SOUVENIR

National Conference
on
Managing Agro-Biodiversity in North Eastern India

(From Biodiversity to Bio-Wealth)
(NCMAN-2024)

October 23-25, 2024

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National Conference
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Managing Agro-Biodiversity in North Eastern India
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Organizers

Indian Society of Plant Genetic Resources, New Delhi
ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya
ICAR-National Bureau of Plant Genetic Resources, New Delhi

Co-Organizers

Protection of Plant Varieties and Farmers Rights Authority, New Delhi
Alliance for Bioversity International and CIAT, New Delhi
Trust for Advancement of Agricultural Science, New Delhi
ICAR-Agricultural Technology Application Research Institute, Zone-VI, Guwahati, Assam
ICAR-Agricultural Technology Application Research Institute, Zone-VII, Umiam, Meghalaya
ICAR-National Research Centre on Orchids, Pakyong, Sikkim

Sponsors

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Directorate of Animal Husbandry & Veterinary, Shillong, Meghalaya
National Bank for Agriculture and Rural Development (NABARD), Shillong, Meghalaya
International Center for Agricultural Research in the Dry Areas (ICARDA), New Delhi
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, Telangana

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PREFACE

We are delighted to present the Souvenir of the **National Conference on Managing Agro-Biodiversity in North Eastern India (NCMAN),** held during October 23-25, 2024. This event is projected to provide a roadmap for improving livelihood as well as food and nutrition security for better health through optimal, efficient and sustainable use of agro-biodiversity, which includes the animals and fisheries of northeastern India using innovations through interdisciplinary and inter-institutional scientific collaboration, as well as for ensuring enabling policies to conserve, use, benefit sharing and mainstream the agrobiodiversity of the region.

The national seminar comprises six Technical Sessions with >100 keynote/ invited lectures and oral presentations and >120 posters, one Plenary Session, an evening lecture and a Valedictory Session.

This publication contains articles related to agro-biodiversity, which includes animals and fisheries of north eastern India, their production potential, the current status of research related to genetic improvement, their conservation through use, nutritional and medicinal values, value chain options, socio-economic dimensions (women empowerment, consumption pattern, cost and affordability) and enabling policy support relating to their promotion as alternative sources of livelihood, food, nutrition and health security.

The articles included in this publication give a comprehensive overview of the genetic resource management work being done in north-eastern India, as well as related crops and species in other regions of the country. The organizers duly acknowledge the contributors for submitting the articles, as well as the editors for compiling the publication on time. It is hoped that this collation will be useful for policy makers, students, faculty, and researchers working in this area.

Core Organizing Committee

ACKNOWLEDGEMENTS

The National Conference on Managing Agro-Biodiversity in North Eastern India (NCMAN) is a great opportunity for us, as both organizers and participants, to share mutual experience in such an important field of management of agrobiodiversity including animal and fisheries of northeastern India.

The delegates (>250) comprise participants from the Indian Council of Agricultural Research (ICAR) and its institutes, Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), Alliance for Bioversity International and CIAT, International Center for Agricultural Research in the Dry Areas (ICARDA), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Central and State Universities, Council for Scientific and Industrial Research (CSIR), Meghalaya Biodiversity Board, Directorate of Animal Husbandry & Veterinary, National Bank for Agriculture and Rural Development (NABARD) and other Agencies of Government of Meghalaya, Tea Research Institute, private stakeholders, progressive farmers and entrepreneurs etc.

We would like to express our sincere gratitude to Padma Bhushan Dr. R.S. Paroda, President, ISPGR and Chairman, TAAS, New Delhi for guidance and support to organize the event in northeastern India as well as extended discussions and valuable suggestions.

Support and encouragement by Dr. Himanshu Pathak, Secretary, DARE and Director General, ICAR; Dr. Trilochan Mohapatra, Chairperson, PPV&FRA; Dr. Sanjay Kumar, Chairperson, ASRB, Dr. K. M. Bujarbaruah, Vice-President, NAAS are gratefully acknowledged.

Dr. P.L. Gautam, Chancellor, RPCAU, Bihar; Dr. Anupam Mishra, Vice-Chancellor, CAU, Imphal; Dr. Prabha Shankar Shukla, Vice Chancellor, NEHU, Shillong, Meghalaya and Dr. B. C. Deka, Vice Chancellor, AAU, Jorhat, Assam, Dr. S. K. Chaudhari, Deputy Director General, NRM, ICAR, New Delhi, Dr. G.P. Singh, Director, ICAR-NBPGR, New Delhi are profoundly thanked for the excellent technical and administrative support provided for organizing this Seminar. We also thank for the technical and administrative support by Dr. Vinay Kumar Mishra, Director, ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya.

We thank our co-organizers, Dr. A. K. Mohanty, Director, ICAR –ATARI, Umiam; Dr. G. Kadirvel, Director, ICAR-ATARI, Guwahati and Dr. S. P. Das, Director, ICAR-NRC, Orchid, Sikkim for their technical support and financial assistance in organizing the "Agrobidiversity Exhibition" during the conference.

Special thanks to Dr. R. K. Tyagi, Vice-President, ISPGR; Dr. J. C. Rana, Country Representative, Alliance for Bioversity International and CIAT, New Delhi; Dr. Anuradha Agrawal, Secretary, ISPGR & Director, ICAR- DKMA, New Delhi; Dr. Manjusha Verma, Joint Secretary, ISPGR, New Delhi; Dr. Mohan Lal, Zonal Councillor (NE), ISPGR & PS, CSIR-NEIST, Jorhat, Assam; Dr. Amit Kumar, Senior Scientist- Plant Breeding; Dr. Samir Das, Senior Scientist-Animal Health and Dr. Chandan Debnath, Senior Scientist-Fisheries Sciences form ICAR-NEH, Umiam, Meghalaya and Dr. Harish G. D. Incharge, ICAR-NBPGR Regional Station, Shillong for their critical inputs in developing the technical program and other support.

We duly acknowledge the financial support provided by ICAR, New Delhi; Alliance for Bioversity International and CIAT, New Delhi; PPV&FRA, New Delhi; ICARDA, New Delhi; ICRISAT, Hyderabad; NABARD and Meghalaya Biodiversity Board, Shillong and Directorate of Animal Husbandry & Veterinary, Shillong, Meghalaya.

We place on record the assistance received from the Core Organizing Committee, Local Organizing Committee, Technical Session Co-Chairs, Conveners and Rapporteurs, Poster Session Convener and Co-convener for the smooth conduct of the Conference.

We express our sincere appreciation to public and private sector partners for joining hands with us in this endeavour. We draw our strength from the support of colleagues from different participating institutes in this Seminar. A confluence of people involved in genetic resources management would not have been possible without the cooperation of many government and scientific institutions. We thank each one of them for their role in organizational steps.

October 23, 2024 **Editors**

CHANDRASHEKHAR H. VIJAYASHANKAR
Governor

RAJ BHAVAN
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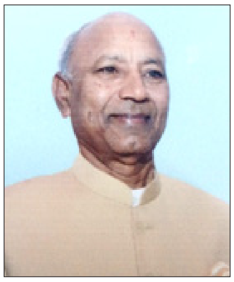

MESSAGE

I am delighted to extend my warmest congratulations to the organizers of the National Conference on Managing Agro-biodiversity in North Eastern India (NCMAN-2024). The conference is an outstanding initiative that brings together researchers, policymakers, and farmers to discuss the critical issue of agro-biodiversity in the North East.

The North Eastern region, with its vast forest cover, diverse climatic conditions, and rich genetic resources, plays a crucial role in India's agricultural landscape. This biodiversity is the foundation of food security, nutrition, and livelihoods for the people of the region, where small and marginal farmers make up the majority of the agricultural workforce. However, the region also faces growing threats from deforestation, climate change, and land degradation, which could lead to the loss of valuable genetic diversity.

By promoting sustainable farming systems, traditional knowledge, and underutilized crops, we can build a future where biodiversity conservation leads to economic empowerment. I congratulate all participants and look forward to the innovative ideas that will emerge from this event.

Best wishes for a productive and successful conference!

(C H Vijayashankar)
Governor of Meghalaya

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Dr R.S. Paroda (Padma Bhushan Awardee)
Founder Chairman
Trust for Advancement of Agricultural Sciences (TAAS)
(Former Secretary, DARE & DG, ICAR)
Avenue II, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi - 110 012

MESSAGE

The food and nutritional security and combating hunger are the key challenges being faced globally. These concerns have further been increased since the COVID-19 pandemic and the Russia–Ukraine and Israel-Palestine disputes, causing severe disruptions for the global food supply chain. The UN Food Systems Summit +2 Stocktaking Moment, held in 2023 has highlighted the role of sustainable, healthy and diversified local food systems for more sustainable outcomes for the people, planet and overall prosperity.

The Indian agriculture and allied sectors including the animal husbandry, horticulture and fisheries have been contributing to around 20% of the country's GDP while sustaining almost 50% of our workforce. The North Eastern region of India has been recognized as one of the major hotspots for remarkable array of agrobiodiversity including plants, animals and fisheries. A comprehensive assessment of the existing agrobiodiversity of North Eastern region is necessary in the light of habitat loss, changing climatic conditions, and diversity needed in our food consumption patterns. This assessment needs to include production potential of the existing genetic resources, the present status of research especially regarding the evaluation, genetic improvement and the conservation, critical for our food, nutrition and environmental security.

I am pleased that the Indian Society of Plant Genetic Resources, ICAR-Research Complex for North-Eastern Region, Umiam, and ICAR-NBPGR are organizing a National Conference on Managing Agrobiodiversity in North-Eastern India (NCMAN) at the ICAR-Research Complex for North-Eastern Region, Umiam, Meghalaya from 23-25, October 2024 in collaboration with the PPV&FRA, Alliance for Bioversity International and CIAT, and TAAS to develop a roadmap for an efficient, long term and sustainable use of the region's agrobiodiversity.

I congratulate the organisers and co-organisers for their timely initiative and wish this Conference a great success.

(R.S. Paroda)

Jai C Rana, Ph.D.

Country Representative – India |
Biodiversity for Food and Agriculture
Alliance of Bioversity International and CIAT
Asia – India Office
G-1, Block B, NASC Complex, DPS Marg, Pusa Campus, New Delhi 110012

MESSAGE

I am happy that Alliance has joined hands with the Indian Society of Plant Genetic Resources and ICAR-National Bureau of Plant Genetic Resources and many others in organizing National Conference on Managing Agrobiodiversity in North-Eastern India (NCMAN) during 23-25, October 2024 at ICAR-Research Complex for North-Eastern Region, Umiam, Meghalaya. I am sure the seminar will bring together various stakeholders working in PGR management to achieve the common goal of nutrition security and environmental sustainability in the North-Eastern Himalayas. At the Alliance, we strive to make food and agriculture systems more sustainable, efficient and inclusive, through sustainably funded science, research-based solutions and inclusive knowledge generation. Our strategy sets out how we work and accelerate impact towards tackling four interconnected global crises: biodiversity, climate, environment and nutrition. Through our work on the ground with partners and beneficiaries, we are unlocking holistic, research-based solutions to these crises, spearheading initiatives at the nexus of agriculture, the environment and nutrition.

I wish the organizers and the participants a successful congregation.

