BIODIVERSITY, ECOSYSTEM SERVICES AND GENETIC RESOURCES

Sima Sinha

Supriya Supal Surin

Shashi Kiran Tirkey

Nutan Verma

Niharika Yaduvanshi

BIODIVERSITY, ECOSYSTEM SERVICES AND GENETIC RESOURCES

Dr. Sima Sinha
Assistant Professor cum Jr. Scientist,Deptt. of Plant Breeding and Genetics
Bihar Agricultural University, Sabour

Dr. Supriya Supal Surin
Junior Scientist cum Assistant professor
Department of Genetics and Plant Breeding ,BAU Ranchi

Dr. Shashi Kiran Tirkey
Assistant professor cum junior scientist
Department of Genetics and Plant Breeding ,BAU,Ranchi

Dr. Nutan Verma
Junior Scientist came Assistant professor
Department of Genetics and Plant Breeding ,BAU, Ranchi

Niharika Yaduvanshi
Ph.D.Scholar
Department of Genetics and Plant Breeding, CSAUAT, Kanpur

PARMAR PUBLICATION

Edition-First –June, 2022

Note: Due care has been taken while editing and printing of the book. The manuscript contains individual author's sole authorized, duly credited/ copyrighted materials. So far as possible also, due care has been taken for any copyright issues.The author/publisher has attempted to trace and acknowledge the materials reproduced in this publication and apologize if permission and acknowledgements to publish in this form have not been given. If any material has not been acknowledged please write and let us know so that we may rectify it.

Not for Sale

ISBN 978-93-921932-2-3

978-93-921932-2-3

Published by:
Mr.Gajendra Parmar, Proprietor,
Parmar Publication
854, KG Ashram,Bhuinphod, Govindpur Road,
Dhanbad-828109,Jharkhand
Email id:gajendraparmar2562@gmail.com
Website: http://www.parmarpublisher.com
http://greenagriprofessionalsociety.com

Cover Page Photo Credits: Mr. Anupam Bharti,Deputy Director, (Agriculture/Horticulture) MGNREGA, Rural Development Department

Cover Page Design,Page Setting, Layout and Limted Copies Printing at Hyderabad by Shri N Suresh Babu

PREFACE

Biodiversity plays a major role in many ecosystem services such as replenishing oxygen through photosynthesis, pollination through bees, bumble bees, birds and bats etc., regulation of global climate, storage and retention of rain water in aquifers and reservoirs, control of floods and soil erosion, nutrient cycling, microbial waste treatment, biological control of pests, etc. Spread of agriculture is at the cost of wetlands, grasslands and forests. Destruction of habitats results in extinction of species. Intensive agriculture is also based on a few high yielding varieties. As a result, there is reduction in the genetic diversity. There is a tendency to grow economically important trees in pure strands, e.g., sal, teak. It drives away or annihilates other species found in forests. The pure strands are liable to be attacked by insects and pathogens.The present manuscript has been prepared for readers which should also be easily understood, reader should be able to scan the list, find the word they're looking for, and learn what it means,define and explain the words, terms, or phrases as simply and transparently as possible in the subject of Biodiversity,ecosystem analysis and Gentic resources..

The idea to bring out the entire such oftenly used terms in the form a book was long felt and stressed upon by the eminent speakers and contributors. Efforts have been taken to proof read the book before printing

The help rendered by Dr. Brajendra, Principal. Scientist, ICAR-IIRR, Hyderabad in framing of the book is thankfully acknowledged. However, we will consider our effort rewarded only if this book serves the requirements of the students/ field practitioners. Readers are welcome to point-out errors and lapses if any, and send their valuable suggestions for improving the quality of this book. It will be a privilege in inviting cooperation of all the faculty/students in removing any error in the book.

June ,2022 Authors/Editors

Table of Content

CHAPTER 1

BIODIVERSITY

Dr.K.Sumathi
Agricultural officer,
Commissionerate of Agriculture,Chepauk, Chennai, Tamil Nadu, 600 005

Biodiversity (Gk bios = life, diversity = forms) or **biological diversity** can be defined as the vast array of species of micro-organisms, algae, fungi, plants and animals occurring on the earth either in the terrestrial or aquatic habitat and the ecological complexes of which theyre a part. This includes diversity within species, between. species and of the ecosystem. Although India has only 2.4per cent of the world's land area, its share of **global species diversity** is an impressive **8.1 per cent**. India's biodiversity is one of the most important in the world. It is **one of the 12 mega-biodiversity countries** of the world. It has about 45,000 species of plants and twice as many species of animals.

MAGNITUDE OF BIODIVERSITY

According to the IUCN (2004), the total number of plants and animal species described so far is slightly more than 1.5 million, but we have no clear idea of how many species are yet to be discovered and described. Scientists have described the range of total number of world's species between 1.7- 1.8 million as in 2010. Total number of plants over earth are approximately 3, 21, 212; total number of vertebrates - 62, 305; total number of invertebrates - 1,305,250 and others (bacteria, cyanobacteria, algae) are approximately 51,563. Thus, number of species over earth totals to 1,740,330.

Biodiversity conservation means protection, upliftment and scientific management of biodiversity to maintain it at its optimum level and derive sustainable benefits for the present as well as future strategies. Thus, there are **three main reasons** to conserve the biological diversity which can be grouped in three categories:

- **Narrow utilitarian** (useful human products like food, fibres, drugs and medicines etc.)
- **Broadly utilitarian** (ecosystem services like provision of pollinators etc. climate regulation, flood and erosion control, ecological balance through nutrient cycling, microbial waste treatment, biological pest control and it also consider aesthetic and cultural values).
- **Ethical utilitarian** (every living species has an intrinsic value though it may not have any direct economic value, and also, every species has a right to live).

- Conservation strategies are broadly of two types - in situ and ex situ.

In situ conservation

In situ conservation means on site conservation. It is conservation and protection of the whole ecosystem and its biodiversity at all levels in **order to protect the threatened species**. However, it is not economically feasible to conserve all biological wealth and all the existing ecosystems. Two alternate methods are being used to save biodiversity. These arc **hotspots** and **protected areas.**

Hotspots

Hotspots are areas with high density of biodiversity or megadiversity which are also the most threatened ones. Ecologically hotspots are determined by four factors as:

- Number of species/species diversity.

- Degree of endemism.
- Degree of threat to habitat due to its degradation andfragmentation.
- Degree of exploitation.

- A hotspot is an area which faces serious threat from human activities and supports a unique biodiversity with representatives of evolutionary processes of speciation and extinction. It is also defined as a geographical zone or ecological niche with a large number of endemic plants.
- **Myers** (1988) initially identified 12 hot spots with 14%of plant species in an area of only 0.2%. Four more hotspots were added by-Myers (1991). Today the number of hotspots identified by ecologists is 34 covering an area less than 2% of land surface with about '20% ofhuman population living there. India has three hotspots - **Indo-Burma, Himalayas** and **Western Ghats - Sri Lanka.**

Protected areas

They are ecoiogicaL/biogeographical areas where biological diversity alongwith natural and cultural resources is protected, maintained and managed through legal or other effective measures. They are delimited on the basis of biological diversity, e.g., **cold desert** (Ladakh and Spiti), **hot desert** (Thar), **wetland** (Assam**), saline swampyareas** (Sunderbans, RannofKutch), mangroves, temperate forests, subtropical forests, etc.Protected areas include **national parks, sanctuaries** and **biosphere reserves.**

National Park

- **National parks** are larger areas of scenic and national beauty maintained for scientific, educational and recreational use. They are **not usually used for commercial extraction of resources.**The first

national park of India **was Jim Corbett National Park** (1936). Some early national parks of world are Yellowstone park (USA) and Royal Park (near Sydney, Australia).

Sanctuaries

Sanctuaries are the tracts of land with or without lake where wild **animals/fauna can take refuge without being hunted**. Other activities like collection of forest products, harvesting of timber, private ownership of land, tilling of land, etc. are allowed. India has 500 (368 in 1988) sanctuaries occupying over 3.6% of geographical area (India 2005).

Biosphere reserve

Biosphere reserves are multi-purpose protected areas which are meant for preserving genetic diversity in representative ecosystems of various natural biomes and unique biological communities by protecting wild populations, traditional life style of tribals and domesticated plant/animal genetic resources. Creation of biosphere reserve was initiated in 1975 under **MAB**programme of UNESCO. Till May 2002,408 biosphere reserves had been established in 94 countries.

Each biosphere reserve has following zones:

- **Core or Natural zone** : No human activity is allowed. The area is undisturbed and legally protected ecosystem.
- **Buffer zone :** It surrounds the core area. Limited human activity is allowed like resource use strategies, research and education.
- **Transition zone(Manipulation zone)** : It is the outermost or peripheral part of biosphere reserve where an active cooperation is present between reserve management and local people for activities like **settlements, cropping, recreation, forestry and other economic uses without disturbing ecology.** Transition zone has

different parts like forestry, agriculture, tourism and restoration regions. **Restoration region** is degraded area which is selected for restoration to near-natural form.

The importance of biosphere reserve includes :

- **Restoration :** Biosphere reserves help in restoration of degraded ecosystems and habitats.
- **Conservation :** They are the means of conserving genetic resources, species, ecosystems and landscapes without uprooting the local people.'
- **Development:** They ensure culturally, socially and ecologically sustainable economic development.
- **Monitoring :** There is a regular monitoring of development and conservation progress.
- **Education and research :** Each biosphere reserve supports education and information about research, restoration, conservation and developmental aspects at the national and global levels.

Sacred forests and lakes (= sacred grooves) are forest patches around places of worship which are held in high esteem by tribal communities. They are the most undisturbed forest patches (island of pristine forests) which are often surrounded by highly degraded landscapes. They are found in several parts of India, e.g., Karnataka, Maharashtra, Rajasthan.nota single branch is allowed to be cut from these forests. As a result many endemic species which are rare or have becomeextinct elsewhere can be seen to flourish here. '

Ex situ conservation

- It is the conservation outside the habitats which includes **offsite collections** and **gene banks.**
- **Offsite collections** are live collections of wild and ; domesticated species in botanical gardens, zoological parks, wildlife safari parks, arboreta (= arboretumsarbouretums), etc. Currently, there are more than 1500**botanical gardens** and **arboreta** (gardens with trees andshrubs) having more than 80,000 species.
- Many of them have **seed banks, tissue culture facilities** and other ex situ technologies.
- The number of zoos/zoological parks is more than 800. They have about 3000 species of mammals, birds, reptiles and amphibians.
- Most of them have well managed **captive breeding programmes**.
- As a result, many animals which have became extinct in the wild, continue to be maintained in zoological parks.
- **Gene banks** are institutes that maintain stocks of viable seeds (seed banks), live growing plants (orchards), tissueculture and frozen germplasm with the whole range ofgenetic variability. 1
- In **seed banks**, seeds are of two types: orthodox and recalcitrant.
- **Orthodox seeds** are those seeds which can tolerate reduction in moisture content (upto 5%), anaerobic conditions and low temperature of -10° to -20°C or even lower for prolonged periods, e.g., cereals, legumes. At intervals, the seeds are allowed to germinate, form plants and develop fresh seeds for storage.

- **Recalcitrant seeds** are those seeds which get killed on reduction of moisture and exposure to low temperature, e.g., tea, cocoa, jackfruit, coconut.
- They can be stored for shorter duration after treatment with fungicides in rooms having humid air and normal oxygen.
- Plants with recalcitrant seeds are grown in orchards where all possible strains and varieties are maintained, e.g., litchi, oil palm, rubber tree, etc.
- **Tissue culture** is carried out through callus formation, embryoids, pollen grain culture and shoot tip culture for those plants which are either seedless, have recalcitrant seeds, variable seed progeny or where clone is to be maintained. The method is useful in maintaining a large number of genotypes in small area, rapid multiplication of even endangered species and for hybrid rescue,
- Preservation at -196°C (liquid nitrogen) can maintain tissue culture, embryos, animal cells/tissues, spermatozoa indefinitely. This is called **cryopreservation.** The cryopreserved material is revived through special technique when required.

INTERNATIONAL EFFORTS FOR CONSERVING BIODIVERSITY

- **Earth Summit** at **Rio de Janerio** (1992), Brazil,promoted Convention on Biological Diversity (CBD) which was signed by 152 nations. Its recommendations came into effect on 29th Dec. 1993. India became a party to this Convention on Biological Diversity in May, 1994.
- **Agenda 21, a product of Earth Summit**, is a blue print for promoting sustainable development of diversity I through social, economic and environmental measures .in the 21st century.

- A second World Summit was held in 2002 in Johannesberg,South Africa. 190 countries attended the summit and pledged to significantly reduce the current rate of 1 biodiversity loss at global, regional and local levels by 2010.
- Some non-governmental organizations (NGOs) like **green peace** provide international support for conservation.
- **World Conservation Union (former IUCN**) is an international, independent organisation which provides leadership, common approach and expertise in arena of conservation.
- Another similar organisation is **World Wide Fund** for **Nature (WWF).**
- Convention in International Trade in Endangered Species **(CITES)** has helped in **restricting poaching and loss of rare species.**
- Restriction on trading in animal products is believed to have saved the elephant from extinction.
- Establishment and maintenance of biosphere reservesare helped by UNESCO under its Man and Biosphere (MAB) programme.

BIODIVERSITY CONSERVATION IN INDIA

- India is centre of origin and natural home of 167 cultivated species. It is **homeland** of some 320 wild relatives of cropplants. The latter include, rice, sugarcane, millets (cropplants), banana, mango (fruit plants), jackfruit, cucurbits,Dioscorea, Alocasia, Colocasia (vegetables), cardamom, black pepper, ginger, turmeric (spices and condiments),Brassicas (oil and vegetables).
- India is the centre of biodiversity for some animal species like Zebu (Bosindicus), water buffalo (Babalusarnee= B.bubalus), Gayal

(Bosfrontalis), chicken (G aliusdomesticus) and camel (Camelusdromidarius)

- **Bamboos and tree cotton also originated in India.**
- india is **secondary home** of some animals (e.g,sheep goat, horse, cattle, yak, donkey) and plants (e.g., maize, potato, tobacco)
- Because of abundant diversity present in the country, its conservation is very important not only for the country but also for rest of the world.
- Both in situ and ex situ conservation measures are being undertaken. It is being conducted by Ministry of Environment and Forests.
- Major ex situ conservation of biodiversity is being managed by National Bureau of Plant, Animal and Fish Genetic Resources.
- There is an **International Crop Research Institute for Semi-Arid Tropics** (ICRISAT) in Hyderabad for conserving germplasm of groundnut, pigeon pea, chick pea, pearl millet and sorghum.
- A number of other centres in India are maintaining hundreds and thousands of present and past varieties of crop plants.

BIODIVERSITY AND CONSERVATION

- India has **10 biogeographical regions** namely, Trans Himalaya, Himalaya, Desert, Semi-Arid, Western Ghats, Deccan Peninsula, Gangetic Plain, Coasts, North-East and Islands. The country is rich in endemic flora and fauna. The **richest regions** are the Himalayas, Western Ghats, Indian Islands and North-Eastern Hills of India. Each biogeographical region has several habitats, biotic communities and ecosystems. The **largest biogeographical**

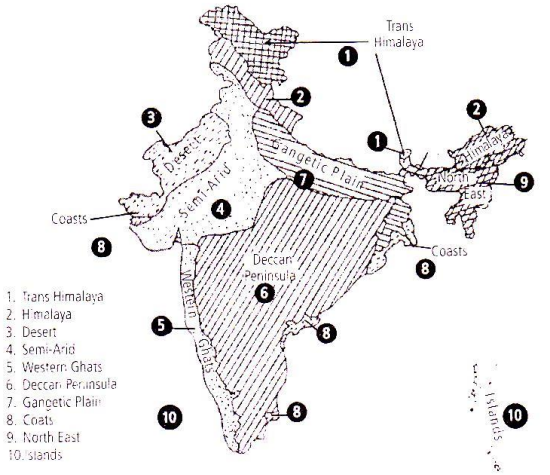


Fig.: Biogeographical regions of India

- **region** is **Deccan Peninsula** and the most biodiversity **rich regions** are **Western Ghats** and **North-East.**

LEVELS OF BIODIVERSITY

- The term biodiversity was coined by **Walter G. Rosen** in 1982. The term was-popularised by Edward Wilson to describe combined diversity at all the levels of biological organisation.
- Biodiversity is of three inter-related hierarchiallevels :genetic diversity, species diversity and community/ ecosystem diversity.
- **Genetic diversity** is the diversity in the numbers and types of genes as well as chromosomes present in different species and also the variations in the genes and their alleles in the same species.
- The genetic variation of Rauwolfiavomitoria growing in different Himalayan ranges might be in terms of the potency and concentration of the active chemical (reserpine) that the plant produces.
- India has more than 50,000 genetically different strains of rice and 1,000 varieties of mango.

- **Species diversity** is the diversity in number and richness of the species of a region. The number of the species per unit area is called **species richness.**Number of individuals of different species represent species evenness or species equitability.
- Western Ghats have greater amphibian species diversity as compared to Eastern Ghats.
- **Community and ecosystem diversity** (ecological diversity) is related to the different types of ecosystems/ habitats e.g., terrestrial (forests, grasslands, deserts etc.) and aquatic (fresh water and marine) ecosystems.
- It is of three types**alpha, beta** and **gamma** diversity.
  - **Alpha (a) diversity** refers to the diversity of organisms I.e., number of species in given community or habitat. It is calculated by the combination of species richness and evenness or equitability.
  - **Beta diversity (between community diversity)** is diversity which develops due to change in a habitat or community along environmental gradients like altitude, latitude, moisture gradient, etc. The greater the difference or turnover of species between the habitats, the greater is the beta-diversity.
  - **Gamma diversity** is also called **regional diversity**. It represents the total richness of species in all the habitats found within a region, geographical area or landscape. When each habitat has a unique biota, gamma diversity is equal to average alpha diversity multiplied by the number of such habitats.
- **Ecosystem diversity is quite high in India** because of the occurrence of a large number of ecosystems like deserts, rain forests, deciduous forests, mangroves, coral reefs, wetlands, estuaries and alpine meadows. **It is quite low in small countries likeNorway.**

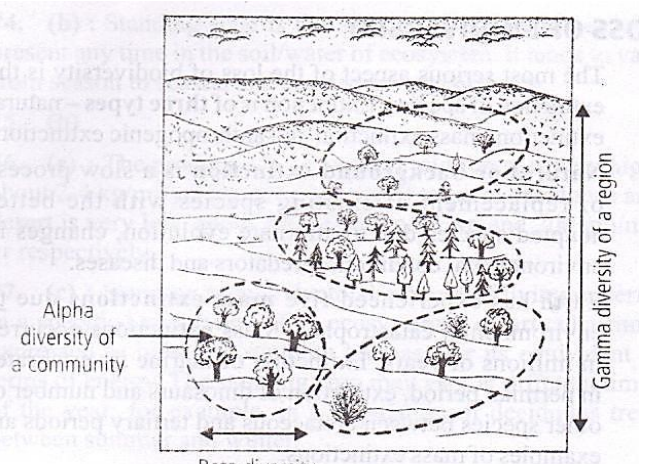


Fig.: Three types of diversity

PATTERNS OF BIODIVERSITY

Latitudinal and altitudinal gradient

- In burring arid ' seiniarid and aquatic habitats, biodiversity shows latitudinal and altitudinal gradients.
- Species diversity decreases as we move away from the equator towards the poles. It increases in temperate areas but reaches the **maximum in tropical rain forests. Maximum diversity occurs in Amazon rain forest of South America** with 40.000 species of plants, 3000 species offish. 1300 birds, 427 mammals, 427 amphibians. 378 reptiles and more than 1.25.000 invertebrates.
- Tropics account for greater biological diversity. Colombia located near the equator has nearly 1,400 species of birds while New York al 41°N has 105 species and Greenland at 71 °N has only 56 species, India, with much of its land area in the tropical latitudes has more than 1,200 species ofbirds.

- There are **some reasons behind the maximum biological diversity of tropical regions**. These are:
  - **Prolong evolutionary time**: Speciation is generally a function of time. Unlike temperate regions which were subjected to frequent glaciations in the past, tropical latitudes have remained relative y undisturbed for millions of years and thus, had a long evolutionary time for **species diversification.**
  - **Constant environment** : Tropical environments, unlike temperate ones, arc less seasonal, relatively more constant and predictable. Such constant environments promote niche specialisation and lead to a greater species diversity.
  - **High productivity :** There is more solar energy available in the tropics, which contributes to higher productivity: this in turn, might contribute indirectly to greater Specific diversity.

Species-area relationships

- German naturalist and geographer **Alexander von Humboldt** while exploring the wildeness of South American jungles found that within a region, the species richness increased with increasing area but upto a certain limit. The relationship between species richness and area turned out to be **rectangular hyperbola** for a wide variety of taxa whether they are birds, bats, fresh water fishes or flowering plants.
- On a logarithmic scale it is a straight line,log S = log C + Z log A
- Here, S is species richness**, Z** is slope of line or regression co-efficient, **C** is Y intercept while **A** is area.

