, 2017.
21. Mishra, B.K. 2010. Conservation and management effectiveness of Similipal Biosphere reserve, Orissa, India, *The Indian Forester*, 136(10): 1310-1320.
22. Rout, S.D. 2008. Anthropogenic threats and biodiversity conservation in Similipal Biosphere Reserve, Orissa, India, *Tiger Paper*, 35(3): 22-26.
23. Pramanik, R; Bhakat, N; Kundu, S and Das, D. 2018. Preliminary study on forest macro-fungi at Purnapani forest of Jhargrm in West Bengal, *International Journal of Life Sciences Research*, **6**(3): 318-323.

ISBN: 978-93-90847-17-4

9. Climate Change-Global Warming-Indian Scenario

Dr. Rajabhuvaneswari Ariyamuthu

Sri Sairam Institute of Technology,
West Tambaram, Chennai.

9.1 Introduction:

Climate change caused by human-caused greenhouse gas emissions is having and will continue to have a substantial influence on people and the environment for years to come. The increase in average global temperatures caused by increased greenhouse gases in the atmosphere is one component of climate change. Sea level rise, changes in precipitation and humidity patterns, increased extreme weather events, and greater climate variability are all effects of rising global temperatures on the Earth. All of these changes are referred to as "climate change."

Climate change is already influencing the future and putting the planet in hazardous situations. Cities are becoming increasingly accustomed to more regular and severe extreme weather occurrences, such as superstorms and heatwaves. More deadly wildfires are already raging, and people are fleeing flooded houses or migrating to avoid rising sea levels. As international governments and corporations work to reduce global greenhouse gas emissions, policies and economies are changing as well. The way energy is generated is also changing, from fossil fuels to carbon-free renewables like solar and wind power. As potential answers, new technologies are being developed, ranging from next-generation nuclear energy to devices that trap carbon from the atmosphere.

Climate is generally roughly defined as the average weather in a certain location, taking into account factors such as temperature, precipitation, humidity, and windiness. Climate, according to a more specific definition, is the average condition and variability of these features throughout time. Both definitions accept that the weather is always changing due to atmospheric instability. And, just as the weather fluctuates from day to day, so does climate, from daily day-night cycles to geologic periods spanning hundreds of millions of years. Climate variation is, in a sense, a redundant expression in—climate is continually changing. There are no two years that are exactly alike, nor are any two decades, centuries, or millennia.

Other aspects of Earth, such as oceans, glaciers and sea ice, land surfaces, and flora, influence and are linked to the atmosphere. They form an interconnected Earth system, in which all components interact and impact one another in a variety of ways.

Climate influences the distribution of vegetation on Earth's surface, but vegetation influences climate by reflecting radiant energy into the atmosphere, transferring water from soil to the atmosphere, and influencing horizontal air movement across the land surface.

Earth scientists and atmospheric scientists are still working to fully comprehend the complex feedbacks and interactions that exist among the Earth system's numerous components. The emergence of an interdisciplinary field known as Earth system science is assisting this endeavor.

Given the huge importance of climate change for people and the environment, university students must have a thorough understanding of climate change subjects, such as causes and effects, mitigation and adaptation, tool and technology use, and effective communication. Because it covers learning issues relating to the physical sciences, biological sciences, environmental science, social science, agriculture, forestry, health and medicine, communications, and public services, understanding climate change is relevant for students across many disciplines. Climate is a statistical description of important quantities in terms of their mean and variability over timescales ranging from months to thousands or millions of years. The classical period is 30 years, and surface variables such as temperature, precipitation, and wind are most commonly used. The status of the climatic system, including a statistical description, is referred to as climate in a broader meaning.

9.2 What Is Climate Change and Why Does It Matter?

Climate change refers to the periodic alteration of Earth's climate caused by changes in the atmosphere, as well as interactions between the atmosphere and several other geological, chemical, biological, and geographical variables within the Earth's system.

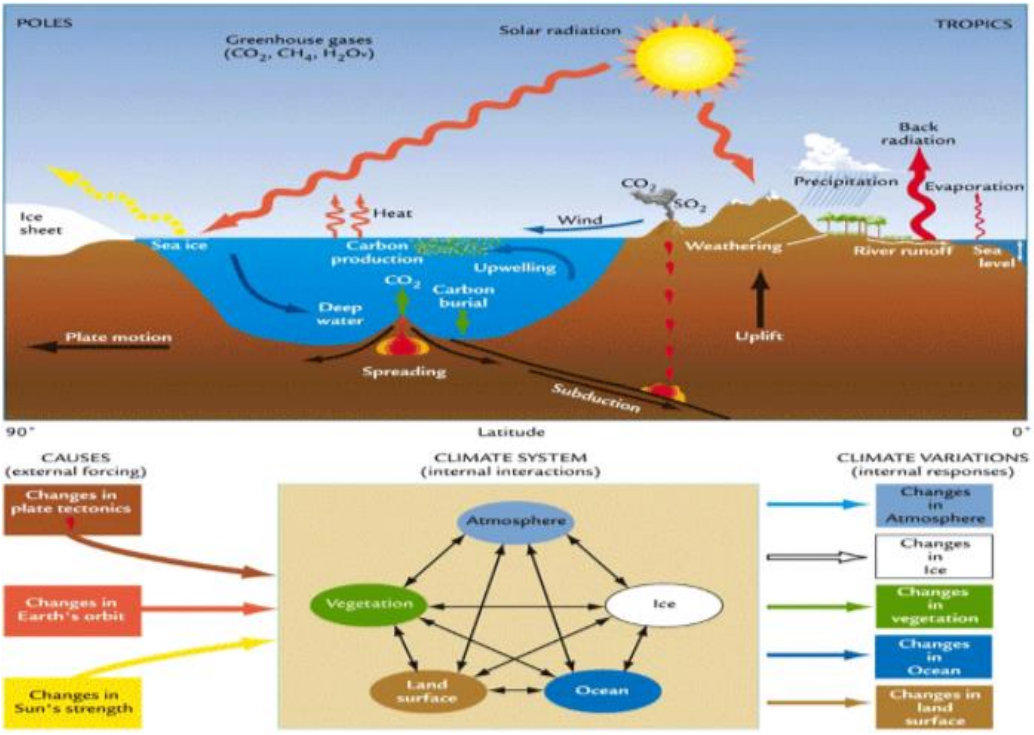


Figure 9.a: Greenhouse Gases and Climate Change

Climate change is defined as the change in the climate of the Earth as a whole or specific climatic pattern in different parts of the world as a result of many reasons. There are various components to climate change analysis. There are worldwide investigations that look at the process of climate change over millions of years, as well as more focused research and monitoring that looks at climatic differences within the last several decades. The differences in ordinary weather parameters and the frequency of extreme weather occurrences are the most important markers of climate change.

Climate change on Earth is caused by multiple basic elements, the most important of which are dynamic processes on the planet, exterior forces such as increases or decreases in solar radiation, and lastly human activities.

Climate change is currently understood as the most recent alteration in the planet's climate the global warming process. The weather is the state of the atmosphere on a given day. The climate is the typical weather condition and is predictable, whereas the weather is a chaotic and dynamic system. The average temperature, precipitation, number of sunny days, pressure, wind speed, air humidity, and other factors all contribute to the climate. Changes in the relief and position of the continents on the planet; changes in the quantity of sunshine; variations in Earth's orbit; changes in the structure of the atmosphere; and the concentration of greenhouse gases are the main variables that influence climate change.

Climate change has become a pressing issue in recent years, as the planet's average temperature has been steadily rising, resulting in a slew of severe consequences. The student who is researching climate change should understand the problem's significance, the variables that influence it, and broaden his knowledge of the subject in general. To analyze a case involving climate change, a student must read extensively and gather sufficient data for the research.

9.2.1 Changes in the Global Climate:

The worldwide climate has shifted dramatically in recent years. The observed change is due to the earth's heating, or an increase in the planet's temperature. Many hypotheses have been made about the causes of earth's temperature variations, with some blaming human beings as the primary source of temperature variation on the planet. Other sources, on the other hand, contradict the claim that humans are the primary cause of global climate change by debunking the arguments provided by those who argue that humans are the primary cause of global climate change. For example, the increase in greenhouse gases and water vapor in the atmosphere are the primary causes of global climate change.

In addition, the usage of aerosols and the domestication of animals have been accused of causing climate change on the planet. Those who disagree with the above-mentioned assumptions argue that a greenhouse gas like carbon dioxide is not a pollutant because it is used by plants for growth. Furthermore, opponents have debunked the notion that climate change is a worldwide phenomenon.

They point out that climate change is regional, and it has a history of rapidly changing, which explains why it will continue to change in the future. Because of the human actions

mentioned, it can be deduced that the investigated process is man-made based on the above-given factors. As a result, this essay investigates why global climate change is caused by humans. Human-caused global climate change is a result of their activity.

This is primarily accomplished through two major activities: factory manufacturing and agricultural operations. Notably, the greenhouse impact is boosted by the two pointed production methods. Because greenhouse gases like carbon dioxide, water vapor, and other gases in the atmosphere are not impermeable to the sun, this has a significant impact on the planet.

They allow the sun to penetrate the atmosphere, absorbing heat from the planet that would otherwise be lost to space, if greenhouse gases were not emitted in large quantities into the earth's atmosphere, there would be no harmful climatic impacts. Alternatively, it should be recognized that, in limited quantities, greenhouse gases in the earth's atmosphere are preferable to a complete lack of them; thus, this could result in a reduction in the atmosphere, rendering the planet uninhabitable.

Thus, transportation and agricultural activities are primarily to blame for the increase of such gases in the environment. Humans continue to advance their modes of transportation from time to time, and pollutant emissions have filled the gaseous envelope that surrounds our globe, resulting in the liberation of road and air transport.

Carbon is released into the atmosphere through these systems. Nitrous oxide, methane, hydrofluorocarbons, sulfur hexafluoride, and perfluorocarbons are among the other greenhouse gases that contribute to global climate change.

It's important to remember that coal-fired power plants are the primary source of these greenhouse gases. Land usage and livestock are two further factors that contribute to global warming. These are human activities that contribute to climate change in several ways. The combustion of fossil fuels, which is a human activity, was the source of the increase in dangerous CO_2 emissions.

Furthermore, due to the shift in land use, these greenhouse gases increased in the atmosphere. Human-caused land-use changes are dominated by deforestation. Because the quantity of carbon dioxide that trees in deforested areas could have absorbed is reduced, this adds to global warming. As a result, the number of greenhouse gases produced in such places doubles. These changes in land use are largely driven by humans, and so make a considerable contribution to global climate change.

It was also interesting in the reasons for climatic changes around the world, and he recognized that the process of human domestication contributes significantly to global warming. The rise in the number of cattle that humans have tamed over time has an impact on this. According to research data, animals occupy over 71 percent of agricultural land, human livestock activities lead to the release of 9 percent carbon dioxide, 37 percent methane, and 63 percent nitrous oxide into the atmosphere as a result of fertilizer use. The usage of aerosols is being blamed for yet another man-made cause of global climate change.

The usage of aerosols is being blamed for yet another man-made cause of global climate change. Because it necessitates the burning of biomass, which begins with deforestation, their usage by humans results in the suspension of droplets or particles in the atmosphere, resulting in a cooling impact.

Aerosols have an impact on industrial pollutants, particularly when soot, ammonium, airborne sulfates, and nitrates are produced. Finally, dust produced by desertification adds to global climate change. However, it is also vital to investigate the arguments made by opponents of global warming caused by people. In contrast, some people believe that carbon dioxide is not a factor in global climate change. This stems from the fact that carbon plays an important function in the atmosphere and has existed throughout human history. Because this chemical element has existed in both large and small concentrations, it supports the idea that it has a minor impact on the environment because plants use it as well.

They believe that change takes a long period and that the fact that humans are blamed for speeding up the process is untrue. Climate change, in their opinion, is a regional issue rather than a global one. This stems from the fact that regional climate changes have been documented to be deteriorating in the past, and this is a trend that will continue in the future.

Human activities have been blamed for the majority of the observed events. Desertification, livestock husbandry, industry, transportation, and the usage of aerosols are all examples of man-made contributions to changes in global climatic conditions. However, not everyone agreed that global climate change is completely a result of human activity. As a result, opponents argue that climatic changes have existed since the dawn of time and that they usually occur regionally rather than globally. This is because the gas has been present on Earth since ancient times, and plants utilize it for growth, refuting the argument that the gas is a substantial contributor to the greenhouse effect and global warming.

These are simply projections, but if nothing is done to alter the tragic trend of climate change, they could happen eventually. Global warming, for example, will boost global temperatures to the point where places currently covered in ice will remain buried in pools of water. This would not only limit people's mobility, but it will also spread several waterborne diseases over the world. Furthermore, changes in the patterns of warm and cold ocean currents may cause catastrophic meteorological events.

Climate Change and Global Warming:

The meaning of 'climate change' is fairly straightforward—a clear, sustained change in the components of climate, such as temperature, precipitation, atmospheric pressure, or winds. Such changes must constitute a clear trend, and be clearly distinguished from the small random variation in these parameters that takes place all the time. Climate may change in a single region or across the whole planet. Throughout the earth's history, climates have changed. The causes are various. Change can be brought about by a variety of factors. These include natural external factors, such as changes in solar emission or slow changes in the earth's orbit; or natural internal processes of the climate or earth system such as volcanic activity; or, as has occurred recently, human-induced (anthropogenic) factors.

Global warming refers to an increase in the average temperature at the surface of the earth or the lower part of the atmosphere. Most climatologists consider that the global warming that we are now experiencing is mainly the result of human actions changing the composition of the atmosphere. However, global warming and cooling have occurred naturally throughout the history of the earth, as a result of natural climate variability. Such changes in the past were usually much slower than the rate of warming that has occurred in the last few decades. The increase in global temperatures measured over recent decades, if it continues, has the potential to seriously disrupt many of the environmental, economic, and urban structures upon which human society depends. Whilst it is possible that some of this warming may have a natural cause, there is mounting evidence that human activity is responsible for most of the measured warming.

The principal contributor to the present phase of global warming is considered to be the enhancement of the natural greenhouse effect. Global surface warming is just one consequence of the changes to the climate being caused by human activity. The various components of the climate and earth system are inextricably linked through complex feedback mechanisms, and a change in one component such as temperature will induce changes and adjustments in other components. Other changes that have either already been observed or are projected to occur as a result of human activity include sea-level rise; changes in rainfall patterns; increases in extreme weather events; decreases in ice mass of glaciers, ice sheets, and sea ice; ocean warming and acidification; changes in ocean circulation; and drying of the land.

Climate Change Influencing Factors: Natural factors have a long-term impact on the climate, ranging from hundreds to millions of years.

Continental Drift: developed millions of years ago when plate dislocation caused the landmass to drift apart. Changes in the physical features and position of the landmass, as well as changes in the position of water bodies, such as changes in the flow of ocean currents and winds, have an impact on climate change.

Volcanic eruptions release gases and dust particles that remain for a long time, causing a partial blockage of the Sun's rays, causing the weather to cool and weather patterns to change.

Changes in Earth's Orbit: A small change in the Earth's orbit affects the seasonal distribution of sunlight reaching the earth's surface around the world. Variations in Earth's eccentricity, fluctuations in the tilt angle of the Earth's axis of rotation, and precession of the Earth's axis are the three forms of orbital variations. Milankovitch cycles, which have a large impact on climate and are well-known for their connection to glacial and interglacial eras, can result from the combination of these factors.

Anthropogenic Factors: It is mostly an increase in global surface temperature caused by humans.

Greenhouse Gases (GHG) absorb heat energy from the sun, rising global temperatures. GHGs absorb most of the infrared released by the Earth's surface rather than solar radiation.

The greenhouse effect, which is created by the interaction of incoming solar radiation with the Earth's atmosphere, is the starting point for global warming.

Aerosols: in the atmosphere can deflect and absorb solar and infrared light. Solar radiation scatters and cools the globe, whereas aerosols absorb sunlight and raise the temperature of the air instead of allowing it to be absorbed by the Earth's surface. Aerosols have a direct impact on climate change through solar radiation absorption and reflection. It can have an indirect effect by changing the formation and properties of clouds. It can even be transported thousands of kilometers through the atmosphere's winds and circulations.

Land-use pattern shift: Crops, land grazing, or industrial or commercial use have mostly replaced forests and land coverings. The amount of moisture evaporated into the atmosphere and the amount of solar energy absorbed increase as forest cover is cleared.

The lower the reflective power the more sunlight is absorbed by the planet, and temperatures rise. If the albedo is higher and the Earth is more reflective, more radiation is reflected into space, causing the planet to cool.

Global Temperature Rise: Since the late 1800s, the planet's average surface temperature has risen by around 1.62 degrees Fahrenheit, owing mostly to rising carbon dioxide and other human-made emissions into the atmosphere. The majority of the warming took transpired in the last 35 years, with the five warmest years on record occurring since 2010.

Ocean Warming: The oceans have absorbed much of the extra heat, with temperatures rising by more than 0.4 degrees Fahrenheit in the top 700 meters, since 1969. The mass of the Greenland and Antarctic ice sheets has shrunk. Greenland lost an average of 286 billion tonnes of ice per year between 1993 and 2016, according to NASA's Gravity Recovery and Climate Experiment, while Antarctica lost roughly 127 billion tonnes of ice per year during the same period. In the last decade, the pace of ice mass loss in Antarctica has tripled.

Glacier retreat is occurring in practically every part of the planet, including the Alps, Himalayas, Andes, Rockies, Alaska, and Africa. Satellite studies show that the amount of spring snow cover in the Northern Hemisphere has reduced during the last five decades, and the snow is melting earlier.

Sea Level Rise: Over the previous century, the global sea level has risen by around 8 inches. However, in the recent two decades, the rate has roughly doubled that of the previous century, and it is increasing slightly each year.

Arctic Sea Ice is melting: The extent and thickness of Arctic Sea ice have been dramatically decreasing over the last several decades.

Extreme Events: Since 1950, the number of record high-temperature events has increased in the United States, while the number of record low-temperature events has decreased. In addition, the United States has seen an increase in the number of severe rainfall events.

Ocean Acidification: The acidity of surface ocean waters has grown by around 30% since the beginning of the Industrial Revolution. This rise is due to humans putting more carbon dioxide into the atmosphere, which is then absorbed by the oceans in greater amounts. The amount of carbon dioxide absorbed by the ocean's upper layer is increasing at a rate of roughly 2 billion tonnes per year.

9.3 Climate Change's Potential Impacts in India:

Extreme Heat:

India's climate has already begun to overheat. Unusual and unexpected hot weather spells are predicted to occur more frequently and across a broader area. Under a 4°C rise, the west coast and southern India are expected to change to new, high-temperature climatic regimes, posing serious agricultural challenges.

Changing Rainfall Patterns:

Since the 1950s, there has been a decrease in monsoon rainfall. The summer monsoon in India will become exceedingly unpredictable if global average temperatures climb by 2°C. An extraordinarily rainy monsoon, which now has a chance of occurring only once every 100 years, is expected to occur every 10 years by the end of the century if global temperatures rise by 4°C. Dry years will be dryer, and wet years will be wetter.

Droughts:

Evidence suggests that portions of South Asia have been drier, with an increase in the number of droughts, since the 1970s. Droughts have significant ramifications. Droughts afflicted more than half of India's crop area in 1987 and 2002-2003, resulting in a massive drop in crop production. Droughts are projected to become increasingly common in several parts of India, particularly in Jharkhand, Orissa, and Chhattisgarh. Crop yields are anticipated to plummet by the 2040s as a result of excessive heat.

Groundwater:

Even without climate change, India's groundwater resources are overexploited to the tune of 15%. Water tables are predicted to continue to fall as a result of increased demand for water from a growing population, more affluent lifestyles, and the services and manufacturing sectors.

Glacier Melt:

Over the last century, most Himalayan glaciers have retreated. Melting glaciers and the loss of snow cover over the Himalayas are predicted to endanger the stability and reliability of northern India's largely glacier-fed rivers if global temperatures rise by 2.5 degrees Celsius. Changes in the Indus, Ganges, and Brahmaputra rivers' flows might have a substantial impact on irrigation, altering the amount of food that can be produced in their basins as well as millions of people's lives.

Sea level rise:

Because India is so close to the equator, sea level rises on the subcontinent would be significantly higher than at higher latitudes. Because the cholera bacterium survives longer in saline water, sea-level rise and storm surges would cause saltwater intrusion in coastal areas, affecting agriculture, degrading groundwater quality, contaminating drinking water, and possibly causing an increase in diarrhea cases and cholera outbreaks. Sea-level rise, tropical cyclones, and riverine floods are all threats to Kolkata and Mumbai, which are both heavily populated cities.

Figure 9.b: Glacier Melt and Sea-Level Rise

9.4 Risks of Climate Crumbliness in India:

Independent research commissioned by members of the G7, "A New Climate for Peace: Taking Action on Climate and Fragility Hazards," lists seven compound climate-fragility risks that pose substantial dangers to the security of states and communities in the decades ahead.

Local resource competition: As the demand for natural resources grows, competition can lead to instability and even violence if appropriate dispute resolution is not in place.