(Jai C. Rana)
Country Representative, South Asia

Pravin Bakshi, IAS
Commissioner & Secretary
Forest and Environment Department
Government of Meghalaya cum Chairman,
Meghalaya Biodiversity Board

MESSAGE

I am pleased to extend my heartfelt congratulations to the organizers of the National Conference on Managing Agro-Biodiversity in North Eastern India (NCMAN-2024). This conference represents a significant opportunity for researchers, policymakers, and practitioners to engage in meaningful discussions and innovations in the field of agro-biodiversity. Reflecting on NCMAN-2024, we acknowledge the profound importance of biodiversity to our region and our shared responsibility for its conservation.

Meghalaya, renowned for its incredible diversity of flora and fauna, is home to countless species that are vital for ecological balance and integral to the livelihoods of local communities. MBB has actively engaged with these communities through the establishment of Biodiversity Management Committees (BMCs). With over 6,484 committees now in operation, we are fostering local participation in the preparation of People's Biodiversity Registers (PBRs). These registers serve as invaluable tools for documenting and preserving our biological heritage for future generations.

As we move forward, we face significant challenges—such as climate change, habitat loss, and biodiversity decline—that demand urgent action. The discussions and insights shared during the conference have provided a solid foundation for collaborative efforts to address these pressing issues. It is essential for all stakeholders, including government agencies, local communities, researchers, and the public, to come together to devise innovative solutions that protect our unique biodiversity. MBB remains steadfast in its commitment to these goals. We invite everyone to join us in this critical mission to safeguard our natural heritage and build a sustainable future for all.

(Pravin Bakshi)

भाकृअनुप उत्तर पूर्वी पर्वतीय क्षेत्र अनुसंधान परिसर

ICAR Research Complex for NEH Region

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निदेशक
Dr. V.K. Mishra, FNAS
Director
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MESSAGE

It is a pleasure to convey my heartfelt thanks to Dr. R. S. Paroda, President of the Indian Society of Plant Genetic Resources (ISPGR), New Delhi, other organizing partners and sponsors of the National Conference on Managing Agro-biodiversity in North Eastern India (NCMAN-2024) for giving us an opportunity to host the national conference at our institute as one of the coorganisers. This conference is a testament to the importance of agro-biodiversity, including animals and fisheries, as a critical component of sustainable agriculture and rural livelihoods, especially in the North East India.

With its unique climatic conditions, the North Eastern region is a biodiversity hotspot that holds immense potential for addressing global challenges such as food security, climate resilience, and sustainable development through transforming biodiversity into bio-wealth, especially through Geographical Indications (GI) tags, crops, and livestock breeds due to their unique quality traits. The region's traditional farming systems, coupled with its wealth of underutilized crops, livestock, and aquatic genetic resources, present an ample opportunities for innovation and growth.

In the recent past, the conservation and sustainable use of biodiversity in the delicate ecology of northeastern India have faced significant challenges from an increase in population-driven needs for food and feed, urbanization, deforestation, habitat loss in wetland areas, and climate change. I hope, the conference will develop some specific solutions to solve the concerns of conservation and sustainable use of genetic resources through the debate and discussion among scholars, scientists, farmers, and policy makers.

Congratulations once again to the organizing team, and I wish the conference great success in shaping a sustainable future for North East India!

(V.K. Mishra)

सत्यमेव जयते

GOVERNMENT OF MEGHALAYA

DIRECTORATE OF ANIMAL HUSBANDRY & VETERINARY

MEGHALAYA: SHILLONG

Dr. Challangga D. Sangma
Director

MESSAGE

It is a pleasure to convey my heartfelt congratulations to the Indian Society of Plant Genetic Resources (ISPGR) and its partners for organizing the National Conference on Managing Agro-biodiversity in North Eastern India (NCMAN-2024) in Meghalaya. This conference is a testament to the importance of agro-biodiversity including animals and fisheries as a critical component of sustainable agriculture and rural livelihoods, especially in the North East.

Due to diverse climatic conditions, the North Eastern region is a biodiversity hotspot that holds immense potential for addressing global challenges such as food security, climate resilience, and sustainable development through transforming biodiversity into bio-wealth. The region's traditional farming systems, coupled with its wealth of underutilized crops, livestock, and aquatic genetic resources, provide an opportunities for innovation and growth.

However, as the population increases and environmental pressures intensify, there is an urgent need for conservation efforts that are both inclusive and innovative. I entrust the focus of this conference on fostering collaboration among scientists, farmers, and policymakers to ensure the sustainable management of the region's genetic resources.

Congratulations once again to the organizing team, and I wish the conference great success in shaping a sustainable future for the North East!

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ICAR-Agricultural Technology Application Research Institute
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Meghalaya -793103

Dr. A. K. Mohanty
Director

MESSAGE

Indeed, it gives me immense pleasure to extend my hearty congratulations to the Indian Society of Plant Genetic Resources (ISPGR) and its partners for organizing the National Conference on 'Managing Agro-biodiversity in North Eastern India' (NCMBN-2024), that envisages a broad range of solutions to restore the diversified biota of the region with high level endemism.

With a diverse range of physiographic and ecoclimatic conditions, North Eastern region serves as the geographical gateway for lots of India's flora and fauna establishing this region as a biodiversity hotspot that holds immense potential for addressing the global challenges such as food security, climate resilience, and sustainable development by transforming biodiversity into bio-wealth. In addition, the indigenous farming systems of the region, coupled with its wealth of underutilized crops, diverse genetic resources of livestock and aquatic species present enormous opportunities for agri-innovations and agri-prenureship. In fact, this conference is a testament to the importance of agro-biodiversity conservation as a critical component for the sustainable growth of North Eastern agriculture through development of entrepreneurship, women empowerment, and rural livelihoods, especially for small farm holders.

I strongly believe that this conference will focus upon fostering collaboration among scientists, extension professionals, farmers, and policymakers to ensure the protection of the treasure trove of the region, *i.e.* sustainable management of its vast genetic resources.

I wish the conference a great success for building a sustainable future for the North East!

(A.K. Mohanty)

ICAR-Agricultural Technology Application Research Institute
Zone-VI, Guwahati
Kahikuchi, Assam -781017

Dr. G. Kadirvel
Director

MESSAGE

It is a pleasure to welcome you to the conference entitled "National Workshop on Managing agro-biodiversity in North-Eastern India" and as we explore and celebrate the unique ecological, cultural, political, and ethnic diversity in Northeast India, the region is a homeland of more than 220 distinct ethnic groups, each with its own language, customs, traditions, varied landscapes from lush valleys to hilly terrains, flora and fauna, making the region a biodiversity hotspot. The unique climatic conditions & culture lead to diverse farming systems in the region, which highlight the remarkable agro-biodiversity. This diversity not only strengthens the resilience of agriculture in the face of climate change but also supports the livelihoods of millions of smallholder farmers. An essential aspect of preserving agro-biodiversity is the protection of traditional farmers' varieties. Farmers in the region have long practiced the conservation of seeds and plant varieties passed down through generations. In this context, the registration of farmers' varieties becomes crucial to safeguarding these genetic resources, ensuring that local farmers benefit from the commercial use of these varieties and contributing to long-term sustainability in agriculture.

This conference aims to dive deeper into the rich and resilience agro biodiversity while highlighting the pressing need for its conservation and sustainable development. I request the scientist, scholars and students to take away many valuable learnings from this conference and I hope that the suggestions, and concrete recommendations from the experts and panellist will be useful in managing the agro-biodiversity in a much better and sustainable way in northeast India.

Best wishes for the successful conference and tangible outcomes for the benefit of the region and for the country as a whole.

(G. Kadirvel)

CONTENTS

Conservation of Plant Genetic Resources in National Genebank of India

Anju Mahendru-Singh[1*] and Anuradha Agrawal[2]
[1]*Head, Division of Germplasm Conservation,*
ICAR-National Bureau of Plant Genetic Resources, New Delhi, India
[2]*Project Director, Directorate of Knowledge Management in Agriculture, ICAR, New Delhi, India*
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Plant Genetic Resources for Food and Agriculture (PGRFA) comprise the diversity of genetic material contained in traditional varieties and modern cultivars as well as crop wild relatives and other wild plant species that can be used now or in the future for food and agriculture (Hong *et al.*, 1996). PGRs are highly valuable raw materials for crop improvement, food and nutritional security and must be preserved not only for utilization in crop improvement programmes but also for posterity. Conservation of PGRs refers to maintaining the diversity of the full range of genetic variation within a particular species or taxa. PGRs can be conserved both *in-situ* and *ex-situ*. *In-situ* conservation is the method of conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties. Biosphere reserves, natural parks, gene sanctuary and on-farm are some examples of *in-situ* Conservation. *Ex-situ* conservation, on the other hand, refers to the conservation of components of biological diversity outside their natural habitats. In 1920, a Russian scientist, Nicholai Ivanovich Vavilov, an avid explorer, first established the Genetic Resource Center at Leningrad where he brought together his worldwide collections of seeds and propagules of a large number of cultivated crops and their wild relatives. Farming communities all over the world are to be credited with the conservation and utilization of biological diversity. *Ex-situ* conservation can be carried out by creating Seed banks and Field Genebanks *etc.* and the more advanced *in vitro* Genebanks and Cryobanks.

The number of genebanks globally has risen to more than 1700. Most of the genebanks are relatively small with around 10000 accessions. However, there are four genebanks with germplasm accessions exceeding 100000. According to the international gene bank databases available in public domain, the National Genebank in India is the second largest genebank next to the National Centre for Genetic Resources Preservation (NCGRP) in the United States of America.

Historical aspect of National Genebank:

As the activities of plant introduction and explorations to bring diverse germplasm at IARI expanded, the need for a full-fledged nodal agency to was realised to plan, co-ordinate, execute and monitor PGR activities at national level. This led to the formation of the National Bureau of Plant Genetic Resources with five Divisions in 1986 *viz.,* Division of Plant Collection and Germplasm Exploration, Division of Germplasm Evaluation, Division of Plant Quarantine, Division of Germplasm Conservation and Division of Genomic Resources (added later). Holistic *ex situ* conservation of PGRs is the mandate of Division of Germplasm Conservation. A National level facility called as National Genebank, India (NGB) was established in 1986 at NBPGR, New Delhi with the objective of conserving PGRs and support sustainable crop improvement programmes. The NGB at NBPGR is the largest gene bank in the world in terms of its infrastructure. Started with four long-term modules, the seed genebank facility was expanded to twelve long term storage (LTS) modules and five medium term storage (MTS) modules commissioned by the then Vice-President of India Shri. K.R. Narayanan, in the presence of Secretary of State, USA in 1996. The seed genebank component of NGB was upgraded by installing improved, energy-efficient machinery with digital monitoring system and this refurbished state-of-the-art facility for ex-situ conservation of ~0.6 million orthodox seeds was dedicated to the nation by the then Agriculture and Farmers' Welfare Minister Shri Narendra Singh Tomar on the 16th August, 2021. Simultaneously, the tissue culture facility operative at NBPGR was transformed into a full-fledged *in vitro* and cryopreservation facility in 1986 with the support of the Department of Biotechnology and was named as the National Facility for Plant Tissue Culture Repository and later as the Tissue culture and Cryopreservation Unit (TCCU). Subsequently, the *in vitro* and cryopreservation facilities in TCCU have also been brought officially under the umbrella of the Division of Germplasm Conservation on 11th May 2023. Thus, National Genebank houses germplasm collections in the form of orthodox seeds called as base collection in the 12 modules of the seed genebank maintained at -18°C, in vitro tissue/ plant cultures of vegetatively propagated crops in the in vitro genebank as well as recalcitrant seeds, embryos, pollen *etc*. at ultra-low (−160 to −196 °C) temperatures achieved through liquid nitrogen in the cryogenebank (fig.1).