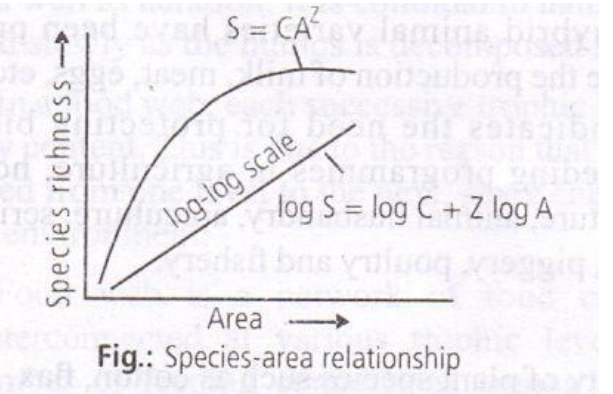


Fig.: Species-area relationship

- **Regression co-efficient** is generally 0.1-0.2 regardless of taxonomic group or region (whether it is the plants in Britain, birds in California or molluscs in New York state, the slopes of the regression line are amazingly similar). However, when the species-area relationship is considered for a very large area like a whole continent, regression coefficient or slope of the line comes to have Z value of 0.6-1.2, e.g., tor frugivorous birds and mammals of tropical forests of different continents, the slope is found to be 1.15

IMPORTANCE OF BIODIVERSITY

- Rich diversity is essential not only for ecosystems but also for the very survival of human race. Species diversity' provides stability to the ecosystems. It is important for maintaining higher levels of productivity and ecosystem health.

Stability of ecosystem

- Biodiversity is essential for stability of an ecosystem. Communities with more species tend to be more stable than those with less species.
- IT is able to resist occasional disturbance. Alien species are unable to find a foot-hold.

- Destruction of a part of ecosystem does not degrade it but the ecosystem is resistant and is able to restore itself after sometime. This has been confirmed by David Tilman's long term ecosystem experiments using outdoor plots.

Sources of food and improved varieties

- Several thousand species of edible plants and animals are known. However**, 85% of the world's food production is met by cultivating less than 20 plant species.**
- Three carbohydrate-rich crops namely, **wheat, corn** (maize) and **rice** alone yield nearly **two-third of the food production.**
- To meet the demands of increasing human population, man not only is exploring new varieties of plants but also animal food.
- Biodiversity is also used as a source material for breeding **improved varieties.** To improve the desired traits, commercial/domesticated species are crossbred withtheir wild relatives. In this way disease resistant and high yielding varieties of crops (e.g., wheat, rice, maize, sugarcane) and fruits have been developed.
- For example, cross breeding of wild rice species (Oryzanivara) has helped in developing new varieties which are resistant to four main rice diseases. Similarly, potato has been made resistant to late blight disease, potato mosaic virus, etc. through cross breeding experiments.
- Also, hybrid animal varieties have been produced to increase the production of milk, meat, eggs, etc.
- This indicates the need for protecting biodiversity for breeding programmes in agriculture, horticulture, floriculture, animal husbandry, apiculture, sericulture, lac culture, piggery, poultry and fishery.

Fibres

- A variety of plant species such as cotton, flax, hemp, jute. Agave, Abaca (Manila hemp) etc. are the major sources of fibres.
- More and more variety of plants are being explored for obtaining superior fibres.

Useful products

- Plant species provide a variety of useful products such as gums, resins, dyes, fragrance, perfumes, waxes, lubricantshydrocarbons, rubber, latex, tannins, paper, tea, coffee, dry-fruits, etc.
- Similarly, animal species provide wool, fur, skin, leather, honey, lac, silk, waxes, lubricants, pearls, ivory, homs, antlers, etc. for trade.

Drugs and medicines

- Large number of substances with therapeutic properties are obtained from variety of plant species. For example, quinine is obtained from the bark of plant Cinchona ledgcriana to combat malaria;**taxol** from the bark of yew trees (Taxusbrevifolia, Taxusbaccata) for treating cancer, etc.
- Ayurvedic medicines available in the market for treating innumerous diseases in man are based on plant products.
- Currently, mere 120plantspeciesareutilizedtoobtain25% of the drugs in the pharmacy.

Scientific value

Animals are used for biological and medical research. Fruitfly, frog, rat.rabbit, guinea pig, dog and monkey are among such valuable animals. New medicines are tested first on animals. Similarly new surgical

techniques are first tried on animals. Animals preceded humans in space. All this necessitates the safety for wild life.

Ecosystem services

- Biodiversity plays a major role in many ecosystem services such as replenishing oxygen through photosynthesis, pollination through bees, bumble bees, birds and bats etc., regulation of global climate, storage and retention of rain water in aquifers and reservoirs, control of floods and soil erosion, nutrient cycling, microbial waste treatment, biological control of pests, etc.

LOSS OF BIODIVERSITY

- The most serious aspect of the loss of biodiversity is the extinction of species. Extinction is of **three types** - natural extinction, mass extinction and anthropogenic extinction.
- **Natural or background extinction** is a slow process of replacement of existing species with the better adapted species due to alternate evolution, changes in environmental conditions, predators and diseases.
- Earth has experienced five **mass extinctions** due to environmental catastrophes. Mass extinctions occurred in millions of years. Extinction of marine invertebrates in permian period, extinction of dinosaurs and number of other species between cretaceous and tertiary periods are examples of mass extinctions.
- **Anthropogenic extinctions are** extinctions abetted by human activities like settlements, hunting, over- exploitation and habitat destruction. The primary cause of the loss of biodiversity is not direct human exploitation but the **habitat destruction** that inevitably results from the expansion of human populations and human activities.

Factors contributing to extinction

- The world is facing accelerated rates of species extinctions, largely due to human interference. There are four major causes- **the evil quartet:**

– Habitat loss and fragmentation
– Overexploitation
– Alien species invasions
– Co-extinctions.

- However, other **factors** also intensify extinctions like **disturbance and degradation, pollution, intensive agriculture and forestry**.
- **Habitat fragmentation** is the process where a large, continuous area of habitat is both, reduced in area and divided into two or more fragments. The most subtle form of **habitat degradation is environmental pollution** and the most common causes are pesticides, industrial chemicals and wastes, emissions from factories and automobiles, and sediment deposits from eroded hill sides. Effects of **pesticide pollution, water pollution** and **air pollution** on environment are well known. Spill-over of oil in sea causes death of several marine algae, fish and sea birds. Pollution, therefore, reduces species biodiversity.
- Increasing human population has escalated the use of natural resources. Dodo, Passenger Pigeon, three subspecies of Tiger and Steller Sea Cow have become extinct in the last 500 years due to **over-exploitation** by humans. Many marine fish populations are declining around the world because of over-harvesting. Some commercially important species arc likely to become endangered.
- Non-native or **alien species** are often introduced inadvertently for their economic and other uses. They often become invasive and drive away the local species. **Water hyacinth** (Eichhorniacrassipes) was introduced in Indian waters to reduce pollution. It has clogged water

bodies including wetlands at many places resulting in death of several aquatic plants and animals. Nile Perch (a predator fish) was introduced in lake Victoria of South Africa. It killed and eliminated ecologically unique assemblage of over 200 native species of small Cichild Fish.

- Certain obligatory mutualistic relationships exist in nature, e.g., Pronubayuccaselles and Yucca. Extinction of one will automatically cause extinction of the other. This is known as **co-extinction.** If the host fish becomes extinct, all the parasites exclusively found on it will also become extinct.
- **Natural disturbance** and **degradation** are caused by spontaneous jungle fire, tree fall, pest infestation, defoliation by insects or locust attack.
- **Man made disturbances and degradation**are more severe. They include cutting of trees, use of fire for clearing, collection of litter and over exploitation for other economically important products.
- **Spread of agriculture** is at the cost of wetlands, grasslands and forests. Destruction of habitats results in extinction of species. Intensive agriculture is also based on a few high yielding varieties. As a result, there is reduction in the genetic diversity. The Amazon rain forest (it is so huge that it is called the **'lungs of the planet')**, harbouring probably millions of species, is being cut and cleared for cultivating soyabeans or for conversion to grasslands for raising beef cattle.
- There is a tendency to grow economically important trees in pure strands, e.g., sal, teak. It drives away or annihilates other species found in forests. The pure strands are liable to be attacked by insects and pathogens.

CHAPTER 2

DIFFERENT METHODS TO MEASURE MICROBIAL DIVERSITY

Dr. Mahanthesh M T
Scientist (Animal Science)
University of Agricultural Sciences, Raichur, Karnataka

Microbial variability has usually been taken as the number of individuals allocated to dissimilar taxa and their distribution among taxa. Understanding the variability of this microbial community in the soil environment is a challenging task. Thus, it is necessary to understand appropriate methods for studying soil microbial diversity. Soil microbiome consists of species diversity and genetic variability, as well as ecosystem biodiversity (Ovreas, 2000). Some organisms in nature can be studied through standard culturing techniques but not all because absence of universal artificial media and growth conditions for all the organisms. Instead of cultivating diverse organisms in pure form we can study microbial world with the help of metagenomics by joining traditional microbiology and molecular biology techniques at once. According to Handelsman (1998) Metagenomics is the study of genetic material recovered directly from environmental samples. The chief goal of metagenomics is to explore almost limitless biodiversity. Metagenomics combines the power of genomics, bioinformatics and systems biology. For better understand of the soil microbial diversity investigators can use one or methods combination which given below for accumulating the maximum information using their individual standard sample size (Figure 1).

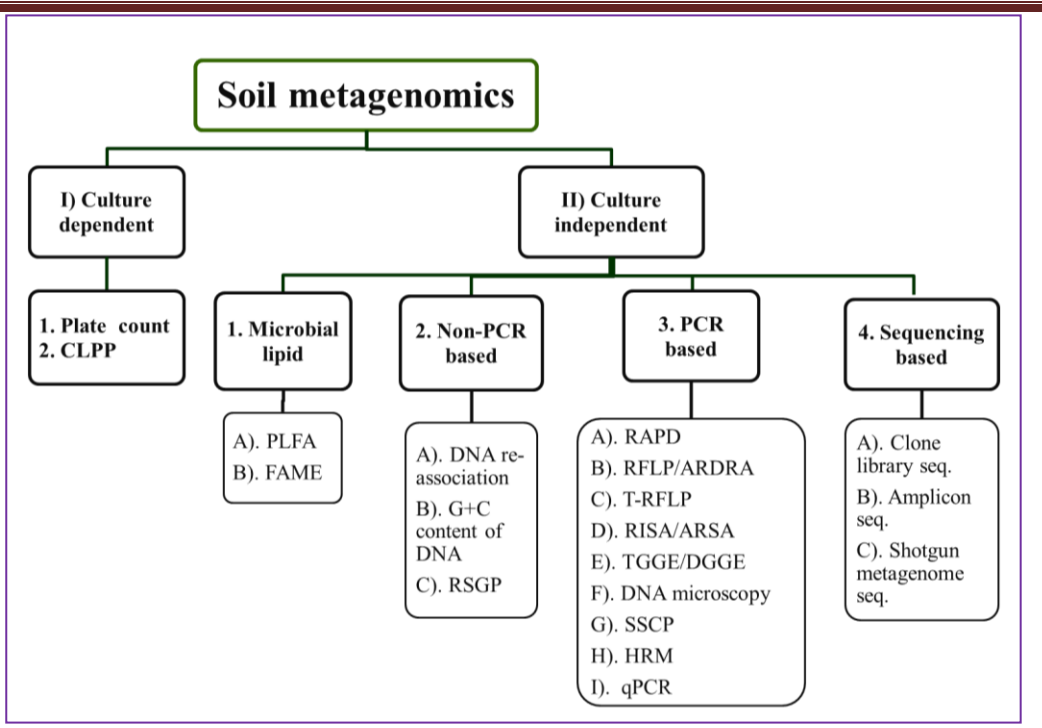


Fig.1. Different methods for studying microbial diversity present in the soil. (Sabale*et al.,*2019**).**

I) CULTURE DEPENDENT METHODS

1. Plate count

Microbial diversity was measured using selective plating and direct viable counts. Plate count is a traditional and culture dependent method and it is fast, inexpensive and can provide information on the active, heterotrophic component of the population. Major drawback of this method includes the difficulty in extracting bacteria or spores from soil particles or biofilms (Tabacchioni*et al.,* 2000) and inability to culture a greater number of fungal and bacterial species. In addition, plate growth favorsfor those microorganisms with fast growth rates and those fungi species that produce large numbers of spores (Dix and Webster, 1995). In this method unculturable microorganisms are not detected. Altogether of these

restrictions, it can influence the apparent variability of the microbial community.

2. Community level physiological profiling (CLPP)

Community level physiological profiling (CLPP) is unique of the most extensively used culture-dependent method for examining soil microbial communities has been that of community-level physiological profiles (Konopka *et al.,* 1998). This method takes advantage of the traditional approaches of bacterial taxonomy in which bacterial species are recognized based on their utilization of different carbon sources. CLPP have been allowed by the use of a commercial taxonomic system, known as the BIOLOG® system, which is presently obtainable and has been extensively used for comparing metabolic activity of heterotrophic soil microbial communities from different habitats using redox chemistry. (Lehman *et al.,* 1995; Garland, 1996, Sabale*et al.,*2019). At present BIOLOG developed several microtiter plates for identification of aerobes, anaerobes, yeasts and filamentous fungi (Sabale*et al.,*2019). This method is fast, suitable and can help to recognize over 2900 bacteria, fungi and yeast. The main disadvantage is microbes which are able to grow in high-nutrient conditions can only cultivable and studied. Other drawback is it favors fast growing organisms and only represent culturable fraction of microbial community.

II) CULTURE INDEPENDENT METHODS

The culture-dependent approaches failure to study the majority of the nonculturable microbial diversity in the microbiome which can be overcome through the biomolecules such as lipids, DNA, RNA and proteins. The soil structure and humic acids fluctuates from one place to another place and time to time the extraction of biomolecules is quite challenging task.

However, in past few years new techniques emerging for staying of soil microbial diversity.

1. Microbial lipid-based techniques

A) Phospholipid fatty acid analysis (PLFA)

Phospholipid fatty acids are potentially valuable signature molecules because of their existence in all living cells. Phospholipid fatty acid (PLFA) analysis has been used as a culture-independent method of assessing the structure of soil microbial communities. Phospholipids are found exclusively in cell membranes and can help as significant indicators of active microbial biomass as different to non-living microbial biomass. The presence of a particular organism in soil revealed by the presence of specific fatty acids related to that organisms or groups of organisms. The usefulness of this method in determining uncultured community variations connected with soil management practices (Hill *et al.,* 2000).

B) Fatty acid methyl ester (FAME)

A biochemical technique provides details about the microbial community composition based on groupings of fatty acids which make up a relatively constant proportion of the cell biomass is fatty acid methyl ester (FAME) analysis (Ibekwe and Kennedy, 1998). Specific fatty acids exist in cells of soil microbiome distinguish major taxonomic groups within a community. So, analteration in the fatty acid profile would denote a variation in the microbial population. The fatty acids are take-out directly from soil followed by derivatization to give the particular FAMEs, which are then examined by gas chromatography (Ibekwe and Kennedy, 1999). By using multivariate statistical analysis FAME profiles of diverse soils can be compared (Rastogi and Sani, 2011).

Bacterial fatty acids are extremely conserved because of their role in cell structure and function and they are chief elements of the lipid bilayer of bacterial membranes and lipopolysaccharides and used widely for

identification and taxonomic purposes. This method used for identification of bacteria is fast, efficient, reproducible and used for the identification of both clinical as well as environmental isolates. Even though FAME analysis is one technique to study microbial diversity analysis, it is a poor method troubled with limitations like it needed lot of material approximately 130 to 150 spores study the potential fungal diversity. The cellular fatty acid structure can be influenced by external factors such as temperature and nutrition (Graham *et al.,* 1995).

2. Non-PCR based techniques

A) DNA re-association

DNA re-association is a measure of genetic complexity of the microbial community used to study diversity from the environmental samples by extracting total DNA, purified, denatured and allowed to re-anneal. The degree of re-association will depend on the resemblance of sequences present in the sample. The degree at which DNA re-association will decline in the same proportionately the complexity or diversity of DNA sequences will increase (Theron and Cloete, 2000).

B) Guanine plus cytosine (G+C) content of DNA

The difference in the G + C (guanine + cytosine) content of DNA can be used to examine the diversity in soil bacteria (Nusslein and Tiedje, 1999). The microorganisms which are taxonomically associated groups only fluctuate between 3% and 5% G+C content (Tiedje*et al.,* 1999). The benefit of this method is no PCR bias with all DNA extraction, uncovering rare members in the microbial populations and fewer dominant microorganisms in the community can be identified and analyzed. But it requires large amount of DNA. It can be used along with other PCR based methods like DGGE (Denaturing gradient gel electrophoresis) or TGGE (Temperature gradient gel electrophoresis) for better accessibility of the soil microbiome.

C) Reverse sample genome probing (RSGP)

In this technique microbial community composition is analyzed with the help of genome microarrays. RSGP has four steps: (i) Genomic DNA is isolated from pure cultures, (ii) Cross-hybridization test [DNA fragments with greater than 70% cross-hybridization are considered to be the same species and less than 70% are of different species] (iii) Genome arrays are prepared by noticing known amounts of denatured genomic DNAs from all recognized standards onto a solid support and (iv) Random labeling of a defined mixture of total community DNA and internal standard, hybridization of the labeled probe with the genome array and finding and analysis of the individual dot hybridization data (Greene and Voordouw, 2003). This method covers the uncultured component of ecological microbial communities but the major limitation of this technique is low levels of gene expression cannot be quantitated because of low level of hybridization, which limits the use of this technique.

3. PCR based methods

Polymer chain reaction (PCR) has been used to overcome the confines of culture-based methods, microbial lipid-based techniques and non-PCR based methods. DNA extracted directly from the environment can act as a template for PCR. PCR targeting the 16s rDNA has been used widely to examine prokaryote diversityand permits recognition of prokaryotes.Whereas 18s rDNA and internal transcribed spacer (ITS) regions used to study fungal communities. With the help of using universal or specific primers target DNA (16S, 18Sor ITS) is amplified, and the resultant products are separated in diverse ways and accordingly analyzed (Pace, 1997).

A) Random amplified polymorphic DNA (RAPD)

Randomly amplified polymorphic DNA polymerase chain reaction (RAPD-PCR) is a simple and quick method for determination of organism inherent diversity at various taxonomic levels (William *et al.,* 1990). In this method PCR amplifies random primers, the amplified products are examined with gel-electrophoresis and the gel images are analyzed with imaging systems. After that RAPD bands are scored and the polymorphic bands are used to measure genetic diversity. RAPD analysis was used to examine metagenome diversity in soil microbiome of arid zone plants (Sharma *et al.,* 2013) and in soil affected by industrial pollutants (Tilwari*et al.,* 2013).

B) Restriction fragment length polymorphism (RFLP)/amplified ribosomal DNA restriction analysis (ARDRA)

Restriction fragment length polymorphism (RFLP) also recognized as amplified ribosomal DNA restriction analysis (ARDRA). His technique is used to study microbial diversity that dependson DNA polymorphism. PCR-amplified ribosomal DNA is digested with base pairs cutting restriction enzyme and diverse lengths are noticed using agarose or non-denaturing polyacrylamide gel electrophoresis (PAGE) in case of community's analysis (Tiedje*et al.,* 1999). ARDRA is a DNA fingerprinting method built on PCR amplification of 16S rDNA using primers for conserved regions, subsequently restriction enzyme digestion and agarose gel electrophoresis and it was used effectively to examine and compare the microbial diversity in copper contaminated soils (Smit *et al.,* 1997). With the help of RFLP banding pattern clones can be screened. And the structural change in microbial communities can also be identified (A-Deya*et al.,* 1995), but not as a measure of diversity or detection of specific phylogenetic groups (Liu *et al.,* 1997). In diverse communities banding pattern analysis with RFLP become complex and because single species have four to six restriction fragments (Tiedje*et al.,* 1999).

C) Terminal restriction fragment length polymorphism (T-RFLP)

T-RFLP is a method that addresses some of the confines of RFLP and follows the same principle as RFLP excluding that one PCR primer is labeled with a fluorescent dye, such as 6-FAM (Phosphoramidite fluorochrome 5-carboxyfluorescein) or TET (4,7,2V,7V-tetrachloro-6-carboxyfluorescein) and it notice only the labelled terminal restriction fragment (Liu *et al.,* 1997).So, T-RFLP fingerprints allowing the analysis of composite communities as well as providing evidence on diversity as each visible band represents a single operational taxonomic unit or ribotype (Tiedje*et al.,* 1999). T-RFLP banding pattern help to measure the richness and evenness along with similarities between samples. It has higher resolution and more comprehensive than the cultivation-based methods. Along with the help of recent developments in bioinformatics this method is useful to study huge number of soil samples (Osborn *et al.,* 2000). T-RFLP also has some limitations like PCR biases, choice of universal primers etc. The existing primers are based on 16S rRNA, 18S rRNA or ITS databases, which till contain mostly sequences from culturable microbes, and therefore true representative of the microbial diversity may not be possible in a sample (Liu *et al.,* 1997).

D) Ribosomal intergenic spacer analysis (RISA)/automated ribosomal intergenic spacer analysis (ARISA)

Ribosomal intergenic spacer analysis (RISA) or automated ribosomal intergenic spacer analysis (ARISA) is usually used DNA-based community fingerprinting method whose principle similar to RFLP and T-RFLP (0vreas, 2000). RISA is based on the length polymorphism of the ribosomal intergenic spacer (IGS) region between the 16s and 23s rRNA genes extensively used to profile microbial diversity in a variety of ecological niche. The intergenic spacer (IGS) regions is amplified by PCR, denatured and separated on a polyacrlyamide gel under denaturing conditions. And

this region may encode tRNAs and is helpful for distinguishing among bacterial strains and closely related species because of difference in length, sequence and size of the IGS fragment (Fisher and Triplett, 1999). In RISA, polymorphisms of the sequence are noticed using silver stain while in ARISA the forward primer is fluorescently labeled and is automatically detected using laser. ARISA is a quick and effective community analysis technique and have some traditional PCR limitations, whereas RISA is time consuming, requires more quantity of DNA and silver staining is low as well as the resulting resolution become low.