Insecurity of livelihood and migration: Climate change would exacerbate the human insecurity of people who rely on natural resources for a living, potentially forcing them to migrate or turn to unlawful sources of revenue.

Extreme weather and disasters: Extreme weather and disasters worsen fragility concerns and can raise people's vulnerability and grievances, particularly in conflict-affected areas.

Food prices and availability are anticipated to be volatile as a result of climate change, which will likely affect food production in many places, raising prices and market volatility while also increasing the danger of riots, rioting, and civil unrest.

Transboundary water management: Transboundary waters are frequently a cause of contention; as demand rises and climate change affects water supply and quality, competition over water usage will likely put further strain on existing governance systems.

Sea-level rise and coastal degradation: Even before low-lying communities are flooded, rising sea levels will undermine their viability, resulting in social disruption, displacement, and migration, as well as increased tensions over maritime boundaries and ocean resources.

Climate policies' unintended consequences: As climate adaptation and mitigation strategies become more widely implemented, the likelihood of unintended negative consequences particularly in unstable contexts will rise.

The need for adaptation: The major impacts and threats of global warming are widespread. Increasing ocean temperatures cause thermal expansion of the oceans and in combination with meltwater from land-based ice, this is causing sea-level rise. Sea levels rose during the 20th century by 0.17 meters. By 2100, the sea level is expected to rise between 0.18 and 0.59 meters.

There are uncertainties in this estimate mostly due to uncertainty about how much water will be lost from ice sheets, for example, Greenland is showing a rising loss of mass in recent years. Increased melting of sea ice and freshwater influx from melting glaciers and ice sheets also has the potential to influence global patterns of ocean circulation.

As a result of global warming, the type, frequency, and intensity of extreme events, such as tropical cyclones, floods, droughts, and heavy precipitation events, are expected to rise even with relatively small average temperature increases.

Adaptation is a process through which societies make themselves better able to cope with an uncertain future. Adapting to climate change entails taking the right measures to reduce the negative effects of climate change by making the appropriate adjustments and changes. There are many options and opportunities to adapt.

These range from technological options such as increased sea defenses or flood-proof houses on stilts, to behavior change at the individual level, such as reducing water use in times of drought and using insecticide-sprayed mosquito nets. Other strategies include early warning systems for extreme events, better water management, and improved risk management, various insurance options, and biodiversity conservation.

Because of the speed at which change is happening due to global temperature rise, it is urgent that the vulnerability of developing countries to climate change is reduced and their capacity to adapt is increased and national adaptation plans are implemented.

Future vulnerability depends not only on climate change but also on the type of development path that is pursued. Thus, adaptation should be implemented in the context of national and global sustainable development efforts. The international community is identifying resources, tools, and approaches to support this effort.

9.5 India's Climate Change Response:

The National Action Plan on Climate Change (NAPCC) outlines current and future climate mitigation and adaptation policies and strategies. Solar Energy; Enhanced Energy Efficiency; Sustainable Habitat; Water; Sustaining the Himalayan Ecosystem; Green India; Sustainable Agriculture; and Strategic Knowledge for Climate Change are the eight-core "national missions" identified in the Action Plan, which will continue until 2017. The majority of these missions have significant modification requirements.

The National Renewable Energy Fund (NCEF) was established by the Indian government in 2010 to finance and promote clean energy programs as well as to fund clean energy research in the country. The fund's corpus is built by levying a cess of INR 50 for every tone of coal produced locally or imported.

India has agreed to three commitments as part of the Paris Agreement. By 2030, India's greenhouse gas emission intensity as a percentage of GDP would be decreased by 33-35 percent compared to 2005 levels. In addition, non-fossil fuel sources would account for 40% of India's power capacity.

The International Solar Alliance (ISA) was launched by India and France at the United Nations Climate Change Conference in Paris on November 30, 2015, in the presence of Mr. Ban Ki Moon, former UN Secretary-General.

Emission Standards for the Bharat Stage (BS): Vehicle emissions are one of the leading causes of air pollution, prompting the government to implement the BS 2000 (Bharat Stage 1) vehicle emission standards in April 2000, followed by BS-II in 2005. In 2010, BS-III was rolled out across the country.

However, in 2016, the government opted to follow worldwide best practices and bypass BS V completely, opting for BS-VI instead.

9.6 Concerns in India Regarding Climate Changes:

India has questioned the UN's haste to declare climate change an international security concern, potentially granting the Security Council the authority to act on it, and has highlighted the approach's flaws. According to India, a "simple Council resolution" to take over climate change enforcement would jeopardize the Paris Agreement and multilateral attempts to develop solutions.

Climate change is a global security hazard in the twenty-first century. To reduce future threats to the planet we share and the peace we seek, we must act now.

9.6.1 How Can India Deal with The Repercussions of Climate Change?

The way to go is to take an 'adaptation' strategy. The interconnection of rivers and the usage of GM crops must be prioritized in this regard. Globally, climate action has been mitigation-centric,' with the majority of programs geared at reducing future global warming. 'Mitigation' is more necessary in wealthy countries, but for developing countries like India, the focus should be on 'adaptation,' or methods to deal with the unavoidable effects of climate change that have already occurred, such as severe storms, floods, and droughts.

Adaptation' is akin to shielding yourself from an impending punch. India has likewise been focused on mitigation; now is the time to shift the focus to "adaptation." And for adaption, two essential measures have to be taken,

The first is to give a major boost to a 150-year-old concept: river interconnection (ILRs). With floods and droughts likely to strike different sections of the country at the same time, there is no choice but to implement ILR as soon as possible. The Himalayan and Peninsular, with 14 and 16 links, respectively, are two parts of it.

The plan is to construct a dam on one river so that the water level rises at the canal's head, allowing water to flow to the next river by gravity. India now has 5,100 major dams with walls at least 15 meters high; ILR will require an additional 3,000. The project will also include the construction of 15,000 kilometers of new canals. I realized, ILR will bring 35 million hectares of new land under agriculture, more than twice the area of Andhra Pradesh, as well as 34,000 MW of additional hydroelectricity.

Genetically modified crops are the other adaptive measure. Climate-smart agriculture relies heavily on GM technologies. Drought-resistant crops and crops that produce more on the same piece of land would be required to reduce climate-damaging 'land usage.' India has been a vocal opponent of genetically modified foods. GM technology, on the other hand, has been in use for more than two decades, and millions of people have eaten GM foods for years.

9.6.2 Policy Analysis: The Need for a Comprehensive Plan:

Climate change mitigation is the most effective strategy to reduce the threat posed by these climate-fragility hazards. However, because climate change is already occurring, we must act now to control and mitigate these dangers. We need to address significant policy and institutional gaps in three areas to break down sectoral barriers that stymie attempts to address climate-fragility risks:

Climate change adaptation: programs assist governments in anticipating the negative effects of climate change and taking steps to prevent, mitigate, and respond to those effects.

Development and humanitarian assistance programs assist states and communities in strengthening their economic, governance, and social capacities, as well as improving their shock resistance.

By decreasing tensions and fostering an atmosphere conducive to long-term peace, peace-building and conflict prevention programs address the causes and impacts of fragility and conflict.

9.6.3 Climate Change in the Future:

Climate change has had a profound impact on the global economy and population health in a variety of ways.

Climate change, according to meteorologists, will have a considerable impact in the next decades, particularly on the sustainability of water supplies. For example, because of the consequences of global warming, more than 1,100 counties in the United States are at risk of experiencing water shortages in the next thirty years. This implies disaster for a variety of industries that rely on water sustainability. The industrial sector, for example, is expected to be the hardest damaged. This is because practically all of their operations rely on water. The machinery that drives the manufacturing process must be kept cool so that it does not catch fire.

Furthermore, practically all of the items being manufactured are handled in liquid form, with water as the solvent. The agricultural industry, on the other hand, may come to a halt. Although irrigation has always been a viable option for raising crops, the anticipated water limitations may mean that the available water will be insufficient to support effective irrigation. As a result, agricultural enterprises may be forced to close since there will be nothing to process. In essence, such a situation could result in humanity's extinction. Water is such an essential component of life that no human can go three days without it.

It claims one of the world's largest densities of economic activity, as well as a big number of poor people who rely on the natural resource base for their survival, with a high reliance on rainfall. By 2020, India's water, air, soil, and forests are likely to be under the most strain anywhere on the planet. Water resources will be one of the most major ways that climate change will affect people's lives in India. While water is necessary for life, it is also capable of wreaking havoc in the form of disastrous floods and droughts. These shocks will only be exacerbated by a changing climate.

9.7 References:

1. hhttps://www.cambridge.org/
2. https://academic.oup.com/
3. https://www.reference.com/
4. https://www.theverge.com/
5. https://www.barrons.com/
6. https://www.economist.com/

ISBN: 978-93-90847-17-4

10. Indian Medicinal Plants- An Overview

Dipu Samanta

Department of Botany,
Dr. Kanailal Bhattacharyya College,
Howrah.

Samadrita Deb

Ex-postgraduate Student,
Department of Botany,
University of Calcutta.

Abstract:

Medicinal plants are the source of macro-nutrients, micro-nutrients, vitamins and useful phytochemicals. And these components are necessary for treating various health related problems. Actually, this type of plants is used as tonic, decoction, aqueous extract, raw materials, herbal products or as dry powder. A large number of populations depends on medicinal plants. Here we are discussing about some common but valuable medicinal plants and their uses.

Keywords: Diseases, Herbs, Medicinal Plants, Plant, Treatment.

10.1 Introduction:

Introduction: India is the origin of Ayurvedic and Unani system of medicine. Many plants are the basis of this type of medical systems. Every plant has more or less medicinal properties. There are so many plants in the world which people have been using for many ages as medicine for various purposes. Many of them grow around our house and very common to us such as Tulsi (*Ocimum sanctum*), ashwagandha (*Withania somnifera*), kulekhara (*Hygrophila auriculata*), ginger (*Zingiber officinale*), basok (Justicia adhatoda) and so on. People in rural areas are most dependent on medicinal plants for the treatment of several diseases. For primary healthcare, a large number of world populations use raw plant materials, processed plant materials and herbal products (According to WHO). People also believe that natural plant products are much more secure than the synthetic drugs (Srivastava, A.K, 2018).

10.2 Some Medicinal Plants of India and their uses:

a. Tulsi (*Ocimum Sanctum*): This herb belongs to the family Lamiaceae. Plant's extract has anti-microbial, anti-inflammatory, anti-tumour, antibacterial, anti-ulcerogenic, antistress, antihypertensive, antipyretic and antioxidant properties (Das & Vasudevan, 2006). Two flavonoids orientin and vicenin from leave of *Ocimum sanctum* show radioprotective effects (Lam et al, 2016).

b. Kalmegh (*Andrographis Paniculata*): Kalmegh, king of bitters is an annual herbaceous plant and it belongs to Acanthaceae family. The plant has antibacterial, anti-HIV, antispasmodic, anticarcinogenic, antidiabetic, antipyretic, hepatoprotective, nimatocidal and antioxidant activities (Niranjan et al,2010). It lowers the blood sugar by increasing the secretion of insulin and control blood pressure.

c. Brahmi (*Bacopa Monniera*): This plant is used as nerve tonic to improve memory and prevent stress and anxiety. It has neuro-psychopharmacological effects (Singh & Dhawan, 1997). It is used to treat Alzheimer's disease and attention deficit hyperactivity disorder (ADHD) by enhancing brain functions.

d. Thankuni/ Gotu Kola (*Centella Asiatica*): This herbaceous perennial flowering plant belongs to the family apiales. Phytochemical such as asiaticoside of this plant has wound healing power (Shukla et al, 1999). The herb is also used to treat diabetes mellitus, fever, diarrhoea, asthma, hepatitis and syphilis.

e. Kulekhara (*Hygrophila Auriculata*): This medicinal herb is used to increase blood hemoglobin and prevent anaemia. Leaf extract is useful for treatment of stomach pain, diarrhoea and dysentery. It is also used to treat diabetes.

f. Ghritkumari (*Aloe Vera*): It is good for skin and hair care. It has moisturizing potential. Aloe vera juice from the flesh of leaf lowers the blood sugar level and helps to cure digestive problems. It has healing (wound and burn) property, also anti-inflammatory and immunomodulators (Choi and Chung, 1999).

g. Basak (*Justicia Adhatoda*): Leaf extract of basak is quite effective in preventing various problems of lungs and regimen. Methanolic extract of the leaf shows anti-microbial property and anti-microbial agents may be useful for chemotherapy (Pa & Mathew, 2012).

h. Drumstick Plant (*Moringa Oleifera*): Prevent arthritis pain, liver problems and high blood pressure. Leave and drumstick are used as food and have high nutritional values. Several parts of the plant show antibacterial, anti-microbial, anti-inflammatory, antidiabetic, antifungal, antipyretic, antioxidant, hepatoprotective and cholesterol lowering activities (Anwar et al, 2007).

i. Laajvanti/ Mimosa (*Mimosa Pudica*): This herb is good for the treatment of diarrhoea, dysentery, vomiting and so on. Roots of the plant are used to treat asthma, fistula, leucoderma, jaundice and ulcer. Leave extract is good for treating conjunctivitis and hemorrhages. Root decoction is used to reduce toothache (Joseph et al, 2013).

j. Ashwagandha (*Withania Somnifera*): This medicinal plant belongs to the family solanaceae. It helps to reduce depression, stress, anxiety and improves memory and brain function. It can lower the blood sugar level, control diabetes and increase male fertility.

It can work against Parkinson's and Alzheimer's diseases, tardive dyskinesia and drug addiction (Kulkarni & Dhir, 2008).

k. Turmeric (*Curcuma Longa*): Turmeric powder is good for skin and liver. It is used to treat conjunctivitis, smallpox, chickenpox, wound, liver problems, urinary tract infection and so on (Dixit et al, 1988). Sometimes, turmeric powder is consumed with milk to boost immunity.

l. Ginger (*Zingiber Officinale*): This herb plays an effective role on cold, cough, nausea, vomiting, dizziness, digestion problem, menstrual pain, constipation and arthritis. It is a cholesterol lowering, antithrombotic and anti-inflammatory agent (Thomson et al, 2002).

m. Amlaki/ Amla (*Phyllanthus Emblica*): Amla is good for hair health. It provides strength to hair follicles, treat dandruff and enhances hair growth. Amla fruit is rich in vitamin-C. It purifies blood, improves liver, kidney and heart health and boost immune system. It helps to lose weight, improves eye sight, prevents bone and tooth decay.

n. Methi/ Fenugreek (*Trigonella Foenum-Graecum*): Aqueous extract of Fenugreek shows immunomodulatory effects (Hafeez et al, 2003). Drinking methi tea is useful for treatment of diabetes and weight loss. It is effective to prevent hair fall, hair thinning and dandruff.

o. Sarpagandha/ Indian Snakeroot (*Rauvolfia Serpentina*): The plant is highly beneficial to treat hypertension, epilepsy, fever, liver ailments, edema and so on. In India, it is applied to treat snakebites, high blood pressure and mental illness, pneumonia, asthma, fever, AIDS, spleen disease, skin diseases, rheumatism and veterinary diseases (Dey & De, 2011).

p. Haritaki/Myrobalan (*Terminalia Chebula*): Dry fruit powder of this plant is useful for treatment of indigestion, several cardio-problems, ulcer, acne, boost immunity and female fertility. It can help to lose weight, prevents cold and cough.

q. Ivy Gourd (*Coccinia Grandis*): It is used as vegetable and good source of iron, nutrient. People are used to treat constipation, cold, fever, epilepsy. Leave and stems are widely used for diabetes treatment.

r. Satamuli/ Shatavari (*Asparagus Racemosus*): Satamuli is used by ayurvedic practitioner to treat liver problems, nerve related disorder, inflammation, liver diseases and some infectious diseases (Goyal et al, 2003).

s. Mulethi (*Glycyrrhiza Glabra*): Daily use of licorice tea boost immunity. It cures cold and cough (especially dry cough), throat infection. Glabridin, active compound of mulethi is responsible to reduce pigmentation in the skin.

t. Bahera (*Terminalia Bellirica*): It is used to treat dysentery, respiratory tract infection, cold, cough and sore throat. It is also used as astringent and laxative.

10.3 Discussion:

Medicinal plants play an important role in rural areas for treatment of several diseases. Many people are dependent on herbal products because natural plant products are safe and

have less side effects than the synthetic drugs. And as a result, there is a great demand for herbal medicines or products. So, there is a need to conserve herbal or medicinal plants for future. In India, National Medicinal Plant Board (NMPB) works on the promotion of cultivation of medicinal plants under the Govt. scheme of National Mission of Medicinal Plants (2008-09) and National Ayush Mission (NAM). For sustainable conservation of medicinal plants, we should not collect too many threatened medicinal plants from the wild. on the body. Not only that, we should make people aware conservation and proper utilization of medicinal plants and also to do research on medicinal plants.

10.4 Conclusion:

Medicinal plants play important role in primary healthcare. But we need to know about the proper use of medicinal plants because overdose and wrong dosage of herbal products may lead to dangerous effects. On the other hand, many herbal trees are now on the verge of extinction. So, it is our duty to protect and conserve important medicinal plants.

10.5 References:

1. Srivastava, Akhileshwar kumar. (2018). Significance of medicinal plants in human life. 10.1016/B978-0-08-102071-5.00001-5.
2. Das, S.K & Vasudevan, D. M. (2006). “Tulsi: the Indian holy power plant,” Indian Journal of Natural Products and Resources, vol. 5, no. 4, pp. 279–283.
3. Kit Ying Lam, Anna Pick Kiong Ling, Rhun Yian Koh, Ying Pei Wong, Yee How Say, “A Review on Medicinal Properties of Orientin”, Advances in Pharmacological and Pharmaceutical Sciences, vol. 2016, Article ID 4104595, 9 pages, 2016. https://doi.org/10.1155/2016/4104595
4. Niranjan A, Tewari S, Lehri A. Biological activities of Kalmegh (Andrographis paniculata Nees) Indian J Nat Proc Resour. 2010; 1:125–35.
5. Singh HK, Dhawan BN. (1997): Neuropsychopharmacological effects of the Ayurvedic nootropic Bacopa Monniera Linn. (Brahmi). Indian J Pharmacol 29: 359–36
6. Shukla, A., Rasik, A.M., Jain, G.K., Shankar, R., Kulshrestha, D.K., hawan, B.N. (1999).
7. In vitro and in vivo wound healing activity of asiaticoside isolated from Centella asiatica,
8. Journal of Ethnopharmacology, Volume 65, Issue 1, Pages 1-11, ISSN 0378-8741,
9. https://doi.org/10.1016/S0378-8741(98)00141-X.
10. Choi, S. and Chung, M.H. (2003). A review on the relationship between aloe vera components and their biologic effects, Seminars in Integrative Medicine, Volume 1, Issue 1, Pages 53-62, ISSN 1543-1150, https://doi.org/10.1016/S1543-1150(03)00005-X.
11. Pa, R. and Mathew, L. (2012). Antimicrobial activity of leaf extracts of Justicia adhatoda L. in comparison with vasicine, Asian Pacific Journal of Tropical Biomedicine, Volume 2, Issue 3, Supplement, Pages S1556-S1560, ISSN 2221-1691, https://doi.org/10.1016/S2221-1691(12)60452-3.
12. Anwar F, Latif S, Ashraf M, Gilani AH (2007) Moringa oleifera: a food plant with multiple medicinal uses. Phytother Res 21:17–25

13. Joseph, Baby & George, Jency & Mohan, Jeevitha. (2013). Pharmacology and Traditional Uses of Mimosa pudica. International Journal of Pharmaceutical Sciences and Drug Research. 5. 41-44.
14. Kulkarni, S.K & Dhir, A. (2008). Withania somnifera: An Indian ginseng, Progress in Neuro-Psychopharmacology and Biological Psychiatry, Volume 32, Issue 5, Pages 1093-1105, ISSN 0278-5846.
15. Dixit V. P, Jain P, Joshi S. C. Hypolipidaemic effects of Curcuma longa L. and Nardostachys jatamansi, DC in triton-induced hyperlipidaemic rats. Indian J Physiol Pharmacol. 1988; 32:299–304.
16. Thomson, M., Al-Qattan, K, K., Al-Sawan, S.M., Alnaqeeb, M.A., Khan, I., Ali, M. (2002). The use of ginger (Zingiber officinale Rosc.) as a potential anti-inflammatory and antithrombotic agent, P Leukotrienes and Essential Fatty Acids, Volume 67, Issue 6, Pages 475-478, ISSN 0952-3278, https://doi.org/10.1054/plef.2002.0441
17. Hafeez, B.B., Haque, R., Parvez, S., Pandey, S., Sayeed, I., Raisuddin, S. (2003). Immunomodulatory effects of fenugreek (Trigonella foenum graecum L.) extract in mice, International Immunopharmacology, Volume 3, Issue 2, Pages 257-265, ISSN 1567-5769, https://doi.org/10.1016/S1567-5769(02)00292-8.
18. Dey, A and De, N. (2011). "Ethnobotanical aspects of Rauwolfia serpentina (L). Benth. Ex Kurz. In India, Nepal and Bangladesh," Journal of Medicinal Plant Research, vol. 5, no. 2, pp. 144–150.
19. R K Goyal, R.K., Singh, J. Lal, H. (2003). ASPARAGUS RACEMOSUS - AN UPDATE. Indian Journal of Medical Sciences, Volume 57, Number 9, pp. 408-414.