Sources of PGRs conserved in the National Genebank: A substantial number of accessions in the NGB have been brought through plant collection and exploration activity carried out as per the National Exploration Plan (NEP) which involves scientists from regional stations, crops-based institutes (ICAR), SAUs and KVKs. These include landraces, farmers' varieties, wild and weedy relatives etc. The next major category of seeds conserved in the NGB includes those developed by breeders including varieties, hybrids and their parental lines released and notified through CVRC, special germplasm such as Recombinant Inbred Lines, Near Isogenic Lines, mutants *etc*. Genetic stocks with special features or trait-specific germplasm identified/ developed by breeders recommended for registration by the national level Plant Germplasm Registration Committee *etc.* (fig.2). In addition, repatriated seed is also conserved in the National Genebank.

Fig.1. Glimpse of world's 2nd largest seed genebank (A); Asia's largest *in-vitro* repository (B) and Cryogenebank (C) housed in the ICAR-NBPGR, New Delhi

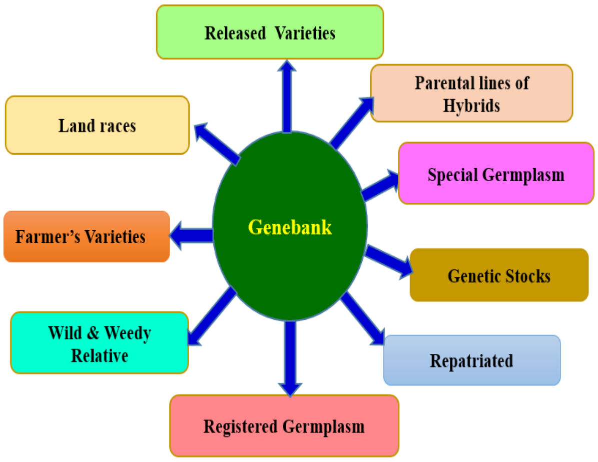

Fig.2. Major categories of seeds conserved in seed genebank of NGB, India

A detailed description of PGR conservation activities can be found at www.nbpgr.org.in; Aravind *et al.* (2019) and Agrawal *et al.* (2019). A brief account is given below:

How is conservation in seed genebank achieved:

The conventional seedbanks are capable of storing only orthodox seeds. These are seeds whose moisture can be reduced to 3-7% without damage or loss of viability. More than 90% of the crop species have orthodox type of seeds and hence can be easily stored in seedbanks. Seeds stored at -20C or long-term storage are referred to as *base collections,* while seed samples for stored for use within 0-~5 years are referred to as *active collections*. Once the seeds are acquired, their passport information such as collection details, biological status and information on unique trait and pedigree details if it's a breeding line/ genetic stock or cultivar, are carefully checked for uniqueness to avoid duplication of accessions in the genebank. The global gene bank standards (FAO, 2014) are followed for each of the next steps such as pest-free status, adequate seed viability (ISTA, 2021), number of seeds to be conserved etc. Before storage, the moisture content is brought down to the range of 3-7% by drying at 15±5% RH and 15±5°C temperature. Once the desirable moisture is achieved depending on the species, the seeds are packed immediately in a container for storage. Commonly utilized containers in genebanks include glass bottles, aluminium cans, aluminium foil packets and plastic bottles. National Genebank uses aluminium foil packets due to their ease of sealing and resealing, as well as their space-saving characteristics. The packets are barcoded with all the essential information and are stored in the LTS modules at a designated location. In the NGB, the documentation of genebank holdings involves two types of information files: passport data descriptors and Genebank management descriptors. Passport data descriptors encompass details like the Name of the Crop, Taxonomic Code, Cultivar Name, Collector No, Other ID, and Location in the Gene bank. National Identity Number also known as Indigenous Collection (IC) is given to each unique collection while an EC (exotic collection) number denoted the seed imported by Bureau for an indenter and conserved after its multiplication. On the other hand, Genebank management descriptors include information such as seed quantity, seed germination percentage, seed moisture percentage, source of material, and date of storage. The steps in the entire process of conservation in NGB are outlined in the Flow Chart (fig. 3).

Regeneration of the conserved germplasm:

It is the process of restoration/rejuvenation of germplasm accessions either intended for long-term conservation in base collection or already conserved in the base collection with low seed viability and/or low seed quantity. Regeneration requires crop-specific knowledge and expertise. The protocols for regeneration of only some crop species have been developed world over. Regeneration being a resource intensive and time-consuming process, should be carried out only when essential to save resources and to avoid unnecessary exposure to risks (Dulloo *et al*., 2008). In NGB, regular monitoring of viability is carried out for about 1% of the random accessions annually that have completed 10, 20 or 30 years of conservation in that year. Regeneration is undertaken when the seed viability falls below 85% of the initial viability during periodic monitoring of viability or if the quantity falls below 250 for self-pollinated and below 1000 for cross pollinated accessions. Seeds of several hundred thousand accessions have been distributed/supplied to breeders and researchers for various research based activities. In the process, the seed is multiplied and stored back in MTS for further distribution. Thus, seed multiplication and regeneration are achieved in collaboration with Regional Stations of NBPGR and designated National Active Germplasm sites (49 NAGS) which are mostly the crop based Institutes/ Agricultural Universities of the National Agricultural Research and Extension System (NARES) of the ICAR.

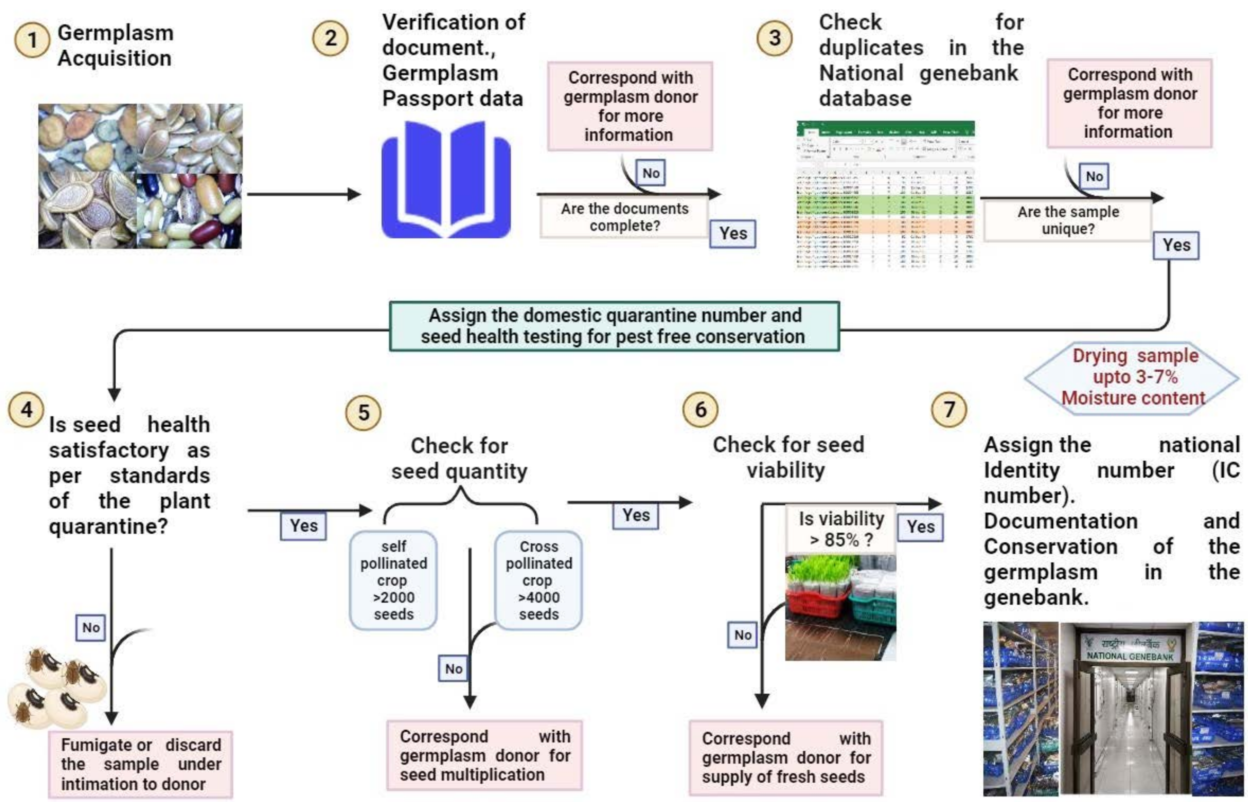

Fig. 3. Flow chart for steps in seed conservation in the seed genebank

How is the conservation in the *in vitro* genebank achieved:

In-vitro conservation techniques including tissue culture and cryopreservation offer distinct advantages including safe conservation in a small space, free from pests/pathogens and vagaries of nature, season-independent multiplication, cost effectiveness and easier exchange mechanisms. Plant cells, tissues, or organs are grown and maintained in sterile containers with a nutrient-rich medium. This method is useful for species that are difficult to conserve as seeds or whole plants. The species can be conserved for both short to medium term and for long term (*In vitro* Active Genebank). The aim of short- and medium-term storage is to reduce the growth of plantlets and to prolong the subculture interval while minimizing or eliminating a risk of genetic instability generated through tissue culture manipulations. Short-to medium-term conservation (a few months to 2–3 years) is achieved through growth reduction which is generally attained by modifying the culture medium and/or the environmental conditions. Flow chart in (fig. 4) depicts the sequential processing of the explants. The *in vitro* genebank of NGB has focussed on the clonally propagated crops, medicinal, aromatic, rare, endangered and threatened species, of indigenous as well as exotic origin, from diverse agroecological conditions. In case of horticultural crops, special attention has been given for fruits, tubers, bulbs, spices and medicinal and aromatic species. Since the last three decades, conservation of germplasm of these species is being carried out by innovation and adoption of latest appropriate techniques (Agrawal *et al.,* 2019). Micropropagation or *in vitro* multiplication protocols have been developed and/or refined in 30+ crop species at the Bureau. These include horticultural plants like *Aegle marmelos*, *Allium*, *Bacopa monnieri*, *Artocarpus lakoocha, Colocasia esculenta*, *Curculigo orchioides*, *Curcuma* spp., *Dahlia* sp., *Elettaria cardamomum*, *Fragaria* spp., *Gladiolus*, *Hedchium* sp., *Homalemena*, *Kaempferia* spp., *Morus indica*, *Musa* spp., *Naregamia alata, Piper* spp., *Pyrus communis Rubus* spp., *Sauropus androgynous* , *Vanilla planifolia, Xanthosoma sagittifolium* and *Zingiber* spp. etc. Whilst most protocols achieve multiplication through enhanced axillary bud proliferation, a few are also through indirect adventitious regeneration, somatic embryogenesis and male buds.