E) Temperature/denaturing gradient gel electrophoresis (TGGE/DGGE)

Originally these two techniques were developed to notice point mutations in DNA sequences. DGGE was expanded to examine microbial genetic diversity by Muyzer *et al.* (1993). TGGE uses the same principle as DGGE except the gradient is temperature rather than chemical denaturants and both approaches used for studying microbial diversity in soil. From the soil samples DNA is extracted and amplified with the help of universal primers and targeting part of the 16S or 18S rRNA sequences. The 5'end of the forward primer contains 40 bp (16S rRNA) or 50 bp (18S rRNA) GC clamp to ensure that at least part of the DNA remains double stranded. This is essential so that separation on a polyacrylamide gel with a gradient of increasing concentration of denaturants (formamide and urea) will occur depend on melting behavior of the double-stranded DNA. If the GC-clamp is absent, the DNA would denature into single strands. The Advantages of DGGE and TGGE include being reliable, reproducible, fast, and slightly inexpensive, providing synchronized analysis of multiple samples; and having the ability to follow changes in microbial populations (Muyzer, 1999). Limitations of DGGE/TGGE include PCR biases, laborious sample handling, as this could potentially influence the microbial community and variable DNA extraction efficiency (Kirk *et al.,* 2004).

F) DNA microarray

Nucleic acid (DNA/RNA) hybridization together with DNA microarrays notice and identify bacterial species using specific probes to measure microbial diversity soil or other any environmental samples. A single chip contains probes which are designed from the known sequences ranging in specificity from domain to species can be tagged with markers (fluorescent) at the 5′-end (Theron and Cloete, 2000). There are two different types of microarray chips viz., (i) 16S rRNA gene microarray or PhyloChip and (ii) Functional gene microarray or GeoChip. The amplified products from the soil DNA is hybridized against the known molecular probes, which are attached on the DNA microarrays. The hybridized spots are spotted and scored using microscopy. Benefit of this method is evaluation of the samples is rapid and replicated but risk of cross hybridization may bethere while examining the environmental samples (Gentry *et al.,* 2006).

G) Single-strand conformation polymorphism (SSCP)

This technique had been used effectively for analyzing the structure and dynamics of microbial communities (Schwieger and Tebbe, 1998). DNA fragments are amplified, followed by denaturation and separation in non-denaturing polyacrylamide gel based on difference in DNA secondary structure (Lee *et al.,* 1996). In the absence of denaturant DNA, fragments of equal size will be folded and mobility depend DNA sequence. In principle the SSCP analysis should be easier to carry out than DGGE or TGGE, as no primers with GC-clamp or specific apparatus for gradient gels are required. A major restriction of this method is PCR bias and a single bacterial species may yield numerous bands due to the presence of several operons.

H) High resolution melt curve (HRM)

High resolution melt (HRM) curve involves Real time PCR (qPCR) amplification followed by a melting curve composed using a fluorescent dye. In this method the nucleic acids extracted first and followed by qPCR with fluorescent labeled dye. The amplified 16S rRNA gene products melts between the temperatures fluctuating from 72°C - 95°C, and fluorescence measurements taken at every 0.1°C increment. The melt region is auto called by the melt analysis software (Precision Melt Analysis) (Hjelmso *et al.,* 2014). By using this method, the effects of herbicide on soil bacterial diversity were efficiently studied (Arabet *et al.,* 2014).

I) Real time PCR (qPCR)

Real-time PCR also referred as quantitative PCR (qPCR) has emerged as a promising tool for examining diverse soil microbial communities by targeting ribosomal gene specific to different species (Kabir *et al.,* 2003). It is based on the real-time detection of a reporter molecule whose fluorescence increases as PCR product accumulates during each amplification cycle (Raeymaekers, 2000). The qPCR method is somewhat exceptional among approaches of community analysis in that it allows for a relatively rapid yet quantitative assessment of the abundances of specific phylogenetic groups of microorganisms in soil.

Real-time PCR uses either intercalating fluorescent dyes such as SYBR Green or fluorescent probes (TaqMan) to measure the accumulation of amplicons in real time during each cycle of the PCR. In each cycle the accumulated amplicon concentration was recorded by software during the early exponential phase of amplification which allows the quantification of genes (or transcripts) when they are proportional to the starting template concentration. qPCR is sensitive to starting template concentration and measures template abundance in a large dynamic range of around six

orders of magnitude. Additionally, now reverse transcription (RT) analyses are coupled with qPCR methods in RT-qPCR assay, to quantify gene expression and relating biological activity to ecological function (Sabale*et al.,* 2019).

4) Sequencing based methods

A) Clone library sequencing

DNA extracted directly from soil is a valuable basis of new genetic information and is accessible by using cloning libraries. In this method, initially DNA is extracted from environment sample and subsequently 16S rRNA is amplified either partially or fully and these amplified sequences are ligated and cloned in a suitable vector. After that individual clones containing organism specific 16S rRNA gene fragments were purified and sequenced. The sequences were later assigned to a taxonomic node with the help of a sliding scale of similarity thresholds (Schloss and Handelsman, 2004). The Phylum, class, order, family, subfamily placement of microorganisms determined when a clone surpasses similarity thresholds of 80, 85, 90, 92, 94 respectively. The similarity threshold of database sequence falls below85% then the clone was considered to represent a novel class.

B) Amplicon sequencing

Besides direct sequencing of the total DNA extracted (metagenome) targeted methods are often used, which include amplification of single genes before sequencing. In this method first soil DNA is extracted and then 16S/18S rDNA genes are amplified by using specific set of primers. And then the amplified fragments are purified, adapters are ligated and then by usingNGS platform the library of clones were sequenced. After sequencing the dataset found is compared with Ribosomal Database Project (RDP) for recognition of soil microbial community with greater accuracy that in particular site. Highly complex micro biota can also resolve

accurately with the help of NGS (Rossell*et al.,* 2016). Marker genes are usedfor accurate data analysis and interpretation and the important steps that should be considered was given in 2017 by Scholer and his associates (Sabale*et al.,* 2019).

C) Shotgun metagenome sequencing

Shotgun metagenomic DNA sequencing is a comparatively new and powerful environmental sequencing method that provides insight into microbial communities and provides an unbiased view on the phylogenetic community biodiversity and function (Sharpton, 2014). In this method, high quality DNA extracted from all cells in a community, and instead of targeting a specific genomic locus for amplification, all DNA is cut into tiny fragments that are independently sequenced using available or desired sequencing platform. Then the obtained data is analyzed with the help of MEGAN or webbased software MG-RAST for picturing or comparison of the pictures of microbial world. The analysis of metagenomic sequences is complicated due to the complex structure of the data (Sabale*et al.,* 2019).

References:

Aislabie, J., Deslippe, J.R. and Dymond, J.R. 2013 Soil microbes and their contribution to soil services. In:Dymond JR (ed) Ecosystem services in New Zealand: conditions and trends. *Manaaki Whenua Press,Lincoln,* pp 143–161.

Smit, E., Leeflang, P. andWernars, K. 1997. Detection of shifts in microbial community structure and diversity in soil caused by copper contamination using amplified ribosomal DNA restriction analysis. *FEMS Microbiology Ecology.*;23(3):249-261.

Arabet, D., Tempel, S., Fons, M., Denis, Y., Jourlin-Castelli, C. and Armitano, J. 2014. Effects of a sulfonylurea herbicide on the soil

bacterial community. *Environmental Science and Pollution Research.*;21(8):5619-5627.

Bar-On, Y.M., Phillips, R.and Milo, R. 2018. The biomass distribution on Earth. *Proc Natl Acad Sci USA. https ://doi.org/10.1073/pnas.17118 42115.*

Beneduzi, A., Peres, D., Vargas, L.K., Bodanese-Zanettini, M.H. andPassaglia, L.M.P.2008. Evaluation of genetic diversity and plant growth promoting activities of nitrogen-fixing bacilli isolated from rice fields in South Brazil. *Appl Soil Ecol* 39: 311–320

Compant, S., Van Der Heijden, M.G.A. andSessitsch, A. 2010. Climate change effects on beneficial plant–microorganism interactions. *FEMS Microbiol Ecol. https ://doi.org/10.1111/j.1574-6941.2010.00900 .x*

DeSantis, T.Z., Brodie, E.L., Moberg, J.P., Zubieta, IX., Piceno, Y.M. and Andersen, G.L. 2007. High-density universal 16S rRNA microarray analysis reveals broader diversity than typical clone library when sampling the environment. *Microbial Ecology.*;53(3):371-383.

Dix, N.J. and Webster, J. 1995. Fungal Ecology. Chapman & Hall, London.

Fisher, M.M., Triplett, E.W., 1999. Automated approach for ribosomal intergenic spacer analysis of microbial diversity and its application to freshwater bacterial communities. *Appl. Environ*.

Garland, J.L., 1996. Patterns of potential C source utilization by rhizosphere communities. *Soil Biol. Biochem.* 28, 223–230.

Gentry, T.J., Wickham, G.S., Schadt, C.W., He, Z. and Zhou, J. 2006. Microarray applications in microbial ecology research. *Microbial Ecology*.;52(2):159-175.

Graham, J.H., Hodge, N.C. and Morton, J.B., 1995. Fatty acid methyl ester profiles for characterization of Glomalean fungi and their endomycorrhizae. *Appl. Environ. Microbiol*. 61, 58– 64.

Greene, E.A. and Voordouw, G. 2003. Analysis of environmental microbial communities by reverse sample genome probing. *Journal of Microbiological Methods*.;53(2):211-219.

Handelsman, J., Rondon, M.R., Brady, S.F., Clardy, J. and Goodman, R.M. 1998. Molecular biological access to the chemistry of unknown soil microbes: A new frontier for natural products. *Chemistry & Biology*.;5(10):R245-R249.

Hill, G. T., Mitkowski, N. A., Aldrich-Wolfe, L., Emele, L. R., Jurkonie, D. D., Ficke, A. and Nelson, E. B. 2000. Methods for assessing the composition and diversity of soil microbial communities. *Applied soil ecology*, 15(1), 25-36.

Hjelmso, M.H., Hansen, L.H., Baelum, J., Feld, L., Holben, W.E. and Jacobsen, C.S. 2014. Highresolution melt analysis for rapid comparison of bacterial community compositions. *Applied and Environmental Microbiology.*;80(12):3568-3575.

Ibekwe, A.M. and Kennedy, A.C. 1998. Phospholipid fatty acid profiles and carbon utilization patterns for analysis of microbial community structure under field and greenhouse conditions. *FEMS Microbiol. Ecol.* 26, 151–163.

Ibekwe, A.M. and Kennedy, A.C. 1999. Fatty acid methyl ester (FAME) profiles as a tool to investigate community structure of two agricultural soils. *Plant Soil* 206, 151–161.

IPCC. 2007. Climate change 2007 synthesis report. *IPCC, Geneva*

Kabir, S., Rajendran, N., Amemiya, T. and Itoh, K. 2003. Quantitative measurement of fungal DNA extracted by three different methods using real-time polymerase chain reaction. *J. Biosci. Bioeng.* 96:337-343

Kirk, J. L., Beaudette, L. A., Hart, M., Moutoglis, P., Klironomos, J. N., Lee, H. and Trevors, J. T. 2004. Methods of studying soil microbial diversity. *Journal of microbiological methods*, 58(2), 169-188.

Konopka, A., Oliver, L., Turco, Jr.and R.F. 1998. The use of carbon substrate utilization patterns in environmental and ecological microbiology. *Microb. Ecol.* 35, 103–115.

Lee, D.H., Zo, Y.-G. and Kim, S.J. 1996. Nonradioactive method to study genetic profiles of natural bacterial communities by PCRsingle strand conformation polymorphism. *Appl. Environ. Microbiol.* 62, 3112– 3120.

Lehman, R.M., Colwell, F.S., Ringelberg, D.B. and White, D.C. 1995. Combined microbial community-level analyses for quality assurance of terrestrial subsurface cores. *J. Microbiol*. *Meth*.22, 263–281.

Liu, W.T., Marsh, T.L., Cheng, H. and Forney, L.J. 1997. Characterization of microbial diversity by determining terminal restriction fragment length polymorphisms of genes encoding 16S rRNA.

Malla, M.A., Dubey, A., Yadav, S., Hashem, A. and Allah, E.F.2018. Exploring the human microbiome: the potential future role of next-generation sequencing in disease diagnosis and treatment. *Front Immunol* 9:1–23.

Massol-Deya, A.A., Odelson, D.A., Hickey, R.F. andTiedje, J.M. 1995. Bacterial community fingerprinting of amplified 16S and 16S–23S ribosomal DNA gene sequences and restriction endonuclease analysis (ARDRA). In: Akkermans, A.D.L., van-Elsas, J.D., de-Bruijn,

F.J. (Eds.), *Molecular Microbial Ecology Manual.* Kluwer Academic Publishing, Boston, pp. 3.3.2 1 –3.3.2 8.

Forchetti, G., Masciarelli, O., Alemano, S., Alvarez, D. and Abdala, G.2007. Endophytic bacteria in sunflower (Helianthus annuus L.): isolation, characterization, and production of jasmonates and abscisic acid in culture medium. *Appl Microbiol Biotechnol* 76: 1145–1152

Muyzer, G. and Smalla, K. 1999. Application of denaturing gradient gel electrophoresis (DGGE) and temperature gradient gel electrophoresis in microbial ecology. *Antonie van Leeuwenhock* 73, 127– 141.

Muyzer, G., Waal, E.C.D. and Uitterlinden, A.G. 1993. Profiling of complex microbial populations by denaturing gradient gel electrophoresis analysis of polymerase chain reaction-amplified genes coding for 16S rRNA. *Appl. Environ. Microbiol*. 59, 695– 700.

Nusslein, K. and Tiedje, J.M. 1999. Soil bacterial community shift correlated with change from forest to pasture vegetation in a tropical soil. *Appl. Environ. Microbiol*. 65, 3622–3626.

Osborn, A.M., Moore, E.R.B. andTimmis, K.N. 2000. An evaluation of terminal-restriction fragment length polymorphisms (TRFLP) analysis for the study of microbial community structure and dynamics. *Environ. Microbiol*. 2, 39– 50.

Ovreas, L. 2000. Population and community level approaches for analyzing microbial diversity in natural environments. *Ecology Letters*. 3: 236-251.

Pace, N. R. 1997. A molecular view of microbial diversity and the biosphere. *Science*. 276: 734-740.

Raeymaekers, L. 2000. Basic principles of quantitative PCR. *Mol. Biotechnol*. 15:115-122.

Rastogi, G. and Sani, R.K. 2011.Molecular techniques to assess microbial community structure, function, and dynamics in the environment.*Microbes and Microbial Technology: Agricultural and Environmental Applications. New York:* Springer Science+Business Media, LLC;

Rossell, R., Romoli, O., Vitulo, N., Vezzi, A., Campanaro, S., De Pascale, F. and Valle, G. 2016. Direct 16S rRNA-seq from bacterial communities: a PCR-independent approach to simultaneously assess microbial diversity and functional activity potential of each taxon*. Scientific reports*, 6, 32165.

Sabale, S. N., Suryawanshi, P. P., andKrishnaraj, P. U. 2019. Soil Metagenomics: Concepts and Applications. In Metagenomics-Basics, Methods and Applications. IntechOpen.

Schloss, P.D. andHandelsman, J.2004. Status of the microbial census. *Microbiol Mol Biol Rev* 68: 686–691

Scholer, A., Jacquiod, S., Vestergaard, G., Schulz, S. and Schloter, M. 2017. Analysis of soil microbial communities based on amplicon sequencing of marker genes. *Biology and Fertility of Soils*. 53(5):485-489.

Schwieger, F. and Tebbe, C. C. 1998. A new approach to utilize PCR single-strand-conformation polymorphism for 16s rRNA gene-based microbial community analysis. *Applied and Environmental Microbiology.* 64: 4 870-4 876.

Sergaki, C., Lagunas, B. andLidbury, I. 2018. Challenges and approaches in microbiome research: from fundamental to applied. *Front Plant Sci. https ://doi.org/10.3389/fpls.2018.01205*

Sharma, G. Verma, H.N. and Sharma, R. 2013. RAPD analysis to study metagenome diversity in soil microbial community of arid zone plants. Proceedings of the National Academy of Sciences, India Section B: *Biological Sciences*.;83(2):135-139.

Sharpton, T. J. 2014. An introduction to the analysis of shotgun metagenomic data. *Frontiers in plant science*, 5, 209.

Solbrig, 0. T. 1991. From Genes to Ecosystems: A Research Agenda for Biodiversity. IUBS, Paris. 128pp.

Tabacchioni, S., Chiarini, L., Bevivino, A., Cantale, C. and Dalmastri, C. 2000. Bias caused by using different isolation media for assessing the genetic diversity of a natural microbial population. *Microb. Ecol*. 40, 169– 176.

Taule, C., Mareque, C., Barlocco, C., Hackembruch, F., Reis, V.M., Sicardi, M. andBattistoni, F.2012. The contribution of nitrogen fixation to sugarcane (Saccharum officinarum L.), and the identification and characterization of part of the associated diazotrophic bacterial community. *Plant Soil* 356: 35–49

Theron, J. and Cloete, T.E. 2000. Molecular techniques for determining microbial diversity and community structure in natural environments. *Critical Reviews in Microbiology.;*26(1):37-57. *DOI: 10.1080/10408410091154174*

Tiedje, J.M., Asuming-Brempong, S., Nusslein, K., Marsh, T.L. and Flynn, S.J. 1999. Opening the black box of soil microbial diversity. *Appl. Soil Ecol*. 13, 109– 122.

Tilwari, A., Chouhan, D. and Sharma, R. 2013. Random amplified polymorphic DNA (RAPD) analysis of microbial community diversity in soil affected by industrial pollutants: Reference to Mandideep

Industrial Area. *African Journal of Microbiology Research*.;7(30):3933-3942.

Van Der Heijden, M.G.A., Bardgett, R.D. and Van Straalen, N.M.2008. The unseen majority: soil microbes asdrivers of plant diversity and productivity in terrestrial ecosystems. *Ecol Lett* 11:296–310.

References:

Important molecular marker related references in rice:

Isozymes:

Glaszmann JC (1987) Isozymes and classification of Asian rice varieties. *Theor Appl Genet* 74:21-30 RAPDs:

Mackill DJ (1995) Classifying japonica rice cultivars with RAPD markers. Crop Sci 35: 889-894 RFLPs: Zhang Q, Maroof MAS, Lu TY, Shen BZ (1992) Genetic diversity and differentiation of indica and japonica rice detected by RFLP analysis. *Theor Appl Genet* 83:495-499

AFLPs: Zhu J, Gale MD, Quarrie S, Jackson MT, Bryan GJ (1998) AFLP markers for study of rice biodiversity. *Theor Appl Genet* 96:602-611

SSRs:

Cho YG, Ishii T, Temnykh S, Chen X, Lipovich L, Park WD, Ayres N, Cartinhour S, McCouch SR (2000) Diversity of microsatellites derived from genomic libraries and Genbank sequences in rice (Oryza sativa L.) *Theor Appl Genet* 100:713-722

McCouch SR, Chen X, Panaud O, Temnykh S, Xu Y, Cho YG, Huang N, Ishii T, Blair M (1997) Microsatellite marker development, mapping and applications in rice genetics and breeding. *Plant Mol Bio* 35:89-99

McCouch SR, Teytetman L, Xu Y, Lobos KB, Clarke K, Walton M, Fu B, Maghirang R, Li Z, Xing Y, Zhang Q, Kono I, Yano M, Fjellstrom R, Declerck G, Schneider D, Cartinhour S, Stein L (2002) Development and mapping of 2240 new SSR markers for rice (Oryza sativa L.). *DNA Res* 9:199-207

Parsons BJ, Newbury HJ, Jackson MT, Ford-Lloyd BV (1997) Contrasting genetic diversity relationships are revealed in rice (Oryza sativa L.) using different marker types. *Mol Breed* 3:115-125

Powell W, Morgante M, Andre C, Hanafey M, Vogel J, Tingey S, Rafalski A (1996) The comparison of RFLP, RAPD, AFLP and SSR (microsatellite) markers for germplasm analysis. *Mol Breed* 3:225-238

Prasanth SR, Parani M, Mohanty BP, Talame V, Tuberosa R, Parida A (2002) Genetic diversity in cultivars and landraces of Oryza sativa subsp.indica as revealed by AFLP markers. *Genome* 45:451-459

SNP:

Ayers NM, McClung AM, Larkin PD, Bligh HFJ, Jones CA, Part WD (1997) Microsatellites and a single nucleotide polymorphism differentiate apparent amylose classes in an extended pedigree of US rice germplasm. *Theor Appl Genet* 94:773-781

References

Anders, S., Reyes, A. and Huber, W. (2012). Detecting differential usage of exons from RNA-seq data. *Genome res*, **22**(10)**,** 2008-2017.

Gupta, R., Dewan I., Bharti, R. and Bhattacharya, A. (2012). Differential Expression Analysis for RNA-Seq Data. *ISRN Bioinformatics,* Article ID 817508, 8.