ISBN: 978-93-90847-17-4

11. Macrobrachium Lamarrei: A Jack of all Trades

Chayan Munshi

Enrolled at International Health Management Programme,
Berlin School of Business and Innovation,
Potsdamer Strasse, Berlin, Germany.

Koushiki Bhattacharya

Student, Department of Zoology,
Visva Bharati University,
Santiniketan, sIndia.

Abstract:

Macrobrachium lamarrei is a highly abundant aquatic prawn species (freshwater), is rather an understudied organism. Interestingly, it is semi-transparent in appearance. Fundamental studies on this organism have indicated its capability as an excellent model for research on ecotoxicology, neurobehavioral biology, developmental biology, ecology and climate change. Separately, it has an impact on the food security aspects. Through this article we want to highlight this species for further valuable research and believe this species is a substantially important species in the spotlight.

11.1 Introduction:

Macrobrachium lamarrei (Arthropoda: Crustacea: Decapoda), is a freshwater species (Figure 11.a) that is abundant in various types of freshwater bodies, like ponds, rivers, lakes etc. It has an average length of 3.5 cm.

The body is distinctly divided into cephalothorax and abdomen. The species is already established as a delicacy in different parts of the Indian subcontinent and has an optimum occurrence as a native species.

It must be noted that the species is on an important stratum of the food chain. In addition, prawns are very importantly taken into account due its participation in crustacean food security aspects.

Bose et al., (2021) recently elucidated the commercial role and food security traits of M. lamarrei and the indicated that this highly occurring species can have a positive impact on the economically weaker rural population regarding getting protein rich food in an affordable price.

Figure 11.a: *Macrobrachium lamarrei* (Photograph taken by Chayan Munshi)

Several researchers consider prawns and shrimps as an excellent model organism under the phylum Arthropoda as these crustaceans can be used very significantly in ecosystem-based research, precisely in aquatic climate change research, aquatic ecology, and evolutionary biological research. In this article we are elucidating *Macrobrachium lamarrei* as one model aquatic invertebrate which is can be used effectively in the diverse biological research.

11.2 General Biology of *Macrobrachium Lamarrei*:

Sharma and Subba (2005) calculated the fecundity of eggs in *M. lamarrei* in terms of total number of eggs per weight of the female. This species has a big range of fecundity (69-143 eggs per female), depending on the season and body length (Hussain and Manohar, 2016). The high fecundity rate of the species led to an easy availability throughout the year. Ovigerous or berried prawns carry their eggs in the ventral portion of their abdomen. The eggs remain attached with the pleopods by a gelatinous substance. Dinakaran et al., (2013) described the event of fertilisation in *M. idella idella,* which is similar to *M. lamarrei.* The sperms from the spermatophores fertilise the ova in the thorax (ova are released from the ovary, situated in the thoracic region). Fertilised eggs are further placed within the pleopods and are incubated there. The development of the eggs occurs in the pleopods and finally females release larvae directly in the water (Figure 11.b). The hatching temperature strictly ranges from 24^{o} C to 30^{o} C; however, the ideal temperature is 27^{o} C. Fertilised eggs are deep green in colour and with the advancement of the development the colour of the eggs fades out and finally turns transparent. The shape of the fertilised eggs is elliptical and in the last stage it becomes ovoid (as it possesses the larvae inside). Newly fertilised eggs have huge yolk content. With the progress of the development, the yolk area decreases (Rashid et al., 2013).

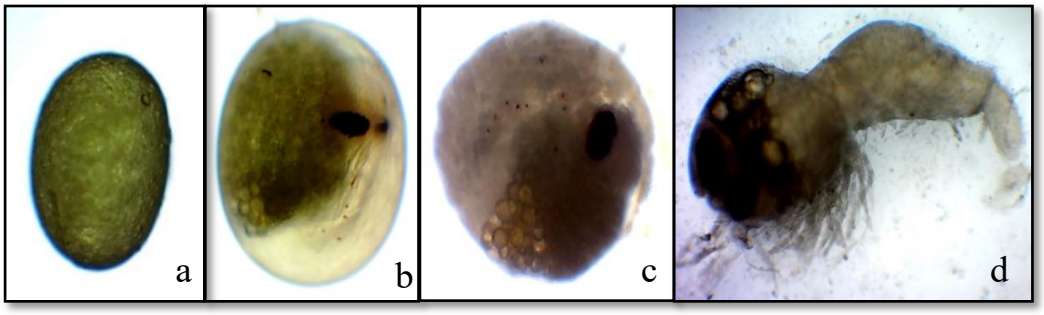


Figure 11.b: Sequential egg development stages in *Macrobrachium lamarrei* (a) non eyed stage; (b) two eyed stages; (c) larva containing stage; (d) larva

11.3 Advantages of The Semi-Transparent Appearance:

Semi-transparent species are considered to be great for visual tracking of the internal systems, as external observation can be done easily. Visual imaging is very prone to experimental artefacts and the experiments can help to find accurate and reliable information as well. Investigations conducted on live cells has gained acceleration in the last decade.

This can help to provide an insight into the working methodologies of certain cell-based metabolic processes. Fluorescent protein and synthetic fluorophore technology have aided quite a bit in this kind of experiment. Live-cell imaging has become an important tool in the case of biological advancement. Similarly, working on live animals has also become an integral part of biological research. This is more facilitated when the research is going on in a transparent or semi-transparent organism. To be precise, methodologies in the case of visual live imaging become easier with the help of semi-transparent species as one will be able to observe the flow of fluorescent and luminescent stains within the organism with appropriate scientific devices.

Examination of the species becomes simple when the researcher wishes to observe into a specific behavioural trait and the underlying internal physiology in the organism. This has proven to be helpful in numerous fields like developmental biology, pharmacology, and several other biomedical research disciplinary areas. Technical success lies in the circumstance when imaging experiments can be conducted successfully in a healthy and functioning environment.

Macrobrachium lamarrei can be very helpful in the case where the ongoing research is about administering a certain stimulus to observe the behavioural and physiological changes in the organism. Internal components tracking is easy with fluorescence or bioluminescence. Although there can be some complications about sufficient spatial and temporal resolution and also importantly toxicity should not be induced, the overall observation process becomes very easy and convenient. As the entire process is facilitated in the presence of a semi-transparent species like *Macrobrachium lamarrei,* it is advisable that this be used for further research in several biological fields.

11.4 Toxicological Aspects:

Increasing anthropogenic activities have become a serious threat to the ecosystem due to release of contaminants in the environment. These contaminants include hazardous synthetic chemicals and natural contaminants like heavy metals, pesticides, microplastics etc. In particular, aquatic ecosystems are being heavily exposed to such pollutants and the resident organisms are being affected. Acute toxicity can affect the physiology of the organisms and eventually causes death. However, low, non-lethal concentration with a chronic exposure can led to several physiological threats.

Ecotoxicology has evolved as one of the most important spheres in biology. Behavioural toxicity is one of the most significant areas in this field that can help to assess behavioural alterations and underlying neurological disorders in organisms, due to several toxic hazards. It has been found in a series of experiments that arsenic trioxide can stimulate repetitive grooming in *Macrobrachium lamarrei,* a freshwater prawn species (Munshi and Bhattacharya, 2020).

Grooming is already established as a behavioural marker of neurological stress in animals (Kalueff et al., 2016). It can be predicted with this experiment that repetition in the grooming behaviour can indicate neurotoxicity by arsenic and induce autism spectrum disorder within a short period of time as well (Munshi et al., 2021). A comparative ethogram study of *M. lamarrei* in both arsenic contaminated and uncontaminated study strongly indicate behavioural alterations (Figure 11.c).

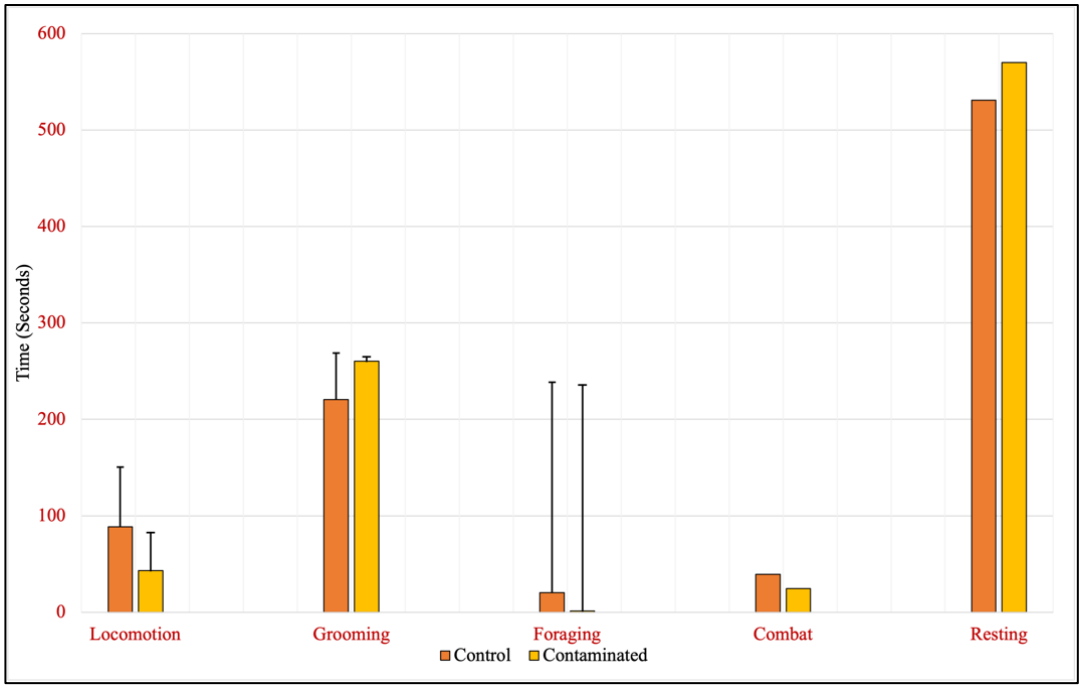


Figure 11.c: Comparative ethogram of *Macrobrachium lamarrei*

As per the prior reports on *Macrobrachium lamarrei*, there is evidence to support that environmental contaminants can induce behavioural alterations in this species (Munshi and Bhattacharya, 2020; Singh, 2014; Verma, 2012; Lodhi et al., 2006; Upadhyay and Shukla, 1986; Murti and Shukla, 1984; Murti and Shukla, 1984) (Figure 11.d). It has been demonstrated in some pilot studies that the change in the aquatic environment leads to immediate behavioural change in this species.

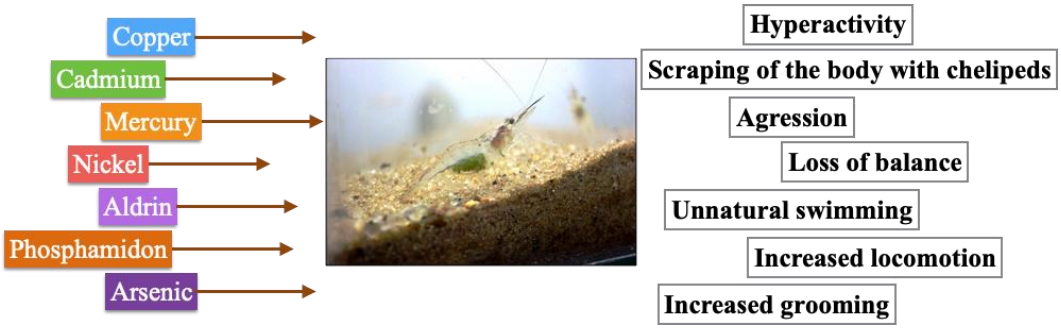


Figure 11.d: Demonstrating the effects of contaminants on (Munshi and Bhattacharya, 2020; Singh, 2014; Verma, 2012; Lodhi et al., 2006; Upadhyay and Shukla, 1986; Murti and Shukla, 1984; Murti and Shukla, 1984)

11.5 Discussion:

Aquatic ecosystems broadly include vast research perspectives, due to the complex biodiversity in several aquatic ecosystems. It is highly believed by biologists that assessment of the effects of environment or climate change in biological system can be done in terms of the analysis of several biological biomarkers. For past few decades, toxicologists have been highly concerned in working with fish (an effective vertebrate model) to understand altered physiology and behaviour due to acute and chronic environmental contaminant exposure.

Since the last few decades, climate change has been a matter of global research and an issue of concern. Global warming, ocean acidification, drought, and environmental pollution are included within this concern. The aquatic ecosystem is directly affected by the impact of climate change. The impact of climate change on aquatic organisms has been studied extensively over the past few years. The effect of climate change on different aquatic organisms can be assessed in terms of behavioural manifestation. There are few organisms in the vast ecosystem of waters, but only few are considered as models to evaluate several biological activities. These models should have certain characteristics like ecological importance, population, sensitivity to the environment and easy to work with.

Fishes are the most common vertebrates used for these kinds of studies. Among the aquatic invertebrates, prawns are considered. Prawns are included as significant models in these studies as they are found in both marine and freshwater ecosystems in different varieties. Therefore, the prawn model can be considered to be important and prominent in the indexing of climate change. Consequently, *Macrobrachium lamarrei* can be considered as an important model to study behavioural plasticity due to climate change. Honey bees are

used very widely among the terrestrial arthropods in neuro-ethological research. Through this article we want to highlight those prawns are most promising models and bioindicators among the aquatic arthropods in biological research. This is because, ecotoxicological, behavioural ecology, neurobehavioral, developmental biology and food security research can be conducted simultaneously with prawn. Precisely, *Macrobrachium lamarrei* is one semi-transparent species that can pose as an exceptional model to study diverse biological phenomena and can contribute to contemporary research work.

11.6 Conflict of Interest:

We declare no conflict of interest.

11.7 Acknowledgement:

The authors acknowledge Professor Shelley Bhattacharya, (Former Professor, Department of Zoology, Visva Bharati University, India) for her support and guidance.

11.8 References:

1. Bose, M., Jas, K., Chakravorty, A., Bhattacharya, D., Pramanik, S., Poddar, P., Surana, A., Sen, K., and Munshi, C., 2021. Commercial Importance of a Freshwater Prawn, Macrobrachium lamarrei: a case study on its food security aspects. *Scientific Journal of Business and Innovation*, *1*, pp.1-4.
2. Dinakaran, G.K., Soundarapandian, P. and Varadharajan, D., 2013. Embryonic development of the Palaemonid prawn Macrobrachium idella idella (Hilgendorf, 1898). *Cell and Developmental Biology*, *2*(1), pp.1-6.
3. Hussain, S. and Manohar, S., 2016. Reproductive aspects of freshwater prawn, Macrobrachium lamarrei lamarrei (HM Edwards 1837) in Upper Lake at Bhopal. *International Journal of Fisheries and Aquatic Studies*, *4*, pp.208-211.
4. Kalueff, A.V., Stewart, A.M., Song, C., Berridge, K.C., Graybiel, A.M. and Fentress, J.C., 2016. Neurobiology of rodent self-grooming and its value for translational neuroscience. *Nature Reviews Neuroscience*, *17*(1), pp.45-59.
5. Lodhi, H.S., Khan, M.A., Verma, R.S. and Sharma, U.D., 2006. Acute toxicity of copper sulphate to fresh water prawns. *Journal of Environmental Biology*, *27*(3), pp.585-588.
6. Munshi, C. and Bhattacharya, S., 2020. Behavioural toxicity of arsenic trioxide: Alteration in auto-grooming behaviour of a freshwater prawn, Macrobrachium lamarrei. *Austin J Environ Toxicol*, *6*(1), pp.1029.
7. Munshi, C., Das, D., Biswas, P., Sen, K., Mondal, N., Mukherjee, S., Bhowmick, R. and Kundu, P., Bhattacharya, S., 2021. Arsenic induced patterns of auto-grooming response over time in *Macrobrachium lamarrei*: a study on behavioural plasticity. *Austin J Environ Toxicol*, *7*(1), pp.1037.
8. Murti, R. and Shukla, G.S., 1984. Acute toxicity of mercuric chloride and cadmium chloride to freshwater prawn, Macrobrachium lamarrei (H. Milne Edwards). *Acta hydrochimica et hydrobiologica*, *12*(6), pp.689-692.

9. Murti, R. and Shukla, G.S., 1984. Effect of Aldrin on the Carbohydrate Metabolism of a Freshwater Prawn Macrobrachium lamarrei (H.-M. EDWARDS) Crustacea, Decapoda. *Acta hydrochimica et hydrobiologica*, *12*(5), pp.549-552.
10. Rashid, M.A., Shahjahan, R.M., Begum, R.A., Alam, M.S., Ferdous, Z. and Kamruzzaman, M., 2013. Fecundity and embryonic development in three Macrobrachium species. *Journal of Entomology and Zoology Studies*, *1*(1), pp.1-11.
11. Sharma, A. and Subba, B.R., 2005. General biology of freshwater prawn, Macrobrachium lamarrei (H. Milne-Edwards) of Biratnagar, Nepal. *Our nature*, *3*(1), pp.31-41.
12. Singh, P. (2014). Effect of sub-acute exposure of copper sulphate on oxygen consumption and scaphognathite oscillations of fresh water prawn *Macrobrachium lamarrei* (Crustacea- Decapoda). *International Journal of Advanced Research, 2*(9), pp.88-93.
13. Upadhyay, O.V. and Shukla, G.S., 1986. Impact of phosphamidon on the carbohydrate metabolism of a freshwater prawn, Macrobrachium lamarrei. *Environmental research*, *41*(2), pp.591-597.
14. Verma, R.S., 2012. Acute toxicity of nickel to fresh water prawns. *Turkish Journal of Zoology*, *36*(4), pp.534-542.

ISBN: 978-93-90847-17-4

12. Birds of Prey of Agroecosystem

Dr. Manoj Kumar

Department of Zoology,
Punjab Agricultural University,
Ludhiana, Punjab.

12.1 Introduction to the Group:

Raptors also known as birds of prey, are predatory birds whose powerful talons and beak, as well as their speed and keen vision, allow them to detect and catch their prey during flight. The word "raptor" comes from the Latin word "rapere," which means to seize or plunder & to carry away. Today, the word is used to describe a group of birds also known as "birds of prey." All birds share some common traits such as feathers, wings, laying eggs, and being warm-blooded. They feed on animal flesh, distinguished by a hooked bill and sharp talons. Most of these bird's hunt and feed on other smaller bird species, rodents or fish. A huge diversity of predatory birds is found all over the world. There are more than 500 species of raptors found throughout the world, and different types of raptors can be found in every type of habitat. From frozen tundras and scorching deserts to dense forests and bustling cities, raptors are key apex predators in every environment. Raptor is a generic term for all birds of prey. Raptors are carnivorous birds with strong bills, large talons, and exceptional flight capabilities. Orders Falconiformes (the diurnal birds of prey) and Strigiformes (the owls) represents a clear definition of bird of prey, a bird that has very good eyesight for finding food, strong feet for holding food, and a strong curved beak for tearing flesh. Accipitridae is a family of *birds of prey*, which includes hawks, eagles, kites, harriers and Old-World vultures. These birds have powerful hooked beaks for tearing flesh from their prey, strong legs, powerful talons and keen eyesight. Falconidae is a family of diurnal birds of prey. They differ from hawks, eagles and kites in that they kill with their beaks instead of their talons. There are 62 species worldwide and 15 species of this family occur in India (Grimmett et al. 1998; Ali 2002; Kler &Kumar 2015; Praveen *et al.* 2016, Kaur and Kumar 2021, Zagorski and Swihart 2021).