How is the conservation in cryogenebank achieved:

The term cryopreservation is used for the process of storage of living material at ultra-low temperatures in liquid nitrogen (−196 °C) or its vapour phase (−150 °C). At this temperature, all cellular, metabolic and biochemical events stop, and the plant material can be stored without any changes or deterioration for extended time periods. Plant cryopreservation methods have evolved rapidly, providing opportunities for long-term storage of valuable germplasm of many clonally propagated and recalcitrant seeded species. Liquid Nitrogen (LN) aids in achieving the long-term base collections (*In vitro* Base Genebank) of crops for use in the distant future, functioning as a safety backup for similar collections held in clonal repositories, field gene banks (FGB) or in situ conserved material that normally is subject to threats from natural disasters. Classical cryopreservation techniques (controlled freezing) comprise steps of tissue dehydration followed by slow cooling (at rates of 0.1 to 4°C/min) of the explant, down to a defined pre-freezing temperature (usually of −30 to −40 °C) and rapid immersion in LN. The new and advance techniques of cryopreservation rely upon vitrification which is achieved by direct immersion in LN without the freeze concentration step of slow cooling and by exposing the cells to extremely concentrated (7 to 8 M) cryoprotectant solutions which do not allow crystallization of water in the cells.

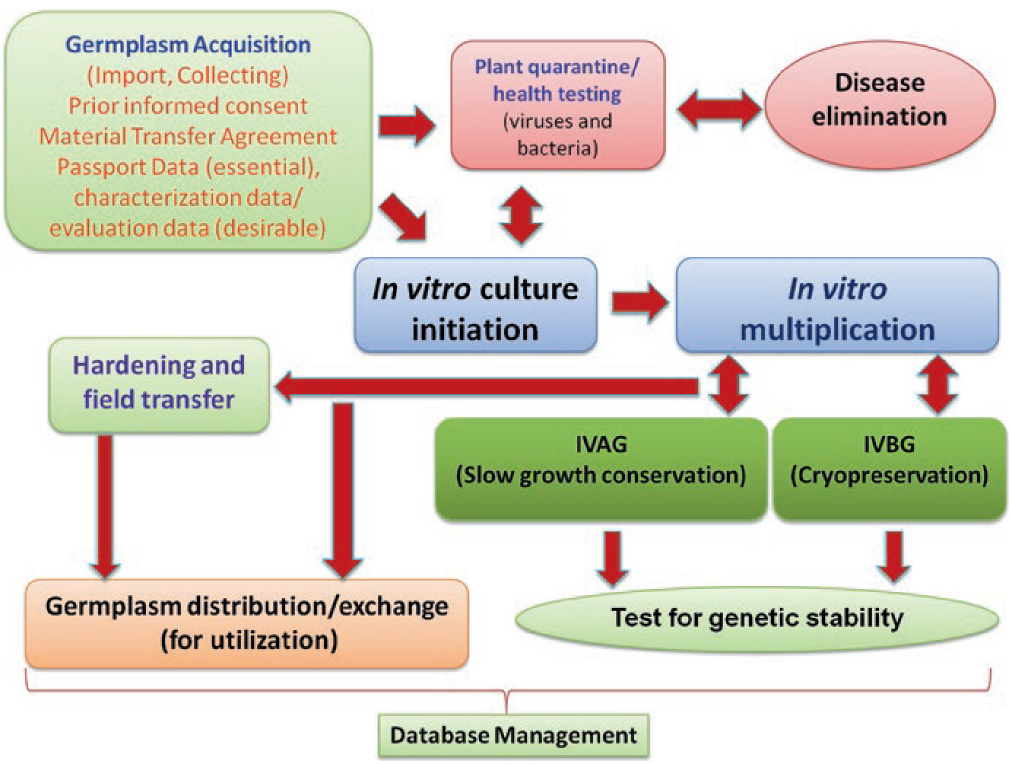

Fig. 4. Processing and conservation flow of clonally propagated plants in the NGB

A major thrust has been given on cryopreserving horticultural species at NBPGR, since the last two decades (Agrawal *et al.,* 2019). Cryopreservation protocols have been developed/refined using in vitro/ex vitro derived shoot tips/meristems in species of *Allium*, *Bacopa*, *Citrus*, *Dahlia*, *Dioscorea*, *Ensete glaucum*, *Gentiana*, *Garcinia*, *Gladiolus*, *Malus*, *Morus*, *Musa*, *Picrorhiza*, *Pyrus*, *Rubus* and *Vaccinium* spp. and vegetative buds of *Malus domestica*, *Pyrus communis, Prunus armeniaca etc*. Major success has been achieved in two genera, namely, *Allium* and *Musa.* In *Musa*, the droplet-vitrification method has been optimized for efficient and practical cryopreservation by optimizing the duration of treatment of sucrose and PVS2 to the meristematic clumps ('cauliflower'-like proliferating meristems). Plants regenerated from the cryopreserved meristem flowered, fruited and exhibited true-to-typeness on the basis of morphological and molecular markers. More concerted efforts are required to achieve success for other PGRs such as litchi, guava, pomegranate, jackfruit, coconut *etc.*

In addition to tissues, protocols for other explants such as embryos and embryonic axes, dormant buds, pollen as well as the non-orthodox seeds have been developed in-house and are being deployed to conserve some of the difficult-to-conserve species using classical methods. Cryo protocols were standardized in non-orthodox seeds/buds of *Ardisia macrocarpa, Cornus capitata, Corylus ferox, Docynia indica, Dillenia indica, Etlingera fenzlii, Eriobotrya japonica, Maclura cochinechinensis, Catunaregam spinos, Musa spp., Prunus napaulensis, Pyracantha cranulata, Pyrus pashia, Sorbus cuspidata, Zanthoxyllum armatum, Tamilnadia uliginosa, Vaccinimum glaucoalbus, Prunus sp. etc.* Besides, dessication and freezing sensitivity studies have been carried out and crticial moisture content for successful cryoconservation deciphered for a number of other species in the last few years.

Status of conservation in the National Genebank, India

Seed Genebank

Starting with only a few thousand accessions in the Plant Introduction Division and initial years of the Bureau, the impetus through mega projects such as the National Agricultural Innovation Project (NAIP) effected from 2006 and National Innovations in Climate Resilience Agriculture (NICRA) in 2011 resulted in enhanced conservation activities. Bureau has conducted 2,885 explorations conducted by ICAR-NBPGR along with its Regional Stations in collaboration with ICAR crop-based institutes, State Agricultural Universities (SAUs), Krishi-Vigyan Kendras and other stakeholders. These activities have led to the rapid conservation of seeds of landraces, farmers' varieties, crop wild and weedy relatives. Breeders were sensitized to share their important advanced breeding materials as well as released varieties, genetic stocks and special germplasm. Simultaneously, clonally propagated plants were conserved in FGB as well as through complementary strategies of in vitro storage and cryopreservation. The status of the number of accessions of germplasm in different crop groups is depicted in Table 1. The number of accessions conserved in NGB stands at 4,70,513 as on 30th September, 2024 and in this respect, NGB is the second largest seed genebank in the world next to the National Plant Germplasm System of USA. These accessions belong to more than 2000 species of crops and their wild and weedy relatives. Largest collections in NGB have been made in cereals especially rice (177589) followed by legumes (69181) and oilseeds (63561) groups. The two most priced collections of rice namely Assam Rice Collection (ARC) and the Richaria Collection (RC) are also conserved in the NGB. Out of the 12000 ARC accessions, NGB currently has 8189 and out of the 20000 collections of Dr. Richaria from across the country, NGB has secured 14000 accessions. Efforts are on to retrieve the remaining accessions through repatriation from IRRI genebank and in collaboration with IGKV, Raipur.

The number of accessions of landraces, farmers' varieties, varieties developed by breeders and released and notified through Central Varietal Release Committee conserved in NGB are listed for different crop groups in Table 1. It has been made mandatory in 2007 to get an IC number and seed before submitting the variety release proposals to CVRC and therefore, all identified varieties with seeds are by default conserved in the NGB. Varieties of clonally propagated plants including many horticultural crops are alotted IC number once the certificate of deposition is received from the concerned NAGS. The same follows for the explored materials established in the in vitro and cryogenebank. Crop wild relatives and endangered species present the most difficulties in collection and conservation due to low seed quantity and seed dormancy encountered in them. Curators in the genebank carry out supportive research to understand the nature of seed (Orthodox/ recalcitrant) and development of dormancy breaking protocols while the explorers and collectors spend considerable time to get the new species identified and correctly named.

The crop wild relatives where the seed number is very small or belong to the recalcitrant category are conserved in the Cryogenebank facility. Table 1 provides the update on the number of crop wild relatives conserved in the seed genebank of NGB.

Table 1. Plant genetic resources conserved in seed genebank of the national genebank, India (as on 30th September, 2024)

Crop group	#Accessions	# Landraces/ Farmers Var.	#Released Varieties	#CWR/Wild/ relatives
Cereals	177589	13683	4338	4076
Millets	60484	16338	925	91
Forages	7535	1555	194	189
Pseudocereals	8271	1623	46	355
Legumes	69181	10658	1274	1041
Fibre	17186	32267	1282	925
Vegetables	29719	243	931	820
Fruits & Nuts	305	6070	1187	5641
Oilseeds	63511	07	02	54
Medicinal & Aromatic plants	9549	1190	124	380
Ornamental	749	15	34	17
Spices, Condiments and Flavour	3715	1178	71	70
Agroforestry	1713	208	04	168
Duplicate Safety Samples	10235	-	-	-
Trial Material (Wheat, Barley)	10771	-	-	-
Total	**4,70, 513**	**84950**	**10412**	**13827**

In vitro and cryogenebank

Presently, 2041 accessions 1,861 accessions of 171 species belonging to 69 genera of fruits, tuber and bulbous crops, spices, plantation and industrial crops as well as medicinal, aromatic and rare/endangered plants in the form of ~44,000 slow-growing cultures, conserved in culture room conditions and/or at low temperature are maintained as In Vitro Active Genebank (IVAG, Table 2, fig. 4). Cryopreservation of the in vitro conserved germplasm is routinely carried out in the IVBG (in the liquid phase of LN) for long term storage and has been successfully achieved in 347 accessions out of the 2041 accessions (Table 2).

Table 2. Status of *in vitro* active genebank (IVAG) and *in vitro* base benebank (IVBG) in the *in vitro* repository of the NGB, India (as on 30th September, 2024)

Crop group	# Genera	# Species	# Cultures	# Accessions in IVAG	# Accessions in IVBG
Tropical fruits	3	20	10,000	449	105
Temperate and minor fruits	11	42	9,000	410	34
Tuber crops	6	15	8,000	530	14
Bulbous and other crops	6	16	4,200	187	166
Medicinal and aromatic plants	33	46	8,300	232	28
Spices and Industrial crops	10	32	4,500	233	0
Total	**69**	**171**	**44,000**	**2,041**	**347**

Cryoconservation of seeds, embryos, embryonic axes, dormant buds, pollen and meristems/ shoot tips at ultra-low temperatures (-176^{0}C to -196^{0}C) is achieved by storage in vapour phase of liquid nitrogen. The NGB has 13047 accessions in the cryogenebank (Table 3) which include 7990 accessions of recalcitrant and intermediate seeds crops, 3990 accessions of orthodox seed crops, buds of 389 PGRs and pollen grains of 673 accessions belonging to different crop groups. In this base collection, ~1000 accessions of Indian *Citrus* germplasm comprising rootstocks and wild, rare and endangered species such as *C. indica, C. macroptera, C. megaloxycarpa, C. latipes, etc.,* cryopreserved by techniques of desiccation-freezing, encapsulation and vitrification. Other horticultural species with substantial collections that are cryopreserved are *Buchanania lanzan, Capparis sp., Manilkara hexandra, Piper nigrum, Juglans regia, Prunus amygdalus, P. armeniaca, Morus spp. and Malus* cultivars (Malik and Chaudhury, 2016).