Mortazavi, A., Williams, B. A., McCue, K., Schaeffer, L. and Wold, B. (2008). Mapping and quantifying mammalian transcriptomes by RNA-Seq. *Nat Methods*, **5**(7), 621-628.

Robinson, M. D. and Oshlack, A. (2010). A scaling normalization method for differential expression analysis of RNA-seq data. *Genome Biol,* **11**(3)**:**R25.

Robinson, M. D., McCarthy, D. J. and Smyth, G. K. (2010). edgeR: a bioconductor package for differential expression analysis of digital gene expression data. *Bioinformatics,* **6**(1)**,** 139-140.

Yingtao, B. I., and Davuluri, R.V. (2013). NPEBseq: nonparametric empirical bayesian-based procedure for differential expression analysis of RNA-seq data. *BMC Bioinformatics*, **14**:262.

CHAPTER 4
GENETIC RESOURCES AND BIODIVERSITY IN RICE

L. V. Subba Rao and V. Ravindra Babu
ICAR-Indian Institute of Rice Research
Rajendranagar, Hyderabad 500 030 TS

1. Introduction

The term Biodiversity encompasses the variety of all life on earth. It is defined as the variability among living organisms and the ecological complexes of which they are part, including diversity within and between species and ecosystems. Biodiversity manifests at three levels. (1) Species diversity which refers to the numbers and kinds of living organisms. (2) Genetic diversity which refers to the genetic variation within a species and (3) Ecosystem diversity which is the variety of habitats, biological communities that occur in the biosphere (Kumar and Asija, 2003). Biodiversity maintains ecological balance and drives the process of evolution. Gradual changes in ecological communities and extinction of species is part of natural process. But accelerated loss largely attributed to human activity leading to extinction of species has become a cause of concern (Frankel and Brown 1984). As against the estimated loss of one species a year prior to human intervention, today about one thousand species become extinct every year. According to the World Conservation Monitoring Centre under the aegis of the International Union for Conservation of Nature and Natural Resources, the number of species on the verge of extinction is around 19,100. The disquieting fact is that largest number of endangered plant species are from tropics and the cause is the reported destruction of 17 million hectares of tropical forests each year. Therefore, it is not conservation alone but, access to sustainable use and

benefit sharing related to genetic resources were addressed and negotiated in the Convention on Biological Diversity (CBD) signed by 178 countries and India became a party to the convention since 1994. In the recently concluded fourth meeting of the conference of parties on CBD it was concluded that the emphasis should be on the ecosystem approach under which species and landscapes are viewed primarily as an integral part of their encompassing ecosystem.

With wide range of agro-climatic conditions (tropical, subtropical, temperate) and age old cultivation of diverse agri-horticulture / agro-forestry crop plants, India is one of the important regions of diversity of crop plants. It holds prominent position among the eight Vavilovian centres of crop plants origin, with 2.4% of global land area accounting for 7-8% of recorded species of the world. Out of 2,40,000 economic plant species recounted by Zeven and Zhukovsky (1975) distributed in 12 mega gene centres of crop diversity, 160 species are enumerated in Hindustani gene centre, distributed in eight diverse phyto-geographical /agro-ecological regions of India. Agro-biodiversity comprises of wild relatives, land races and traditional cultivars of several cereals, millets, legumes, vegetables, fruits, forages, fibres, sugarcane, spices, condiments and medicinal & aromatic plants (Paroda, 1988).

2. Rice Genetic Resources

Rice is one of the most ancient crops being cultivated for over 10,000 years. Genetic diversity in *Oryza* species far exceeds that in other crops. There are two cultivated species of rice in the world. Asian rice (*Oryza sativa* L.) had its origin in South and Southeast Asia and is now cultivated worldwide, whereas the African rice (*O.glaberrima*) was domesticated in parts of West Africa and remains locally important in some farming systems in that region. According to Chang (1976) and Watabe (1976) hypothesis, Asian cultivated rice is believed to have originated in an area stretching across

Assam district of India, Upper Myanmar, North Thailand, North Lao PDR and the South western province of China and domesticated in Himalayan foot hills and / or Assam – Yunnan area which stretched from Northeastern India to Southwestern China. The Chang-Watabe hypothesis has also been supported by several genetic studies (Vavilov 1926). Vavilov's hypothesis postulates that a high level of genetic diversity in cultivated plants will be observed in a particular area where the species was domesticated from its ancestral species.

The major sources of genetic diversity in rice are (a) cultivated rice *Oryza sativa* gene pool consisting of primitive cultivars, land races, and improved high-yielding varieties; (b) wild species of *Oryza* and related species and genera comprising primary, secondary, and tertiary gene pool. Primary gene pool is one which contains races that usually belong to the same biological species as cultigens and can produce fertile hybrids with the other cultigens (Harlan and de Wet, 1971). The estimated number of varieties for *O. sativa* is more than 1,40,000 including primitive varieties / land races and improved varieties (Jackson, 1995). These make up an important component of primary gene pool. The full spectrum of rice germplasm includes: (a) wild *Oryza* species and related genera, (b) Natural hybrids between the cultigen and wild relatives and primitive cultivars, (c) Germplasm generated in the breeding programmes including pure line or inbred selections of farmers varieties, F1 hybrids and elite varieties of hybrid origin, breeding materials, mutant, polyploids, aneuploids, etc., (d) Commercial types, obsolete varieties and special purpose types.; (e) induced mutants, obtained through physical and chemical mutagenesis; (f) somaclonal variants -- obtained through tissue and cell culture procedures; and (g) transgenic plants -- novel sources of genetic diversity.

Throughout the long history of rice cultivation, farmers have selected rice strains adapted to many different agro-climatic regions of the world. It has been estimated that more than 2,15,000 rice accessions have been conserved in various gene banks worldwide of which about ten per cent represent the wild species. To date, about 80, 646 accessions including over 3000 accessions of wild rice representing 21 species of *Oryza* and 11 related genera are conserved and maintained in the gene bank at the International Rice Research Institute (IRRI), Philippines (Mishra *et al.,* 2002).

India is traditionally rich in the diversity of rice including the wild progenitors. More than 200 wild rices were collected from the primary and secondary centres of origin comprising of Jeypore - Koraput region, Eastern, North-eastern hills, Chhattisgarh and Pennisular India. Collection of rice germplasm in the country was initiated by Parnell (Madras Province) Hector (Bengal) and Graham (Central Provinces) between 1910 and 1920. Subsequently, rice research workers in different parts of the country undertook sporadic collection surveys in their regions. Systematic and organized attempts to collect the rice germplasm, however, started with the Jeypore Botanical Surveys in late fifties and early sixties, which resulted in the collection of over 1750 accessions from the Jeypore tract of Orissa. Closely following this, about 900 accessions, largely of local rice cultivars were added from Manipur. During 1965-1980, two major collection surveys were undertaken in the North-eastern India and Chhattisgarh area in Central India. The PL 480 supported scheme in North eastern states of India led to a collection of 6,700 local rice cultivars and land races. In the late seventies Dr. R.H. Richaria and his colleagues collected about 20,000 accessions of rice from the eastern region of Madhya Pradesh. A very large number of cultivars have been collected and being maintained at various research stations in the country. Recent collections from different parts of the country have added 334 wild accessions and 700 accessions of varieties to

the national collection. The total germplasm of rice on hand with different agencies is estimated to be around 70,000 (Table 1).

3. Utilization of genetic resources

3.1 Identification of agronomic traits in primary gene pool

India has the largest area under rice (44 million hectares) which is grown under diverse conditions. Rice is cultivated exclusively as a rainfed crop with no standing water after 24 to 48 hours of rain as in upland areas. It is also raised in areas where standing water depth touches 5 metres or more. The rice culture in Kuttanad district of Kerala is below the mean sea level, while those in the states of Jammu and Kashmir are at an altitude of 2000 meters above msl. Rice is cultivated under a wide range of rainfall distribution pattern (drought, submergence, deepwater); distinctly different soils (coastal and inland salinity, alkalinity, acidity), agro-climatic zones (warm humid to cool dry) and seasons. Four major rice ecosystem recognized are : irrigated, rainfed lowland, rainfed upland and flood prone (Khush, 1984).

Three main rice seasons are: *pre-kharif* (Kattera / Ahu / Aus / Virappu / Swarnavari) wherein the crop is sown during March-April; *kharif* (Sarwa / Sali / Samba / Mundakar / Aman) with sowing done in June-July; and *rabi* (Dalwa / Dalua / Boro/ Poonja / Narari) with crop sown in November-December. However, in certain parts of the country like in the states of Tamil Nadu and Kerala there are five overlapping seasons based on onset of monsoon and availability of water.

Local germplasm which is suitable for varied agro-climatic situations prevailing in different parts of the country have been consciously selected and improved upon by the local farmers. These varieties are well adapted to the local situations although their yields are low. Some of these land races

are either cultivated as they are even today or pure line selections have been made and improved varieties have been released and subsequently also utilized in the breeding programmes (Table 2).

The Assam Rice Collection (ARC) and the rice germplasm from Pattambi (Ptb) Kerala have been a rich donor source for resistance to many major pests / disease. Since the inception of the All Indian Coordinated Rice Improvement Programme (AICRIP) systematic evaluation of these rice collections is being undertaken through greenhouse and multi location field testing. A network project initiated by the Directorate of Rice Research (DRR) in 1995 was instrumental in evaluating 14000 gemrplasm accessions for major pests and disease like BPH, stem borer (SB), gall midge (GM), leaf folder (LF), blast (Bl), bacterial leaf blight (BLB) and sheath blight (Sh.Bl) at 12 hot spot sites. Several new sources of resistance against these pests have been identified (DRR, 1998). Some of the important sources of resistance widely used in breeding for pest resistance are listed in Table 3 and include ARC 6650, Manoharsali, Ptb 33, Ptb 21 for BPH; Siam 29, Ptb 18, Ptb 10, Eswarakora, for gall midge; TKM 6 for stem borer; Tetep, Tadukan, Maroberekan, Lacrosee - Zenith-Nira, DV 85 for BLB; Ptb 2, Latisail, Ptb 18, ARC 14766 for RTV. So far, nine genes for resistance to brown planthopper, eight for green leafhopper, five for white backed planthopper, nine for gall midge have been identified in cultivated rice germplasm. Resistance to stem borers is polygenic in nature and none of the donors has high level of resistance. Some of the important land races selected for inland salinity include Damodar, Dasal, Getu and Kalarata while for coastal salinity Pokkali, Nona Bokhra, Nonasail, Vytilla 1, SR 26B, Bhurarata are the well adapted varieties. Using some of the above mentioned donors CST7-1, Lunishree, Vikas, CSR 10, CSR 13, CSR 23, CSR 27, CSR 30 Panvel 1, Panvel 2, Usar 1, PVR 1 etc., have been developed and released for these adverse soil conditions prevailing in about 8.6 million hectares in India.

3.2 Rare traits in wild species:

Wild species are an important reservoir of useful genes such as those for resistance to major diseases and insect pests, tolerance for abiotic stresses and diversification of cytoplasmic male sterility and other agronomic traits (Table 4). An Indian accession of wild species *Oryza nivara* (AA genome) is the only source or resistance to one of the strains of grassy stunt virus (GSV 1) (Khush 1977). High level of resistance to blast and sheath blight in accessions of *O. minuta* and to RTV in accessions of *O rufipogon* has been reported. Successful introgression several useful genes from wild species into cultivated rice has been reported (Brar and Khush, 1995). The genes from *O. officinalis* have been used in developing brown planthopper (BPH) resistant varieties. A new gene *Xa21* conferring resistance to all six races from *O. longistaminata*. is being extensively used for incorporating BLB resistance. The widely used and the only source of cytoplasmic male sterility is based on the Wild Abortive (WA) source from the wild relative *Oryza sativa* F. *spontanea*. *O. rufipogon* has been used in mapping the yield QTLs (Jena and Khush 1987; Siddiq 2002).

3.3 Development of high yielding varieties :

Utilizing the pest resistance sources varieties like Chaitanya, Triguna, Pavizham, Jyothi, Khandagiri, Neela for BPH resistance; Phalguna, Abhaya, Samaridhi, Erramallelu for gall midge resistance; Vikramarya and Nidhi for RTV resistance; Ajaya for BLB resistance; Rasi, Krishnahamsa, and several hill rices like HPU 741, VL Dhan 221 for blast resistance have been developed. Varieties which have multiple pests resistance are Shaktiman for RTV, GLH and GM; Suraksha for Blast, BPH and GM; Kanakam for Blast, RTV and BPH; Eriemaphou for Blast, BPH and GM; Birupa for Blast, RTV, BPH and GM; Ksheera for Blast, RTV, BPH, WBPH and GM; Swarnadhan for Blast and Sheath Blight. Upland varieties, in general, survive either through escape mechanism facilitated by early maturity or

avoidance mechanism by the stress induced root elongation to reach moisture zones. Of the several land races, gora land races from Bihar are known for drought avoidance through good root system and N 22 escapes dought through early maturity. HYVs like Prasanna, Tulasi, Rasi, Ratna, Vandana, Anjali, IR 4575 and Varaalu have good drought recovering ability and have been used for yield improvement. Pure line selections from the local types in Bihar led to the identification of BR 14, BR 15 and BR 46 improved varieties possessing submergence tolerance. In addition to these Patnai 23, Pankaj, Sabita, Jalamagna, Jal Lahari etc., have been extensively used in developing of HYVs for submergence.

Among the speciality rices of export quality, Basmati 370 was selected at Kala Shah Kaku (now in Pakistan) in 1933 and Type 3 which came to be known as Dehradun Basmati at Nagina in Uttar Pradesh. Taroari Basmati the traditional land race which gets highest premium for its unique quality features was selected from HBC 19. All the high yielding export quality Basmati varieties such as Haryana Basmati, Kasturi, Ranbir Basmati and Basmati 385 are derivatives of Basmati 370; while Yamini (CSR 30) and Vasumati have in their lineage Pakistan Basmati and Pusa Basmati has Karnal Local (HBC 19) as one of the immediate parents in Basmati background. Yamini (CSR 30) is the first basmati rice developed having dual adaptability for non-stress (normal) and sodic and saline soils. The local varieties and introductions which were used as donors in the development of varieties for high altitude areas possessing cold tolerance include CH 1039, CH 988, Shenei, K 78-13, Giza 14, Khonorullu etc.

4. Role of local communities in conservation :

Rich ethnic bio-diversity occurs in the tribal dominated tracts of India. In fact, the tribal communities are the custodians of a very vast genetic wealth of native genotypes. The possible reasons for richness of plant diversity that is witnessed in the country is not only due to rich ecological diversity but

also due to the preponderance of religious rituals and ethnic customs of the communities. The past linkages with Indo-Chinese-Indonesian, Chinese-Japanese and the Central Asian region helped in augmenting our crop plant resources. The influx of genetic material in the distant past from the Mediterranean and African regions has also resulted in the accumulation and diversification of enormous genetic variability (Rana, 1993). The ancient travelers, invaders and religious missionaries have also contributed significantly towards enriching the Indian gene centre. Consumer preference has played a predominant role in brining enormous genetic diversity in rice. Rice varieties have been exclusively selected for a variety of rice based products such as rice flakes, popped rice, idli, dosa, papads, appam, murukus, etc. There are rice varieties identified for curing several human ailments such as 'Baisoor' for treating epilepsy, 'Lai cha' for pregnant women to deliver healthy babies, 'Maharaji' to give women strength during antenatal period and 'Aalcha' for treatment of skin diseases. Basmati rices have been selected for their pleasant aroma and extra elongation on cooking. Scores of highly glutinous puttu rices have been preserved by the tribals of north eastern hill states for making rice cakes etc. In addition, numerous aromatic short grain varieties with superior grain quality are unique to different states in the country (Shobha Rani & Krishnaiah, 2001). Some of the land races are still under cultivation by the farmer despite their low yield only for their quality features. Some of the Chakuwa rices of northeastern India are "instant rices" highly suitable for ready-to-eat preparations (puffed and soft rice).

5. Threat to rice biodiversity:

Crop genetic diversity is the basis of our food supply and therefore the basis of our very survival. Landraces, traditionally grown primitive cultivars and wild relatives of cultivated plants are the basic raw materials that sustain the present day crop improvement programmes. These will also be required to

meet the aspirations of future generations who may require altogether new sources of genes while facing unforeseen challenges of more virulent pathogens and pests and hostile climatic factors and abiotic stresses such as salinity, drought and unfavourable temperatures. The valuable plant genetic resources are getting rapidly eroded mainly due to their replacement by few modern varieties and also due to habitat alteration/loss. The large-scale spread of modern, high-yielding varieties is causing concern since genetic base of rice has become narrow. Flood-prone systems are being replaced by irrigated systems which may eventually lead to the loss of distinct deepwater rices. Wild species of rices are threatened with extinction as a result of loss of habitat. This genetic erosion is taking place at a time when new tools of biological research enable scientists to focus as much on the diversity of genes as on the diversity of genotypes. Although there has been considerable success in protecting and preserving the biodiversity of rice during the past decades, much remains to be accomplished.

6. *In situ* and *ex situ* conservation

India has the largest networks of protected areas with 553 national parks and sanctuaries providing *in situ* conservation of plant and animal biodiversity. Besides, eight biodiversity rich areas have been designated as biosphere reserves to conserve respective ecosystems. Five of the protected areas have been designated as world heritage sites under the UNESCO's world heritage programme.

India has also taken timely action for the collection and long term *ex situ* conservation of the rich biodiversity available in the country by *in situ* protection of habitat and ecosystem implemented by Ministry of Environment and Forests and *ex situ* by the establishment of National Bureau of Plant Genetic Resources (NBPGR) in 1976. The Bureau coordinates plant explorations for collection, facilitates the introduction and exchange, ensures medium and long term conservation, compiles data base on plant genetic

resources and offers training in all the aspects of management of agro biodiversity.

7. Conclusions

As can be made out from the foregoing account history of rice cultivation is the history of mankind. Any threat to the biodiversity in rice is a direct threat to the survival of mankind. Changes in the environment during the last two centuries due directly to the activities of the mankind have been destabilizing the delicate ecological balance maintained through millions of years of organic evolution. These changing environment like global warming, greenhouse effects and looming threat of water scarcity are going to make the task of feeding the ever the growing human population a formidable task. Rice with its genetic repertoire of adaptability is the only crop that can offer solutions to this daunting goal. Hence our concern should be to conserve this natures gift of genetic diversity in rice.

References:

Brar, D.S and G.S. Khush (1995). Wide hybridization for enhancing resistance to biotic and abiotic stresses in rainfed lowland rice. Pages 901-910. In fragile lines in fragile ecosystems, IRRI, Manila, Philippines.

Chang T.T. (1976). The origin, evolution, cultivation, dissemination and diversification of Asian and African rices. Euphytica 25: 431-441.

Directorate of Rice Research (DRR)(1999). Evaluation of Rice Germplasm for Biotic Stresses – Final Report 1993-1998. Directorate of Rice Research, Hyderabad, pp.341+89.

Frankel O.H. and A.H.D. Brown (1984). Current plant genetic resources-A critical approval in Genetics. New Frontiers (Vol. IV) New Delhi, India: Oxford and IBH publishing Co. Pvt. Ltd.

Harlon, J.R. and J.M.J. De Wet (1971). Toward a rational classification of cultivated plants Taxon 20: 509-517.

Jackson, M.T (1995). Protecting the heritage of rice bio-diversity. Geo Journal. 35: 267-274.

Jena K.K., and G.S. Khush (1987). Introgression of genes from *O.officinalis* wall et Watt. To cultivated rice *O. sativa*. Theor. Appl. Genet. 80: 737-745.

Khush G.S. (1977). Disease and insect resistance in rice. Adv. Agron. 29:265-361.

Khush, G.S. (1984). Terminology for rice-growing environments. International Rice Research Institute, P.O. Box. 933, Manila, Philippines.

Kumar U. and M.J. Asija (2003). Bio-diversity: The natural Biological capital of the Earth. Pages 1-24. In Bio-diversity-Principles and conservation. Agrobios (India), Jodhpur. India.

Mishra B., N. Shobha Rani and L.V. Subba Rao (2002). Conservation of Plant Bio-diversity and Farmer's participatory varietal approach in Rice. Paper presented in the workshop on "Bio-diversity conservation", 12-14, August 2002, NIRD, Rajendranagar, Hyderabad – 50030

Paroda R.S (1988) Genetic resources Activities in India – some considerations. In Plant Genetic Resources – Indian perspective; Edited by R.S. Paroda, R K Arora and K P S Chandel. NBPGR, New Delhi.

Rana. R.S. (1993). India takes a lead in Conservation of Plant Genetic Resources. Indian Farming; October 1993: 37-45.

Shobha Rani N and K. Krishnaiah (2001). Current status and future prospects for improvement of aromatic rices in India. Pages 49-78 In Specialty rice of the world ; Breeding, Production and Marketing. Tech. Eds. Ram C. Chodhury & D.V. Tran Ed: R. Duffy FAO Rome.

Siddiq, E.A. (2002). Enhancement of yield through innovative Genetic Approaches in Rice. Final Report (1997-2002) ICAR, PD 155.

Vavilov ,N. I. (1926). Studies on the origin of cultivated plants. Bull Appl. Bot 16: 139-248

Watabe T. (1976). Route of rice introduction (in Japanese). Tokyo: Nippon Houson Kyoukai

Zeven, A.C. and P..M. Zhukovsky (1975). Dictionary of cultivated plants and their centres of diversity. Centre for Agricultural Publishing & Documentation, Wageningen, 219p.