Predator and prey interactions often have a great influence on the life of organisms, such as habitat selection, selection of feeding sites, sociality and group living and vigilance (Lima and Dill, 1990). They can also generate morphological adaptations and counter adaptations in the predator and prey species to enhance performance of capturing and escaping, respectively. Size, morphology, and hunting strategy have probably coevolved among predatory species to maximize success in hunting their most common prey (Dawkins, 1982). In birds, the predator is typically larger than the prey, and because size has profound effects on aerodynamic performance during the hunting (Cade, 1960; Howland, 1974, Kaur and Kumar 2021, Zagorski and Swihart 2021). Variations in shape and size of bird of prey is well known fact i.e. eagles tend to be large birds with long, broad wings and massive feet. Booted eagles have legs and feet feathered to the toes and build very large stick nests. Ospreys, a single species found worldwide that specializes in catching fish and builds large stick nests. Kites have long wings and relatively weak

legs. They spend much of their time soaring. They will take live vertebrate prey, but mostly feed on insects or even carrion. The true hawks are medium-sized birds of prey that usually belong to the genus *Accipiter*, are mainly woodland birds that hunt by sudden dashes from a concealed perch. They usually have long tails for tight steering. Buzzards are medium-large raptors with robust bodies and broad wings, or, alternatively, any bird of the genus *Buteo*. Harriers are large, slender hawk-like birds with long tails and long thin legs. Most use a combination of keen eyesight and hearing to hunt small vertebrates, gliding on their long broad wings and circling low over grasslands and marshes. Vultures are carrion-eating raptors of two distinct biological families: the *Accipitridae*, which occurs only in the Eastern Hemisphere; and the *Cathartidae*, which occurs only in the Western Hemisphere. Members of both groups have heads either partly or fully devoid of feathers. Falcons are medium-size birds of prey with long pointy wings. They belong to the *Falconidae* family, many are particularly swift flyers. Owls are variable-sized, typically night-specialized hunting birds. They fly almost silently due to their special feather structure that reduces turbulence. They have particularly acute hearing. Many of these English language group names originally referred to particular species encountered in Britain. As English-speaking people travelled further, the familiar names were applied to new birds with similar characteristics. Names that have generalized this way include: kite (*Milvus milvus*), sparrow-hawk (*Accipiter nisus*), goshawk (*Accipiter gentilis*), kestrel (*Falco tinninculus*), hobby (*Falco subbuteo*), harrier (simplified from "hen-harrier", *Circus cyaneus*), buzzard (*Buteo buteo*). Some names have not generalised and refer to single species (or groups of closely related (sub) species); merlin (*Falco columbarius*), osprey (*Pandion haliaetus*) (Manakadan and Pittie 2001; Ali 2002; Praveen *et al.* 2016; Kler & Kumar 2017, Zagorski and Swihart 2021, Kaur and Kumar 2021).

Raptors are known to display patterns of sexual dimorphism. It is commonly believed that the dimorphisms found in raptors occur due to sexual selection or environmental factors. Dimorphisms can also be the product of intrasexual selection between males and females. It appears that both sexes of the species play a role in the sexual dimorphism within raptors; females tend to compete with other females to find good places to nest and attract males, and males competing with other males for adequate hunting ground so they appear as the healthiest mate. In birds of prey, the opposite is the case. For instance, the kestrel is a type of falcon in which males are the primary providers, and the females are responsible for nurturing the young. In this species, the smaller the kestrels are, the less food is needed and thus, they can survive in environments that are harsher. This is particularly true in the male kestrels. It has become more energetically favorable for male kestrels to remain smaller than their female counterparts because smaller males have an agility advantage when it comes to defending the nest and hunting. Larger females are favored because they can incubate larger numbers of offspring, while also being able to breed a larger clutch size. A recent study discovered new connections between migration and the ecology, life history of raptors. Some worker reports that the clutch size and hunting strategies have proved to be the most important variables in shaping distribution areas, and also the geographic dissimilarities may mask important relationships between life history traits and migratory behaviors.

12.2 Review of the Group in Brief, Pertaining to India:

The avifauna of India includes around 1314 species including 4.8% endemic to India (Praveen *et al.* 2016). As cities grow and expand, urbanization replaces native habitats with new man-made systems where natural and anthropogenic components interact (Parsons *et al.* 2006; Kler *et al.* 2015, Zagorski and Swihart 2021, Kaur and Kumar 2021). Bird communities respond to this environmental variation in several ways. Habitat loss, destruction and degradation are the major threats to avian species richness and diversity. But there are a number of bird species that survive successfully in the urban matrix. Consequently, urban environments can no longer be viewed as lost habitat for wildlife, but rather as new habitat that, with proper management, has the potential to support diverse bird communities. Most of the earlier research directed towards determining the habitat needs of various birds has centered on 'natural' communities, while urban ecosystems have been largely ignored. Now a days, urban avifauna are becoming increasingly appropriate targets for research and conservation efforts (Mortberg and Wallentius 2000, Kler and Kumar 2015; Arora *et al.* 2016) particularly when human population, social and demographic trends predict further urbanization. The city buildings are well documented to provide nesting, roosting and perching sites for some bird species. However, permanent presence of humans and higher densities of non-native predators have potential to affect avian nest placement (Mazumdar and Kumar 2014; Kler and Kumar 2015b; 2017). With the rapid expansion of urban development, the importance of understanding the relationship between avian fauna and urban habitats is evident.

12.3 Diversity and Distribution in Agro-Ecosystem of North-West Region in India (Special Reference to Agro-Ecosystems of Punjab):

12.3.1 Punjab Agro-Ecosystem:

Punjab has a rich bird fauna comprising 328 species of birds (Jerath and Chadha, 2006; Toor *et al.* 1982). The Punjab state, with an area of 50,362 km^2, is situated in the north western part of the country. It extends from latitude 29°33' to 32°32' North and longitude 73°55' to 76°50' East with an average elevation of 300 m above mean sea level. The state has been classified into five agro-climatic zones i.e. sub-mountain undulating zone, undulating plain zone, central plain zone, western plain zone and western zone on the basis of homogeneity, rainfall pattern, distribution, soil texture, cropping patterns etc. The climate of Punjab is characterized by extreme hot and extreme cold conditions. Annual temperatures in Punjab range from 1°C to 46°C (min/max), but can reach 49°C in summer and 0°C in winter. It has three defined seasons; summer, monsoon and winter. Summer season tends to be very hot and very dry and it ranges from April through June with average highs in May and June hovering around 40 °C. A slight decrease in average temperature and an increase in humidity is witnessed in the monsoon season which runs from July

through September with an annual precipitation average range between 960 mm in the sub-mountain region and 460 mm in the plains. Average temperature tends to decrease during the months of October and November. The winter months (December to February) are relatively mild with warm days and chilly nights and March is a transitional month from winter to summer. A total of 189 species of birds belonging to 17 orders, 56 families and 117 genera recorded during the surveys conducted in more than 240 villages of 19 districts of Punjab since last six years.

The present bird recordings were further compared with the "Checklist of Birds of Punjab and Chandigarh" by Toor *et. al.,* (1982) which recorded 240 bird species belonging to 17 order, 56 families and 150 genera. During this study 111 resident birds' species and 77 migrant species were recorded as compared to 147 resident and 93 migrant birds species reported by Toor *et. al.* (1982). Kler (2005) also recorded 64 species, belonging to 11 orders and 29 families from the crop fields of six districts of Punjab. A total of 97 bird species belonging to 14 orders and 40 families were also reported by Kler (2005; 2009) from the villages of Ludhiana districts of Punjab.

Kler (2010) had sighted 70 species of birds in different crop ecosystems. Comparative record has shown that there were 65 species common between the former and the present study. There were 5 bird species which were not observed during the present survey. Some species were found to be habitat specific and their future conservation effort can be carried out in specific habitats.

Out of these 189 bird species, eighteen bird species falls under birds of prey category (Table 1) (Javed and Kaul 2002; Kler and Kumar 2015a). These bird species come under two orders i.e. Falconiformes and Strigiformes and four families i.e. Accipitridae, Falconidae, Pandionidae and Strigidae. Based on the resident status 12 were resident, 5 resident migrant and 1 migrant species. Keeping in view the IUCN list, 1 species each comes under vulnerable, neat threatened & endangered categories and rest were in least concern category (IUCN 2001).

It draws attention to the fact that there is urgent need to focus on the conservation of these three bird species (Eastern Imperial Eagle, Pallied Harrier and Egyptian Vulture) and their habitat so that there will be upgradation of their conservation status. Based on the feeding habits, 7 species feed on Small vertebrates, fishes, mice, rat, small birds, eggs and reptiles; 10 on both insects and small vertebrates and one on carrion (Egyptian Vulture).

The preferred habitat of these bird of prey includes Agricultural & Residential area (5); Agricultural, Residential & Uncultivated area/forest/barren land (2); Agricultural & Uncultivated area/forest/barren land area (8); agricultural area & aquatic Habitat/ponds/canal/river/wetland (1) and Uncultivated area/forest/barren land area (2).

Table 12.a: Bird of prey observed in agro-ecosystem of north-west region in India

Sr. No.	Order	Family	Common Name	Scientific Name	Status	Food	IUCN status	Habitat
1	Falconiformes	Accipitridae	Besra Sparrow Hawk	*Accipiter virgatus* (Temminck, 1822)	R	SV, I	LC	D
2			Black-shouldered Kite	*Elanus caeruleus* (Desfontaines,1789)	R	I, SV	LC	AB
3			Black Kite	*Milvus migrans* (Boddaert,1783)	R	I, SV	LC	AB
4			Crested Serpent-Eagle	*Spilornis cheela* (Latham, 1790)	R	SV	LC	AD
5			Changeable Hawk Eagle	*Spizaetus cirrhatus* (Gmelin, 1788)	R	SV	LC	AD
6			Egyptian Vulture	*Neophron percnopterus* (Linnaeus,1758)	RM	Carrion	EN	D
7			Eastern Imperial Eagle	*Aquila heliacal* Savigny, 1809	RM	SV	VU	AD
8			Oriental-Honey-Buzzard	*Pernis ptilorhyncus* Temminck, 1821	RM	I, SV	LC	AD
9			Pallied Harrier	*Circus macrourus* Gmelin, 1770	M	SV	NT	ABD
10			Shikra	*Accipiter badius* (Gmelin,1788)	R	I, SV	LC	AB
11			Tawny Eagle	*Aquila rapax* (Temminck, 1828)	R	SV	LC	ABD
12			White-eyed Buzzard	*Butastur teesa* (Franklin, 1832)	R	SV, I	LC	AD
13		Falconidae	Common Kestrel	*Falco tinnunculus* Linnaeus,1758	RM	I, SV	LC	AD
14		Pandionidae	Osprey	*Pandion haliaetus* Linnaeus,1758	RM	SV	LC	AC
15	Strigiformes	Strigidae	Barn Owl	*Tyto alba* (Scopoli, 1769)	R	SV	LC	AD
16			Spotted Owlet	*Athene brama* (Temminck,1821)	R	I, SV	LC	AB
17			Eurasian Eagle-Owl	*Bubo bubo* (Linnaeus, 1758)	R	I, SV	LC	AB
18			Collared Scops-Owl	*Otus bakkamoena* Pennant,1769	R	I, SV	LC	AD

Habitat: Type A - Agricultural Habitat; Type B -Residential area: Urban/Rural; Type C - Aquatic Habitat/ponds/canal/river/wetland; Type D-Uncultivated area/forest/barren land. **Status:** R -Resident, RM - Resident migrant; M- Migrant. **Food Habit:** I - Insectivorous; SV – Small vertebrates/fishes/mice/rat/small birds/eggs/reptiles); Carrion. **IUCN Status:** EN – Endangered; VU – Vulnerable; NT - Near Threatened; LC - Least Concern. (Kler and Kumar 2015a, b)

The commonly observed birds of prey in agro-ecosystem of Punjab are discussed below:

Shikra *Accipiter badius* (Gmelin, 1788)

The Shikra *Accipiter badius* (Gmelin, 1788) comes under order Ciconiiformes and family Accipitridae. It is a lightly built hawk, 33 cm, ashy blue grey above, white below cross-barred with rusty brown. Female browner above and larger. Immature, brown and rufous above with brown vertical streaks on the underside. Tail with broad, blackish cross bands. It is usually present Singly or pairs in lightly-wooded country, open wooded country and avoids heavy forests. Flight swift, several rapid wing strokes followed by glide. Fond of groves of large trees in villages and cultivation. It feeds on Lizards, mice, birds, squirrels, etc. The nesting season ranges from march-June and nest is an untidy loose platform of twigs, like a crow's Nest: lined with grass and roots, high up in a large leafy mango or such like trees. The clutch size is 3-4 and eggs are bluish white, faintly speckled and spotted with grey. It is beneficial to farmers and agricultural ecosystem.

Spotted Owlet *Athene brama (Temminck,1821)*

The Spotted Owlet *Athene brama (Temminck,1821)* comes under order Strigiformes and family Strigidae. It is 21cm having Grayish brown plumage, spotted white. Yellowish eyes, brown whitish buff nuchal collar, no ear tuffs. Sexes alike. It is resident, Pairs or small parties, roosts during day in leafy branches, tree cavities or a cavity in a wall, ruins and groves of ancient trees. Villages, towns, cities, ruins, cultivation, grooves of old trees, open

forests. It feeds on Beetles, moths, locusts, other insects. Also prey on lizards, mice and small birds. The nesting season is from November to April and nest is Untidy pad of tow or fibres in tree holes, hollows in crumbling walls, ceilings and roofs. The clutch size is 3-4 white roundish oval eggs. It is beneficial to agricultural ecosystem.

Barn Owl *Tyto alba* (Scopoli, 1769)

The Barn Owl *Tyto alba* (Scopoli, 1769) comes under order Strigiformes and family Strigidae. It has white face, black eyes, white to golden buffy under parts finely spotted with black, golden grey upper parts which are finely spotted with black and white. Lack wing patches. Its size approximates 36cm with wings and tail appear uniform during flight. It is resident, widespread but very local subcontinent and associated with people, nests in buildings especially within cities and villages, also in caves and wells. It feeds on rats and mice, hence has economic importance. The nesting season is undefined, all Year and nest is a collection of straws, twigs, rags into tree hollow, holes in walls. The clutch size is 4-7, eggs are white smooth roundish.

Black-shouldered Kite *Elanus caeruleus (Desfontaines, 1789)*

The Black-shouldered Kite *Elanus caeruleus (Desfontaines, 1789)* comes under order Falconiformes and family Accipitridae. The Black-shouldered Kite is dainty hawk, 33cm, ashy grey above, with white below. Black line above eyes. Black patches on shoulders,

When closed, the wing tips extend beyond the short, square, white tail. It usually inhabits well-wooded country and cultivation, thin deciduous forests and grasslands. Avoid dense jungles as well as arid plains. crepuscular, but also active in daytime, Also hovers in mid-air to scan the ground and parachutes down in steps with motionless wings raised vertically above the body. It feeds on Locusts, crickets, mice, lizards, etc. The nesting is practically all around the year and nest is loose, untidy, crow-like, twigs lined with roots and grass, in small trees. The clutch size is 3-4 eggs having yellowish white color, densely blotched with brownish red. It is beneficial to agricultural ecosystem.

The Collared Scops-owl *Otus bakkamoena*

The Collared Scops-owl *Otus bakkamoena (Pennant, 1769)* comes under Order Strigiformes and family Strigidae. The owl is grey brown or rufous brown in color and 24 cm in length, also known as little horned owl. It has a pale half collar on upper back and sexes alike. It is usually present in open deciduous forest and groves of trees in or near towns and villages. It feeds on small beetles, insects, mice and lizards. The nesting season ranges from January – April and nest is a natural hollow in a tree-trunk. The clutch size is 3-5 and eggs are white in color and spherical in shape. The Collared Scops-owl is beneficial to farmers as its diet mainly includes insects.

The Black Kite Milvus migrans

The Black Kite *Milvus migrans (Boddaert,1783)* comes under order Falconiformes and family Accipitridae. The Black Kite is large brown hawk having forked tail and grey brown or rufous brown in color, 61 cm in length. Sexes alike and can be seen singly or gregariously scavenging in towns and villages. It is usually present in neighborhood of human habitations and confirmed commensal of man. It feeds on Offal, garbage, earthworms, winged termites, lizards, mice, disabled or young birds. The nesting season ranges from January – June and nest is an untidy platform of twigs, iron wire, tow, rags, rubbish, up in a large tree or on roof or cornice of building. The clutch size is 2-4 and eggs are dirty pinkish, white, lightly spotted and blotched with reddish brown. It is beneficial to farmers and agricultural ecosystem.

Egyptian Vulture *Neophron percnopterus* (Linnaeus,1758)

One of the most picturesque birds of prey which graces the shores of Malta during its migratory route is the **Egyptian Vulture** *Neophron percnopterus* (Linnaeus,1758), also known as the white scavenger vulture. Although this bird is usually present locally during autumn, it can sometimes be seen during winter and spring as well. It's not very big, being only around 56cm in length. However, the distinctive wedge shape of its tail makes it conspicuous, since its flights are concentrated during the warmer parts of the day. It feeds on carrion as well as rodents and reptiles, as well as eating the eggs of other birds. It is mostly white in colour with black wing tips and a yellow beak, and it usually builds its nest amidst the crags and cliffs on the coast.

Crested Serpent-Eagle *Spilornis cheela* (Latham, 1790)

The Crested Serpent-Eagle *Spilornis cheela* (Latham, 1790) comes under Order Falconiformes and family Accipitridae. It is a medium-large, dark brown eagle, with rounded wings and a short tail. The bird is dark brown with promiant black and white nuchal crest, full when erected. The bare facial skin and feet are yellow. The underside is spotted with white and yellowish-brown color.

During perching the wing tips do not reach until the tail tip. The tail and underside of the flight feathers are black with broad white bars. It is usually present in better wooded areas. It feeds on frog lizards, rats, snakes etc. The nesting season ranges from December to March and nest is a large stick platform, lined with green leaves, high in lofty forest tree, preferably near streams or clearing. Egg mostaly single, creamy or yellowish white boodly blotched with redish brown color. It beneficial to farmers as its diet also includes rats.

12.4 Importance of the Group (Ecological/Economic):

The presence of raptors in the wild serves as a barometer of ecological health. Birds of prey are predators at the top of the food chain; because threats like pesticides, habitat loss, and climate change have the most dramatic impact on top predators, we refer to them as indicator species. Researching the population trends of raptors provides a cost-effective and efficient means to detecting environmental change, allowing us to take conservation action that is driven by the latest scientific data. Raptors also play an important ecological role by controlling populations of rodents and other small mammals.

12.4.1 Farmers Friends:

Since many of the smaller raptors feed on insects and larger one's prey on rodents, many farmers truly appreciate them. The American kestrel, a smaller falcon, and the Eastern screech owl feed on insects. The great horned owl and the red-tailed hawk feed on rodents. Grasshoppers, cutworms, as well as rabbits and field mice are capable of destroying entire fields of crops if left to reproduce freely without any birds of prey to feed on them. Controlling pests through this method is called biological control. If a farmer can control pests by natural predation, he has no need to use pesticides or insecticides, which helps protect the environment.

12.4.2 Natural Balancer:

Raptors feed at the top of many food chains. Mice, field rats, rabbits, squirrels and other rodents, as well as fish, insects, amphibians and reptiles may have years when their population explodes due to good weather and a surplus of food. This is a common experience with fish, amphibian and even snake populations. Birds of prey help to balance the size of these populations.

12.4.3 Barometer of Ecological Health:

Raptors have been called "ecological barometers," which simply means they help us gauge how healthy a habitat is. Birds of prey are extremely sensitive to many environmental changes in an ecosystem. They can even sense chemical and pollutant levels that can give people an early warning of any impending airborne threats. Pesticides and other chemicals can build up in our environment and are passed on to animals. This can lower raptor populations due to birds ingesting prey riddled with toxins, which in turn signals scientists that a possible problem exists.

12.4.4 Disease Management:

Some of the larger birds of prey like the turkey vulture feed primarily on carcasses of dead animals. Occasionally, they will prey on weak or sick animals. This feeding habit actually helps the environment by getting rid of diseased animals or their carcasses to prevent further spread of any disease the animal was carrying. The stomach acids of the turkey vulture are so powerful that it is resistant to most bacteria and germs. This is probably why the turkey vulture has been around 40 to 50 million years. Several species of vultures and condors besides the turkey vulture practice feeding on dead animals and making the environment safe for other animals.

12.5 Threat and Conservation Status:

The main threats to the birds of prey are the results of different anthropogenic activities which leads to changing land-use patterns, intensification of agriculture, excessive use of pesticides, poisoning, collision, electrocution from large structures related to urbanization, habitat degradation, hunting, disturbance at breeding sites and many more clandestine factors. For the safe guard of these species and being our moral duty to conserve them for future generation; we must peruse a directed result oriented approach to achieve the goal in a sustainable way. Awareness and education are the foremost step needed to be taken as soon as possible to avert the catastrophic consequences.

12.6 Acknowledgement:

Authors are grateful to the Head, Department of Zoology, Punjab Agricultural University, Ludhiana and AINP on VPM, ICAR, New Delhi for forviding financial support and necessary facilities. Contribution of photographs by AINP on VPM (Agricultural Ornithology), Department of Zoology, PAU, Ludhiana is also acknowledged.