Table 3. Status of Cryogenebank in the NGB, India (as on 30th September, 2024)

Crop group	No. of accessions
Recalcitrant & Intermediate	**7990**
Fruits & Nuts	4560
Spices & Condiments	239

Plantation Crop	121
Agroforestry & forestry sp.	1645
Industrial Plants (Jatropha, Pongamia, Salvadora, Oil palm)	1365
Medicinal & Aromatic Plants, Orchids	60
Orthodox	**3995**
Cereals	289
Millets and Forages	294
Pseudo-cereals	76
Grain Legumes	816
Oilseeds	683
Fibres Crops	69
Vegetables	620
Medicinal & Aromatic Plants	1029
Narcotics & Dyes	35
Miscellaneous *Sp.*	84
Dormant Buds	**389**
Pollen Grains	**673**
Total	**13047**
Genomic resources	**2194**
Total	**15241**

Registered Germplasm

Breeders are always in search of PGRs which have superior traits of economic value. Thus, a good amount of their time is spent in evaluation and identification of PGRs with unique, novel and superior traits. Also, during the process of breeding, research and experimentation to develop varieties using such PGRs, further ones possessing multiple traits are developed. Now while, the mechanism for release and notification of released varieties was very well in place, a mechanism for such PGRs that are novel, unique and distinct with academic, scientific and applied value had been missing. Consequently, most of such valuable material remained underutilized or lost once the concerned scientist shifted to another assignment/ organization. Therefore, the need was felt during the 90s to recognize the efforts of researchers for developing the potentially valuable germplasm and to inventorize, document and bring all such genetic resources into public domain, facilitating their safe and accelerated use in research and crop improvement. The mechanism of plant germplasm registration was then developed to identify and document potentially valuable PGRs as well as recognize the accomplishment of the researchers responsible for identifying or developing these trait-specific unique germplasms. PGR registration is accomplished through a high-level Plant Germplasm Registration Committee chaired by the Deputy Director General (Crop Sciences) and NBPGR as the nodal implementation agency for facilitation of registration. A developer is required to submit application online using the NBPGR website link http://nbpgr.org.in/nbpgr2023/germplasm-registration-information-system/ by referring to the guidelines on http://nbpgr.org.in/nbpgr2023/germplasm-registration-guidelines/. Starting from 1996, 53 meetings of Plant Germplasm Registration Committee have been held till 30th September 2024 and 4693 proposals have been considered. Based on scrutiny of received proposals, 2284 potentially valuable germplasm accessions belonging to 275 crop species have been registered and conserved in seedgenbank/FGB (fig 5, Singh *et al.*, 2024). Brief information about registered germplasm is published in the Newsletter of NBPGR and Annual Report of the ICAR. Plant Germplasm Registration Notice with one-page note on the registered germplasm is also published in the Indian Journal of Plant Genetic Resources.

Crop group	Current status
Cereals and Pesudocereals	817
Millets	158
Fibre and Forages	130
Grain Legumes	226
Vegetables	142
Oilseeds	276
Commercial Crop	124
M & AP & Spices and Masticatory	140
Fruits and Nuts	85
Tubers	61
Ornamentals	107
Narcotic/Beverages	09
Agro-forestry	09
Grand Total	**2,284**

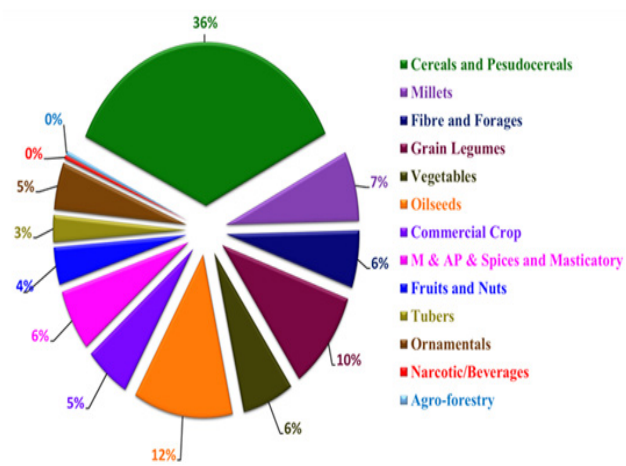

Fig. 5. Crop group wise representation of trait-specific germplasm registered during 1996-2024

Status of conservation of Germplasm of the North-Eastern Region of the India

India's North-Eastern (NE) region consists of eight states *viz.*, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim. Together these states cover ~262,179 kilometer^2 of the geographical area of the country. The NE region is characterized by a multitude of eco-geographical, anthropological and climatic diversity resulting in richness of natural resources particularly the water and forests that harbour a wide array of flora and fauna. Among the eight hotspots of Biodiversity world over, four are found in India. The NE region forms an important part of the Indo-Burma hot spot of biodiversity also known as the 'Cradle of Flowering Plants'. About 50% flora of the country is found in the NE region alone. Cultivated and wild relatives of several cereals, pulses, oilseeds, fiber crops, ornamentals, fruits and vegetables, spices, medicinal and aromatic plants, plants yielding timber and woods, gums, resins, tannins *etc.* are very much predominant in the region. About 8000 species are reported from this region (Tandon *et al*., 2009; Sarma and Sharma, 2015). NE region has been an important region for explorations by NBPGR and its collaborating Institutions in the country. Special drives for explorations for the PGR collections during the periods 2011-13 and 2016-2019 have largely enriched the NGB. Explorations in these drives have covered specific areas of the NE region during different years *viz.,* Majuli river island and Char areas of Brahmaputra basin and Tribal dominated areas, Bodo Land (Assam), Lohit and other districts and Anini, Anjaw, Changlang and Upper Siyang (Yinkiyong) districts bordering to China and Myanmar (Arunachal Pradesh), Mon, Kiphire, Tuensang and Zunhobo to districts (Nagaland), Saiha and Lawngtlai districts bordering to Myanmar (Mizoram), Garo, Khasi and Jaintia Hills (Meghalaya) *etc.*

Rice is the staple cereal in the entire NE region and up to three crops of rice per year are harvested by the farmers. Accordingly, the largest diversity of rice has been collected from this region. 12872 accessions of cereals but only 1545 legumes and 1433 oilseeds and still lower number of accessions of other crop groups have been deposited in the NGB (Tables 4 & 5). 6822 landraces and 905 Crop wild relatives and wild accessions have been brought in. Some of the diverse germplasm collected from NE region include orange-fleshed (carotenoid-rich) cucumber from Manipur and Mizoram; brown-netted cold tolerant cucumber from Meghalaya; extremely pungent bird's eye chilli from Mizoram and Nagaland, *Tubo capsicum anomalum* a wild *sp.*/ allied to chilli collected from Arunachal Pradesh; long boll (11.1 cm) tree cotton from Mizoram; light brown-linted (naturally coloured) tree cotton from Tripura, popcorn type maize having cylindrical, thin and conical-shaped cobs from Nagaland, yellow-fleshed watermelon from Anjaw, Arunachal Pradesh, cut-leaf mustard (*Brassica juncea* subsp. *integrifolia*) from Arunachal Pradesh, rare and deep-water rice landraces (Batu, Indi, Mia, Dol, Jul, Dhepa, Tulsi, Dubari, Ikarasali and Dhusuri) from Assam, cold tolerant rice landraces (Lahi, K. Botha, Sikota Lahi and Dal Boradhan) from Arunachal Pradesh, good-to-taste landraces Signal and KhayaNache from Tripura and so on. *Herpetospermumo perculatum* used as leafy vegetable collected from Nagaland is described as a new species.

Table 4. Crop group wise and state-wise status of total no. of accessions of north- eastern region conserved in National Genebank as on 30th September 2024

Crop group	Arunachal Pradesh	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Sikkim	Tripura	Grand Total
Agroforestry	13	09	02	-	-	-	-	-	24
Cereals	2130	4860	1358	1270	1011	1300	643	300	12872
Fibre	03	114	04	56	26	56		18	277
Forages	08	20	09	07	01	07	15	03	70
Fruits & Nuts	04	02	-	-	01	-	-	-	07
Grain legumes	191	208	248	279	129	209	199	82	1545
Medicinal & Aromatic plants	79	149	13	06	12	16	11	01	287
Millets	430	71	28	34	3	70	75	37	748
Oilseeds	324	387	144	110	177	147	99	45	1433
Ornamental	08	06	02		09		01		26
Pseudocereals	244	43	25	26	11	88	101	03	541
Spices Condiments and Flavour	13	56	-	09	-	-	66	07	151
Vegetables	297	417	93	229	258	192	65	144	1695
Grand Total	**3744**	**6342**	**1926**	**2026**	**1638**	**2085**	**1275**	**640**	**19676**

Table 5. Status of landraces/crop wild relatives (CWRs) and released varieties (RV) of north-eastern region conserved in National Genebank (as on 30th September, 2024)

Crop group	# Species	# Landraces	#CWR	RV
Agroforestry	19	01	11	-
Cereals	14	4030	80	75
Fibre	19	38	188	-
Forages	15	07	55	-
Fruits & Nuts	06	01	05	-
Grain legumes	35	465	42	18
Medicinal & Aromatic plants	93	53	162	-
Millets	12	383	27	09
Oilseeds	32	1056	93	14
Ornamental	11	10	11	01
Pseudocereals	18	240	39	01
Spices Condiments and Flavour	11	41	10	01
Vegetables	101	497	182	29
Grand Total	**386**	**6822**	**905**	**247**

However, very few trait-specific germplasm from NE region have been registered and conserved in the NGB (fig. 6, 7, 8). Majority of the registered traits belong to the commercial crops.