Table 1 : Size of rice germplasm available at various centers in India

State/Institute	Location	No. of accessions maintained
Andhra Pradesh	Maruteru, Jagtial, Ragolu etc.	3251
Assam	Titabar	984
	Karimganj	2231
	North Lakhmpur	79
Bihar	Patna	2020
	Pusa	812
	Sabour	355
CRRI, Cuttack (Orissa)	Cuttack	16345
DRR, Hyderabad (A.P.)	Hyderabad	10219
Himachal Pradesh	Malan	496
Kerala	Ambalavayal	150
	Vytilla	
	Moncompu	
Chhattishgarh (MP)	Raipur	20256
Orissa	Bhubaneshwar	840
Punjab	Kapurthala	734
Rajasthan	Banswara	2570
Tamil Nadu	Coimbatore	3445
	Aduthurai	6000
Uttar Pradesh	Faizabad, Almora, Pantnagar	5102
West Bengal	Chinsurah	2150
	Bankura	980
	Hathwara	600
Total		79619*

These are working germplasm collection and may contain deuplicates.

Table 2 : Important (pure line) selections from the germplasm stocks

Variety	Selection from	Released State	Salient Feature
Adamchini	Uttar Pradesh local	Uttar Pradesh	Aromatic short grain
Adday	West Bengal local	Sikkim	Fine quality
Ambemohar	Maharastra local	Maharastra	Aromatic short grain
Badashabhog	Orissa local	Orissa	Aromatic short grain
Badashah Pasand	Uttar Pradesh local	Uttar Pradesh	Aromatic short grain
CB I	West Bengal local	West Bengal	RTV tolerance
CB II	West Bengal local	West Bengal	RTV resistance
Dubraj	Madhya Pradesh local	Madhya Pradesh	Aromatic small grain
FR 13A	Orissa local	West Bengal	Flood tolerance
FR43B	Orissa local	Orissa	Flood tolerance
GEB 24	Tamil Nadu (Konamani mutant)	Tamil Nadu	Fine quality
Govind bhog	Bihar local	Bihar	Aromatic short grain
HR 47	AP local	AP	Aromatic short grain
Kalanamak	Uttar Pradesh local	Uttar Pradesh	Aromatic short grain
Kataribhog	West Bengal local	West Bengal	Aromatic short grain
Lalmati	Uttar Pradesh local	Uttar Pradesh	Aromatic short grain
Latisail	Bangladesh local	West Bengal	RTV resistance

Sepecies	Useful traits
Oryza alta	High biomass
Oryza australiensis	BPH resistance, drought tolerance
Oryza baarthii	Bacterial Leaf Blight resistance, drought avoidance, sheath blight
Oryza brachyantha	Yellow stem borer, Bacterial Leaf Blight, BPH and leaf folder resistance

Oryza eichengeri	BPH, Green Leaf Hopper, WBPH resistance
Oryza grandiglumis	High biomass
Oryza granulata	Yellow stem borer, Bacterial Leaf Blight, BPH resistance, Shade tolerance, adaptation to aerobic soils
Oryza latifalia	High biomass, sheath bright resistance
Oryza longistaminata	Drought tolerance
Oryza meridionalis	Elongation ability
Oryza meyeriana	Shade tolerance, adaptation to aerobic soils
Oryza minuta	BPH, Green leaf hopper, WBPH, Bacterial leaf blight and blast resistance, sheath blight tolerance
Oryza nivara	Grassy stunt virus resistance, sheath blight tolerance
Oryza officinalis	BPH, Green leaf hopper, WBPH resistance
Oryza punctana	BPH resistance
Oryza rideleyi	Shade tolerance, stem borer, blast and Bacterial Leaf Blight resistance
Oryza rufipogon	Sources of GMS, Sheath blight

CHAPTER 4
DIVERSITY IN RICE GERMPLASM

Dr. Kemparaju K. B

Senior scientist, Hybrid Rice, CIS, IIRR, Rajendranagar, Hyderabad-30

Rice (*Oryza sativa L.*) is the world's most important staple crop and a primary source of food for more than half of the world's population. More than 90 per cent of the world's rice is grown and consumed in Asia where 60 per cent of the earth's people live. Therefore, its production always holds a key position in the overall food security of the world.Rice provides 85 per cent of total calories and 50-80% protein requirement in developing countries. It is cholesterol free , low in sodium, gluten free, non allergenic, easy to digest and has only little amount of fat. It is very rich in carbohydrates (78%) consisting of amoylose (15-37%) and amylopectin fraction. The true digestibility or rice is 98 per cent with biological value of 81 per cent and protein efficiency ration is 2. It contributes sufficient amount of protein (8-10 per cent) and vitamin-B to human diet. It is also rich is essential amino acids, like lysine and tryptophan having 3.06 and 1.20/16g N, respectively.Rice is the staple food crop of India, providing 30% of caloric requirement for more than 70% of Indian people. It occupies highest area among all the crops grown in the country. India stands first in rice area with 43.8 million hectares (m ha) and second in production with 93.4 million tonnes (mt) after China and productivity being 2.13 tonnes/hectare (t/ha) (milled rice basis) (2006-07). Within the country, rice is major crop which accounts for 35.4% of area and 42.9% of total food grain production, 43.5% of the area and 45.9% of the total cereal production in the country (Table) thus playing a pivotal role in the food and livelihood security of the people.

Centers of Origin- Primary and secondary

Centers of origin: Rice is regarded as a first cultivated crop of Asia. Preserved rice grains were found in China around 3000 B.C. Paddy grains found during excavation at Hastinapur (India) around 1000-750 B.C. considered as an oldest sample in the world. Southwest Himalayas has various types and varieties and indicated probable centre of origin. De Condolle (1886) and Watt (1862) mentioned south India is its centre of origin. Vavillov suggested that India and Myanmar should be regarded as the centre of origin of cultivated rice. Thus it indicates that there might have been two centres of origin of our cultivated rice; South-eastern Asia (India, Myanmar and Thailand) for **primary centre of origin** of *Oryza sativa* and West Africa for *Oryza glaberrima.* The genus *Oryza* comprises 22 valid species in which only *Oryza sativa* and *Oryza glaberrima* are only cultivated (D. Chatterjee1948). *Oryza sativa* is grown in all rice growing areas, but *Oryza glaberrima* is confined to the West Africa only. The wild types are still found present day in Africa, Southern America and South East Asia, Australia and Antartica at distinct geographical habitats.

Crop systematic:

Species Relationship: Rice belong to the genus *Oryza* , sub tribe Orygianeae of the family Gramineae. It is the plant species which enjoyed with remarkable genetic diversity. There are 22 recognized species are found in genus *Oryza* (Table 1) The wild species found throughout the tropics, especially in the basins of Amazon, Niger, Ganges, Brahmaputra and Mekong and islands of Sri Lanka, Madagaskar and Papua Guinea. They expressed remarkable range of adaptation to different ecologies. In wild species, 7 are tetraploids(2n=48) and rest are diploid(2n =24) Currently, only two species Oryza sativa and O. glaberrima both diploid

(2n=24) are in cultivation. Oryza sativa is widely cultivated all over the world whereas *O. glaberrima* is concentrated to Africa.

Table 7: Chromosome number, genomic composition, distribution and potential useful traits of *Oryza species.*

Species	2n	Genome	Distribution	Useful or potentially useful traits[a]
O. sativa complex				
O. sativa L.	24	AA	World wide	Cultigen
O. nivara Sharma et Shastry	24	AA	Tropical and subtropical Asia	Resistance to grassy stunt virus, blast, drought avoidance
O.rufipogan Griff.	24	AA	Tropical and subtropical Asia, tropical Australia	Elogation ability, resistance to BB, source of CMS
O .breviligulata A. Chev. Et Roehr.	24	A^gA^g	Africa	Resistance to GLH, BB, drought avoidance
O. glaberrima Steud.	24	A^gA^g	West Africa	Cultigen
O. longistaminata A. Chev. Et Roehr.	24	A^gA^g	Africa	Resistance to BB, drought avoidance
O. meridionalis Ng	24	A^mA^m	Tropical Australia, ,Indonesia	Elongation ability, drought avoidance
O. glumaepatula Steud.	24	$A^{gp}A^{gp}$	South & central America	Elongation ability, deep water rice Source of CMS
O. officinalis complex				

O. punctata Kotschy ex Steud.	24	BB	Africa	
O. minuta J.S.Pesl. ex C.B.Presl.	48	BB CC	Philippines and Papua New guinea	Resistance of sheath blight, BB, BPH, GLH
O. officinalis Wall ex Watt	24	CC	Tropical & subtropical "Asia ,tropical Australia	Resistance of thrips, BPH, WBPH, GLH
O. fhizomatis Vaughan	24	CC	Sri Lanka	Drought avoidance, rhizomatous
O. eichingeri A.Peter	24	CC	South Asia & East Africa	Resistance to Yellow mottle virus BPH, WBPH, GLH
O. latifolia Dsv. Production	48	CC DD	Central & South America	Resistance to BPH, high biomass
O.alta Swallen	48	CC DD	Central & South America	Resistance to striped stem borer, high biomass production
O. grandiglumis (Doell) Prod.	48	CC DD	Central & South America	High biomass production
O. australiensis Domin.	24	EE	Tropical Australia	Drought avoidance, Resistance to BPH,
O. brachyantha A. Chev.et Roehr.	24	FF	Africa	Resistance to YSB, LF, whorl maggot, tolerance to laterite soil
O. meyeriana complex				
O. granulate Nees et Arn.ex Watt	24	CG	South & Southeast Asia	Shade tolerance, adaptation to aerobic soil

O. meyeriana (Zoll. Et Mor.ex Steud.)Baill	24	CG	Southeast Asia	Shade tolerance, adaptation to aerobic soil
O. ridleyi complex				
O.longiglumis jansen	48	HHJJ	Iran Jaya, ,Indonesia & Papua New guinea	Resistance to blast, BB
O. ridleyi Hook.f.	48	HHJJ	South Asia	Resistance to stem borer, whorl maggot ,blast, BB
Unknown genome				
O. schlechteri Pilger	48	Unknown	Papua New guinea	Stoloniferous

[a] BPH= brown plant hopper; WBPH= white backed plant hopper; YSB=Yellow stem borer, BB=bacterial blight; LF=Leaf folder, CMC= cytoplasmic male sterility

(source: Singh et al., 2000: Aromatic rices, Oxford & IBH, New Delhi, pp 230)

***Oryza* species complex:** There are four recognized *Oryza* species complex i.e.

- ***Sativa* complex:** This complex consists of two cultivated species and six wild taxa. All of them have the *AA* genome and form the primary gene pool for rice improvement. Wild species closely related to *O. sativa* have been variously named. The weedy types of rice have been given various names, such as '*fatua*' and '*spontanea*' in Asia and *Oryza stapfii* in Africa. These weedy forms usually have red endosperm and commonly called 'red rice'. These weedy species may be more closely related to *Oryza rufipogon* and *Oryza nivara* in Asia and to *Oryza longistaminata* or *Oryza breviligulata* in Africa. One of the species, *Oryza meridionalis*,

is distributed across tropical Australia. This species is often sympatric with *Oryza oustraliensis* in Australia.

- ***Officinalis* complex:** It comprised of nine species and is also called the *Oryza latifolia* complex (Tateoka, 1962). This complex has related species groups in Asia, Africa and Latin America. The tetraploid species *Oryza minata* is sympatric with *Oryza officinalis* in the central islands of Bohol and Leyte in the Philippines. *Oryza eichingeri*, grows in forest shade in Uganda. It was found distributed in Sri Lanka (Vaughan, 1969). Two species of this complex, *Oryza punctala* and *O. eichingeri*, are distributed in Africa. Three American species of this complex, *O. latifolia*, *Oryza alta* and *Oryza grandiglumis* are tetraploid. *Oryza latifolia* is widely distributed in Central and South America, as well as in the Caribbean Islands. A diploid species *O. australiensis*, occurs in northern Australia in isolated populations.

- ***Meyeriana* complex:** This complex has two diploid species, *Oryza granulate* and Oryza meyeriana. *Oryza granulate* grows in South Asia, South-East Asia and south-west China. *Oryza meyeriana* is found in South- East Asia. Another species, *Oryza indandamanica* from the Andaman Islands (India), is a sub-species of *O. granulate*. The species of this complex have unbranched panicles with small spikelets.

- ***Ridleyi* complex:** It comprised of two tetraploid species, *Oryza ridleyi* and *Oryza longiglumis*. Both species generally grown in shaded habitats, near rivers, streams or pools. *Oryza longiglumis* is found along the Komba River, Irian Jaya, Indonesa, and in Papua New Guinea. *Oryza ridleyi* grows across South-East Asia and as far as Papua New Guinea.

Subspecies of species *Oryza sativa:*

Domestication of wild rice (*O.nivara* Sharma et Shastry) to coltivayed rice (*O.sativa* Linnaeus) and side distribution has caused differentiation into several geographical races. These races have further differentiated based on characterization and environmental adaptation and a large number of rice cultivars have thus been created around the world, which are grouped in different subspecies and ecotypes. Based on geographical distribution and morphological characters species *O.sativa* is found to have three subspecies: **i**. *indica*, **ii**. *temperate japonica and* **iii***. tropical japonica(earlier javanica*).(Table:8)

Table 8: Comparison of characteristics of rice cultigens sub species of *Oryza sativa*

Characteristics	indica	*japonica*	*javonica*
Grain			
Length/width	Narrow	Large	Short
Grain type	Long to medium	Short and round	Large and bold
Grain Texture	Non-sticky	sticky	Intermediate
Awns	Usually absent	Usually present	Native cv present
Improved cv absent Pubescence of lemma & palea	Spare	Dense	Dense
Grain shattering	Easily	Not easily	Not easily
Plant status			
Plant colour	Light green	Light green	Deep green
Tillering	High	Low	Low
Plant height	Tall	Medium	Short

Texture of plant tissue	Hard	Hard	Soft
Physiological traits			
Photoperiod	Sensitive	Non-sensitive	Non- sensitive
Lodging	easily	Not easily	Not easily
Main Location	India, south &central China & Indonesia	java	Japan & Korea

Eco-specific rice group: Diverse ecological situations in areas of rice cultivation have given rise to the following major eco-specific rice varieties with specificity for season, situation, and system:

Aus group: Early maturing, photo insensitive types - can be grown across the seasons except in the winter.

Aman group: Late types mostly photoperiod sensitive and flower during specific time regardless of when they are sown or transplanted.

Boro group: Perform best as a summer crop. When sown during winter they tolerate cold temperature in the early vegetative stage better than the other groups.

Gora group: Short duration, can withstand a certain degree of moisture stress during its growing period.

Basmati group: Specific to regions in the northern parts of Indian subcontinent, possessing extremely valuable quality traits like long slender fine grains, aroma, flavor, etc.

Rice: a model plant for genetics and plant breeding research

Rice plant considered model plant for research with endowed the following features-

1. Adapted to diverse agro-climatic conditions
2. Short life cycle, self pollinated with only 12 chromosomes
3. Large amount of genetic variability
4. Smallest size of genome among cereals (430 Mb while wheat has 15,000 Mb)
5. Dense molecular map (4000 DNA markers)
6. Many agronomically important genes/QTL mapped, MAS practiced (BB, blast, gall midge, submergence)
7. Genes transferred from wild species across cross ability barriers
8. 8Map based gene cloning –*Xa1, xa5, Xa26, Xa27, Pib, Pikh, sd1*
8. Novel genetic resources for functional genomics-DNA insertion lines, deletion mutants, YAC, BAC, EST libraries
9. High throughput methods developed (gene chips, microarray) for gene discovery and gene expression
10. Easy to transform indica and japonica cultivars (transgenic rice) Indica and japonica genomes sequenced (new era in functional genomics and reverse genetics)

Rice genetic resources:

It is estimated that more than 140,000 rice varieties including primitive varieties / land races and improved varieties are available world wide. Genetic diversity is fundamental to the crop improvement programs and it has already played a key role in the development of high yielding varieties.

For sustainable conservation and utilization of the valuable rice genetic resources for present and future needs, concerted efforts were made by the National Bureau of Plant Genetic Resources (NBPGR) (New Delhi) in collaboration with DRR (Hyderabad), CRRI (Cuttack) and state agriculture universities (SAUs) in collection, conservation, evaluation and safe exchange of germplasm and its management activities . Currently 87,732 rice germplasm accessions including wild species are conserved in the national gene bank facility at NBPGR (Table 36). Many donors tolerant to pest/diseases, abiotic stresses and quality rice have been identified and utilized in rice improvement programmes (Table 9).

Table 9: Total rice accessions conserved at NBPGR, New Delhi

Species	No. of acc.	Species	No. of acc.
Oryza alta	1	*Oryza minuta*	2
Oryza australiensis	10	*Oryza nivara*	334
Oryza barthii	6	*Oryza nivara* x *rufopogon*	2
Oryza brachyantha	2	*Oryza officinalis*	9
Oryza eichingeri	2	*Oryza punctata*	7
Oryza glaberrima	113	*Oryza rhizomatis*	5
Oryza glumaepatula	3	*Oryza rufipogon*	265
Oryza grandiglumis	1	*Oryza spontanea*	29
Oryza latifolia	3	*Total*	800
Oryza longiglumis	2	*Oryza sativa* L.	86932
Oryza meridionalis	4	*Total*	87732

CHAPTER 5

ENDANGERED AND THREATENED PLANT SPECIES OF UTTAR PRADESH, INDIA

Sujit Kumar[1], BP Singh[2] Srijan Yadav[3], Birendra Kumar[4] and S.C. Singh[5]

[1]- U.P. Council of Agricultural Research, Lucknow, [2]
[3]- UG Student, ANDUAT, Kumarganj, Ayodhya
[4,5]- Central Institute of Medicinal and aromatik Plants, Lucknow.

Abstract

Plants are the ultimate wealth occupying the major share among visible bioresources on the planet and hence need attention for their conservation and sustainable utilization. It is therefore, very essential to strengthen the scientific and technological base to ensure the sovereign rights by the nations on their natural resources and also claim the rights of the benefits accruing from the value of biodiversity. On global basis, the International Union for Conservation of Nature and Natural Resources have estimated that about 10 percent of the world's vascular plant species are under varying degree of threats.Through manifold human impacts in various spheres, the future of a large number of species has been jeopardized. The rate at which the species are being lost is very alarming and has caused concern allover the world. Increasing population of the world is a matter of concern causing climate change and degradation of forests leading to vanishing of a number of species. In the tropical forest, 350 million ha have been deforested at the rate of 0.8% per year and about 500 million ha of secondary and primary forests have been degraded. Further, the primary forests are irreplaceable for sustaining tropical biodiversity. As of today, few

truly undisturbed tropical forests exist in world. Forests degraded by repeated logging and fires, while secondary and plantation forests, are rapidly expanding. Further biodiversity values are substantially lower in degraded forest. When it comes to maintaining tropical biodiversity, there is no substitute for primary forests, he said that due to 0.8% per year deforestation, currently 2-5 species are lost per hour or 14000-40000 species per year. Thus, of the 3 billion populations existing on Earth, on an average 220 populations per species i.e. 1800 species per hour are being lost from the tropical forests alone. Elaborating on the consequences of global warming, Prof. Singh said that elevated temperature of the biosphere will result into melting of polar ice, increase in sea level (flooding of major cities).

The rate at which the species are being lost is very alarming and it is estimated that *c.* 25% of the total species of higher plants will be lost in the next few decades and another 25% by the end of this century. The most widely accepted estimate made by IUCN and WWF is that about 60,000 higher plant species could become extinct or reach near extinction by the middle of the century. This figure amounts to one of the four species of all the higher plant species known to exist on the earth. The state of Uttar Pradesh is located in the north western part of the country having an area of 243,290 km^2 with approximately 200 million populations. The state covers large part of the highly fertile and densely populated Upper Gangetic Plain. It shares an international border with Nepal to the north and in the north and north-west other states like Delhi, Haryana, and Uttarakhand; in west Rajasthan; in the south Madhya Pradesh; in south-eastChhatisgarh and Jharkhand and in the east Bihar states.According to 2011 recorded data, forest area in the state is 6.88 % of the geographical area of Uttar Pradesh. In tarai region Tarai-Duar Savanna and grassland are found while moist deciduous trees grow in the Upper Gangetic Plain including along its river banks. Dry deciduous forests, sal and teak forests and thorny forests

make the state rich in species diversity. It is estimated that in Uttar Pradesh about 30 plant species are facingendangerment in one or other category of IUCN and some species listed/coated by CITES (Convention on International Tradein Endangered Species) and hence enumerated.

1.Abelmoschus moschatus Medic.(Malvaceae): Muskadana. An erect hispid undershrub with a long slender tap root. Leaves variable; lower suborbicular in outline, cordate, angular or palmately 3-7-lobed, upper narrower, hastate or sagttate at base with linear –oblong or triangular bes. Flowers solitary, axillary, yellowish with dark purple centre. Capsules narrowly oblong, beaked; seeds subglobose-reniform. Vulnerable in the state.

Status: The species has been depleted due to destruction of habitat in the state.

Medicinal Uses: Seed- antiseptic, stomachic, tonic, carminative, aphrodisiac, antihysteric, antidote for snake-bite (Husain *et al.* 1992).

2. **Acorus calamus**L. (Araceae): Bach, Sweet Flag. Perennial herb with aromatic rhizome. Leaves ensiform with sheathing bases. Peduncle and spathe leaf like; spadix sessile, dense flowered, cylindric. Flowers bisexual; sepals 6, orbicular, concave, tips incurved; stamens 6, filament linear, flat, anther reniform.