12.7 References:

1. Ali S (2002) *The Book of Indian Birds.* 13th Edt., Bombay Natural History Society, Oxford University Press Inc. Bombay.
2. Arora A, Kumar M and Kler T K (2016) Avian diversity in urban, periurban and rural residential areas of Ludhiana. *Ind. J. Appl. Res.* 6 (2): 478-79.
3. Cade T J (1960) *Ecology of the peregrine and gyrfalcon populations in Alaska* Berkeley, California. University of California Press.
4. Dawkins R (1982) *The extended phenotype*. Oxford University Press.
5. Grimmett R, Inskipp C and Inskipp T (1998) Birds of the Indian subcontinent. Oxford University Press.
6. Howland H C (1974) Optimal strategies for predator avoidance: the relative importance of speed and manoeuvrability. *J Theor Biol.* 47: 333 -350.
7. IUCN (2001) *IUCN Red List Categories and Criteria: Version 3.1*. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK, ii + 30 pp.
8. Javed S and Kaul R (2002) *Field Methods for Bird Surveys*. Bombay Natural History Society; Department of Wildlife Sciences, Aligarh Muslim University, Aligarh and World Pheasant Association, South Asia Regional Office (SARO), New Delhi, India.
9. Jerath N, Puja and Chadha J (2006) Biodiversity in the Shivalik Ecosystem of Punjab. Punjab State Council for Science and Technology.
10. Kler T K (2005) Status of avian fauna in agricultural ecosystem of Punjab State. *Pestology* 29(10): 45-50.
11. Kler T K (2009) Avian diversity observed in some agricultural habitats of Ludhiana Punjab. *Pestology* 33(10): 46-51.
12. Kler T K (2010) *Studies on the avian community organization and foraging ecology in relation to phenological changes in Rabi and Kharif crops of Punjab*. Ph.D. Dissertation. Punjab Agricultural University, Ludhiana, India
13. Kler T K and Kumar M (2015a) Avian fauna recorded from the agricultural habitat of Punjab state. *Agri. Res. J.* 52 (3): 83-90.
14. Kler T K and Kumar M (2015b). Prevalence of bird species in relation to food habits and habitat. *Agri. Res. J.* 52 (1): 50-53.
15. Kler T K and Kumar M (2017) Agriculturally Important Birds of Punjab. All India Network Project on Vertebrate Pest Management (Agricultural Ornithology), Department of Zoology, Punjab Agricultural University, Ludhiana
16. Kler T K, Vashishat N and Kumar M (2015) Bird composition in urban landscape of Punjab. *Int. J Adv. Res.* 3 (5): 1113-18
17. Lima S L and Dill L M (1990) Behavioral decisions made under the risk of predation: a review and prospectus. *Can. J. Zool.* 68: 619-640.
18. Manakadan R and Pittie A (2001) Standardised common and scientific names of the birds of the Indian subcontinent. *Buceros* 6 (1): i-ix, 1-38.
19. Mazumdar A and Kumar P (2014) Difference in nesting ecology of purple sunbird *Nectarinia asiatica* among urban and rural habitats in New Delhi, India. *Avocetta* 38: 29-35
20. Mortberg U and Wallentius H G (2000) Red-listed forest bird species in an urban environment assessment of green space corridors. *Landsc. Urban Plan.* 50: 215-226.
21. Parsons H, Major R E and French K (2006) Species interactions and habitat associations of birds inhabiting urban areas of Sydney, Australia. *Austral. Ecol.* 31: 217–227.

22. Toor H S, Chakravarthy A K, Dhindsa M S, Sandhu P S and Rao P K 1982. *A checklist of birds of Punjab and Chandigarh*. Punjab Agricultural University, Ludhiana, India.
23. Kaur H and Kumar M (2021) Avifaunal diversity in Egyptian clover (*Trifolium alexandrinum*) crop fields of Ludhiana, India. *J. Ent. and Zoo. Stud.* 9(3): 410-414.
24. Zagorski M E and Swihart R K (2021) Raptor resource use in agroecosystems: cover crops and definitions of availability matter. *Avian Cons. Eco.* 16(1):1.

ISBN: 978-93-90847-17-4

13. Biofertilizer – A Potential Approach for Sustainable Agriculture

Santhanambika M. S., G. Maheswari

Department of Zoology,
Avinashilingam Institute for Home Science and Higher Education for women,
Coimbatore, Tamil Nadu, India.

Abstract:

The sustainability of soil and plant health is determined by the beneficial plant-microbe interactions in the rhizosphere. The increased use of inorganic fertilizers has residual effects on the environment, groundwater, and soil micro-flora that ultimately has made the soil to lose its biological activity. This can be reinstated by providing the soil with artificially cultured beneficial microorganisms in the form of biofertilizers. These biofertilizers increase soil fertility by enhancing biological nitrogen fixation or solubilizing the insoluble phosphate or producing hormones, vitamins, and other plant growth-promoting factors. This chapter deals with the significant biological agents as potencial biofertilizers for variety of soil types and climatic conditions.

Keywords: Biofertilizers, sustainable agriculture, microorganisms.

13.1 Introduction:

Plants require specific minerals to provide nutrients essential for their growth and development. Nitrogen and phosphorus are responsible for yield and their proper availability is essential for optimum crop yield (Abbasdokht and Gholami, 2010). The fertilizers containing NPK are applied in soil to improve the crop productivity, but it is not utilized by crops completely.

The remaining fertilizer pollutes the soil, ground and surface water sources through percolation and surface run-off during the monsoon period. There are some other nutrients that contaminate the water bodies leading to Eutrophication. The enormous amount of chemical fertilizers is utilized to reload soil nitrogen and phosphorus, which has caused harmful effects on the environment. Now, agriculture is getting interested in diminishing the detrimental outcomes of commercialized farming and opting out for sustainable agriculture. The emerging importance of biofertilizer will help restore the environment (Whitelaw, 2000). Bio-fertilizers is anticipated to lessen the demand for chemical fertilizers and pesticides as they diminish the health of the soil. (Market watch, 2022)

Biofertilizers are eco-friendly agro-inputs consisting of live or latent efficient strains of nitrogen-fixing, phosphate solubilizing, plant growth-promoting, potassium solubilizing or sulfur-oxidizing microorganisms. It aims to accelerate the microbial process augmenting the availability of nutrients that can be taken up by plants to increase the number of beneficial microbes in the soil (Mahdi *et al.,* 2010). They are supposed to be a safe

alternative to chemical fertilizerssupporting sustainable agriculture. During 1950s to 1970s, considerable number of nitrogen-fixing bacteria were found to be associated with crops. Several soil microbiologists suggests that nitrogen-fixing bacteria associated with the plants may be the source of agronomically significant nitrogen inputs to the sugarcane crop in Brazil (Ray and Handerson, 2001). Many microorganisms (bacteria, fungi, and algae) are considered beneficial for agriculture and used as biofertilizers. Microbial consortia are inoculated in the field to improve and supply nitrogen, phosphorus, potassium, and other essential elements necessary for the proper growth of plants. Microorganisms produce a range of extra cellular enzyme which has the potential to mediate utilization of organic sources of nitrogen and phosphorus in soil (Saxena and Joshi, 2002).

Microbes effectively induce plant growth as they secrete plant growth promoters (auxins, abscisic acid, gibberellic acid, cytokinin, ethylene) and affect seed germination and root growth (Ramarethinum*et al.* 2005). They also play considerable role in decomposition of organic materials and enrichment of compost.

13.2 Types of Biofertilizers

The different types of biofertilizers used in agriculture are as follows:

A. Nitrogen-fixing biofertilizers e.g. *Rhizobium Spp*., *Azospirillum Spp.* and Cyanobacteria,
B. Phosphate solubilizing biofertilizer e.g. *Bacillus Sp*., *Pseudomoona Sp*. and *Aspergillus Sp*.
C. Phosphate mobilizing biofertilizers e.g. Mycorrhiza,
D. Plant growth-promoting biofertilizer e.g. *Pseudomonas Spp*.,
E. Potassium solubilizing biofertilizer e.g. *Bacillus Spp*. and *Aspergillus niger,*
F. Potassium mobilizing biofertilizer e.g. *Bacillus Spp.* and
G. Sulfur oxidizing biofertilizer e.g. *ThiobacillusSpp*

Few of the commonly used biofertilizers are discussed in this chapter.

13.2.1 Nitrogen Fixing Biofertilizers:

Nitrogen fixation is converting dinitrogen into nitrogen compounds. *Rhizobium* species are a group of bacteria that fix atmospheric nitrogen symbiotically and stimulate the growth of plants. The enzyme system of bacteria supplies a constant source of reduced nitrogen to the host plant, and the plant in turn provides nutrients and energy for the activities of the bacteria (Singh *et al.,* 2008). *Rhizobium* increases plant growth in various ways such as the production of plant growth hormones, vitamins, siderophores, solubilization of insoluble phosphates, induction of systemic disease resistance, and enhancement in stress resistance (Hussain *et al.,* 2009). The *Azospirillum*inoculation increases germination rate, dry weight accumulation of nitrogen and grain yield, and changes the plants' growth stages (Boddey and Döbereiner, 1988). It fixes nitrogen and helps to absorb water and nutrients for the root system. *Azospirillum* release phytohormone like auxin which enhance root branching and root elongation which is beneficial for plants in dry areas (Dobbelaere *et al*., 1999 and Steenhoudt and Vandereyden, 2000).

Cyanobacteria such as *Nostoc, Anabena, Oscillatoria, Aulosira, Lyngbya*etc are phototrophic. They enrich the soil in paddy field by fixing atmospheric nitrogen and Supplying Vitamin B Complex and growth promoting substance making the plant thrive (Sharma, 1986).

13.2.2 Phosphate Solubilizing Biofertilizers:

Bacteria have more potency than fungi in solubilizing phosphorus (Alam *et al.,* 2002). Phosphorus solubilizing bacterial strains include the genera *Bacillus, Pseudomonas Rhizobium* and *Enterobacter* in conjunction with *Penicillium* and *Aspergillus fungi* (Whitelaw, 2000). Phosphorus solubilizing biofertilizers enhance phosphorus mobility leading to its uptake in the plant body,improving plant growth (Yadav *et al.*, 2011). The application of phosphorus solubilizing biofertilizers reduces the soil pH resulting in the increased solubility of some other minerals, including iron, zinc, manganese and copper. All together, plant nutrient uptake is increased (Saber and Kabesh, 1990)

13.2.3 Plant Growth-Promoting Biofertilizers:

Recently ability of plant growth-promoting rhizobacteria is also studied for microbial control. It is also known as microbial pesticides e.g. *Bacillus spp.* and *Pseudomonas fluorescens.* It was found by Paul *et al.* (2003) that *Pseudomonas fluorescens* application to the Black pepper rhizosphere resulted in the easy mobilization of the essential nutrients in the rhizosphere and resulted in enhanced uptake of nutrients, which reflected in increased plant biomass.

13.2.4 Potassium Solubilizing Biofertilizers:

Cultivating high-yielding crop varieties continuously has led to the exhaustion of potassium levels in the soil faster. Bacterial strains including *Acidothiobacillus ferrooxidans, Paenibacillus* spp., *Bacillus mucilaginosus, B. edaphicus,* and *B. circulans* dissolve silicate minerals and release potassium by the production of organic, inorganic acids and exchange reactions (Etesami *et al.,* 2017). Inoculating the seeds and seedlings with potassium solubilizing biofertilizer resulted in a significant enhancement in germination, seedling vigor, plant growth, yield, and potassium uptake by plants under greenhouse and field conditions (Anjanadevi *et al.,* 2016).:

13.3 Application of Biofertilizers:

They are produced in liquid, powder or granules and applied to soil, compost, seed, seedling and plant leaves. There are three ways in using biofertilizers as:

A. Inoculation to seed: Seeds are soaked in the mixture of nitrogen and phosphorus fertilizers, left to dry and sown as soon as possible.
B. Sowing seedling root dip: It is specific for rice. The seedlings are sowed in the water bed with biofertilizer and kept for 8 to 10 hours.
C. Field application: Biofertilizers and compost are blended and kept overnight. This mixture is scattered on to the fields where the seeds has to be sown.

Some liquid biofertilizers can be sprayed to plant leaves (Malusa, 2012).

13.4 Trends Influencing The Growth Of The Biofertilizers Market:

The need for a sustainable alternative to chemical fertilizers is expected to drive the growth of the biofertilizers market. Biofertilizers, unlike traditional fertilizers, boost the nitrogen and phosphorus accessible to plants in a more natural way. Growers can customize the microorganisms employed to the needs of specific plants thanks to the various kinds available. Even for inexperienced small farmers, biofertilizers are simple to use. Chemical fertilizers often result in too much phosphate and nitrogen in the soil, whereas biofertilizers do not harm the land or the environment. Furthermore, it is also safe for human health as it is devoid of any chemicals. Biofertilizers help to lessen reliance on costly petroleum-based chemical fertilizers. Due to a scarcity of fossil fuels, chemical fertilizer prices may rise beyond the grasp of small consumers. Biofertilizers are a low-cost, easy-to-use alternative to petrochemical fertilizers. This cost-effectiveness is expected to drive the growth of the biofertilizers market.

Biofertilizers bring the soil back to normal fertility and bring it back to life naturally. They increase the amount of organic matter in the soil and improve the texture and structure of the soil. The improved soil is more water-retentive than previously. Biofertilizers enrich the soil with essential elements such as nitrogen, proteins, and vitamins. They convert nitrogen from the atmosphere and phosphates from the soil into plant-friendly forms. Natural insecticides are also produced by some animals. This feature is expected to drive the growth of the biofertilizer market. The increasing need to improve yields is expected to drive the growth of the biofertilizers market. Because of the nitrogen and phosphorus they give to the soil, biofertilizers can boost production by up to 30%. Plants grow better during droughts when the soil texture and quality are improved. Biofertilizers aid in the development of stronger root systems and improved plant growth. Harmful organisms in the soil, such as fungi and nematodes, are also reduced by biofertilizers (Valuates report, 2022).

13.5 Constraints in the use of biofertilizer:

A. Only particular strain will have the ability to survive both in the broth and the inoculant carrier.
B. If the suitable carrier is not available, it is not easy to maintain the shelf life of the biofertilizer. The commonly used carriers are peat, lignite, charcoal, farmyard manure, soil, rice husk. It should have a good moisture-holding capacity, free from toxic substances (Bhattacharjee and Dey, 2014)
C. Lack of awareness among farmers
D. It provides lower nutrient density than chemical fertilizers, and hence more product is often required for the same effect
E. Production of biofertilizer requires specific machinery
F. They are often plant specific; what works on one crop does not work on another
G. It can never be exposed to direct sunlight
H. The optimum temperature for its storage will be from 0 °C to 35 °C and has a much shorter shelf-life than chemical fertilizers
I. It possessesa strong, distinctive odor

13.6 Conclusion:

Microbes capable of decomposing the organic matter faster could be a potent biofertilizer for the quick release of nutrients. The ordinary decomposition can be accelerated and the time taken for composting is reduced by 4 to 6 weeks by the inoculation of microbes. Bio-fertilizers are cheaper and significant in affecting the yield in crops. After using it continuously for 3 – 4 years, there will be no need to apply biofertilizers because parental inoculums will be established to get sufficient nutrients for growth and multiplication. They improve soil texture, pH, and other properties of soil. They produce plant growth-promoting substances e.g., IAA amino acids, vitamins etc. Therefore, more awareness should be created among the cultivars to utilise the biofertiliser for both good yield and replenish the soil fertility in a sustainable way.

13.7 References:

1. Abbasdokht, H. and A. Gholami. 2010. The effect of seed inoculation (*Pseudomonas putida* + *Bacillus lentus*) and different levels of fertilizers on yield and yield components of wheat (*Triticum aestivum*L.) cultivars. World Aced. Sci. Eng. Technol., 68: 979-983.
2. Alam, S., S. Khalil, N. Ayub and M. Rashid. 2002. *In vitro* solubilization of inorganic phosphate by phosphate solubilizing microorganism (PSM) from maize rhizosphere. Int. J. Agric. Biol., 4: 454-458
3. Anjanadevi, I.P., John, N.S., John, K.S., Jeeva, M.L. and Misra, R.S. 2016. Rock inhabiting potassium solubilizing bacteria from Kerala, India: characterization and possibility in chemical K fertilizer substitution. *J.Basic Microbial*. 56:67-77.
4. Bhattacharjee, R., & Dey, U. (2014). Biofertilizer, a way towards organic agriculture: A review. *African Journal of Microbiology Research*, *8*(24), 2332-2343.
5. Boddey, R.M. and Döbereiner, J. 1988. Nitrogen fixation associated with grasses and cereals: Recent results and perspectives for future research. *Plant Soil*, 108: 53-65.
6. Dobbelaere, S., Croonenborghs, A., Thys, A., Broek, A.V. and Vanderleyden, J. 1999. Phytostimulatory effect of *Azospirillumbrasilense*wild type and mutant strains altered in IAA production on wheat. *Plant Soil* 6: 155-164.
7. Etesami, H., Emami, S. and Alikhani, H. A. 2017. Potassium solubilizing bacteria (KSB): Mechanisms, promotion of plant growth, and future prospects A review. J. Soil Sci.PlantNutr., 17 (4)
8. Hussain, M.B., Mehboob, I., Zahir, Z.A., Naveed, M. and Asghar, H.N. 2009. Potential of *Rhizobium* spp. for improving growth and yield of rice (*Oryza sativa* L.). *Soil Environ*. 28(1): 49-55.
9. Itelima JU, Bang WJ, Sila MD, Onyimba IA, Egbere OJ (2018) A review: biofertilizer-a key player in enhancing soil fertility and crop productivity. J MicrobiolBiotechnol Rep2(1): 22-28.
10. Mahdi SS, Hassan GI, Samoon SA, Rather HA, Showkat AD, *et al.* (2010) Bio-fertilizers in organic agriculture. Journal of Phytology 2(10): 42-54.
11. Malusa E, Sas-Pasz L, Ciesielska J (2012) Technologies for Beneficial Microorganisms Inocula Used as Biofertilizers. The Scientific World Journal 2012: 491206.
12. Market watch, 2022: https://www.marketresearchengine.com/biofertilizer-market-report

13. Paul, D.; Srinivasan, V.; Anandraj, M. and Sarma, Y.R. (2003). *Pseudomonas fluorescens* mediated nutrient flux in the black pepper Rhizosphere microcosm and enhanced plant growth. 6th International PGPR workshop, 5-10 October, Calicut, India
14. Ray, R.N. and Handerson, G. (2001). Endophytic nitrogen fixation in sugarcane: Present knowledge and futureapplications, Technical expert meeting on increasingthe use of biological nitrogen fixation (BNF) inagriculture, FAO, Rome
15. Saxena, P. and Joshi, N. (2002). In: Role of Microorganisms in the decomposition of organic wastes matter. Ph.D.Thesis, Gurukul Kangri University, Haridwar
16. Sharma, V.K. (1986). A review of recent work on pesticide studies on the nitrogen fixing algae. J. Env. Biol. 7(3): 171-176.
17. Singh, B., Kaur, R. and Singh, K. 2008. Characterization of *Rhizobium* strain isolated from the roots of *Trigonellafoenumgraecum*(fenugreek). *Afri. J. Biotechnol*., 7(20): 3671-3676.
18. Steenhoudt, O. and Vandereyden, J. 2000. *Azospirillum*, freeliving nitrogen fixing bacterium closely associated with grasses: genetic, biochemical and ecological aspects. *FEMS Microbiol. Rev*., 24: 487-506.
19. Valuates report, 2022. https://www.prnewswire.com/in/news-releases/biofertilizer-market-size-to-reach-usd-4459-5-million-by-2028-with-a-cagr-of-8-4-valuates-reports-893325796.html
20. Whitelaw, M.A. 2000. Growth promotion of plants inoculated with phosphate solubilizing fungi. Advance Agron., 69: 99-151
21. https://blog.teamtrade.cz/biofertilizers-what-are-the-pros-and-cons/
22. https://www.onlinebiologynotes.com/biofertilizer-advantages-types-methods-of-application-and-disadvantages/

ISBN: 978-93-90847-17-4

14. Indigenous Tribes as Ecopreservers of Blue Mountain

Layana Nelson, G. Maheswari

Department of Zoology,
Avinashilingam Institute for Home Science and
Higher Education for Women,
Coimbatore, Tamil Nadu, India.

Abstract:

The Nilgiri Hills is home to tribal groups, including the Toda, Kota, Badaga and Kurumba. They traditionally relied on each other for different goods and services in a complex trade network. Tribe's customs and conventions depend on the conservation of nature and biodiversity. Various schemes have been initiated by the Government to promote their wellbeing and encourage their sustainable activities. This paper deals with different tribes inhabiting Nilgiri mountain, their heritage, customs and environment protection activities.

Keywords: Tribes, Nilgiri hills, customs, heritage, environment.