Crop Group	No. of acc.
Commercial Crops	45
Medicinal & aromatic Plants	20
Cereals	14
Ornamental	11
Spices	02
Grand Total	**92**

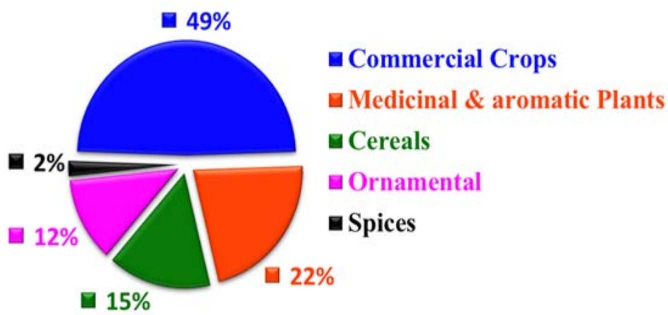

Fig. 6. Crop group wise representation of trait-specific germplasm in North-East Regionduring 1996-2024

Developing Institute	No. of acc.
TTRI, TRA, TES, Jorhat, Assam	45
CSIR-NEIST, Jorhat, Assam	27
RARS, Titabari, Jorhat, Assam	6
ICAR-NRCO, Pakyong, Sikkim	6
ICAR-RC NEH Region, Manipur Centre, Imphal, Manipur	6
ICAR-Krishi Vigyan Kendra, Lamphelpat, Imphal, Manipur	2
Grand Total	**92**

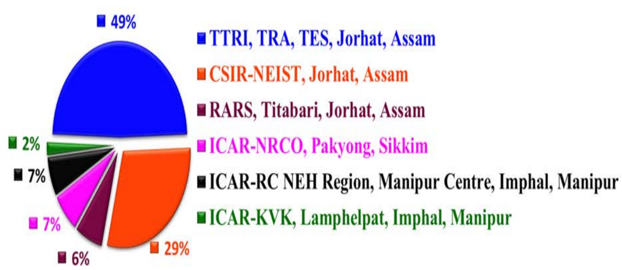

Fig.7. Representation of trait-specific germplasm registered during 1996-2024 by individual institutes and states from North-East Region

Rice *(Oryza sativa)*
(IC647171, INGR22113)

For high resistance to leaf and neck blast

Ginger *(Zingiber zerumbet)*
(IC640711, INGR2116)

For high essential oil yield, average rhizome essential oil 0.75% on fresh weight basis

Tea *(Camellia sinensis)*
(IC610193, INGR14038)

For above average (110:100) Darjeeling Flavour

Orchids *(Dendrobium nobile)*
(IC653270, INGR24075)

For high quercetin (phenolic) content (1679.3 mg/kg) in stem. Contains bioactive compound Ethylamine (Embramine) and 1,6-Methanonaphthalen 5 (1H)-one, octahy-dro2,4a,8a-trimethyl (1S,2S,4aR,6R, 8aS) detected for the first time in *Dendrobium nobile*

Elephant Ears *(Caladium sp.)*
(IC650758, INGR23115)

With leaf color green, Midrib color green, Three leaf spot pink/red/white

Lemon grass
(Cymbopogonflexuosus)
(IC635431, INGR20053)

For more than 48% of C Methyl isoeugenol, Myrcene more than 39% in the essential oil

Fig.8. Some examples of germplasm with unique/superior traits registered with by different organizationsin the North-East Region

Considering the very large number of species of flora and fauna including important PGRs flourishing in the NE region, there is a need for more concerted exploration efforts for conserving more and more germplasm in the genebanks for posterity in view of rapidly degrading forest and arable land for commercial activities which is leading to loss of important biodiversity in this region.

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Utilization of Genetic Resources of Maize from North-Eastern Himalaya with Special Reference to *'Sikkim Primitive'* - A Unique Landrace with Extraordinary Prolificacy

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Abstract

Maize landraces serve as the goldmine for novel genes imparting to tolerance to biotic and abiotic stresses, adaptability and nutritional quality traits. Worldwide, maize landraces are grown in specific area for special trait(s) as preferred by the farming community. In India, North-Eastern Himalayan (NEH) region is rich in diverse maize landraces, some of them being unique globally. However, utilization of these maize landraces in breeding programmes has been limited. Here, we discuss the importance of maize landraces as a source of diverse traits, besides mentioning some of the most promising landraces available globally. We present the extent of genetic diversity present in NEH-based maize landraces using morphological, cytological, biochemical and molecular markers. The distinctiveness of *Sikkim Primitive* – a unique landrace for its extraordinary prolificacy has been mentioned in detail. We also mention the genetic and genomic analysis undertaken on *Sikkim Primitive* for dissecting prolificacy in maize.

Key words*:* Corn, Population, Breeding, Genetic Improvement, Farmers' Variety, Locals

Introduction

Maize has emerged as the crop of choice for its diversified usage as food, feed, fodder and fuel (Erenstein *et al.,* 2022; Hossain *et al.,* 2023; Tarekegne *et al.,* 2024). Maize (*Zea mays ssp. mays*) belongs to the tribe, *Maydae* and family, *Poaceae* (Doebley, 2004). It possesses somatic chromosome number of 20, a genome size of 2.3 gigabase and more than 32,000 genes (Schnable *et al.,* 2009). Maize originated 9000 years ago from a single domestication event and occurred in teosinte grass (*Z. mays ssp. parviglumis*) grown in plenty surrounding the *Balsas* river basin in the lowlands of South-West Mexico (Matsuoka *et al.,* 2002). Later, Yang *et al.* (2023) proposed that maize was further hybridized with *Z. mays ssp. mexicana* in the highlands of central Mexico after 4000 years of domestication. Thus, modern maize genome is an admixture of both *parviglumis* and *mexicana* genomes. Doebley *et al.* (1990) discovered genes regulating the morphological differences between maize and teosinte. Several loci including *teosinte branched1* (*tb1*) (Studer *et al.,* 2011; Dong *et al.,* 2019), *teosinte glume architecture1* (*tga1*) (Doebley, 2004; Wang *et al.,* 2005; Wang *et al.,* 2015; Studer *et al.,* 2017), *grassy tillers1* (*gt1*) (Whipple *et al.,* 2011; Wills *et al.,* 2013; Wang *et al.,* 2023), *upper plant architecture1* (*upa1*) (Tian *et al.,* 2019), *upper plant architecture2* (*upa2*) (Tian *et al.,* 2019) and *tassel replace upper ears1* (*tru1*) (Dong *et al.,* 2017) have played pivotal role in transforming wild-grasses into cultivated maize (Hossain *et al.,* 2016). Following its domestication, maize initially diversified in the highlands of Mexico. Selection efforts further resulted in the emergence of a diverse array of maize races adapted to various environments (Merrill *et al.,* 2009). In addition, diversification of these landraces occurred through mechanisms such as mutation, migration, and genetic drift. It further diffused throughout the Americas over thousands of years, and following the discovery of the New World by Columbus on October 12, 1492, maize was first introduced into Europe (Mir *et al.,* 2013). Trade and colonization introduced it further into all parts of the world including Asia and Africa likely within a century (Prasanna and Sharma, 2005). Even today, many South American landraces are found in Italy and Spain. In Brazil, maize landraces were derived from crossing between introductions from United States and types cultivated by native tribes and European colonizers after the discovery of American Continent (Paterniani, 2000).

Though hybrid technology especially single cross hybrid has paved the way for high grain yield potential in maize, climate change coupled with ever increasing population warrants the development of more productive and climate resilient maize hybrids rich in nutritional quality. So far, a miniscule and of genetic diversity available in maize germplasm has been utilized in the development of improved cultivars worldwide. Maize landraces serve as the goldmine for novel genes that can be utilized in the maize improvement programme.

Landraces: a foundation for modern maize

Landraces are local varieties of domesticated crops that continue to be used in traditional agriculture by rural communities and are not part of formal breeding programs (Monroyi-Sais *et al.,* 2024). Landraces are also known by various terms, such as heirloom, ancient, traditional varieties, farmer, creole, folk, or local varieties (Villa *et al.,* 2005). Other synonyms commonly used for related landraces include maize race, ecotype, and native maize variety (Elisa *et al.,* 2022). The practice of saving seeds of local maize types for food and ceremonial use, year after year, led to the development of diverse subgroups and open-pollinated varieties (OPVs) in the Americas (Xolocotzi 1985, Samayoa *et al.,* 2018,). Unlike hybrids, landraces are heterogeneous, consisting of a mixture of genotypes repeatedly selected by farmers for special traits such as resistance to biotic and abiotic stresses, flowering patterns, ear characteristics, plant type, prolificacy, taste and other desirable traits (Guzzon *et al.,* 2021).

Broadly, maize landraces can be categorized into two groups: old landraces found in the New World (Central and South America), and new landraces distributed globally (Van Heerwaarden *et al.,* 2011). The latter maintained significant genetic diversity prior to the widespread adoption of maize hybrids (Hong *et al.,* 2024). Landraces are often identified based on their names, which are given by local farmers according to characteristics such as ear shape, color, grain shape, texture, plant type, vegetative cycle, or deliberate use (Burt *et al.,* 2019). Examples of such names include: '*White Palamo*', '*Elote Conico*', '*Purple-Pink Xuxuyul*', '*Yellow Conico*', '*White Cacahuacintle*' and '*Red Ladrillo*' (Elisa *et al.,* 2022). Some of the important maize landraces available worldwide include '*Northern Fints*', '*Southern Dents*', and '*Corn Belt Dents*' from the US, '*Tuxpeno*', '*Celaya*', '*Chapalote*', '*Olotillo*', '*Serrano*', '*Jala*' and '*Cacahuacintle*' from Mexico, '*Cuban Flint*' from Cuba, '*Coastal Tropical Flint/ Costeno*' and '*Tuson/Puya*' *from the* Caribbean and Northern South America, '*Cateto*' and '*Cristal*' from Brazil and Argentina, '*Kenyan Yellow*' from Africa, '*Peruvian Purple*' from Peru, '*Nepalese Hill Maize*' from Nepal, '*Hopi Blue Corn*' from North America, '*Italian Eight-Row Flint*' from Italy, and '*Sikkim Primitive*' and '*Gurez*' from India. The genetic foundation of many modern maize hybrids can be traced back to one of these landraces such as '*Corn Belt Dents*', '*Northern Flints*' and '*Southern Dents*' (Goodman and Brown 1988; Troyer 1999).

Landraces: A key to adaptation in a changing climate

To ensure food security in the scenario of climate change, landraces hold great promise for genetic improvement of maize (Frona *et al.,* 2019). The increasing frequency of drought in many regions globally poses a significant challenge to modern agriculture (Wiebe *et al.,* 2019). While a slight increase in temperature can benefit crop yields in temperate areas, it can be detrimental to food security in tropical and subtropical regions (Lobell and Burke, 2008). Landraces offer valuable resources for breeding programs due to their increased multi-trait adaptability and stress tolerance compared to modern cultivars (Wild *et al.,* 2024). Landraces, with broad genetic diversity, are crucial for enhancing adaptability and expanding the maize gene pool with respect to resistance to various biotic and abiotic stresses, besides culinary taste and nutritional quality (De Kort *et al.,* 2021). Modern genomic tools have enabled the exploration of allelic diversity and molecular mechanisms underlying adaptation and agronomic traits in maize landraces (Corrado and Rao 2017; Guan *et al.,* 2022). Additionally, landrace diversity is essential for the phytochemical contents or secondary metabolites, such as carotenoids and phenolics (Guzzon *et al.,* 2021; Palacios-Rojas *et al.,* 2020). These secondary metabolites contribute towards the stress tolerance of landraces (Elisa *et al.,* 2022). Moreover, landraces hold significant potential for improving quality traits in modern maize cultivars (Tamang *et al.,* 2024).

Landraces across the globe are being utilized to improve maize (Prasanna, 2010). Reid *et al.,* (1990) investigated a set of races of Mexico, which shows difference in altitudinal adaptations and found them to be resistant to the European corn borer, *Ostrinia nubilalis*. The *'Nal-tel', 'Chapalote'* and *'Palomero'* landraces from Mexico shows resistance to the maize weevil, (Arnason, 1994). The maize cultivar, 'Dan340' derived from the landrace *'Lvda Red Cob'* in China, is known for its many beneficial traits, including resistance to diseases and lodging, high combining ability and broad adaptability (Zhao *et al.,* 2022).