Status: This species is vulnerable due to over exploitation for its rhizome which are used in essential oil industry.

Medicinal Uses: Sedative, analgesic, hypotensive, respiratory, depressant, eupeptic, antithermic, emmenagogue, tranquilizer, aperitive, antiasthmatic (Husain *et al.* 1992).

3. **Andrographis paniculata**Wall. ex Nees (Acanthaceae): Kalmegh.
   Erect annual herbs. Leaves 4-10 cm long, linear-lanceolate, acute or acuminate. Flowers whitish-pink, in axillary and terminal racemes. Capsule flat, tapering at both ends; seeds numerous, subquadrate, rugose.

Status: The species is vulnerable in the state because the herb is used in pharmaceutical industries.

Medicinal Uses: Plant- febrifuge, tonic, alterative, anthelmintic, dysentery and dyspepsia; root and leaves- febrifuge, stomachic, tonic, anthelmintic (Husain *et al.* 1992).

4. **Asparagus adscendens**Roxb. (Liliaceae): Safed Musli. Suberect prickly shrub with tuberous root. Spines straight. Cladodes in dense tuft of 6-20, filiform, terete. Flowers white in long racemes. Perianth segments spreading; stamens shorter than the perianth.

Status: Vulnerable species due to indiscriminate collection of tuberous roots which are used as tonic and aphrodisiac in pharmaceutical industry.

Medicinal Uses: Tuberous roots- antidiarrhoeal; root- bark- aphrodisiac, tonic, as a substitute for *Asparagus officinalis* (Husain *et al.* 1992).

5. **Asparagus racemosus**Willd. (Liliaceae): Satawar. Woody, much branched scandent or straggling spinous shrub with tuberous roots. Spines recurved. Cladodes in tuft of 2-6, falcate, triquetrous. Flowers white in solitary or fascicled racemes. Berries subglobose.

Status: Vulnerable species due to indiscriminate collection of tuberous roots which are used as tonic, aphrodisiac and galactagogue.

Medicinal Uses: Tuber- demulcent, diuretic, aphrodisiac, tonic, alterative, antiseptic, in diarrhoea, galactogenic (Husain *et al.*1992). The tuberous roots are used as an ingredient of the Ayurvedic preparation MENTAT, which is given for nervous disorders (Anonymous Vol.1. p. 101.2004).

Preparations and Formulations: Satawari-ghrita, Phal-ghrita, Narayantaila, Vishnu-taila, Satyamulayadi-louha, Satavari-panak, etc. (Sharma *et al.*2000).

6. **Baliospermum montanum**(Willd.) Muell.-Arg. (Euphorbiaceae): Danti. An erect shrub. Leaves alternate, variable in shape and size; upper lanceolate, sinuate-toothed, coriaceous. Flowers yellowish-green, apetalous, arranged in panicles; male globose with 10-20 stamens. Capsules obovoid- trigonous, hairy.

Status: Endangered species in the state because of its roots which are used in pharmaceutical industry and due to habitat loss also.

Medicinal Uses: Leaf- antiasthmatic, wound healing; stem- antiodontalgic; root- in jaundice, anasarca; root and seed oil- in dropsy, cathartic; seed-purgative,stimulant, rubefacient; seed oil- in rheumatism (Husain *et al.* 1992).

Preparations and Formulations: Dantyarista, Dantyadi-churna, Dantiharitaki, Abhayarista, Dantayadi-lep, Kaisor-guggulu, Laghu-visgarva-taila, etc. (Dey 1980).

7. **Boswellia serrata**Roxb. ex Colebr. (Burseraceae): Salai Guggul. A medium-sized deciduoustree. Leaves imparipinnate. Panicle axillary

or terminal. Flowers bisexual, sometimes polygamous. Fruit a drupe with 3-5 stones.

Status: It is vulnerable due to its bark and wood which are used in pharmaceutical industries.

Medicinal Uses: Gum- diaphoretic, stimulant, antirheumatic, in pulmonary, nervous and skin diseases, scrofulous affections, urinary disorders, sores, obesity; oil- antigonorrhoeic, demulcent, in chronic ulcers, colic, aphthae, dysmenorrhoea, sore nipple, ringworm, diseases of bones, buboes; gum and oil- astringent, diuretic, emmenagogue (Husain *et al.* 1992).

8. **Cassia sophera**L.(Caesalpiniaceae). Kasmard. Erect shrub pubescent young parts. Leaves 14- 20 cm long, rachis with conical glands at base, grooved; leaflets 6-12 pairs, lanceolate, acute or acuminate. Flowers yellow in axillary and terminal corymbose racemes. Pods subterete with inflated sutures.

Status: Threatened in the state due to destruction of habitats.

Medicinal Uses: Leaves- antiseptic, in ringworm, anthelmintic; plant- in bronchitis (Husain *et al.* 1992). Leaves used by local people in piles.

9. **Celastrus paniculatus** Willd. (Celastraceae): Malkangni, Jyotishmati. Large twining shrubs with pendulous branches. Leaves 5-10 cm long, suborbicular or obovate, crenate, acuminate. Flowers yellowish green, unisexual in elongated terminal panicles. Capsules globose; seeds 3-6, enclosed in a red aril.

Status: This species is critically endangered in the state due to indiscriminate collection.

Medicinal Uses: Stem-bark-abortifacient; seed-emetic, laxative, stimulant, aphrodisiac, in gout and rheumatism, in fever, in leprosy, in paralysis, oil in beri-beri (Husain *et al.* 1992).

Preparations and Formulations: Jyotismati taila, Jyotismati-kalpa, Karanjadi-yog, Laghu-vish-garva-taila, etc. (Dey 1980).

10. **Chlorophytum tuberosum**Baker (Liliaceae). Safed Moosli. Small herb with Small perennial herb with tuberous roots, up to 20 cm tall. Leaves 15- 30 cm long, strap- shaped or linear- lanceolate, 6-12, all arising from the base acute- acuminate, margin entire or wavy. Flowers white on small scape. Fruits three- edged capsule.

Status: The species is critically endangered due to indiscriminate collection of its tuberous roots which are used as aphrodisiac and tonic in pharmaceutical industry.

Medicinal Uses: Tubers- tonic, aphrodisiac, galactagogue, strength and vigour, fever, leucorrhoea, etc.; in northern Nigeria its tubers are crushed to produce a lotion used to treatguinea- worms (Google search).

Preparations and Formulations: Tuberous roots are used in more than hundered formulations related to vigour, strength, immunity, sex related problems, as tonic, galactagogue, aphrodisiac.

11. **Clerodendrum serratum**(L.) Moon (Verbenaceae): Bharangi. Erect shrub with quadrangular stem. Leaves opposite or ternate, ovate-

elliptic, subsessile. Flowers bluish-purplish in terminal, pyramidal panicles. Drupe sub- globose or broadly obovoid, 2-4- lobed, blackish at maturity.

Status: The species is vulnerable in the state due to destruction of habitat.

Medicinal Uses: Root- anticatarrhal, antiasthmatic, in bronchitis; leaf- febrifuge, antidote for snake-bite (Husain *et al.* 1992).

Preparations and Formulations: The plant forms one of the ingredients of the Ayurvedic drug *Kasadamana,* an effective expectorant and antitussive remedy (Anonymous Vol. 2 p.69.2004).

12. Costus speciosus(Koenig ex Retz.) Smith (Costaceae): Kewankand. Erect perennial herb. Leaves 15-30 cm long, oblong or oblanceolate, acute or acuminate, arranged spirally, base rounded. Flowers white, in dense terminal spikes. Capsule 3- gonous. Seeds black with a white aril.

Status: The species is endangered in the state, because of its high utility in steroidal drugs.

Medicinal Uses: Rhizome- astringent, bitter, purgative, anthelmintic, antiinflammatory, stimulant, in gout (Husain *et al.*1992).

13. Cressa creticaL. (Convolvulaceae). Rudravanti. A small, erect, densely branched annual with densely hairy crowded leaves, white flowers and ovoid capsules.

Status: Vulnerable due to habitat loss.

Medicinal Uses: Plant- tonic, aphrodisiac, expectorant, antibilious (Husain et al. 1992).

14. **Curculigo orchioides**Gaertn. (Hypoxidaceae): Kali Musli. Perennial herbwith tuberous roots.Leaves radical, oblong- lanceolate, entire, acuminate. Flowers yellow on a short scape; perianth segments yellow. Capsules sessile in the axil of bracts.

Status: The species is vulnerable due to its indiscriminate collection and use in pharmaceutical industries.

Medicinal Uses: Rhizome- tonic, demulcent, diuretic, antidiarrhoeal, antiasthmatic, aphrodisiac, in skin diseases, piles, in jaundice (Husain *et al.* 1992).

15. **Drimia indica**(Roxb.) Jessop (Liliaceae). Jangli Pyaj, Indian squill. Perennial scapigerous herb with ovoid tunicated bulbs. Leaves linear-lanceolate, ensiform, acute. Flowers pale-brown, white at margin in tall racemose scape. Capsule triquetrous, ellipsoidal, loculicidal. Seeds many flat, black.

Status: This species is critically endangered in Uttar Pradesh because its roots are used in medicine.

Medicinal Uses: Bulb- cardiac stimulant, in the preparation of Chandi Bhasma used in paralytic affections, expectorant, digestive, diuretic, emetic (may cause cardiac depression when used in large dose), cathartic, deobstruent, emmenagogue, antirheumatic, antiasthmatic, antidropsical, anticalculous, antileprotic, in jaundice, skin diseases, haemorrhages from kidney and uterus; substitute of Europian Squill *Drimia maritima* (Husain et al. 1992).

16. **Euphorbia acaulis**Roxb. (Euphorbiaceae). Van Mooli. Dwarf glabrous herb with stout stout underground cylindric rootstock; leaves radical, subsessile, oblanceolate, margin curled; flowers in cyathia, yellow, arranged in cymes on long peduncle, arising from the rootstocks.

Status: This species is critically endangered because of its roots which are collected for medicinal purposes..

Medicinal Uses: In paralysis, gout and rheumatism (Prakash 2011).

17. **Euphorbia neriifolia** L. (Euphorbiaceae). Sehund. Erect much-branched large shrubs. Branches terete, with 5 more or less spirally twisted ribs. Spines sharp persistent divergent from a tubercled base. Involucres ternate, yellowish the lateral ones pedicelled and bisexual; the central flower usually male and sessile, glands transversely oblong, yellow.

Status: Plant species is vulnerable due over exploitation of its latex in medicinal industry. Also listed in appendix II of CITES.

Medicinal Uses: Milky juice- used as purgative, rubefacient, expectorant antirabies, ascites, anasarca, to remove warts and cutaneous eruptions; root-antiseptic, antidote for scorpion-sting and snake-bite, fish-poison (Husain *et al.* 1992). A herbal mixture prepared from decoction of *E. neriifolia* leaves, *Nigella sativa, Pterocarpus santalinus,* and few grains of opium is applied externally for quincy, mumps and sore throat. A medicated thread, *Kshara sutra* prepared by using fresh latex of the plant, alkaline powder from *Achyranthes aspera* and turmeric powder offers an effective embulatory and safe alternative treatment for patients with fistula-in-ano (Anonymous Vol.3.p.114.2005).

Preparations and Formulations: Vajra-kshar, Snuhugadi-taila, Snuhugadivati, etc.(Dey 1980).

18. **Gloriosa superba**L. (Liliaceae): Kalihari. Climbing perennial herbs. Leaves 7.5-20 cm long, ovate-lanceolate, cordate, acuminate, narrowed into a coiled tendril at apex. Flowers solitary or sub-corymbose, lower half yellow and upper half red. Capsules linear- oblong.

Status: The plant is critically endangered in the state because of indiscriminate collection of its roots which are the source of colchicine.

Medicinal Uses: Tuberous root-tonic, antimalarial, stomachic, anticancer, cholagogue, purgative, in rheumatism, alterative; anthelmintic, in leprosy, piles, starch from root antigonorrhoeic; leaf antiasthmatic (Husain *et al.*1992).

Preparations and Formulations: Kasisadi-taila, Languli-rasayan, Laghuvis- garva-taila, etc.(Dey 1980).

19. Gymnema sylvestreR. Br. ex Schultes (Asclepiadaceae): Gudmar. Twiningshrub, young branches and stem terete, pubescent. Leaves broadly elliptic- obovate or oblong, shrtly acuminate on apex, rounded to cordate at base. Flowers in umbelliform cymes, pale yellow. Follicles lanceolate. Glabrous. Seeds nearly ovoid or oblong, pale brown, broadly margined.

Status: The plant species is vulnerable in the state along the border of Madhya Pradesh.

Medicinal Uses: Leaf- antidiabetic, laxative, stimulates the heart and circulatory system, activates the uterus, in parageusia, furunculosis; plantdiuretic, antibilious, in sore eye; root- emetic, expectorant, astringent,stomachic, antidote for snake-bite (Husain *et al.* 1992).

20. **Helicteres isora**L. (Sterculiaceae): Marorfali. Erect densely stellate tomentose large shrubs. Leaves bifarious obovate, suborbicular, obliquely cordate at base, abruptly acuminate, irregularly crenate-serrate, scabrous-tomentose, especially on the lower surface. Flowers reddish solitary or in few-flowered minutely bracteolate cymes. Fruits composed of 5 spiraly twisted tomentose follicles on a long gynophore. Seeds tubercled, numerous.

Status: Vulnerable in the state due to habitat loss and fruits which are used in medicine.

Medicinal Uses: Fruits- anthelmintic, antidysenteric, emetic, decoction in fever; leaf- eczema and other skin diseases; root- cough and asthma (Anonymous 1992).

21. **Helminthostachys zeylanica** (L.) Hk. *f.* (Ophioglossaceae). Kamraj. Terrestrial or epiphytic perennial with sout rhizome. Leaves 1-2 per stem, with common stalk divided into sterile, laminate, tophophore and fertile sporophore; leaf bases dilated, clasping, forming sheath, open or fused, surrounding successive leaf primordial.

Status: The plant is critically endangered in the state.

Medicinal Uses: Plant- aperient, intoxicant, anodyne, used in sciatica (Chopra et al. 1956).

22. Hemidesmus indicus(L.) R. Br. (Periplocaceae): Anantmul. Twining shrub. Leaves variable, oblong-elliptic, elliptic, linear-lanceolateostly apiculate at apex, obtuse at base. Flowers in 5-15- flowered, subsessile, fasciculate cymes. Follicles linear, violet, upto 15 cm long. Seeds flattened, black.

Status: This species is vulnerable in the state because of habitat loss and improper collection of root which is used in pharmaceutical industries.

Medicinal Uses: Plant used as substitute for sarsaparilla; demulcent, alterative, diaphoretic, tonic, diuretic, as blood purifier, in leucorrhoea, syphilis, rheumatism, loss of appetite, scorpion- sting and snake-bite (Chopra *et al.* 1956); root- in fever, leucorrhoea, diaphoretic, antidote for snake bite and scorpion- sting, galactogenic, urinary trouble, in rheumatism, skin diseases; latex- relieves inflammation of eyes (Husain *et al.* 1992).

Preparations and Formulations: Sarivadi-kwath, Sarivadi-vati, Sarivadyavaleha, Sarivadyasav, etc. (Sharma *et al.* 2000).

23. Indigofera tinctoriaL. (Fabaceae): Neel. Erect much branched shrub. Leaves imparipinnate,leaflets 7-13, elliptic or oblong, obtuse or retuse. Flowers lilac red in axillary racemes. Pods cylindrical, turgid, straight or slightly curved, 8-12- seeded.

Status: Vulnerable in the state.

Medicinal Uses: Leaf- antiinflammatory, in hydrophobia; plant- in asthma, in piles, in epilepsy, leucoderma, enlargement of liver and spleen; nervous disorders, in ulcers and skin diseases, lumbago; root- diuretic, in hepatitis

(Husain *et al.* 1992). The plant has potential as a contraceptive drug in Unani system of medicine (Anonymous Vol.3.p.335.2005).

24. Indopiptadenia oudhensis (Brandis) Brenan (Fabaceae). Medium-sized handsome trees. Branches sometimes prickly. Leaves double compound, each leaf has two pair of pinnae on long stalks; leaflets kidney- shaped in pairs, 5-10 cm. flowers greenish- yellow. Pods upto 30 cm long, 15-20- seeded.

Status: Ristricted to Eastern Tarai districts such as Gonda, Balrampur, Shravasti, etc. and depleting from its natural habitat and endangered.

25. Ipomoea nil(L.) Roth (Convolvulaceae): Kaladana. Annual hairy twiners. Leaves 5-12 cm long, ovate-cordate, entire or 3-lobed, lobes ovate-acuminate; Flowers deep blue tinged with pink, 1-5 together. Capsules ovoid or subglobose, glabrous; seeds 4-6, glabrous, black.

Status: Vulnerable in the state due to habitat loss.
Medicinal Uses: Seeds- purgative and used as substitute of Jalap(Anonymous 1992).
Preparation and Formulation: Krishnabijadi-churna (Dey 1980).

25. Litsea glutinosa(Lour.) Robinson (Lauraceae). Medalakri. A small tree with white pubescent branches. Leaves ovate-lanceolate, acute at apex, rounded or cuneate at base. Flowers in large compound umbels, usually in subumbellate clusters at the apex of slender stalks. Fruits globose, 8-9 mm across, on small, thickened perianth- tube.

Status: Endangered due to over expoitation of its bark which is used as base material in essential oil industry for making aggarbattis.

Medicinal Uses: Bark- demulcent, astringent, emollient, aphrodisiac, antidiarrhoeal, in bruises and in dressing of wounds; oil from berry- antirheumatic;leaf- antispasmodic (Husain *et al.*1992).

26. Mucuna pruriens Baker (Fabaceae): Kewanchh. Climbing annuals with appressed hairy branches. Leaves 3-foliolate and stipellate; leaflets ovate rhomboid, membranous. Flowers dark purple in drooping racemes. Pods slightly cylindrical, upto 8 cm long, hooked at the tip, clothed with dense pale brown or greyish irittating bristles. Seeds 5-6, on oblong funicular hilum.

Status: Endangered in the state due to habitat loss.

Medicinal Uses: Leaf- in ulcer; root- emmenagogue, diuretic, purgative, in dropsy, febrifuge, in kidney trouble, elephantiasis; seed- aphrodisiac, nerve tonic, astringent; sting hair on fruits- mild vesicant, vermifuge, in liver and gall bladder diseases (Husain *et al.* 1992).

Preparations and Formulations: Vanari-gutika, Mashabaladi-pachana, Musalipaka, Kapikachchhu-churna, Kapikachchhu pak, etc. (Dey 1980; Sharma *et al.* 2000).

27. Perilla frutescens (L.) Britt. (Lamiaceae). Bhanjiri. Erect hairy annual aromatic herbs. Leaves ovate, coarsely toothed, acute. Flowers white in whorls of two, forming long, erect, axillary and terminal racemes. Nutlets globose.

Status: This plant species is vulnerable in the state.

Medicinal Uses: Plant- sedative, antispasmodic, antiasthmatic, stomachic, tonic, antirheumatic, in cephalic, pulmonary and urinary troubles, flu, nausea, sunstroke, uteritis, dyspepsia; leaf, stem and seed- diaphoretic; flower- carminative.

28. **Piper longum**L. (Piperaceae): Pippali. Creeping or rambling perennial herbs, rooting at nodes. Leaves up to 11 cm long, ovate-suborbicular, cordate, acuminate, entire. Flowers greenish-yellow, unisexual, in cylindrical spike.

Status: The plant species is endangered in the state.

Medicinal Uses: Fruits- carminative, as liniment for rheumatic pains and paralysis; roots- diuretic, stimulant, sudorific; root and fruits- stomachic, analgesic, in epilepsy, leprosy and inflammation, emmenagogue, cholagogue, anthelmintic, in diseases of respiratory tract (Husain *et al.* 1992). Indian long pepper forms one of the ingredients of an Ayurvedic erbal medicine, *Pippali rasayana,* used for the treatment of chronic dysentery and worm infestation and also reported to show antigiardial and immuno- stimulatory activity in mice infected with *Giardia lamblia* trophozoites. It gave up to 98% recovery from the infection.The plant is one of the ingredients of the Ayurvedic drug, *Trikatu* whose constituents and piperine are reported to possess bioavailability enhancing activity which increases the efficacy of the co-administered Ayurvedic formulations or medicaments. It is an ingredient of the Ayurvedic drugs, *Mrityunjayarasavati* used for chronic sinusitis and *Anand Bhairava Ras* used for the treatment of amoebiasis (Anonymous Vol.4.p.319.2003).

29. **Plumbago zeylanica**L. (Plumbaginaceae): Chitrak. Subscandent undershrubs. Leaves 4-10 cm long, ovate, acute, lower portion of

the petiole auricled. Flowers white, in spike like racemes. Capsules oblong, enclosed within the persistent calyx. Seeds oblong.

Status: This species is vulnerable because of its root which are overexploited for its medicinal uses in pharmaceutical industries.

Medicinal Uses: Leaf- in rheumatism; leaf and root- abortifacient; root- appetizer, sudorific, relieves muscular pain, diuretic, vesicant, in diarrhoea, expellent of phlegmatic humours, in skin diseases, leprosy, aphthae, abscesses, in influenza, black water fever, piles, anasarca; root-bark- antiperiodic; milky juice- in scabies and ulcers (Husain *et al.* 1992).