14.1 Introduction:

The Nilgiri Hills is a region of mountains, forests and tea plantations located in southern India where the states of Tamil Nadu, Kerala and Karnataka all come together and rise to a height of 2,400 meters. The highlands are rolling grasslands with patches of temperate forest known as shoala. The Nilgiri Hills receive over 14 feet of rain a year, the second highest rate in India. Over 80 percent of this rain falls during monsoon season which runs from June to August. On the southern, windward side of the hills the forests are wet and lush. The forests on the northern, leeward side are arid and scrubby. The controlled environment is otherwise known as the social environment. Both types of environments directly or indirectly influence characters, customs, conventions, beliefs, taboos, and other livelihood strategies of human society (Karthikeyan, 2014). Plants are playing an important role in the health of millions of people's lives in many villages of India in their day-to-day life by its traditional usage (Poorani et al., 2016). Herbal medicine is the foundation for about 75–80% of the world population, mainly targeting primary health care in the developing countries because of better cultural acceptability, compatibility with human body and lesser side effects. It is a country rich in indigenous herbal resources that grow on their varied topography and under changing agro climatic conditions permitting the growth of almost over 6000 plants used in traditional, folk and herbal medicines. In fact, colonial rule brought in the first radical change in resource use in the Indian subcontinent and it gradually transformed natural resources to grow commercial economic activity and generate revenue and profit. Nilgiris is situated at an elevation of 900 to 2636 meters above MSL. Its latitudinal and longitudinal dimensions being 130 KM (Latitude: 10 – 38 WP 11-49N) by 185 KM (Longitude: 76.0 E to 77.15 E). The Nilgiris is bounded on North by Karnataka State on the East by Coimbatore District, Erode District, South by Coimbatore District and

Kerala State and as the West by Kerala State. In Nilgiris District, the topography is rolling and steep. About 60% of the cultivable land fall under the slopes ranging from 16 to 35%. The Nilgiris District comprises of six Taluks that is Udhagamandalam, Kundah, Coonoor, Kotagiri, Gudalur and Pandalur. These Taluks are divided into four Panchayat Unions viz., Udhagamandalam, Coonoor, Kotagiri and Gudalur, and two Municipalities as Wellington Containment and Aruvankadu Township. The District consists of 88 Revenue Villages and 15 Revenue Firkas. There are three Revenue Divisional in this District viz., Udhagai, Coonoor and Gudalur. There are 35 Village Panchayat and 11 Town Panchayat in this District. The Nilgiri region is inhabited by the following tribal groups—the Paniya, Toda, Kota, Irula, Kattunayaka, Mullu Kurumba, Urali Kurumba, and Jenu Kurumba, etc. All these communities represent the relationship with the forests, and they had an intimate knowledge on flora and fauna of their territories. The different tribal communities are present at different socio-economic levels based on their occupation patterns and culture of some of these tribal ethnic groups over a period. The study was undertaken to gain knowledge on tribal community, customs and conventions, Government schemes to promote their socio-economic status with the following objectives.

14.2 Objectives:

A. To portray the heritage, customs and legends of tribal communities in Nilgiri District
B. To examine the challenges faced by the tribal people
C. To analyze the Government schemes to promote the tribal lifestyle

14.3 History:

A. History of Nilgiri hills dates back to many centuries.
B. The holy Rishi, Valmiki quoted Nilgiri hills in his epic, the Ramayana.
C. This name has been found also in the epic, Silappadikaram written in the 5th–6th century ad by Prince Ilanko Adikal
D. The kurunji flower which blooms every twelve years giving the slopes a bluish tinge to the mountain and hence the name Blue Mountain to the hills.
E. At the start, Todas occupied the the Ooty area and the Kotas the Kotagiri area.
F. 1550 C.E.: The Badagas migrated from the Mysore Plateau,
G. 1602: Portuguese priest, Ferreiri, explored the hills and identified the Toda people.
H. 1810: Englishman Francis Buchanan from British East India Company failed to survey the Nilgiris Hills jungles. Followed by him, John Sullivan, the Collector of Coimbatore just south of the Nilgiris, sent two surveyors, Keys and Macmohan, to study the hills.
I. 1819: A thorough exploration of Ooty Hill and the region was submitted by and "the existence of a tableland possessing a European climate." Was discovered and submitted by J.C. Whish and N.W. Kindersley
J. John Sullivan, the Collector of Coimbatore, who went up the same year and built a home, had been the first European resident of the hills. The suitability of the climate in this hill was reported by him to the Madras Government. The Europeans soon thereafter settled in the valley for year round and for summer stays. The valley became a summer resort with the British government using the hills for a summer capital.
K. 19th Century – By the end of 19^{th} century, roads were established, and the railway tracks were constructed and become the tourist spot.

14.4 Tribes in Nilgiris District:

One of the most biodiverse regions of the Western Ghats, the Nilgiris (the blue mountains) comprise part of a larger mountain chain known as the Western Ghats and has been the homeland of native tribal peoples. An important tribe residing in Nilgiri hills are as follows.

14.4.1 Toda:

The Toda people designates a small pastoral community that live on the isolated Nilgiri plateau of Southern India. They traditionally trade dairy products with their Nilgiri neighbors. Toda religion rely on the buffalo, and they perform rituals for all dairy activities. Afforestation by the State Government of Tamil Nadu has also taken a toll on their grazing land. That has threatened to undermine Toda culture by greatly diminishing the buffalo herds. The Kota represent the most closely related people to the Toda, both ethnically and linguistically. The Toda lands now belong to the Nilgiri Biosphere Reserve, a UNESCO designated International Biosphere Reserve.

14.4.2 Irula:

The Irula are a Scheduled tribe lives in northern Tamil Nadu and the Nilgiri Hills. They are sort of like a cross between tribals and ordinary southern Indians. Many live in two-room houses with a separate room with a sacred fire. They harvest millet with impossibly small sickles for harvesting individual grain heads. Much of their traditional land has been lost to tea and coffee plantations. The Irula are known for being inspired musicians. They produce their own flutes and drums and are employed by other tribes such as the Toda and Badaga to perform at their funerals.

During Irula funerals a priest goes into trance and is asked by the family of deceased whether the death was natural or the result of sorcery. If the latter is the case a number of rituals are performed before the deceased is buried. After month a stone is placed in a temple to give the deceased a place to stay. The Irula marriage process used to be initiated by a trial cohabitation initiated with a delivery of firewood to the bride's family's house by the groom, but this is no longer practiced. A standard bride price is paid in the presence of elders. The marriage ceremony revolves around the tying of a necklace around the bride's neck. If a wife is unable to produce a child, the husband is allowed to take a second wife. Some women have tattoos and wear toe rings.

14.4.3 Kurumbas:

The Kurumbas are another group that lives in the Nilgiri Hills. There are seven major Kurumba groups: the Alu (milk)-Kurumbas, Palu (milk) -Kurumbas, Betta (hill)-Kurumbas, Jenu (honey)-Kurumbas, Mulla (net)- Kurumbas, Urali (village)-Kurumbas, and Mudugas. Each group is regarded as a separate ethnic group, with its own religious beliefs and other cultural features. There are about 15,000 Kurumbas and about a third of them live in the Nilgiri District. Others are scattered across southern India. The Kurumbas have traditionally been hunters and gatherers. They forage a variety of foods from the forest and hunted and trapped birds and animals. They lived in rock shelters and caves and grew bananas, mangos

and jackfruit in forest gardens. Deforestation had driven them out of their traditional villages into the plains, where they work in tea and coffee plantations. The Kurumbas have a reputation of being sorcerers. Traditionally, the Badaga hired an individual Kurumba man who act as hraduan for a specific village. This was a lifelong job that was passed down from father to son. This individual over agricultural festivals and was employed as a diviner, exorcist. and sed gerbs, spells and rituals to cure the sick. Because of the knowledge of sorcery Kurumba were greatly feared. When bad things happened, they were often blamed.

14.4.4 Nayaka:

The Nayaka are another group that lives in the Nilgiri Hills. Traditionally regarded as honey collectors and people of the forest, they are also known as the Jenu Kurumba, Kattu Naikr, Kattu Nayaka, Naicken, Naikr and Sola Nayaka. They have traditionally lived in huts in the forest and migrated every six to 18 months. There are only around 1,400 of them. Nayaka have no history of animal husbandry or cultivation other than having a few fruit trees near their huts. They have traditionally subsisted primarily on wild yams, nuts, berries and fruit that they collected and fish and trapped animals.

They sometimes hunted deer with dogs. They also collect items from the forest such as medicinal herbs that can be traded for things they need like grain, cooking pots and utensils. They also have worked on plantations and done other work to make money. Nayaka have no formal marriage ceremony. A couple is generally regarded as married when they start sleeping together and sharing the same hearth. The Nayaka are friendly but independent. They generally don't form strong lasting relationships outside their conjugal families. Their religious beliefs are mostly animist with some Hindu deities in their pantheon of gods and spirits. The only life-cycle event that they honor with a ritual is death.

14.5 Customs and Conventions of The Tribes:

The tribes throughout India have the most distinguished customs and conventions which are parallel to preserving the nature. In Tamilandu, the Nilgiris is the protected biosphere area where is the abode of the six primitive tribes namely, Kurumbas, Kattunaickens, Irulas, Todas, Paniyas, Kotas. They lead nature based peculiar life. The Todas life focus on fire making, trees and plant sacredness (Tudr tree), sun worship, moon veneration, reverence of light, stone cult and worship for rain. As the Kattunaicken which means king of the jungle, their economy is based on forest resources. The traditional honey harvesting, and ethno-medical practices are the major role for their economy leading their daily life (Karthikeyan, 2014).

The other tribes Irulas, Paniyas, Kotas, Kurumbas are also dependent upon the forest and its resources for their life system. It is not only in the case of these tribes, but also applicable to throughout India. Hence, the Tribal society is nature based one. The economy for their daily life is determined by forest resources. The forest environment limits and determines their culture. Sometimes, the laws framed by the Government as constitutional laws and other environmental laws disturbing and degrading the tribal life system (Karthikeyan, 2014).

14.6 Houses and Food Habits:

A typical Alu Kurumba village or motta (or kombhai) is made up of five to six huts scattered on the steep wooded slopes of the Nilgiris. Individual huts stand alone on a flattened piece of land and are home to a nuclear family. Constructed from a bamboo backbone with walls made of criss- crossing bamboo strips and grass, they are often fortified with mud and cow dung and support a tiled roof. A small partition, a metre deep and a metre high, divides the interior space into the kitchen and the living or sleeping room. The kitchen or ittumane (food house) has a narrow one-foot-high ledge running the length of a wall. This ledge holds the fireplace and the utensils. Steel vessels have replaced the traditional bamboo vessels and leaves used earlier.

The sleeping room or vagamane serves for all other purposes. The houses open to flattened verandahs or thinnamanne that are used for social purposes. Many of the Kurumbas now live in the government settlements that are brick houses with tin roofs.

The Kurumba ancestors gathered honey and cultivated small patches of raagi, saami and other grains for food and survival. Small patches of coffee and raagi are still grown in the villages though. Coffee and tea are popular drinks.

Even children as young as five are given black sweetened coffee to drink in the mornings. Jackfruit, another plangt growing in abundance in the Nilgiris is also eaten in generous quantity in its raw and cooked form. With most of the kurumbas working on the plantation, they have to leave home in the morning and return only after five in the evening. This allows them only two meals (ittu) a day. The meal consists of rice (replacing raagi) and a curry. The kurumbas eat fish, chicken and goat meat. Chewing tobacco and drinking alcohol, irrespective of gender are also popular.

14.7 Types of Marriages:

Marriage is a set of cultural patterns to sanction parenthood and to provide a stable background for the care and rearing of children. The tribal marriages can be classified into the following types:

14.7.1 Monogamy:

In this type of marriage one man married to one woman or one woman marries one man (Chandrakantha, 2014). The husband and wife may or may not be (usually not) related to each other before marriage, most of the Indian tribes practice monogamy.

14.7.2 Polygamy:

It is the marriage of one person with more than one person of the opposite sex (Chandrakantha, 2014). It has two sub types:

(a) Polygyny (b) Polyandry.

(a) Polygyny:

In this type of marriage one man marries to several women. The husband and wives may or may not be related to each other before marriage. Wives may be related among themselves. When the wives are related to each other as sisters it is called as sororal polygyny. If they are not related as sisters, it is called non-sororal polygyny. Polygyny is found among the Naga tribes, the Gond, the Baiga and the Toda. It is also found among the Lushai, Juang and the Kondh. Polygyny is practiced among the tribals due to several reasons (Chandrakantha, 2014). First, it is practiced due to the imbalance of the sex ratio, where women outnumber men. The second reason is that the practice of polygyny accords higher status and prestige.

(b) Polyandry:

Polyandry, marriage of a woman to two or more men at the same time. the term derives from the Greek polys, "many," and anēr, andros, "man." When the husbands in a polyandrous marriage are brothers or are said to be brothers, is called adelphic, or fraternal, polyandry. Todas for several centuries practiced polyandry. A Toda woman when married was automatically married to her husband's brothers (Encyclopedia, 2008).

14.8 Government Schemes for Tribals:

Governor Banwarilal Purohit said that the Central and State Governments were implementing numerous welfare schemes to ensure tribal communities had access to housing, drinking water facilities, sanitation and access to roads and community spaces.

At the Tribal Youth Empowerment and Entrepreneurship Conference was organised.to mark the 102nd birth anniversary of the founder of the Nilgiri Adivasi Welfare Association (NAWA), S. Narasimhan here on 17th July 2019, Monday. Mr. Purohit announced that the State Government was running 24 Government Tribal Residential Schools and one Ekalavya model school in the Nilgiris to promote education among tribal communities. "Tribal students receive free education in professional courses for which the Government provides total subsidy.

Recently, the Government sanctioned the construction of 300 houses in Gudalur block alone," he said, adding that it was important that these facilities were fully utilised by tribal communities. The ultimate goal of both Government and forest dwellers/the tribes is unanimously preserving the forest and natural resources (Karthikeyan, 2014).

There are some suggestions to bring forth to preserve the tribal rights while framing the environmental laws for conservation (Karthikeyan, 2014).

- The role of women, both in conservation and livelihood protection is recognized and protected.
- A new Conservation Law and Forest Law be drafted, with provisions for protecting the indigenous knowledge and rights of indigenous / forest dwelling communities in accordance with the Conservation of Biodiversity.

- The President of India and State Governors should be asked to exercise their powers for withholding the application of forestry laws in scheduled areas with due modification to suit the specific conditions of the areas and the communities living therein.
- The laws related to protected areas and forests will not however, harm the forest dwellers / the tribes.
- When the laws executed, the victims should be properly subsistence.
- The confiscated lands should be given back to the tribes as it is the main resource of their daily life.
- The punitive action must be taken against the officers and authorities those who are violating the environmental laws and tribal laws.
- The laws alienated tribal land should be withdrawn.

Some of the programmes are to develop land use planning for forest area to cultivable area to conserve soil, water and increase productivity of land, economic upliftment of the tribes in an isolated settlement and ensure people participation in all developmental activities (Karthikeyan, 2014).

14.9 Conclusion:

The tribal people in the Nilgiri biosphere of Tamil Nadu, South India have their own culture, language and skill set. Their customs, conventions and livelihood strategies are strongly knitted with environmental elements. The dependence with nature of their culture is unavoidable according to topographical dogmas. Each activity of their life system is nature based. The social set up, economy and not break their relationship with nature. The laws framed by the authority should preserve the life of the tribes and the environment to enhance eco restoration, eco development, eco preservation while taking care of socio- economic and needs of Nilgiris District in Tamil Nadu.

14.10 References:

1. Karthikeyan, B. 2014. Tribes of Nilgiris (India) and Environmental Laws., International Journal of Humanities and Social Science, 4 (23): 242-247
2. Poorani, N. Revathy, M. Kulothungan, S. and Paneerselvam, A. 2016. Diversity, distribution and indigenous knowledge of medicinal plants in elambalur village of perambalur district, International Journal of Current Research, 8 (3): 27349-27352, ISSN 0975-833X
3. Chandrakantha, K. M. 2014. Tribal Marriage System in India - A Sociological Analysis, International Journal of Research and Analytical Reviews, 1 (4): 90-98, 2348-1269
4. Mongabay Series: Environment and Elections Nature and tribal welfare takes a back seat during the elections in the Nilgiris by Bhanu Sridharan on 18 April 2019
5. https://factsanddetails.com/india/Minorities_Castes_and_Regions_in_India/sub7_4h/entry-4217.html
6. https://www.yourarticlelibrary.com/essay/marriage-among-the-tribals-in-india/47423
7. https://www.newworldencyclopedia.org/entry/nilgiris_district
8. https://nilgiris.nic.in/about-district/
9. https://chennaifocus.in/2012/03/07/know-tamilnadu-tribes-kurumbas-of-nilgiris/
10. https://psichologyanswers.com/library/lecture/read/37582-what-is-polyandry

11. https://www.thehindu.com/news/cities/Coimbatore/welfare-schemes-to-ensure-tribal-people-have-access-to-basic-amenities/article27190360.ece
12. Encyclopædia Britannica, Toda. Retrieved July 8, 2008 https://www.newworldencyclopedia.org/entry/Toda_people

ISBN: 978-93-90847-17-4

15. Evaluation of Biochemical Parameters and Antioxidant Activity of Alpha Terpineol on DMBA Induced Rats

Valsala P., Gunavathi V., Santhy, K. S.

Department of Zoology,
Avinashilingam Institute for Home Science and
Higher Education for Women, Coimbatore.

Abstract:

The present study aimed to assess the efficacy of Alpha terpineol, an important compound present in *M. piperita,* for its antitumor activity in DMBA induced breast tumour in rat model. Experimental animals are sorted into six groups, Group I: Normal Control, Group II: DMBA (25mg/Kg), Group III: DMBA + Tamoxifen (5mg/Kg), Group IV: DMBA + Alpha terpineol (20mg/Kg), Group V: DMBA + Alpha terpineol (40mg/Kg) and Group VI: Alpha terpineol alone (20mg/Kg). The DMBA is a powerful carcinogenic agent and is used to induce tumours in animals. Rats were treated twice per week for 4 weeks with DMBA (25 mg/Kg body weight dissolved in olive oil) orally. After the experimental period, the animals were fasted overnight and sacrificed by cervical decapitation, the blood was collected from the control and the experimental groups of rats; the serum was separated out for the analysis of the serum biochemical parameters and antioxidant parameters. The treatment with Alpha terpineol reduced the Cholesterol, uric acid, ALP, TP, TGL, BUN, SGOT and SGPT and brought to near normal levels. Alpha terpineol had significantly improved antioxidant enzymes such as SOD, catalase, GPX and GSH similar to the standard drug treated rat, whereas LPX levels were significantly reduced. The curative effect was found to be dose-dependent in animals treated with Alpha terpineol. Some of the damaged breast patterns were restored to near normal by the treatments.

Keywords: Biochemical parameters, antioxidant parameters, Alpha terpineol, DMBA, Tamoxifen

15.1 Introduction:

Breast cancer has been called the second most common cancer after lung cancer. It is one of the leading causes for death in women worldwide, surpassing the cervical cancer (Jemal *et al.,* 2011). In Malaysia, a current report shows breast cancer as the most often diagnosed cancer. The International Agency for analysis in Cancer (GLOBOCAN) estimate the ASR (age-standardized rate) of carcinoma in Malaysia as 38.7 per 100,000, reporting carcinoma as high among general population of Malaysia (Youlden *et al.,* 2014). Cancer-therapeutic medicine had associate impact of damage to the normal cells and tissues (Alakhova and Kabanov *et al.,* 2014). The relapse after chemotherapy, second primary neoplasm, and resistance to chemotherapeutic medicine have additionally been occurring in breast cancer patients (Beckwitt *et al.,* 2018). The best remedy to those unpreventable side effects is the use of natural products (Othman and Ahmed, 2013).

Alpha terpineol, a volatile monoterpenoid alcohol, is the major element of essential oils of many species of aromatic plants like *Origanium vulgare* L. and genus *Ocimum canum* Sims. It can be isolated from a variety of sources like cajeput oil, pine oil and petitgrain oil (Bauer *et al.,* 2001). A-Terpineol is usually present in a mixture of 3 isomers specifically β-γ-and terpinen-4-ol (Itani *et al.,* 2008).

Moreover, it exhibited an anti-proliferative activity, which may be used in the prevention or even treatment of tumour, because it was found that α-T had a potent antioxidant capability against completely different human neoplastic cell lines (breast, lung, prostate, female internal reproductive organs and leukaemia). This inhibits the progress and stimulation of the cell death in cancer cells by means of an inhibition of NF-κB activity (Hasan *et al.,* 2010).

Additionally, alpha terpineol possesses a huge range of biological applications as it shows an antihypertensive and antiproliferative result on human erythroleukemic cells (Sabino *et al.,* 2013), as well as anti-inflammatory properties (Held *et al.,* 2007). Therefore, the current study investigated the relationship between breast cancer and chemo preventive result of Alpha Terpineol to protect against DMBA (7,12-dimethylbenz(a)anthracene) induced mammary cancer in female Sprague Dawley rats.

15.2 Materials and Methods:

15.2.1 Chemicals:

DMBA was procured from Sigma Chemical Company St. Louis, MO, USA. All Other chemicals and materials used in the study are of highest purity and standards which are commercially available.

15.2.2 Experimental Animals:

Sprague–Dawley rats (Female, 130 -180g body weight) were used for the study. The experiments were planned and executed in compliance with ethical standards approved by the Institutional Animal Ethics Committee (IAEC) of Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore (AIW: IAEC: 2017: ZOO: 01 dated02/12/2017). The selected rats were kept in plastic cages at the institutional animal house and kept at room temperature of 22ºC under 12 h light/dark cycles. All the animals were fed with standard food and water adlibitum.

15.2.3 Tumour Induction and Drug Treatment:

The DMBA is a powerful carcinogenic agent and is used to induce tumours in animals. Rats were treated twice per week for 4 weeks with DMBA (25 mg/kg body weight dissolved in olive oil) orally. After the experimental period, the animals were fasted overnight and sacrificed by cervical decapitation, the blood was collected from the control and the experimental groups of rats; the serum was separated out for the biochemical analysis. All the vital organs were washed with ice cold saline, removed, trimmed and stored.