A collection from Mexico known as '*Michoacan-21*', which is the source of the *latente* gene, has recovered from severe drought stress (Sharma *et al.,* 2005). It is resistant to permanent seedling wilting and tissue desiccation, with high transpiration under irrigation and low transpiration under stress. Besides, landraces such as '*GalTrini'* and '*SITexas'* from Nuevo Leon, Mexico identified as the most water deficit tolerant (Gonzalez-Hernandez *et al.,* 2021). Nigerian landraces from Burkina Faso (*TZm1162, TZm1167, TZm1508*) and Togo (*TZm1472*) showed remarkable drought stress and heat stress tolerance (Nelimor *et al.,* 2020). '*Tuxpeno Sequia'* is a highly productive early maturing drought tolerant lowland race, and is favourable to fertile soils, and is widely used in maize improvement programmes.

In rural African areas landraces are very nutritious with presence of gene which is adaptable to adverse situations (water stress, salinity and high temperatures (Dwivedi *et al.,* 2016; Yang *et al.,* 2019). Multiple aleurone layer (MAL) of '*Coroico'* maize (a South American race of fluory maize), *'San Martin-105'* and *'San Martin-119'* can be used for higher accumulation of minerals such as iron and zinc (Wolf *et al.,* 1972; Lim *et al.,* 2019; Paulsmeyer and Juvik, 2023). Maize landrace '*Burr's white*' was identified in '100 generation of corn' experiment at University of Illinois, USA for high protein, oil, and fatty acid content (Hopkins *et al.,* 1899; Dudley *et al.,* 2004). The selected strains were further used to detect quantitative trait loci (QTL) for enhanced protein and fatty acid composition (Willmot *et al.,* 2006). A study by Daood *et al.* (2003) identified promising landraces with high concentrations of carotenoids, from the germplasm collection at the Institute for Agrobotany, Hungary.

Stringens *et al.* (2013) successfully derived doubled haploid (DH) lines from maize landraces that exhibited high grain yields comparable to elite cultivars. This finding suggests the potential of using landrace-specific DH lines for introgression into elite cultivars. The elimination of potentially lethal alleles during DH line development is likely a contributing factor to this success. Furthermore, the significant genetic distance between landrace specific DH lines and elite lines indicates their potential to broaden the genetic base of elite germplasm (Stringens *et al.,* 2013). Landrace oriented DH lines are also considered as ideal sources for association mapping and allele mining due to their rapid decrease in linkage disequilibrium (LD) and low population structure.

Farmers' continuous maintenance of maize landraces is often driven by specific intrinsic, relational, and instrumental values (Monroy-Sais *et al.,* 2024). However, there is a lack of research on how these values are adequately integrated into broader agricultural policies. The *'Green Revolution'* model, with its primary focus on maximizing yield and profit, has negatively impacted agro-biodiversity and the livelihoods of farmers worldwide (Mulyoutami *et al.,* 2023). Despite efforts to collect and preserve maize landraces since the 1940s, many unnamed races have been lost in history prior to these efforts (Curry, 2022). This loss of agrobiodiversity has shifted attention towards the critical need for landrace maintenance (Monroy-Sais *et al.,* 2024). The Wellhausen-Anderson Maize Genetic Resource Centre in CIMMYT, Mexico conserved over 27000 maize accessions comprising world's largest maize landraces' collection from 64 countries over the world, representing 90% of diversity of maize in Americas (Wen *et al.,* 2011). In India, National Bureau of Plant Genetic Resources (NBPGR) conserves nearly 9000 maize accessions collected from North Eastern Himalayan (NEH) region and some areas of Northern West Bengal. Of these, approximately 60% are landraces and populations.

Considering the utmost importance of landraces in maize, a segmented seed sector characterized by both improved landraces and improved maize varieties or hybrids has been proposed by Hellin *et al.,* (2014). In this model, the public and private sectors could continue to provide improved varieties to farmers, while other stakeholders, including farmers themselves, would generate seeds of improved landraces for its sale and exchange. In countries like Costa Rica and Honduras, farmers have expressed a strong preference for hybridization between improved varieties and landraces (Almekinders *et al.,* 1994). Such 'creolization' process, which involves the development of 'Criollo varieties' through hybridization, offers smallholder farmers access to both the improved technology and local adaptation without the need for annual seed purchases (Bellon and Risopolous, 2001).

Maize diversity in the Indian Himalayas

Grant and Wellhausen (1949) conducted studies on landrace diversity in India, discovering significant variability in the NEH region and the North-Western Highlands of India. The NEH region of India is reservoir of maize landrace diversity with adaptability to varied agro-climatic conditions. A composite known as '*Parbhat'* has been developed at Punjab Agricultural University (PAU), Ludhiana using Suwan-1, a well-known OPV from Thailand. It displays a high yield, stability in performance, and multiple disease resistance (Dhillon *et al.,* 2001, 2002). ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora also developed hybrids named as '*Him-128*' and '*Him-129*' utilizing various landraces of Jammu & Kashmir and Uttarakhand states of India (Prasanna *et al.,* 2011). Similarly, Govind Ballabh Pant University of Agriculture & Technology (GBPUAT, Pantnagar) developed '*Pant Composite Makka-4*' a OPV from popular maize landraces (*DLR-1, DLR-2* and *DLR-3*) collected from Uttarakhand.

Maize landrace diversity in North-Eastern Himalayas

The remarkable diversity of maize in the Indian Himalayan region led to the speculation that maize may have originated in Asia (Anderson, 1941). Maize is generally believed to have been introduced to the Old World after Columbus's discovery of America (Mir *et al.,* 2013). However, the diversity of Himalayan landraces, particularly NEH-adapted landraces challenges this notion suggesting a pre-Columbian introduction. The mention of maize grains in *Vedic* literatures further substantiates the theory (Randhawa, 1980; Singh *et al.,* 2022). A few ancient Indian and Chinese literatures from 5^{th} and 13^{th} centuries AD, respectively, also corroborated an early introduction of maize before the Portuguese invasion. Although debated, the sculptures of Hoysala temples of Karnataka can also be accounted as a proof. Despite scarce literature backing the history of maize cultivation in the Indian subcontinent, the studies on distinct heterochromatic knobs of NEH landraces differentiate them from the New World maize genotypes and make them resemble the Mexican teosinte and primitive Caribbean and South American (Andean highlands) maize germplasm suggesting a pre-Columbian introduction and subsequent spread across Southeast Asia (Kumar and Sachan, 1993; Prasanna and Sharma, 2005; Singh, 2019).

Sikkim Primitive was first collected by N.L. Dhawan in 1960s who christened it as *Sikkim Primitive* (Dhawan, 1964). The primitive group of maize, consisting of various popcorn races, spread across the Eastern Himalayan regions (Kumar *et al.,* 2015). Examples of these primitive groups include *'Poorvi Betapa', 'Arun Tepi', 'Murli', 'Tirap Nag-Sahypung'* and *'Alok Sapa'* (Kumar *et al.,* 2015). The popcorn, high prolificacy and drooping tassel of the majority of NEH landraces indicate primitive characteristics apart from widely introduced new world flint-maize genotypes. The waxy traits found in Southeast Asia including NEH region are atypical to New World flint and dents, but similar to Aegean (Greece) materials, proposes an ancient cross-Atlantic introduction from Americas to Mediterranean region, followed by a spread through 'silk route' to Southwest China with further spread in Southeast Asia due to congenial ecology (Anderson and Brown, 1952; Sorenson and Johannessen, 2004). Furthermore, the presence of maize cobs in ancient tombs in Sichuan province of China, as well as the rich maize diversity concentrated in Himalayan highlands including China, India, Nepal, Bhutan and Myanmar also suggest a trans-Pacific introduction with Asia as the merging point of both cross-Atlantic and cross-Pacific introduction (Anderson and Brown, 1952).

Several NEH landraces have been collected and studied by various researchers in the pre- and the post-independence era (Anderson, 1945; Stonor and Anderson, 1949; Ono and Suzuki, 1956; Dhawan, 1964; Thapa, 1966; Singh, 1977; Sachan and Sarkar, 1982; Sharma and Prasanna, 2005; Rahman and Karuppaiyan, 2011; Kumari, *et al.,* 2017; Sharma and Pradhan, 2023). The maize landraces of NEH have been characterized at both morphological and molecular level (Prasanna, 2010). Bhat and Chandel (1998) used isozyme markers and revealed that Indian maize landraces cultivated in the NEH region were found to have similarity with Mexican landraces. Baruah *et al.* (2024) reported wide genetic diversity among 83 NEH-based maize landraces for various morphological traits, and biochemical parameters such as anthocyanins and phlobaphenes. Phenotypic and molecular analysis was conducted on 132 maize landraces/locals, which included 69 accessions from eight states in the NEH (Prasanna and Sharma, 2005). Prasanna *et al.* (2005) conducted the first detailed report on molecular characterization of 27 selected Indian maize landraces from various agro-ecological zones, and of these, 10 landraces were selected from the NEH region of India. Later, Sharma *et al.* (2010) characterized 48 landraces, including *Sikkim Primitive*, with the property of prolificacy using SSR markers using a population bulk DNA fingerprinting strategy. A study of SSR-based diversity was also carried out among 48 selected landraces from the NEH region of India (Singode and Prasanna, 2010). Natesan *et al.* (2020) characterized 26 maize landraces from the NEH region of India for the *crtRB1* gene using a gene-based marker. They found 10 out of 26 landraces possess favourable allele of *crtRB1* gene and identified provitamin-A rich maize landraces.

Sikkim Primitives – a unique maize landrace of NEH

Of the various landraces from NEH, landraces from Sikkim province have raised special interests among maize breeders. The most important maize landraces of Sikkim include *'Murali Makkai', 'Seti Makkai', 'Pahenlo Makkai', 'Rato Makkai', 'Baiguney Makkai', 'Lachung Makkai', 'Sherung', 'Tempo Rinzing', 'Garberey', 'Khukurey', 'Kalo Makkai', 'Putali Makkai', 'Chaptey Makkai', 'Kuchungtakmar Makkai', 'Bancharey Makkai', 'Kuchungdari'* and *'Gadbade Makkai'* (Prasanna, 2010). Among these, *Sikkim Primitive* also known as Murali Makkai is distinct exclusively used for commercial offerings by the

Buddhist community in the area (Dhawan, 1964). Two accessions *viz*., *Sikkim Primitive*-1 (purple grains) and *Sikkim Primitive*-2 (yellow grains) were first collected in 1960s from Sikkim (Dhawan, 1964). They grow at mid-elevations of 2000-2700 m in the humid tropical cloud forest of Sikkim and is believed to be a primitive form of ancestral maize. The key features of the *Sikkim Primitive* include 7-9 ears per plant compared to compared to 1-2 ears per plant in modern maize (Sachan and Sarkar, 1982). It also lacks apical dominance, and possesses uniformity in ear size, popcorn-type kernels, and tall plants with drooping tassels for the effective fertilization (Anderson, 1945; Singh, 1977). The ears of the *Sikkim Primitive* variety are small, thin and cylindrical, occasionally tapering, measuring between 6-12 cm in length featuring 8-12 irregular rows (Singode and Prasanna, 2010).