30. **Psoralea corylifolia**L. (Fabaceae): Babchi. An erect annual herbs or undershrubs with gland dotted branches. Leaves simple, broadly ovate-rounded, gland dotted. Flowers purplish in dense long-peduncled heads;calyx teeth lanceolate;corolla exserted. Pods subglobose-ovate.Seeds blackish.

Status: Endangered in the state due to infection during flowering and fruiting or its its reproductive behaviour.

Medicinal Uses: Root- dental caries; leaf- antidiarrhoeal; seed- in skin diseases mainly leucoderma, anthelmintic, diaphoretic, febrifuge, stomachic deobstruent, in scorpion- sting, antibilious (Husain *et al.* 1992). Seeds are powdered and administered orally with warm water in a dose of 5g/day in case of eczema (Anonymous Vol. 4. p. 419.2003).

Preparations and Formulations: Buchki-taila, Vidanga-lep, etc. (Dey 1980).

31. Pterocarpus marsupium Roxb.(Fabaceae). Bijasal. Medium- sized to large deciduous trees. Leaves 15-22 cm long, imparipinnate; leaflets 5-7, eliptic or ovate- lanceolate acute, entire. Flowers yellowish in much branched,brown pubescent terminal panicles. Pods orbicular, compressed, winged.

Status: Vulnerable in the state due to habitat loss and heartwood used in pharmaceutical industries.

Medicinal Uses: Leaf on boils, sores, and other skin diseases; kino from incision in barkastringent, antidiarrhoeal, haemorrhage, pyrosis, haematurea, tongue disease, locally in leucoderma; wood- antibiotic, in diabetes; flower and kino from bark- febrifuge (Husain *et al.*1992).

32. Pygmaeopremna herbacea(Roxb.) Mold. (Verbenaceae). Perennial, aromatic, dwarf herbs, with a stout woody base. Leaves opposite, decussate, appressed to the ground, obovate- rounded-elliptic, obtuse or rounded at apex, acute or cuneate at base. Flowers greenish-creamish-yellow, in pedunculate, corymbose panicles. Drupes green, black on drying, glabrous.

Status: This species is critically endangered in the state due to overgrazing.

Medicinal Uses: Root preparation- given internally for rheumatism; plant- used in scorpion- sting and snake-bite (Chopra et al. 1956). Plant is used as folk remedy in the Yunan province of China to reduce inflammation and to cure malaria (Anonymous Vol.4.p.397.2003).

33. Rauvolfia serpentina(L.) Benth. ex Kurz (Apocynaceae): Sarpgandha. Glabrous erect undershrubs. Leaves 7.5-18 cm long, elliptic-lanceolate

or obovate-oblanceolate, whorled, acute or acuminate. Flowers whitish-pink. Drupes ovoid, black when ripe, single or didymous.

Status: This species is vulnerable because its roots are indiscriminately collected for pharmaceutical industries; also listed in CITES.

Medicinal Uses: Leaves- removes opacity of cornea of the eyes; rootincrease uterine contractions, hypotensive, in mental disorders (Husain *et al.*1992).

Preparations and Formulations: Sarpagandhadichurna, Sarpagandha-yog, Sarpagandha-vati, etc. (Sharma *et al.* 2000).

34. Uraria picta(Jacq.) Desv. ex DC. (Fabaceae): Prisniparni. Robust erect perennial suffruticose herbs or undershrubs. Leaves variable, lower simple or 3-foliolate, rounded or oblong; upper 5-9- foliolate, linear-lanceolate, blotched, white along the veins. Flowers purplish in dense cylindrical heads. Pods 3-6- jointed. Seeds white, shining.

Status: It is vulnerable because of habitat loss and its roots which are used in medicine.

Medicinal Uses: Plant- antidote to the poison of phursa snake (*Echis carinata*); root and pod- in prolapse of anus in infants; root- febrifuge, bechic; fruit- in mouth sore of children (Husain *et al.* 1992).

Preparations and Formulations: Sudarsan-churna, Dasamula (Dey 1980).

BIBLIOGRAPHY

Anonymous 1947-1976. The Wealth of India. Raw Materials Vols. 11. CSIR, New
Delhi.

Anonymous 1985, 1988, 1992. The Wealth of India. Raw Materials (Revised).
Vol. I, II, III. CSIR, New Delhi.

Anonymous 2004. Wealth of India. First Supplement Series Vol. 1-5. Publication
and Information Directorate, New Delhi.

Dey, A.C. 1980. Indian Medicinal Plants used in Ayurvedic Preparations. Dehra Dun.

Duthie, J.F. 1903-1922. Flora of Upper Gangetic Plain and the adjacent Siwalik and Sub-Himalayan Tracts (2Vols). Calcutta.

Husain, A. Virmani, O.P., Popli, S.P., Misra, L.N., Gupta, M.M., Srivastava, G.N., Abraham, Z. and Singh A.K. 1992. Dictionary of Indian Medicinal Plants. CIMAP, Lucknow.

Prakash, Anand 2011. Uses of some threatened and potential ethnomedicinal plants among the tribals of Uttar Pradesh and Uttarakhand in India. Souvenir: National Conference on Forest Biodiversity: Earth's Living Treasure pp. 93- 99.

Raizada, M.B. 1976. Supplement to Duthi's Flora of Upper Gangetic Plain and of the adjacent Siwalik and Sub-Himalayan Tracts. Dehra Dun.

Rastogi, R.P. and Mehrotra, B.N. 1988-1998. Compendium on Indian Medicinal Plants. 6 Vols. CDRI, Lucknow and NISC, New Delhi.

Rau, M.A. 1969. Flora of Upper Gangetic Plain and of the adjacent Siwalik and Sub-Himalayan Tracts (Check List). Dehra Dun.

Sharma, P.C. Yelne, M.B. and Dennis, T.J.2000-2001. Database on Medicinal Plants used in Ayurveda. 3 Vols. CCRAS, New Delhi.

Singh, S.C. 2011. Plant Genetic Resources of CSIR-CIMAP, Lucknow. CIMAP, Lucknow.

Singh, S.C. and Khanuja, S.P.S. 2006. Lucknow Flora- The Plant Wealth of the Region. Central Institute of Medicinal and Aromatic Plants, Lucknow.

Singh, S.C. and Shah, N.C. 1990. New Record for Upper Gangetic Plain from Lucknow District. *J. Econ. Tax. Bot.* 14(3):748-750.

Singh, S.C. 1993.*Spilanthes uliginosa* Sw. A New Record for Gangetic Plain. *J. Bomb. Nat. Hist. Society* 90(3):541-542.

CHAPTER 5

BIODIVERSITY AND CONSERVATION OF UNEXPLOITED AND UNDERUTILIZED LEAFY VEGETABLES IN CHHATTISGARH STATE OF INDIA

Vivek Kumar Kurrey

Department of Vegetable Science, I.G.K.V., Raipur, Chhattisgarh (492012), India

*Corresponding author: vivekkumar.kurrey@gmail.com

Introduction

India has richest diverse genetic resources. Globally, there are 400 species of vegetable crops with about 80 species of major and minor vegetables reported to have their origin in India. In India 175 species of major and minor vegetables crop are grown in India. Presently, India is at second position in the production in world after china with the area of 9.20 million hectares and production of 162.18 million tones. However consumption of vegetables per capita per day is far below the recommended requirement of 300 gm/day/capita. There for the gap underutilized and unexploited vegetables can play a very important rile under adverse conditions.

The state of Chhattisgarh in India situated in the eastern India, has three agro climatic zones viz., Chhattisgarh plain, Bastar plateau and Northern hills region. Its climate is of dry sub humid type. The average annual rainfall is about 12000-1500 mm which is largely contributed by south west monsoon. Chhattisgarh state covers an approximate area of 137.9 lack hectare and lies between the latitude $21^{o}16^{\prime}$N, longitude $81^{o}36^{\prime}$E and at an altitude of 289.56 meters above the mean sea level. Nearly 44% of its Geographical area is covered with forests. These forests

comprise of rich Sal, Teak, and Miscellaneous Forest. The forests are mainly inhabited by indigenous people who are greatly dependent on the vegetables available in this forest for their health and economic well being.

Chhattisgarh, the newly carved out state in the Union of India, has an extremely rich bio-diversity. Chhattisgarh state is endowed with varied soil types, surplus manpower and farmable agro ecological conditions. The forest occupied 46% of total geographical area and varied from 62.2% in Bastar to 47.0 % in northern hills. Chhattisgarh occupies an important place in the horticulture map of the country, horticulture crops occupies an area of 7.5 lakh ha. with a production 8109630 MT. although the area comprise only 13.41 % of the net cultivated area in invested, but the total income generated from horticulture sector accounts to over 33.83 % of total income derived from combined agriculture sector. In Chhattisgarh, many unexploited and underutilized leafy vegetables are being grown in homestead, fallow, *badi* cultivation and forest with less care. These vegetables are highly nutritious and contributing in the poverty reduction, household food security of tribal people. The diverse agro climatic condition viz., Northern hill region Chhattisgarh plain, and Bastar plateau favors the cultivation of various underutilized vegetable crops.

The Agro climatic zone of Chhattisgarh

Agro climatic zone	District
Northern hill region	Surguja, Jashpur, Koria, Balrampur, Surajpur
Chhattisgarh plain	Raipur , Durg, Rajnandgaon, Bilaspur, Dhamtari, Mahasamund, Korba, Raigarh, Kawardha, Janjgir-Champa, Kanker, Baloda bajar, Gariyaband, Bemetara, Mungeli and Balod
Bastar plateau	Bastar, Dantewada, Narayanpur, Bijapur, Kondagaon and Sukma

Out of the 27 districts of Chhattisgarh Bastar, Dantewada, Narayanpur, Surguja and Jashpur are rich in biodiversity of vegetable crops.

What is unexploited and underutilized Vegetable

The underutilized and unexploited vegetables refer to categories of wild and cultivated plats which are commonly applied to species whose potential has not been fully realized. They are grown primarily in their centers of origin of diversity by traditional farmers, where they are still important for the subsistence of local community's .The potential of some underutilized species to become commodity crops should not be underestimated. Unexploited and underutilized leafy vegetables crops are those crops whose potential has not been exploited to the fullest extent. These crops have rightly been termed as the "Crops for the Future" at the global level signifying their importance for the future. Therefore, underutilized crops have to be made competitive so that they do not lose out their competitive counterparts.

Conservation of genetic diversity in underutilized and unexploited leafy vegetables distributed in different phyto-geographical regions has assumed considerable significance due to genetic erosion. Rising in population, deforestation, urbanization, shift in land use pattern, change in cropping pattern and adoption of new varieties leading to mono- cropping are major factor responsible for rapid genetic erosion of several vegetables crops. Hence, there is an urgent need to conserve underutilized vegetable biodiversity.

Unexploited and underutilized leafy vegetables of Chhattisgarh according to
Their local names, in different tribal and local languages

S.N.	Common/Local name	Botanical name	family	Habit
1.	Lal Bhaji	*Amaranthus triicolor* L.	Amaranthaceae	Cultivated
2.	Kheda bhaji	*Amaranthus dubius* Mart.	Amaranthaceae	Cultivated
3.	Chaulai Bhaji	*Amaranthus viridis* L.	Amaranthaceae	Cultivated
4.	Amari Bhaji	*Hibiscus sabdariffa* L.	Malvaceae	Cultivated
5.	Amrul, tinpania Bhaji	*Oxalis corniculata*	Oxalidaceae	Weed
6.	Bathua Bhaji	*Chenopdium album* L.	Chenopodiaceae	Weed
7.	Charota Bhaji	*Cassia tora* L.	Papiolionaceae	Weed
8.	Chench Bhaji	*Corchorus acutangulus* Lam.	Tiliaceae	Cultivated
9.	Chunchunia Bhaji	*Marsilea vestita* Hook.	Marsileaceae	Weed
10.	Nunia bhaji	*Partulaca oleracea* L.	Partulacaceae	Weed
11.	Gumee Bhaji	*Leucas cephalotes* Spreng	Lamiaceae	Weed
12.	Kanda Bhaji	*Ipomoea batatas* Lam.	Convolvulaceae	Cultivated
13.	Karmatta Bhaji	*Ipomoea aquatica* Frosk.	Convolvulaceae	Weed
14.	Methi Bhaji	*Trigonella foenum graceum* L.	Papiolionaceae	Cultivated
15.	Munga Bhaji	*Moringa olerifera*	Moringaceae	Tree
16.	Palak Bhaji	*Spinacea oleracea* L.	Chenopodiaceae	Cultivated
17.	Patawa Bhaji	*Hibiscus cannbinus* L.	Malvaceae	Weeds
18.	Poi bhaji	*Basella alba*	basellaceae	weed
19.	Lal poi bhaji	*Basella rubra*	basellaceae	weed

20.	Sarson Bhaji	*Brassica compestris* L.	Brassicaceae	Cultivated

Leafy vegetable

Leafy vegetable are plant leaves eaten as vegetable, sometimes accompanied by tender petioles and shoots. In Chhattisgarh, the life and economy of the tribal and local people are intimately connected with the natural vegetation. Leafy vegetables play a major role in the nutritional requirement of the tribal and local population in remote parts of the Chhattisgarh. The enormous diversity in geographical and climatic conditions makes the region a gene pool for valuable wild edible and medicinal and nutritious leafy vegetables. These plants have importance in the indigenous system of medicine as well as tribal dietary requirement. It is estimated that about 800 species are consumed as wild edible plants over the country belonging to different genera and families have been reported in India. Wild edible plants not only provide food quantity but also make significant Contribution to the population nutrition throughout the year. Some edible leafy vegetables have great economic value and are highly linked with socio economic development of the tribal communities of the state

Nutritive Value of Leafy Vegetables (Mg. /100gm. of edible part)

Leafy vegetables	**Energy (Kcals)**	**Moisture (g)**	**Protein (g)**	**Fat (g)**	**Mineral (g)**	**Fibre (g)**	**Carbohydrates(g)**	**Calcium (mg)**	**Phosphorus (mg)**	**Iron (mg)**
Amaranthus	93	73	8	1	3	2	12	1130	80	4
Beet greens	46	86	3	1	2	1	6	380	30	16

Drumstick leaves	92	76	7	2	2	1	12	440	70	1
Fenugreek leaves	49	86	4	1	1	1	6	395	51	2
Mustard leaves	34	90	4	1	2	1	3	155	26	16
Spinach	45	92	2	1	2	1	3	73	21	1
Chench bhaji	58	51.4	5.1	1.1	2	1.6	8.1	241	82	7.2
Celery	18	93	1	0	1	1	3	30	38	12
Gogu	56	86	2	1	1	0	10	172	40	1

In present, scenario with increasing population pressure and limited area, there is strong need to promote these underutilized vegetables. For the promotion of these neglected and underutilized species, need to be collection, evaluation and identification, particularly for high yield, quality, resistance to diseases and pests, tolerance to frost, acidity. There is ample scope in future to utilize the untapped genetic diversity in underutilized leafy vegetable crops which will help in proving stability to the economy, employment generation, crop diversification and nutritional security of resources for poor farmers/ citizen at large.

Conclusion

In Chhattisgarh state the land holding patterns reveals that nearly 80% farmers are small and marginal, hence, the underutilized leafy vegetable are ideal for cultivation because of their low input requirement, less production cost, higher nutritive value and high yield .Chhattisgarh is one of the richest reservoirs of genetic variability and diversity of different underutilized vegetable crops which exist in plant types, morphological and

physiological variations, resistance to diseases and pests, adaptability and distribution. It lays emphasis on exploiting the potential usefulness of such a valuable resources, in combating the challenges of food, employment generation and nutr4itiopnal security to the ever increasing population. They could be made competitive if commensurate investments are made on their collection, conservation and scientific exploitation as it is being done for other crops using conventional technology along with innovative utilization of the product with suitable interface with market and industry.

CHAPTER 6

ECOSYSTEM AND ECOLOGY

Dr.K.Sumathi
Agricultural officer,
Commissionerate of Agriculture,Chepauk, Chennai, Tamil Nadu, 600 005

The term ecology (oekologie) is derived from two Greek words-oikos means ‘house or place to live’ and logos means ‘a discussion or study’. Literally, ecology is the study of organisms ‘at home’, in their native environment. The term ecology was first of all introduced by Reiter in 1868. Ecology may be defined broadly as the science of inter-relationship between living organisms and their environments including both the abiotic and biotic environments.The hierarchy in the levels of organisation connected with ecological grouping of organisms is called ecological hierarchy or ecological levels of organisation. Individual organism is the basic unit of ecological hierarchy. Organisms of the same kind may form several populations inhabiting different geographical areas. Biotic community is an assemblage of populations of different species of plants, animals, bacteria and fungi which live in a particular area and interact with one another through competition, predation, mutualism, etc. Ecosystem is a segment of nature consisting of both biological community and its physical environment interacting and exchanging materials as well as energy. Biome is a large regional unit delimited by a specific climatic zone, having a particular major vegetation zone and its associated fauna.No organism can live alone. It has to interact with its immediate surroundings which include both biotic and abiotic factors. Habitat is a specific place or locality characterised by a combination of factors, physical features and barriers where a community resides. Niche or ecological niche (Grinnel, 1917) is a specific part of habitat occupied by individuals of a species which is

circumscribed by its range of tolerance, range of movement, microclimate, type of food and its availability, shelter, type of predator, and timing of activity.

MAJOR BIOMES

- The characteristics of biomes are a direct result of their temperature and rainfall patterns. Biomes are often classified in seven categories :**tropical rain forests, savannahs, deserts, temperate grasslands, temperate deciduous forests, taiga and tundra.** The distribution of seven biomes of the world is correlated to climate, which is affected by latitude, presence of mountains, temperature of surrounding sea and elevation of the land.
- The **tropical rainforest** is abiomeoccuring in regions of high temperature (average 25°C) and high rainfall (200-450 cm per year). This biome is characterized by multistoried vegetation (upto five distinct layers or storeys of vegetation). Further, maximum biodiversity on land is shown by this biome and-productivity of this biome is the maximum.
- Like tropical forests, **savannahs** are found near the equator but in areas having less annual rainfall (90-150cm/year). The vegetation of this biome supports, large grazing herbivores like buffalo, zebra, etc., which are food for carnivores like lions, tigers, etc.
- **Deserts** are the biomes that have 25 cm (10 inches) or less of precipitation annually. Major deserts occur around 20-30 degrees north and south latitude, where the warm air arising from the equator falls. Sahara of North Africa, Thar of West Asia and Gobi of Asia are the most important deserts.
- **Temperate grasslands** experience a greater amount of rainfall than deserts but a lesser than savannahs. They occur at higher latitudes than savannahs but like savannahs are characterized by perennial grasses

and herbs for grazing mammals. Temperate grasslands have different names in different parts of the world, e.g., Prairies of North America, Steppes of Russia, Veldts of South Africa, Pampas of South America, Pusztas of Hungary and Tussocks of New Zealand.

- **Temperate deciduous forests** occur in areas having warm summers, cold winters and moderate amount of precipitation (75-150 cm annually). The trees of this forest loose their leaves during autumn and remain dormant throughout winter.
- The **taiga** or **northern coniferous forests** or boreal forests consist of evergreen, cone bearing trees like spruce, hemlock and fir. The taiga is characterized by long, cold winters with little precipitation.
- The **tundra** encircles the. top of the world. This biome is characterized by desert-like levels of precipitation (less than 25 cm annually), extremely long and cold winters and short warmer summers. This biome covers l/5th of earth's land surface. Tundra is uniform in appearance and is dominated by scattered patches of grasses, sedges and lichens.

RED DATA BOOK AND IUCN

- To highlight the legal status of rare species for the purpose of conservation, the **International Union for Conservation of Nature and Natural Resources** (IUCN) has established the five main conservation categories These are extinct, endangered, vulnerable, rare and insufficiently known species.
- Using the IUCN categories, the World Conservation Monitoring Centre (WCMC) has evaluated and described threats to about 60,000 plant and 2000 animal species in its series of Red Data Books.
- **Threatened species** include those which are endangered, vulnerable, and rare in IUCN categories.

- The great majority of the species on these lists of Red Data Books are plants. However, there are also species of fish (343). amphibians (50), reptiles (170), invertebrates (1355), birds (1037) and mammals (497).
- Red Data Book or Red List was initiated in 1963,The2000 Red List has made assessment of 18,000 species, out of which 11096 species (5485 animals and 5611 plants) are on the threatened list world-wide. The number of threatened species has now gone up to 15,500 (IUCN, 2004).
- Red List has **eight categories of species**.
- These are **extinct, extinct in wild, critically endangered, endangered, vulnerable, lower risk, data deficient and not evaluated species.**

– The taxon that has been completely eliminated or died out from earth is called **extinct,** e.g., Dodo.

– The taxon that is absent in any of its natural or expected habitats in the wild is known as extinct in wild.

– **Critically endangered species** is the taxon which is facing **very high risk of extinction** in the wild and can become extinct any moment in the immediate future, e.g., Berberisnilghiriensis, Podophyllum.

– **Endangered species** are facing a high risk of extinction in the wild in near future due to decrease in its habitat, excessive predation or poaching e.g., Red panda, Blue whale, Asiatic wild ass, Lion tailed macaque.

– **Lower risk species** are threatened species which have lower risk of extinction and, therefore, require only a small attention to become normal flourishing species.

- When the data for making direct or indirect assessment of risk of extinction is deficient, such species are called **data deficient species.**
- **Not evaluated species** are those that has not been evaluated for risk of extinction.