15.2.4 Experimental Design:

Animals are grouped and treatment was given as follows,

- **Group I:** Normal Control {rats were given normal olive oil orally for 16 weeks}.
- **Group II:** DMBA (25mg/Kg) {rats were treated twice per week for 4 weeks with DMBA (25 mg/kg body weight dissolved in olive oil) orally and then continued with or without the vehicle for additional 12 weeks}
- **Group III:** DMBA + Tamoxifen (5mg/Kg) {rats were treated twice per week for 4 weeks with DMBA (as in Group II). Subsequently, they were treated with tamoxifen (5 mg/kg body weight dissolved in olive oil orally) daily for 12 weeks}
- **Group IV:** DMBA + Alpha terpineol (20mg/Kg) {rats were treated with DMBA (as in Group II) for 4 weeks and subsequently, they were treated with Alpha terpineol 20mg/kg and continued for 12 weeks}
- **Group V:** DMBA + Alpha terpineol (40mg/Kg) {rats were treated with DMBA (as in Group II) for 4 weeks and subsequently, they were treated with Alpha terpineol 40mg/kg and continued for 12 weeks}
- **Group VI:** Alpha terpineol alone (20mg/Kg) {rats were treated with Alpha terpineol alone 20mg/kg for 16 weeks to find out cytotoxicity, if any, induced by Alpha terpineol}.

15.2.5 Serum Biochemical Parameters:

Appropriate auto analyser kits (Roche Diagnostics, Indianapolis, USA) were employed for the assessment of various biochemical parameters like alkaline phosphatase (ALP), serum glutamate oxaloacetate transaminase (SGOT), serum glutamate pyruvate transaminases (SGPT), total protein (TP), creatine, urea, uric acid, total cholesterol and Triglycerides.

15.3 Antioxidant Evaluation in Breast Tissue:

Breast tissues were removed and blood was wiped, blotted and gauged with super cold PBS. In potassium chloride solution (1.15 % w/v) tissue homogenate has been prepared (10 % w/v). To get a clear supernatant for estimating anti-oxidant and biochemical parameters, the homogenate obtained was centrifuged for 10 min at 8000 rpm (4°C).

15.4 Statistical Analysis:

The values are expressed as mean values of six rats in each group ± standard deviation. One-way analysis of variance (ANOVA) followed by Duncan's multiple comparisons with least significance difference test were done by statistical software package SPSS 17. A value of $p < 0.01$ was considered statistically significant.

15.5 Result and Discussion

The cholesterol level was analysed in all the experimental groups of animals. In the control group, cholesterol level was found to be 83.63 ± 2.09mg/dl. In the case of DMBA treated

rats, cholesterol level was found to be increased to 94.48 ± 3.04 mg/dl, which was significantly decreased in Alpha terpineol treated rat, 91.54 ± 1.40 and 87.16 ± 1.98 mg/dl respectively. The level of uric acid was found to be significantly decreased in both the Alpha terpineol treated groups, as compared with the DMBA treated animals. Alpha terpineol alone treated group (20mg/kg) did not show any marked change when compared to normal control with regard to the uric acid. In all the control and experimental groups of animals the serum alkaline phosphate level was studied. The ALP level was found to be 76.20 ± 1.83IU/L in the control group. In the case of DMBA treated rats ALP level was found to be enhanced to 95.00 ± 1.56 IU/L, which was markedly decreased in Alpha terpineol treated rats 20mg/kg and 40mg/kg (78.60 ± 1.23 and 78.80 ± 1.55 IU/L) respectively.

The total protein content was determined in all the treated and control groups of rats. In the control group, total protein level was found to be 4.50 ± 0.21 IU/L. In the case of DMBA treated rats total protein level was found to increase to 6.87 ± 0.23IU/L, which was considerably ($P < 0.05$) decreased in Alpha terpineol treated groups 20mg/kg and 40mg/kg (4.85 ± 0.15 and 4.68 ± 0.18IU/L) respectively. The treatment of Alpha terpineol considerably decreased the triglyceride level in 20 and 40 mg/kg treated groups (132.2 ± 5.40 and 133.2 ± 5.89mg/dl) when compared with DMBA treated animals (145.80 ± 7.12mg/dl). The effect of lower dose was found to be significantly higher than the higher dose of Alpha terpineol. The BUN level was analysed in all the treated and control groups of rats. In the untreated group, BUN level was determined to be 16.89 ± 0.44mg/dl. In the case of DMBA treated rats, BUN was found to be increased to 19.57 ± 0.22 mg/dl, which was significantly decreased in Alpha terpineol treated rat,17.88 ± 0.46 and 17.96 ± 0.43 mg/dl respectively.

SGOT level was discovered to be reduced considerably in all the other treated groups when compared with DMBA treated group (39.13 ±1.13 IU/L). The lower dose of Alpha terpineol (20 mg/kg) was found to be more significant (36.31 ± 0.88 IU/L) in comparison with the higher dose, Alpha terpineol 40 mg/kg (36.90 ± 1.40 IU/L). SGPT level shown in Table I indicated an elevated level of enzyme in DMBA treated rat (40.04 ± 0.82 IU/L) when compared to the normal animals (35.28 ± 0.98 IU/L). Alpha terpineol treated groups differ significantly from DMBA treated rat (35.01 ± 1.52 and 34.45 ± 0.88 IU/L) (Table.15.a).

Table 15.a: Effect of Alpha terpineol on serum biochemical parameters

Parameters	**Cholesterol (mg/dl)**	**Uric acid (mg/dl)**	**ALP (IU/L)**	**Total protein (gm/dl)**	**Triglyceride (mg/dl)**	**Blood Urea Nitrogen (mg/dl)**	**SGOT (IU/L)**	**SGPT (IU/L)**
Normal control	83.63 ± 2.09b	4.01 ± 0.44b	76.2 ± 1.83b	4.50 ± 0.21b	116.60 ± .92b	16.89 ± 0.44b	33.62 ± 1.34	35.28 ± 0.98
DMBA (25mg/kg)	94.48 ± 3.04a	6.28 ± 0.32a	95.0 ± 1.56a	6.87 ± 0.23a	145.80 ± 7.12a	19.57 ± 0.22a	39.13 ± 1.13	40.04 ± 0.82
DMBA (25mg/kg) + Tamoxifen(20mg/kg)	86.01 ± 2.81b	4.19 ± 0.4b	77.60 ± 1.98b	4.74 ± 0.2b	120.20 ± 6.01b	17.68 ± 0.35b	36.32 ± 0.81	37.88 ± 0.78

Parameters	**Cholesterol (mg/dl)**	**Uric acid (mg/dl)**	**ALP (IU/L)**	**Total protein (gm/dl)**	**Triglyceride (mg/dl)**	**Blood Urea Nitrogen (mg/dl)**	**SGOT (IU/L)**	**SGPT (IU/L)**
DMBA (25mg/kg) + Alpha terpinol (20mg/kg)	91.54 ± 1.40a	5.61 ± 0.38a	78.60 ± 1.23b	4.85 ± 0.15b	132.20 ± 5.40b	17.88 ± 0.46b	36.31 ± 0.88	35.01 ± 1.52
DMBA (25mg/kg) + Alpha terpenol (40mg/kg)	87.16 ± 1.98b	4.24 ± 0.26b	78.80 ± 1.55b	4.68 ± 0.18b	133.20 ± 5.89b	17.96 ± 0.43b	36.90 ± 1.40	34.45 ± 0.88
Alpha terpenol (20mg/kg)	84.39 ±1.99b	4.02 ± 0.34b	76.40 ± 1.87b	4.60 ± 0.13b	119.0 ± 5.74b	17.41 ± 0.60b	36.01 ± 1.45	34.40 ± 0.79
F- test	*	**	**	**	*	*	*	*
SEd CD (p<0.05)	1.448 3.795	0.752 1.971	5.491 14.386	0.749 1.963	3.724 9.758	0.586 1.535	0.758 1.986	0.632 1.657

Values are expressed as the mean ± S.E.M (n=6); Statistical significance (p) calculated by one way ANOVA followed by Duncan's multiple range test. Significant levels were ** $p < 0.01$; * $p < 0.05$; NS –Non significant. *In vivo* antioxidant studies were carried out on DMBA induced mammary carcinoma in female Sprague Dawley rats because oxidative stress is associated with cancer. The following antioxidant enzymes were determined in the liver tissues of all tested rats. A deep decrease of SOD level was observed in DMBA induced rats (1.06 ± 0.26 U/mg) when compared to normal rats (1.90 ± 0.61U/mg). In the case of DMBA induced rats treated with Alpha terpineol extract (20 mg/kg and 40mg/kg U/mg), the SOD levels found to be increased to (1.84±0.56 and 2.07 ± 0.30 U/mg) as seen in Table II. However, the study was found to be non-significant. A deep decrease of CAT level was observed in DMBA induced rats (15.65 ± 1.69 U/mg) when compared to normal rats (26.44±3.60U/mg). The decrease seems to be statistically significant. When DMBA induced rats were treated with Alpha terpineol extract (20 mg/kg and 40mg/kg), the CAT levels significantly increased to (23.88±1.36 and 24.17 ± 1.60 U/mg). The present study showed a significant decrease in GPx in the DMBA treated group (21.36 ± 1.34 U/mg) when compared with normal control rat (31.27 ± 1.46 U/mg). Both Alpha terpineol treatment groups (20 and 40 mg/kg) showed a significant increase in GPx (29.73 ± 0.80 and 29.41 ± 1.10 U/mg) when compared with DMBA treated group. A deep decrease of GSH level was observed in DMBA induced rats (0.41 ± 0.11 µg/mg) when compared to normal rats (1.33 ± 0.65µg/mg). In the case of DMBA induced rats, GSH level of both the Alpha terpineol treated groups (20 and 40 mg/kg) was found to increase to 1.28 ± 0.54 and 1.27 ± 0.51µg/mg respectively. With administration of Alpha terpineol to the DMBA induced rat, the level of LPx was found to be significantly decreased compared to that of DMBA treated rat. LPx in both the treatment groups Alpha terpineol 20 mg/kg (33.03 ± 1.56 µg of MDA/mg) and 40 mg/kg (33.06± 1.64 µg of MDA/mg) were found to be decreased (Table II). Alpha terpineol alone (20mg/kg) did not show any marked difference when compared to normal control in the LPX (Table.15.b).

Table 15.b: Effect of Alpha terpineol on antioxidant parameters

Parameters	SOD (U/mg protein)	Catalase (U/mg protein)	GPX (U/mg protein)	GSH (µg/mg tissue)	LPX (µg of MDA/mg protein)
Normal control	1.90±0.61a	26.44±3.60	31.27±1.46	1.33±0.65	30.71±0.63
DMBA (25mg/kg)	1.06±0.26b	15.65±1.69b	21.36±1.34b	0.41±0.11b	35.66±0.80a
DMBA (25mg/kg) +Tamoxifen(20mg/kg)	1.82±0.63a	24.59±1.35a	30.01±1.38a	1.30±0.66a	33.36±1.36b
DMBA (25mg/kg) + Alpha terpineol(20mg/kg)	1.84±0.56a	23.88±1.36a	29.73±0.80a	1.28±0.54a	33.03±0.1.56b
DMBA (25mg/kg) + Alpha terpineol(40mg/kg)	2.07±0.30a	24.17±0.86a	29.41±1.10a	1.27±0.51a	33.06±1.64b
Alpha terpineol (20mg/kg)	1.83±0.58a	23.70±1.60a	29.32±1.00a	1.26±0.49a	32.86±1.15b
F- test	NS	*	*	NS	*
Sed CD ($p < 0.05$)	0.3280.859	1.2353.236	0.7642.003	0.3350.878	0.7922.076

Values are expressed as the mean ± S.E.M (n=6); Statistical significance (p) calculated by one way ANOVA followed by Duncan's multiple range test. Significant levels were ** $p < 0.01$; * $p < 0.05$; NS –Non significant.

Biochemical examination of DMBA induced rats in the present study showed marked elevation in ALP, SGOT, and SGPT indicating the hepatotoxic effect of the tumor (Sreejaya *et al.,* 2017). Similarly, triglycerides, lipid profile, and protein profile were also normalized by treatment with Alpha terpineol. Hence, the present study shows that Alpha terpineol extract can mediate suppression of elevated levels of ALP in DMBA-induced rats which suggests the possibility of this test compound to stabilize the plasma membrane (Kalaiselvi *et al.,* 2014). This is also in accordance with the work of Dharmalingam *et al.,* 2016, who reported that a tri herbal formulation of seed coats of Terminalia chebula, dry seeds of E. ganitrus, and leaves of P. cineraria had potential in treating DMBA-induced mammary carcinoma in female Sprague Dawley rats. Uric acid is regarded as a marker of oxidative stress and as an end product of purine metabolism. At its elevated level, it can act as a pro-oxidant. The rapid destruction of tumor cells leads to a release of their intracellular content into the circulation with a marked rise in potassium and phosphate. The increased nucleotide release and turnover results in increased synthesis of uric acid. In the present study, a decrease in uric acid levels in Alpha terpineol treated groups indicate restoration of a normal renal function (Zahan *et al.,* 2011).

Intracellular alterations in cholesterol were accompanied by specific changes of cholesterol in plasma (Sreejaya *et al.,* 2017). The present study reports that Alpha terpineol significantly restores cholesterol level to near normal value. The liver produces triglycerides that may change to cholesterol. In the present study, Alpha terpineol treatment in both doses (20 and 40mg/kg) could restore the total protein content and lipid to a near-normal level suggesting

the stabilization of endoplasmic reticulum leading to protein synthesis. Decreased SOD activity was observed in various cancerous conditions (Selvendiran *et al.,* 2003).

The enzymic antioxidant catalase is widely distributed in all tissues and catalyzes the breakdown of hydrogen peroxide produced by tumor cells. The source of hydrogen peroxide is mainly SOD-mediated dismutation of superoxide radicals, which is generated by various enzyme systems as well as by non-enzymic pathways. Several reports have cited decreased activities of SOD and catalase in various carcinogenic conditions (Kamaraj *et al.,* 2009). CAT is an intracellular antioxidant enzyme that promotes the removal of hydrogen peroxide (H_2O_2) and its conversion to molecular oxygen (O_2) and water. CAT activity is directly regulated by the build-up of H_2O_2 in the tissues (Ogueji *et al.,* 2017a; Nwani *et al.,* 2017). The reduced activities of catalase found in the cancerous condition may be due to the exhaustion of these enzymes in catalyzing the overproduction of hydrogen peroxide by the malignant cells. Several studies had reported the decreased activities of GPx in many cancerous conditions. It is an important intracellular enzyme that breaks down hydrogen peroxide (H_2O_2) to water; and lipid peroxides to their corresponding alcohols mainly in the mitochondria and sometimes in the cytosol (Ighodaro *et al.,* 2018).

The protection of GSH is by scavenging the free radicals, acting as a cofactor for antioxidant enzymes, and accelerating xenobiotic detoxification (Morsy *et al.,* 2020). The decrease in GSH levels in the present study may also be due to a reduction in the substrate obtainable for GSH synthesis. Periyasamy *et al.,* 2015 reported that breast cancer-bearing rats showed an increased level of mammary lipid peroxidation, which involves the process of oxidative degradation of polyunsaturated fatty acids (PUFA), that occur in biological membranes causing the impaired structural integrity, decreased membrane fluidity, inactivation of several membrane-bound enzymes and functions (Massaccesi *et al.,* 2020). Thus, it is reasonable to speculate that carcinogen exposure may result in the peroxidation of PUFA and finally leads to cellular deterioration in the breast tissue (Periyasamy *et al.,* 2015). Bhat *et al.,* 2008 also suggested a strong correlation between carcinogen-induced breast cancer and the initiation of LPO. This is in line with the present study which shows increased lipid peroxidase in DMBA induced rats.

15.6 Conclusion:

The present study evaluated the Biochemical parameters and Antioxidant activity of Methanol extract of Alpha terpineol against DMBA induced Female Sprague Dawley Rats. The Methanol extract treatment of 20mg/kg and 40mg/kg inhibited the tumour activity by restoring the serum biochemical parameters and antioxidant activity. The restoration of these parameters to near normal levels indicate the anti-cancer effect of Alpha terpineol against DMBA induced Female Sprague Dawley Rats.

15.7 References:

1. Alakhova, D.Y. and Kabanov, A.V., 2014. Pluronics and MDR reversal: an update. *Molecular pharmaceutics*, *11*(8), pp.2566-2578.
2. Bauer, K., Garbe, D. and Surburg, H., 2008. *Common fragrance and flavor materials: preparation, properties and uses*. John Wiley & Sons.

3. Beckwitt, C.H., Brufsky, A., Oltvai, Z.N. and Wells, A., 2018. Statin drugs to reduce breast cancer recurrence and mortality. *Breast Cancer Research*, *20*(1):1-11.
4. Bhat, S., Rao, G., Murthy, K.D. and Bhat, P.G., 2008. Seasonal variations in markers of stress and oxidative stress in rats. *Indian Journal of Clinical Biochemistry*, 23(2):191-194.
5. Dharmalingam, Karthick., Ramakrishnan, Stalin., Panchanatham, Sachidanadam.and Palanivelu, Shanthi., 2016. Chemotherapeutic efficacy of tridham and 1, 2, 3, 4, 6-penta-o-galloyl-β-dglucose on antioxidants status and tumour markers in experimental mammary carcinoma in Sprague-Dawley rats. *Asian J Pharm Clin Res.*, 9(5):202-208.
6. Hassan, S.B., Gali-Muhtasib, H., Göransson, H. and Larsson, R., 2010. Alpha terpineol: a potential anticancer agent which acts through suppressing NF-κB signalling. *Anticancer Research*, 30(6):1911-1919.
7. Held, S., Schieberle, P. and Somoza, V., 2007. Characterization of α-terpineol as an anti-inflammatory component of orange juice by in vitro studies using oral buccal cells. *Journal of agricultural and food chemistry*, 55(20):8040-8046.
8. Ighodaro, O.M. and Akinloye, O.A., 2018. First line defence antioxidants-superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPX): Their fundamental role in the entire antioxidant defence grid. *Alexandria journal of medicine*, *54*(4):287-293.
9. Itani, W.S., El-Banna, S.H., Hassan, S.B., Larsson, R.L., Bazarbachi, A. and Gali-Muhtasib, H.U., 2008. Anti-colon cancer components from Lebanese sage (*Salvialibanotica*) essential oil: mechanistic basis. *Cancer biology & therapy*, 7(11):1765-1773.
10. Jemal, A., Bray, F., Center, M.M., Ferlay, J., Ward, E. and Forman, D., 2011. Global cancer statistics. *CA: a cancer journal for clinicians*, *61*(2), pp.69-90.
11. Kalaiselvi, M., Gomathi, D., Ravikumar, G., Devaki, K. and Uma, C., 2014. Therapeutic effect of *Ananuscomosus* peel on breast cancer induced by 7, 12-dimethylbenz (alpha) anthracene. *Plant Science Today*, 1(1):13-21.
12. Kamaraj, S., Ramakrishnan, G., Anandakumar, P., Jagan, S. and Devaki, T., 2009. Antioxidant and anticancer efficacy of hesperidin in benzo (a) pyrene induced lung carcinogenesis in mice. *Investigational New Drugs*, *27*(3):214-222.
13. Massaccesi, L., Galliera, E. and Romanelli, M.M.C., 2020. Erythrocytes as markers of oxidative stress related pathologies. *Mechanisms of Ageing and Development*, 191:111333.
14. Morsy, M.A., Abdel-Aziz, A.M., Abdel-Hafez, S., Venugopala, K.N., Nair, A.B. and Abdel-Gaber, S.A., 2020. The Possible Contribution of P-Glycoprotein in the Protective Effect of Paeonol against Methotrexate-Induced Testicular Injury in Rats. *Pharmaceuticals*, 13(9):223.
15. Nwani CD, Somdare PO, Ogueji EO, Nwani JC, Ukonze JA, Nwadinigwe AO., 2017. Genotoxicity assessment and oxidative stress responses in freshwater African catfish Clarias gariepinus exposed to fenthion formulations. *Drug Chem Toxicol*., 40(3):273–280.
16. Ogueji EO, Nwani CD, Iheanacho SC, Mbah CE, Okeke OC, Ibrahim BU., 2017. Acute toxicity of ibuprofen on selected biochemical and oxidative stress parameters of liver in Clarias gariepinus juveniles (Burchell, 1822). *J Entomol Zool Stud*., 5(4):1060–1068.
17. Othman, E. and Ahmed, A., 2013. Challenges of mega construction projects in developing countries. *Organization, technology & management in construction: an international journal*, *5*(1), pp.730-746.

18. Periyasamy, K., Baskaran, K., Ilakkia, A., Vanitha, K., Selvaraj, S. and Sakthisekaran, D., 2015. Antitumor efficacy of tangeretin by targeting the oxidative stress mediated on 7, 12-dimethylbenz (a) anthracene-induced proliferative breast cancer in Sprague–Dawley rats. *Cancer chemotherapy and pharmacology*, 75(2):263-272.
19. Rao, K.R. and Yip, P., 2014. *Discrete cosine transform: algorithms, advantages, applications*. Academic press.
20. Sabino, E.C., Ribeiro, A.L., Salemi, V.M., Di Lorenzo Oliveira, C., Antunes, A.P., Menezes, M.M., Ianni, B.M., Nastari, L., Fernandes, F., Patavino, G.M. and Sachdev, V., 2013. Ten-year incidence of Chagas cardiomyopathy among asymptomatic Trypanosoma cruzi–seropositive former blood donors. *Circulation*, *127*(10), pp.1105-1115.
21. Selvendiran, K., Prince Vijeya Singh, J., Baba Krishnan, K., Sakthisekaran, D., 2003. Cytoprotective effect of piperine against benzo(a)pyrene induced lung cancer with reference to lipid peroxidation and antioxidant system in Swiss albino mice. *Fitoterapia*, 74:109–115.
22. Sreejaya, S.B., Archana, D. and Santhy, K.S., 2017. Biochemical changes in the serum of experimental animals treated with acorus calamus rhizome. *Studies on Ethno-Medicine*, 11(3):216-220.
23. Youlden, D.R., Cramb, S.M., Yip, C.H. and Baade, P.D., 2014. Incidence and mortality of female breast cancer in the Asia-Pacific region. *Cancer biology & medicine*, 11(2):101.
24. Zahan, R., Alam, M., Islam, S., S Chowdhury, N., B Hosain, S., Mosaddik, A., Jesmin, M. and Haq, M.E., 2011. Anticancer activity of *Alangium salvifolium* flower in Ehrlich Ascites carcinoma bearing mice, 7(3):254-262.

ISBN: 978-93-90847-17-4

16. Antitumor Activity of Allicin on Lung Cancer in Benzopyrene Induced Swiss Albino Mice Model

Zeenath, Gunavathi V., Santhy, K. S.

Department of Zoology,
Avinashilingam Institute for Home Science and
Higher Education for Women, Coimbatore.

Abstract:

The present study aimed to assess the efficacy of Allicin, an important compound for its antitumor activity in benzopyrene induced lung tumour in mice model. Body weight, lung weight, various haematological parameters were analysed. Increase in body weight and reduction in lung weight were observed in Allicin treated groups. RBC, HB and platelets were seen as near normal and reduction in WBC were observed in Allicin 20 and 40mg/kg. In a WBC differential count, increase in neutrophil and a decrease in lymphocyte, monocyte, eosinophil and basophil in benzopyrene treated mice was observed after the Allicin treatment. The results of this study indicated the potential benefits and antitumor activity of Allicin on benzopyrene induced Swiss albino mice.

Keywords: Benzo(a)pyrene, Lung cancer, Allicin, and Hematological parameters.

16.1 Introduction:

Lung cancer is the major common cancer in women and men worldwide. It is a leading cause of cancer death in under developed countries. Metastatic ailment is the most common cause of lung cancer death. In modern medicine, various drugs and therapies are available in the market. But the biggest drawbacks are serious side effects and economic burden. Hence, the present study was aimed to assess the efficacy of isolated compound of Allicin for its antitumor activity in benzopyrene induced lung cancer in Swiss albino mice. Benzopyrene, a polycyclic hydrocarbon in tobacco, plays a major role in the aetiology of lung tumour. It is metabolically activated into benzopyrene 7, 8-diol-9, 10-epoxide, that reacts with DNA predominantly to form DNA adduct and progression of the disease (Mo *et al.,* 2021). The carcinogenesis involves forming of free radicals and peroxidation products, which damages many cellular macromolecules (Kim *et al.,* 2000a).

Allicin is an organo-sulphur compound that chokes malignant growth development in vitro in lung disease, hepatocellular carcinoma, melanoma, colorectal adenocarcinoma (Rajput *et al.,* 2012) and glioma cells (Li *et al.,* 2018). Allicin has been shown to be effective in killing cancer cells derived from kidney (Song *et al.,* 2015), liver, ovary, pancreas, stomach, brain (Cha *et al.,* 2012), bone and lung (Tyagi *et al.,* 2014). It can animate the invulnerable framework to deliver some bioactive anticancer elements which hinder tumour cells and can likewise invigorate the arrival of numerous cytokines which improve the resistant framework (Lichota *et al.,*2018). The present study was designed to analyze the antitumor activity of Allicin against lung cancer through the analysis of haematological parameters, body weight and lung weight.

16.2 Methods and Materials:

16.2.1 Chemicals:

2, 2- diphenyl-1-picrylhydrazyl, Benzo(a)pyrene and Allicin were purchased from Sigma Aldrich chemical company. Ferric chloride and Trichloroacetic acid (TCA) from Hi media and Merck. Ascorbic acid was procured from SDFCL (Biosar, India). All the other solvents and chemicals were of analytical grade.

16.3 *In Vivo* Studies on Benzopyrene Induced Lung Cancer in Swiss Albino Mice:

16.3.1 Experimental Animals:

Healthy male Swiss albino mice (20-25g body weight) were used for the study. The experiments were performed after the approval from the Institutional Animal Ethical Committee (AIW: IEAC.2017: ZOO: 04) and in accordance with the recommendation for the proper care and use of the laboratory animals. Animals were kept in polypropylene cages with sawdust bedding and they were maintained in a controlled environment condition of temperature and humidity on alternatively 12 h light/dark cycles. Standard pellets were given as diet and water was provided ad libitum.

16.3.2 Acute Toxicity Study:

Healthy Swiss albino mice, starved overnight, were divided in to six groups. Group I – V animals were orally fed with Allicin in increasing dose levels of 0, 25, 50, 75 and 100mg/Kg body weight. The animals were observed continuously for first 2 h for any gross change in behavioural, neurological and autonomic profiles or any other symptoms of toxicity and mortality if any, and intermittently for the next 6 h and then again after 24 h, 48 h and 72 h for any lethality or death.

16.3.3 Tumour Induction and Drug Treatment:

Benzopyrene is a powerful carcinogenic agent and is used to induce tumours in animals. Mice were treated twice per week for 4 weeks with benzo(a)pyrene (50 mg/kg body weight dissolved in olive oil) orally. After the experimental period, the animals were fasted overnight and sacrificed, the blood was collected from the control and the experimental groups of mice; the serum was separated out for the biochemical analysis. All the vital organs were washed with ice cold saline, removed, trimmed and stored. Finally, tumour volume, and tumour weight were studied.

16.3.4 Experimental Design:

Animals are grouped and treatment was given as follows,

- **Group I:** Normal Control {mice were given normal olive oil orally for 16 weeks}.

- **Group II:** Benzopyrene (50mg/Kg) {mice were treated twice per week for 4 weeks with benzo(a)pyrene (50 mg/kg body weight dissolved in olive oil) orally and then continued with or without the vehicle for additional 12 weeks}
- **Group III:** Benzopyrene + Paclitaxel (5mg/Kg) {mice were treated twice per week for 4 weeks with B(a)p (as in Group II). Subsequently, they were treated with paclitaxel (5 mg/kg body weight dissolved in olive oil orally) daily for 12 weeks}
- **Group IV:** Benzopyrene + Allicin (20mg/Kg) {mice were treated with B(a)p (as in Group II) for 4 weeks and subsequently, they were treated with Allicin 20mg/kg and continued for 12 weeks}
- **Group V:** Benzopyrene + Allicin (40mg/Kg) {mice were treated with B(a)p (as in Group II) for 4 weeks and subsequently, they were treated with Allicin 40mg/kg and continued for 12 weeks}
- **Group VI:** Allicin alone (20mg/Kg) {mice were treated with Allicin alone 20mg/kg for 16 weeks to find out cytotoxicity, if any, induced by Allicin}.

16.4 Body Weight and Lung Weight Analysis:

A careful record of body weight of all the animals belonging to normal control and different treatment groups was kept throughout the study. The animals were weighed at the beginning of the experiment and then weekly, and finally before sacrifice. At the end of the study, lungs were excised from the mice, washed in normal saline and the weights were measured using digital weighing balance.

16.5 Haematological Analysis:

Haemoglobin (Hb), Red blood cell (RBC), White blood cell (WBC) and platelet (PLT) count were estimated using an auto haematology analyzer (BC-2800 Vet, Mindray Medical Instrumentation, China). Differential leukocyte counts were determined from the blood smears stained with Leishman-Giemsa stain.

16.6 Statistical Analysis:

All numerical data is presented as the mean value ± standard deviation. All the *in vitro* experiments were done in triplicate, and the experiments were repeated at least thrice. The statistical software SPSS version 17.0 was used for the analysis. p value <0.01 was considered significant. *In vivo* antitumor activity of Allicin was determined by applying One-way ANOVA followed by Duncan's multiple range test. Statistical difference was considered significant if p value was less than 0.05 and 0.01.

16.7 Result and Discussion:

16.8 Acute Toxicity Study:

The results of acute toxicity study of Allicin are presented in Table 16.a. No mortality or change in body weight was observed in mice at a dose level of Allicin 0, 25, 50 and 75 mg/Kg body weight. Some clinical signs such as tremors, pilo erection and abdominal

breathing were observed after the oral dosing of 100 mg/Kg but no mortality or change in body weight was observed. These observations indicated that the calculated LD_{50} value (Dixons likelihood method) for the oral doses of the Allicin was found to be more than 100 mg/Kg body weight, accordingly 20 and 40 mg/Kg body weight were taken as low and high dose of Allicin for the experiment.

Table 16.a: Clinical signs of toxicity observed during acute oral toxicity study of Allicin

Dose of Allicin (mg/Kg b.wt)	Latency	Symptoms
0	-	None
25	-	None
50	-	None
75	-	None
100	-	Tremor, Piloerection, abdominal breathing

16.9 Effect on Body Weight and Tumor Growth Analysis:

Table 16.2 depicts the body and lung weight of animals in various treatment groups. Throughout the experimental period, except Group I (Control) all the animals decreased body weight. After tumour induction, at the end of the 16th week, when compared with tumour bearing group II (14.27 ± 1.24mg), the treatment groups III, IV and V (positive control and Allicin 20 and 40mg/Kg) showed increase in body weight 24.50 ± 1.99, 23.66 ± 0.98 and 24.08 ± 1.02 respectively. Allicin alone (20mg/Kg) treated group recorded a weight of 24.42 ± 1.34 when compared with normal control (25.55 ± 1.89) indicates that Allicin has no significant adverse effects on the normal weight. Accordingly, the lung weight which was found to be high in the Group II (342.05±17.30mg) mice was significantly ($p<0.05$) decreased by the paclitaxel treatment and Allicin treatment (20 and 40mg/Kg) (Table 16.b).

Table 16.b: Effect of Allicin on body weight and lung weight of treated groups of Swiss albino mice

Parameters	Body weight (g)	Lung weight (mg)
Normal control	25.55 ± 1.89^{a}	223.58 ± 15.82^{b}
Benzopyrene (50mg/Kg)	14.27 ± 1.24^{b}	342.05 ± 17.30^{a}
Benzopyrene(50mg/Kg) + Paclitaxel (5mg/Kg)	24.50 ± 1.19^{a}	276.59 ± 8.62^{b}
Benzopyrene(50mg/Kg) + Allicin (20mg/ Kg)	23.66 ± 0.98^{a}	261.8 ± 8.72^{b}
Benzopyrene(50mg/Kg) + Allicin (40mg/ Kg)	24.08 ± 1.02^{a}	255.8 ± 9.25^{b}
Allicin alone (20mg/Kg)	24.42 ± 1.34^{a}	249.6 ± 9.63^{b}
F-test	**	**

Parameters	Body weight (g)	Lung weight (mg)
Sed	0.83	7.65
CD ($p< 0.05$)	2.18	20.06

Values are expressed as the mean ± S.E.M (n=6); Statistical significance (p) calculated by one way ANOVA followed by Duncan's multiple range test. Significant levels were ** $p < 0.01$; * $p < 0.05$; NS –Non significant.

16.10 Effect of Allicin on Haematological Parameters:

In our present study, Benzopyrene induced mice showed reduction in haemoglobin and RBC count, when compared to control group, which is an indication of anaemia. Anaemia might occur due to the free radicals resulting from benzopyrene metabolism which leads to direct liver injury.

The free radicals liberated from the liver into the circulation affect the erythrocytic membranes leading to the disturbed haematopoiesis, destruction of erythrocytes and reduction in the rate of their formation and their enhanced removal from the circulation (Nithya *et al.,* 2014).

White blood cells, lymphocytes and neutrophils play a crucial role in the systemic inflammatory response, often observed in cancer patients. Increase in WBC count and alterations in differential count (lymphocytes, monocytes, Eosinophils, Basophils and neutrophils) have been suggested as one of the hallmarks of carcinogenesis.

In the current study the lung cancer bearing animals showed elevated WBC count and neutrophil count with reduced lymphocyte, monocyte, Eosinophils and Basophils in Benzopyrene induced Swiss albino mice. In a differential count of WBC, a significant ($p< 0.05$) decrease in monocyte, Lymphocytes, basophils and eosinophil and an increase in Nutrophilsin benzopyrene induced Swiss albino mice were observed (Sreejaya and Santhy, 2014).

Lymphocytes were significantly reduced in number, in response to stressful condition. Moreover, lymphocytes migrate to the site of inflammations which may be due to toxic effect of benzopyrene (Nithya *et al.,* 2014). This was in accordance with the work of Saeed *et al.,* (2011) who attributed the increase in the WBC count to antioxidant activity of vitamin E and tocopherol quinone. Similarly, Allicin could increase the WBC count, due to its role in free radical scavenging (Hajzadeh *et al.,*2008).

Lymphocytes play akey role in all immune responses and are always directed against the specific foreign antigens (toxins). Lymphocytes were significantly decreased in number in response to stressful condition. In addition, lymphocytes migrate to the site of inflammations which may be resulting due to toxic effect of B(a)P. We observed a significant difference in circulating WBC after Allicin treatment and no significant difference was observed between control and Allicin alone treated animals (Table 16.c).

Table 16.c: Effect of Allicin on haematological parameters

Parameters	Haemoglobin (g/dl)	RBC ($x10^6$ cells/µl)	WBC ($x10^3$ cells/µl)	Neutrophils (%)	Monocytes (%)	Lymphocytes (%)	Eosinophils (%)	Basophils (%)	Platelets ($x10^3$ cells/µl)
Normal control	12.67 ± 0.88a	6.06 ± 0.61a	6.72 ± 1.16b	29.52 ± 1.93a	0.50 ± 0.08a	68.59 ± 1.56b	0.73 ± 0.15a	2.41 ± 0.04a	405.4 ± 9.47a
Benzopyrene (50mg/kg)	8.97 ± 0.69b	3.77 ± 0.82b	12.78 ± 0.99a	47.12 ± 1.56b	0.17 ± 0.05a	38.23 ± 1.71a	0.26 ± 0.14b	1.52 ± 0.02b	367.6 ± 16.00b
Benzopyrene(50mg/kg) + Paclitaxel (5mgmkg)	11.30 ± 0.96a	5.08 ± 0.82a	10.79 ± 1.07b	44.69 ± 1.10a	0.24 ± 0.03b	64.60 ± 1.68b	0.72 ± 0.17a	2.22 ± 0.01a	376.4 ± 15.78a
Benzopyrene(50mg/kg) + Allicin (20mg/kg)	11.56 ± 0.84a	4.86 ± 0.81a	11.00 ± 0.80b	44.80 ± 1.97a	1.41 ± 0.06b	67.24 ± 1.45b	0.66 ± 0.15a	2.17 ± 0.03a	378.2 ± 12.13a
Benzopyrene(50mg/kg) + Allicin (40mg/kg)	11.86 ± 0.90a	4.97 ± 0.58a	12.30 ± 0.71b	46.58 ± 1.51a	0.44 ± 0.09b	67.36 ± 1.66b	0.68 ± 0.12a	2.20 ± 0.05a	377.6 ± 16.30a
Allicin alone (20mg/kg)	11.47 ± 0.54a	4.82 ± 0.84a	10.73 ± 0.86a	44.53 ± 1.14a	1.26 ± 0.07b	66.43 ± 1.70a	0.55 ± 0.15a	2.03 ± 0.06a	376.2 ± 16.17a
F- test	**	**	**	**	*	**	**	NS	**
SED CD($p<0.05$)	0.5171.355	0.4801.258	0.6011.574	0.9962.609	0.1050.277	2.8917.575	0.097 0.255	0.275 0.722	9.20 24.108

Values are expressed as the mean ± S.E.M (n=6); Statistical significance (p) calculated by one way ANOVA followed by Duncan's multiple range test. Significant levels were ** $p < 0.01$; * $p < 0.05$; NS –Non significant.

16.11 Conclusion:

In the current study, significant increase in the activities of these membrane integrity enzymes in Allicin treated animals indicate the protective role of Allicin. From the above results, it can be inferred that Allicin possess significant anticancer effect through its role in prevention of erythrocyte membrane damage and restoration of membrane integrity.

16.12 Reference:

1. Cha, J.H., Choi, Y.J., Cha, S.H., Choi, C.H. and Cho, W.H., 2012. Allicin inhibits cell growth and induces apoptosis in U87MG human glioblastoma cells through an ERK-dependent pathway. *Oncology reports*, 28(1):41-48.
2. HAJZADEH, M., MOHAMMADIAN, N., RAHMANI, Z. and BEHNAM, R.F., 2008. Effect of thymoquinone on ethylene glycol-induced kidney calculi in rats.
3. Kim, H.S., Kwack, S.J. and Lee, B.M., 2000. Lipid peroxidation, antioxidant enzymes, and benzo [a] pyrene-quinones in the blood of rats treated with benzo [a] pyrene. *Chemico-biological interactions*, 127(2):139-150.
4. Li, C., Jing, H., Ma, G. and Liang, P., 2018. Allicin induces apoptosis through activation of both intrinsic and extrinsic pathways in glioma cells. *Molecular medicine reports*, 17(4):5976-5981.
5. Lichota, A. and Gwozdzinski, K., 2018. Anticancer activity of natural compounds from plant and marine environment. *International journal of molecular sciences*, 19(11):3533.

6. Mo, J., Au, D.W.T., Guo, J., Winkler, C., Kong, R.Y.C. and Seemann, F., 2021. Benzo [a] pyrene osteotoxicity and the regulatory roles of genetic and epigenetic factors: A review. *Critical Reviews in Environmental Science and Technology*, 1-39.
7. Nithya, G., Mani, R. and Sakthisekaran, D., 2014. Oral administration of thymoquinone attenuates benzo (a) pyrene induced lung carcinogenesis in male Swiss albino mice. *International Journal of Pharmacy and Pharmaceutical Sciences*, 6(7):260-263.
8. Rajput, S. and Mandal, M., 2012. Antitumor promoting potential of selected phytochemicals derived from spices: a review. *European Journal of Cancer Prevention*, 21(2):205-215.
9. Saeed, M., Villarroel, M., Reisner, A.T., Clifford, G., Lehman, L.W., Moody, G., Heldt, T., Kyaw, T.H., Moody, B. and Mark, R.G., 2011. Multiparameter Intelligent Monitoring in Intensive Care II (MIMIC-II): a public-access intensive care unit database. *Critical care medicine*, 39(5):952.
10. Song, B., Shu, Y., Cui, T. and Fu, P., 2015. Allicin inhibits human renal clear cell carcinoma progression via suppressing HIF pathway. *International journal of clinical and experimental medicine*, 8(11):20573-20580.
11. Sreejaya, S.B. and Santhy, K.S., 2014. Evaluation of Antitumor properties of Rhizome of Acorus calamus L using DALTON'S Ascites Lymphoma Bearing Swiss Albino mice. *Int J Pharm Bio Sci*, 5(4):119 – 125.
12. Tyagi, G., Pradhan, S., Srivastava, T. and Mehrotra, R., 2014. Nucleic acid binding properties of allicin: Spectroscopic analysis and estimation of anti-tumor potential. *Biochimicaet Biophysica Acta (BBA)-General Subjects*, 1840(1):350-356.

ABOUT THE EDITORS

Debabrata Das, *M.Sc., B.Ed., Ph.D. CES (IGNOU)*
Associate Professor and Head,
Department of Botany, IQAC Coordinator,
Government General Degree College, Lalgarh, Jhargram,
West Bengal, India.

Pampi Ghosh, *M.Sc., B.Ed., Ph.D.*
Assistant Professor (SSS) & HOD,
Department of Botany, Seva Bharati Mahavidyalaya,
Kapgari, Jhargram, W.B., India.

G. Maheswari, *M.Sc., Ph.D.*
Assistant Professor (SS),
Department of Zoology,
Avinashilingam Institute for Home Science and
Higher Education for Women,
Coimbatore, Tamil Nadu, India.

J. K. De, *M.Sc., Ph. D, Gold Medalist*
Member, XXIInd Ind. Antar. Sci. Expedt.
Former Scientist-D (Dy. Director)
Zoological Survey of India, M- Block
New Alipore, Kolkata.

KRIPA DRISHTI PUBLICATIONS

Price: ₹599

Kripa-Drishti Publications
A-503 Poorva Heights, Pashan-Sus Road, Near Sai Chowk,
Pune – 411021, Maharashtra, India.
Mob: +91 8007068686
Email: editor@kdpublications.in
Web: https://www.kdpublications.in

ISBN: 978-93-90847-17-4