- Out of these, four categories of species are included under **threatened species**- critically endangered, endangered, vulnerable and lower risk species. Two more categories are also added to them. These are **rare species** and **indeterminate species**.
- **Rare species (R)** are species with naturally small populations, either localised or thinly scattered, which are always at risk from pests/pathogens/predators/ exotic species. Clouded leopard (Neofelisnebulosa) of Himalayas is a rare species.
- **Indeterminate species** are in danger of extinction but the reason is not known, e.g., 3-banded Armadillo of Brazil, short eared rabbit of Sumatra, Mexican prairie dog.

Some examples of primary succession

Hydrosere

- **Hydrosere** is an **ecological succession** in the **newly formed pond or lake**. It starts with the colonization of some phytoplanktons which form the pioneer plant community, and finally terminates into a forest, which is the climax community.
- The various stages together with their chief components of plant species during primary succession in water are:
- **Phytoplankton stage/Pioneer stage** ; Constitutes the pioneer community. Some blue-green algae, green algae, diatoms and bacteria

etc. were the first organisms to colonize the primitive medium of the pond.

- **Rooted submerged stage** : A new habitat suitable for the growth of rooted submerged hydrophytes like Elodea, Utricularia, Potamogeton, Hydrilla etc.
- **Rooted floating stage :** These plants colonize the habitat with their **rhizomes.** They all are rooted floating hydrophytes which include Nelumbo, Limnanthemum, Trapa, Nymphaea etc. Some free floating plants as Azolla, Lemna, Wolffia, Pislia, Salvinia etc. also become associated with the rooted plants, due to availability of salts and other minerals in abundance.
- **Reed swamp stage :** The plants of this community are rooted but most parts of their shoots (assimilatory organs) remain exposed to air. Species of Sagitiaria, Phragmites, Typha etc. are the chief plants of this stage.
- **Marsh or Sedge meadow stage :** Because of the successive decrease in water level and further changes in the substratum, species of Carex, Juncus, Cyperus, Eleocharis, etc. colonize this area.
- **Woodland stage:** Due to disappearance of marshy sedge- meadow stage, soil becomes drier for most time of the year. This area is now invaded by terrestrial plants, which are some shrubs (Salix and Cornus) and trees (Alnus and Populus).
- **Climax forest stage:** Forest stage is the climax community. The woodland community is gradually invaded by several trees e.g., Acer, Quercus.

Lithosere (A xerosere on rock)

- The sequence of successional stages that occur on bare rocks is called **lithosere.** The first inhabitants or pioneers of such a habitat are usually **lichens** in the temperate regions.
- **Crustose lichen stage :** The lichens of this stage are represented by the species of Rinodina, Lecanora, Rhizocarpon etc. They produce some acids which cause weathering of rocks. The dead organic matter of lichens becomes mixed with small (weathered) particles of rocks. As a result, these lichens are replaced by **foliose type of lichens.**
- **Foliose lichen stage** : They can absorb and retain more water and are able to accumulate dust particles which build up the suitable substratum for the moss stage.
- **Moss stage :** A thin soil layer develops on rock surfaces, especially in crevices, and favours the growth of such xerophytic mosses as species of Tortula, Grimmia and Polytrichum.
- **Herbs stage :** This stage is constituted by shallow rooted grasses as Festuca, Solidago, Aristida, etc.
- **Shrub stage :** Due to much accumulation of soil, the habitat becomes suitable for shrub vegetation which starts migrating in the area. This habitat includes the species of Phytocarpus, Rhus etc.
- **Forest stage :** From shrub stage, there develops finally a forest community.

Importance of biotic succession

- It tells us how a biotic serai stage like grasses and herbs of a pasture can be maintained by not allowing the biotic succession to proceed further through interference like grazing and fire.
- Information gained through biotic succession is used in having controlled growth of one or more species by preventing their superiors to invade the area, e.g..maintenance of teak forest.
- Dams are protected by preventing siltation and biotic succession to occur.
- It gives information about the techniques to be used during reforestation and afforestation.

Points to be noted

- **Autogenic succession :** When the succession has begun, the vegetation itself is responsible for replacing itself by changing existing environmental conditions.
- **Allogenicsuccession :** When in succession other conditions (not vegetation itself) are responsible for replacing communities, then it is called allogenic succession.
- **Autotrophic succession** is characterised by early and continued dominance of autotrophic organisms like green plants. It starts in a predominantly inorganic environment and the energy flow is maintained indefinitely.
- **Heterotrophic succession** is characterised by early dominance of heterotrophs such as bacteria, fungi and actinomycetes. It begins in a predominantly organic environment and there is a progressive decline in the energy content.

- **Induced succession** occurs due to extensive external interference. Here the initial community has high productivity which gradually decreases. Agriculture can be deemed as an example of induced succession. Here a steady stage is maintained for an ultimate good harvest.
- Due to environmental thrust and human interference the climax vegetation may retrograde into shrub land or savannah. This is referred to as **retrogressive succession.**
- When the succession doesn't proceed through its normal course and side tracks, the advancement line is called **deflated succession.**

MAJOR ABIOTIC FACTORS

- The abiotic or physical factors affect the structure, behaviour and life history of organisms. The **four types of abiotic factors** are **climatic** (light, air/wind, temperature, humidity, precipitation), **edaphic** (soil), **topographic** (earth surface), and **fire.**

Temperature

- Not only the physiological functions but also the geographical distribution of many plants and animals is governed by temperature.
- Important effects of temperature are :
  - **Metabolic activities :** Since different metabolic activities of plants are controlled by different enzymes which are affected by temperature, therefore, these metabolic activities are affected by temperature, e.g., photosynthesis, respiration, etc.
  - **Reproduction (flowering):** Temperature is also an important factor affecting flowering in plants.

- **Growth and development:** Growth and development are adversely affected by very low and high temperature.

- Based on the temperature, vegetation of the whole world is divided into four major groups :
  - **Megatherms :** plants growing in high temperature throughout the year, e.g., tropical rain forests.
  - **Mesotherms**: plants growing in alternate high and low temperature, e.g., deciduous vegetation.
  - **Microtherms:** plants growing in low temperature, e.g., coniferous vegetation.
  - **Hekistotherms :** plants growing in very lowtemperature, e.g., alpine vegetation.

- On the basis of temperature strata, again three types of aquatic zones are there.**Epilimnion** is the upper stratum which is exposed to sun-rays. It is warmer during summer and comparatively cooler during winter. **Hypolimnion** is the basal stratum where water is always cool.**Metalimnion** is the zone of transition between epilimnion and hypolimnion.

- The **maximum temperature change occurs in** the middle portion of metalimnion, which is called thermocline. It is the short zone in water body where sharp fall in temperature occurs.

- Temperature is very high at oceanic vents in comparison to ocean surface.

- On the basis of temperature need, animals are classified as given below:
  - **Eurythermal / Homeotherms / Endotherms / Warm blooded :** Organisms which can tolerate wide range of temperature. These can

generate their own heat so their body temperature remain constant. Examples- man, birds.

- **Stenothermal / Poikilotherms / Ectotherms / Cold blooded:** Organisms which can tolerate narrow range of temperature. Examples- reptiles, amphibians, fishes.

Water

- Water is an important component of protoplasm being **used as a general solvent, a reactant, a metabolic by-product and an essential material for maintaining turgidity. Water is a resource, a condition and a habitat in itself.** The productivity and distribution of plants is also heavily dependent on water.
- Plants of aquatic habitats are called **hydrophytes.** Clarity of water, salt content, depth and water waves or speed determine the growth and distribution of plants and animals. Organisms found in fresh water have a problem of excess internal water because of **endosmosis.** Organisms found in ocean or salty water have a problem of low internal water content due to **exosmosis.** Some have problem of excreting excess salts obtained from outside. In oceans at a depth of more than 200 m, producers do not occur. Only consumers are found there. For aquatic organisms the quality, (chemical composition, pH) of water becomes important.
- Some organisms are tolerant of a wide range of salinities (**euryhaline,** e.g., salmon) but others are restricted to a narrow range of salinities (**stenohaline,** e.g., shark). Many freshwater animals cannot live for long in sea water and vice versa because of the osmotic problems they would face.

Light

- Light is an important ecological factor as it affects different physiological processes of plants, e.g., photosynthesis, transpiration, movements, flowering, seed germination, etc. Main source of light is sunlight.
- The different effects of light are :
  - Formation of chlorophyll
  - Stomatal movements
  - Growth and development
  - Distribution of plants
  - Flowering
- There is a light zonation in deep lakes and oceans. Littoral zone is shallow coastal region. Light is able to pass through shallow water and reach the bottom. Therefore, producers occur throughout from surface to bottom. **Limnetic zone** is open water zone where water is very deep. Amount of oxygen and light decreases with depth. Limnetic zone has three parts-photic, aphotic and benthic. **Photic zone** is the upper part of limnetic zone to which light can penetrate. Mostly algae flourish in this region. **Aphotic/profundal** zone is the zone of deep water, below the photic zone and above the bottom, to which light does not penetrate. The zone is, therefore, in **perpetual darkness.** Producers do not occur in this part. Instead, only consumers are found. **Benthic zone** is the bottom zone.

Atmospheric humidity

- Moisture in form of invisible vapour in atmosphere is called humidity.
- Atmospheric humidity is generally expressed in terms of elative humidity which is defined as, “amount of vapours in atmosphere as the percentage of total amount which the air, or atmosphere can hold at the existing temperature”.
- The effect of humidity is similar to that of low light intensity.

- Certain plants which grow in high relative humidity are called **hygrophytes,** e.g., lichens, mosses and orchids.

Wind

- Wind is defined as **air in motion.** Wind speed is measured with the help of **anemometer.**
- The effects of wind are more conspicuous on sea coasts and mountains. Important effects of wind are :

– **Lodging:** Flattening of plants against ground due to wind action is called lodging. This generally occurs in grasses (members of gramineae).

– **Dwarfness of plants :** High wind velocity leads to desiccation which leads to loss of turgidity of cells, reduction in cell size and hence dwarfism.

– **Uprooting :** The plants are uprooted by high wind velocity and these plants are called wind falls or wind throws.

– **Distortion in shape of plants** : Occurs due to development only on one side.

– **Abrasions** : The soil particles carried by wind cause abrasions to plants and produce injury or wounds through which infection occurs.

Soil

- Soil is very important ecological factor as it provides water, minerals or nutrients and support**. Warming (1909)** divided plants into five different types on the basis of the soil conditions, i.e., **halophytes** (plants growing in salty or saline soil), **oxylophytes** (plants growing in acidic soil), **psammophytes** (plants growing in sandy soil), **chasmophytes**

(plants growing in rock crevices) and **lithophytes** (plants growing on rocks).

- **Good soil** has following components :**mineral particles** about 40%, organic matter or humus about 10%, soil air 25%, soil water 25%, soil microflora and fauna. **Mineral particles** are the chief components of soil complex and are formed by weathering of rocks. Thus, the correct sequence according to increasing particle size is **: Clay < Silt < Fine sand < Coarse sand < Gravel**.
- Various characteristics of the soil, such as soil composition, grain size and aggregation, determine the percolation and water holding capacity of the soil. These characteristics along with parameters such as pH, mineral composition and topography determine, to a large extent, the vegetation in any area. This in turn, dictates the type of animals that can be supported.

Topographic factors

- The ecological factors which are connected with physical geography of earth constitute physiographic or topographic factors.
- These factors change different climatic conditions which further affect the vegetation. Thus the topographic factors are indirect ecological factors. Important topographic factors are :
  - **Altitude :** Height above the sea level (altitude) is an important topographic factor. With increase in altitude, the climatic conditions go on changing and hence type of vegetation also changes (temperature factor).
  - **Directions of valleys and mountains** : Mountains deflect the winds and also cause condensation of water vapours leading to precipitation.

- **Slope steepness**: Steepness of slope affects amount of solar radiation and hence temperature.
- **Exposure of slopes :** The slopes which are well exposed show different vegetation types than the slopes which are less exposed.

Responses to abiotic factors

- A process by which an organism keeps the internal environment constant despite drastic changes in the external conditions is called **homeostasis.** Living organisms cope with stressful conditions by various methods.
- **Regulate:** Some organisms are able to maintain a constant body temperature and constant osmotic concentration despite changes in the external environment. They are called as **regulators**. Only birds and mammals, and a very few lower vertebrates and invertebrates belong to the category of regulators. All perform homeostasis mostly through thermoregulation and osmoregulation by physiological adjustments and rarely by behavioural changes. Behavioural changes for thermoregulation are observed in some reptiles - basking in the sun or excessive activity during winter, staying in cool moist burrows during summer days etc.
- **Conform** : About 99 percent of animals and nearly all plants do not have a mechanism to maintain a constant internal body environment. Their body temperature changes with the surrounding temperature. These animals and plants in which the osmotic concentration and temperature of body changes according to ambient conditions of water are called **conformers**. Some species are **partial regulators.** They have the ability to regulate body functions to a limited extent; beyond that limit they become conformers.

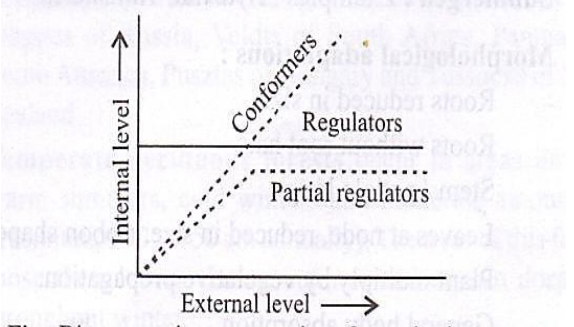


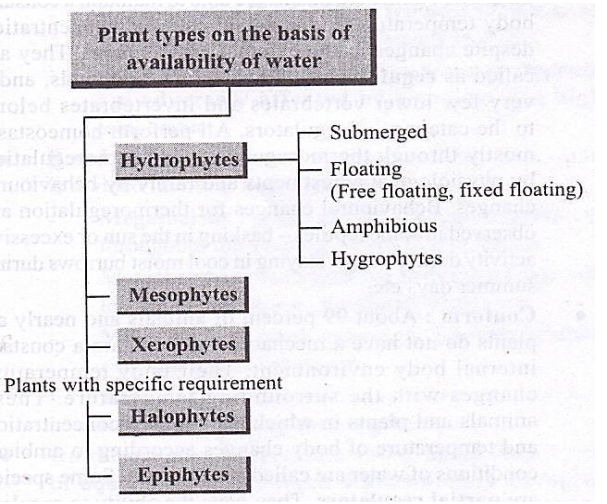
Fig.: Diagrammatic representation of organismic response

- **Migrate:** The organisms can migrate temporarily from the unfavourable habitat to more favourable area and return when unfavourable period is over.
- **Suspend** (stop for a time): Various kinds of thick-walled spores are formed in bacteria, fungi and lower plants which help them survive under unfavourable conditions. These germinate on return of the suitable conditions.
- In animals, the organism, if unable to migrate, might avoid the unfavourable environment by escaping in time. For example, polar bears go into **hibernation** during winter season to escape extreme cold. Some snails and fish undergo **aestivation** to avoid summer-related problems like heat and desiccation. Under favourable conditions, many zooplankton in lakes and ponds are known to enter diapause i.e., a stage of suspended development.

ADAPTATIONS

- Adaptation is any attribute of the organism (morphological, physiological, behavioural) that enables the organism to survive and reproduce in its habitat.

- On the basis of water availability, plants may be grouped as:
  - **Hydrophytes:** Plants requiring plenty of water as in water bodies; fresh water bodies (pond, lake, river etc.) salt water (sea, ocean etc.)
  - **Mesophytes:** Plants which require moderate water as in temperate and tropical regions.
  - **Xerophytes :** Plants growing in extreme dry conditions as in desert, sandy and hilly regions etc.



Hydrophytes

- **Submerged :** Examples : Hydnlla, Vallisneria
- **Morphological adaptations:**
  - Roots reduced in size.
  - Roots without root hair.
  - Stem / petiole long.
  - Leaves at node, reduced in size, ribbon shaped.
  - Plant multiply by vegetative propagation.

- General body absorption.

- **Anatomical adaptations:**
  - Stem without mechanical tissue.
  - Vascular bundle in centre.
  - Cortex large.
  - Air cavities present to provide buoyancy.
  - Stomata either absent or non-functional.

- **Free floating** : Examples- Water hyacinth (Eichhornia), Pistia, Salvinia.
  - **Morphological adaptations** : Large leaves, leaves well developed, reduced roots without root hair.
  - **Anatomical adaptations :** Air cavities large, mechanical tissue absent , stomata on upper surface.

- **Fixed floating:** Floating on surface but rooted at bottom of shallow water bodies. Examples- Nymphaea, Trapa. Marsilea.
  - **Morphological adaptations** : Large leaves, long petiole, root system developed.
  - **Anatomical adaptations:** Large air cavities, leaves with wax to avoid wetting, stomata on upper surface, mechanical / vascular tissues reduced.

- **Amphibious plants (Plants grow in shallow water/ marshy area / swamp area. Examples- Ranunculus /**Sagittaria.
  - **Morphological adaptations :** Shoot long, aerial leaves with stomata, root system well developed, rhizome present.
  - **Anatomical adaptations**: Cuticle present to avoid dessication, vascular bundles well developed, endodermis with thick wall.

- **Hygrophytes :** Examples- Fern grasses (require shady, moist places as in hills and dense forest).
  - **Morphological adaptations :** Leaves broad, shining, hydathodes present to remove excess water.
  - **Anatomical adaptations** : Mechanical and vascular tissues poorly developed.

Mesophytes

- Live in mesic condition i.e., moderate water conditions.

For example garden plants, cultivated / farm crops.

  - **Morphological adaptations :** Stem rigid, leaves large, root system well developed, root cap and root hair present.
  - **Anatomical adaptations** : In leaves - palisade layer has chlorophyll, mechanical and vascular tissue well developed, no wax coating, cuticle poorly developed if present.

Xerophytes

- Plants which live in dry conditions. Examples- Acacia, Prosopis, Zizyphus.
  - **Morphological adaptations :** Deep root system, bushy appearance, woody, stem green, photosynthetic, leaves reduced to spine to prevent water loss..
  - **Physiological adaptations :** Day time closure of stomata, CAM (**crassulacean acid metabolism**) cycle of photosynthesis
  - **Anatomical adaptations :** Thick cuticle, deep sunken stomata, palisade layer well developed and multilayered in leaves,

hypodermis sclerenchymatous, conducting elements are well developed.

Plants with special requirement

Halophytes (Plants growing in saline soils)

- Examples :Avicennia, Mangrove plant like Rhizophora.
  - **Morphological adaptations :** Leaves thin, small, leathery, slimy to prevent water loss. Roots negatively geotropic, such roots are called **pneumatophore (Respiratory root).** Vivipary observed (seed germinate on parent plant). When such seedlings fall down, they are easily anchored with soft mud and produce lateral roots.
  - **Anatomical adaptations** : Shallow root system, lenticles (aeration pore) present, salt glands present to remove salt, stomata present.

Epiphytes

- Small plants present on other higher plant branches to get minerals and moisture from decaying bark and from atmosphere. Examples- Vanda, Orchids.
  - **Morphological adaptations** : Few leaves that are succulent.
  - **Anatomical adaptations :** Thick cuticle, sunken stomata, aerial roots have velamen tissue to absorb or retain moisture.

Ecological adaptations in animals

- Animals also develop strategies to live better in their environment. Adaptation may be **: Short term** - temporary in nature like tanning of skin, increase of heart beat etc. or **Long term** - permanent in nature like typical type of beak, claw etc.
- In animals, most adaptations against environmental changes and stress conditions are physiological and behavioural adaptations, e.g.,

migration, hibernation, aestivation, **camouflage,** mimicry, echolocation, dealing water scarcity, prevention of freezing. Camouflage (cryptic appearance) is the ability to blend with the surroundings or background. It is difficult to distinguish leaf like grasshopper (Arantiarectifolia) or praying mantis (Mantis religiosa) from the surrounding foliage**. Mimicry** is the resemblance of one species with another in order to obtain advantage, especially against predation.

- Animals in colder areas possess thick fur, subcutaneous fat and small extremities. The tail, snout, ears and legs of mammals in colder part are relatively shorter than in the warmer areas - **Allen's rule**. According to this rule, in endothermal animals of colder areas, the extremities like feet, tail, ears, etc. tend to be smaller as compared to their relatives in warmer regions. This minimises heat loss.
- Animals facing **water scarcity** as found in arid or desert areas, show two types of adaptations - reduced water loss and ability to tolerate arid conditions**. Kangaroo rat/desert rat** seldom drinks water and possesses a thick coat to minimise evaporative desiccation. 90% of its water requirement is met from metabolic water, while 10% is met from food. Loss of water is minimised by producing nearly solid urine and faeces. Some organisms show behavioural adaptations to cope with variations in their environment**. Desert lizards** lack the physiological ability, that mammals have, to deal with the high temperatureThey keep their body temperature fairly constant by .behavioural means.

BIODIVERSITY, ECOSYSTEM SERVICES AND GENETIC RESOURCES

Published by:

Mr.Gajendra Parmar, Proprietor

Parmar Publication

854, KG Ashram, Bhuinphod, Govindpur Rd,
Dhanbad-828109,Jharkhand
Email id:gajendraparmar2562@gmail.com
Website: http://www.parmarpublisher.com
http://greenagriprofessionalsociety.com

ISBN: 978-93-921932-2-3

978-93-921932-2-3