Genetic dissection of prolificacy in Sikkim Primitive

Sikkim Primitive landrace has been characterized at morphological, cytological and molecular level. *Sikkim Primitive* has been extensively studied for various morphological traits, and found more closely related to maize (Sachan and Sarkar, 1982). They supported the naming of this landrace as 'primitive' type because of its high prolificacy, photoperiod sensitivity, small grain (popcorn type kernel) and ability to produce abundant pollen. Recently, Kapoor *et al.* (2022) characterized *Sikkim Primitive* using morphological traits. Pandey *et al.* (1986) analysed *Sikkim Primitive* using variation in heterochromatin present in chromosome. Kumar and Sachan (1996) analysed 41 maize landraces from NEH including *Sikkim Primitive* for diversity in pachytene knobs. Despite its discovery in 1960s, the genetic basis of prolificacy in '*Sikkim Primitive*' could not be elucidated till recently. One of the primary reasons has been the heterogenous nature of the landrace especially in cross-pollinated cop like maize. The concerted research effort at ICAR-Indian Agricultural Research Institute (IARI), New Delhi has led to the development of an inbred (MGUSP-101) by repeated selfing of *Sikkim Primitive* landrace (IC-565866). MGUSP-101 possesses all the characteristics of *Sikkim Primitive* including the high prolificacy and popcorn kernels.

Higher prolificacy in teosinte which possesses >50 small sized ears per plant has been implicated due to the *tb1* gene (Studer *et al.,* 2011). *Tb1* is a TCP (Teosinte branched1 of maize, Cycloidea of snapdragon, Proliferating cell nuclear antigen factor1 and 2 of rice) domain transcription factor and possesses role in growth of meristem, initiation of floral primordia, regulation of cell cycle and differentiation (Cubas *et al.,* 1999; Leukens and Doebley, 2001). *Tb1* acts as a master regulatory gene affecting the plant and inflorescence architectures (Studer *et al.,* 2017). *Tb1* codes a basic helix-loop-helix (bHLH) DNA-binding protein which consists of three conserved domains (Leukens and Doebley, 2001). It is responsible for suppression of axillary bud outgrowth on main stem and development of female inflorescence in maize (Doebley, 2004). In maize, *tb1* gene is expressed twice as that of teosinte, and over-expression of the suppressor protein causes reduction of branching in maize as compared to teosinte. This overexpression is due to presence of ~12 kb enhancer region (~58-69 kb upstream of *tb1* coding sequence) in maize (Doebley *et al.,* 1997; Clark *et al.,* 2006). Insertion of *Hopscotch* (~ 58-64 kb) and *Tourist* (~64-69 kb) retrotranspon within this ~12 kb region was observed in maize, while they were absent in teosinte (Zhou *et al.,* 2011; Studer and Doebley, 2012; Vann *et al.,* 2015).

In order to find, whether any unique variation in *tb1* gene is responsible for extraordinary prolificacy in *Sikkim Primitive*, the entire *tb1* gene of MGUSP-101 (*Sikkim Primitive*) was sequenced along with five maize inbreds (LM17, HKI1128, BML7, UMI1200 and CML425) and four teosinte accessions (*parviglumis, perennis, luxurians* and *mexicana*) (Prakash *et al.,* 2020). It was found that *Hopscotch* and *Tourist* transposable elements were observed in the upstream of *tb1* in all maize inbreds, while they were absent in wild relatives. This suggested that a different mechanism other than *tb1*-driven regulation might be responsible for prolificacy in *Sikkim Primitive* (Prakash *et al.,* 2020).

Prakash *et al.* (2019) crossed the prolific inbred (MGUSP-101) with four non-prolific inbreds *viz*., LM13, BML7, HKI161 and HKI1128. Genetic analysis revealed quantitative inheritance pattern of prolificacy with prevalence of non-allelic interactions of duplicate epistasis type has been observed. Dominance × dominance effect was predominant over additive × additive and additive × dominance effects. Total number of major gene blocks governing the prolificacy in *Sikkim Primitive* suggested the involvement of at least one major gene/QTL governing the prolificacy. Further, Prakash *et al.* (2021) developed two $F_{2:3}$ mapping populations by crossing prolific inbred (MGUSP-101) with two non-prolific inbreds, HKI1128 and UMI1200. Bulked-segregant analysis coupled with targeted QTL mapping identified a major QTL (bin: 8.05) explaining 31.7% and 29.2% phenotypic variation in MGUSP-101 × HKI1128 and MGUSP-101 × UMI1200 -derived mapping populations. The novel QTL was designated as 'qProl-SP-8.05' which has not been reported earlier. Earlier, Wills *et al.* (2013) reported a QTL, *prol1.1* located on chromosome-1 with multiple ears from a single node, rather than from each node as observed in *Sikkim Primitive*.

In order to further unravel the genetic architecture of *Sikkim Primitive*, whole genome of MGUSP-101 derived from *Sikkim Primitive* along with three non-prolific (HKI1128, UMI1200, and HKI1105) and three prolific (CM150Q, CM151Q and HKI323) inbreds were sequenced (Prakash *et al.,* 2024). A total of 942,417 SNPs, 24,160 insertions, and 27,600 deletions were identified in *Sikkim Primitive*. The gene-specific functional mutations in *Sikkim Primitive* were classified as 10,847 missense (54.36%), 402 non-sense (2.015%), and 8,705 silent (43.625%) mutations. The number of transitions and transversions specific to *Sikkim Primitive* were 666,021 and 279,950, respectively. Among all base changes, (G to A) was the most frequent (215,772), while (C to G) was the rarest (22,520). Polygalacturonate-4-α-galacturonosyltransferase enzyme involved in pectin biosynthesis, cell wall organization, nucleotide sugar, and amino-sugar metabolism was found to have unique alleles in *Sikkim Primitive*. The analysis further revealed the *Zm00001eb365210* gene encoding *glycosyltransferases* as the putative candidate underlying 'qProl-SP-8.05' for prolificacy in *Sikkim Primitive*. High-impact nucleotide variations were found in *ramosa3* (*Zm00001eb327910*) and *zeaxanthin epoxidase1* (*Zm00001eb081460*) genes having a role in branching and inflorescence development in *Sikkim Primitive* (Prakash *et al.,* 2024). The candidate genes are now being validated and introgressed into elite lines for enhancement of prolificacy in maize at IARI.

Way forward

Despite the presence of ample genetic diversity in maize landraces found in NEH regions, their utilization in maize breeding is still a major bottleneck. Maintenance of landraces needs to be undertaken using large plots to possess true genetic architecture. A strong pre-breeding activity needs to be initiated for derivation of homozygous genetic stocks with the unique trait(s) specific to each of the landraces. DH technology should be intensively utilized to derive homozygous inbreds from each of the unique landraces. Inheritance study followed by identification of locus (loci) underlying a particular trait needs to be undertaken systematically. Validation of gene followed by its introgression through molecular breeding would accelerate the genetic improvement in maize.

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Agrobiodiversity and Food System: Biodiversity Traditional Farming, Community Participation and Nutritional Security in Eastern Himalayan Region

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Agrobiodiversity refers to the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, including crops, livestock, forestry and fisheries. It comprises the diversity of genetic resources (varieties, breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems (agricultural, pastoral, forest and aquatic) as well as the diversity of the agro-ecosystems (FAO, 1999). Agrobiodiversity plays a crucial role in enhancing food security and stabilizing farming systems while boosting agricultural productivity. It also improves nutrition and diversifies food systems, contributing to environmental health by conserving soil and water, maintaining soil fertility, and supporting a variety of living organisms. Beyond providing food and livelihoods, Agrobiodiversity also fulfills other essential needs such as clothing, shelter, and medicine.

Agrobiodiversity and food system in Eastern Himalayan Region

Agrobiodiversity plays a vital role in food systems by providing nutritious foods that are locally accessible and rich in essential dietary components as this diversity enhances the food basket available to local communities and adds to the diversification of cropping systems, which is a key step toward achieving food security and by promoting a variety of crops and livestock, agrobiodiversity helps mitigate the impacts of climate change and has been shown to improve food quality and nutrition and additionally, diversifying cropping systems opens up opportunities for alternative crops, which can increase farmers' incomes and improve nutritional intake (Pandey *et al.,* 2022 and Kahane *et al.,* 2013).The promotion and management of agrobiodiversity are essential for diversifying food systems and ensuring food security among indigenous communities as it supports sustainable diets, preserves cultural heritage, and enhances overall well-being (Pandey *et al.,* 2022). By valuing and incorporating diverse local crops and practices, communities can build healthier food systems that empower them and maintain their traditions. Leveraging the biological and cultural diversity inherent in traditional and indigenous food systems can significantly enhance food and nutrition security, drawing on traditional knowledge of nutrient-rich, agro-biodiverse crops (Vogliano *et al.,* 2021).

The North Eastern Indian states, constituting 52 % of eastern himalyan region namely Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim, and hill districts of Assam, this part of India is a culturally diverse region and also recognized as one of the biodiversity hot spots in the world. Alder-based *jhum* and wet terrace paddy cultivation and Zabo system in Nagaland, rice-cum-fish farming and *jhum* cultivation by Apatani tribe in Arunachal Pradesh, *jhum* and bun (terrace) farming by ethnic Khasi tribe of Meghalaya, rice-based farming in Tripura, organic farming, as well as terrace rice cultivation in the river valleys of Sikkim are the predominant traditional farming systems which are unique and tribe-specific which maintains high cultural and farm agro-biodiversity in the region (Giri *et al.,* 2020). Community-based natural resource management is important for protecting biodiversity and helping local people make a living. In Northeast India, this method has a long history, with communities working together to conserve their natural resources for many generations. (Tungoe *et al.,* 2020). Some of the traditional agricultural systems of Northeast India that are used for the conservation of agrobiodiversity as well as conservation and management of natural resources are discussed below.

Traditional Farming Systems of Eastern Himalayan Region:

a) **Apatani farming systems**-It is a traditional farming system of culturing fish along with paddy by the Apatani tribe of Arunachal Pradesh. It is a multi-purpose water management system, which integrates land, water and farming system by protecting soil erosion, conserving water for irrigation and paddy-cum-fish culture. In rainy season fishes migrate to the crop fields from rivers/ streams/water bodies through excess water flow and flood. These fish are trapped in the paddy fields and grown there for some months. After rainy season when water dries up in the paddy fields, farmers use to collect them from their crop fields and sell them in the market. These fields are supported by strong bunds for preventing leakage of water and retaining it to the desired depth and also to prevent the escaping of cultivated fishes during floods water run-off. Moreover, the cultivation of millet (Sarse) on the bunds of paddy fields is commonly practiced by the farmers in the valley. The loss of soil nutrients from the paddy field is being added by recycling crop residues and use of organic waste of the village.

b) **ZABO system:** "Zabo" is an indigenous farming system of Nagaland. The word "Zabo" means impounding of water. It has a combination of forest, agriculture and animal husbandry with well-founded soil and water conservation base. It has protected forest land towards the top of hill, water harvesting tanks in the middle and cattle yard and paddy fields for storage for the crops as well as for irrigation during the crop period. Special techniques for seepage control in the paddy plots are followed. Paddy husk is used on shoulder bunds and puddling is done thoroughly.

c) **Bari farming system**: Bari is an operational unit in which a number of crops including trees are grown with livestock, poultry and/ fish production for the purposes of meeting the basic requirements of the rural household. The first zone of the backyard/bari comprises of a small area encircling the main house that shows the maximum crop diversity usually represented by only one or two individuals thus allowing the maintenance of many species within a small space. Fragrance plants, spices, medicinal plants, vegetables, and others are observed in this zone. Banana, plantains, citrus were commonly present in the second zone while the third zones mostly exhibited arecanut, jackfruit and other tree species. Bamboos were ubiquitous in the backyards. Pisciculture is another common practice in these farming systems. Fishes are generally reared in dugout ponds behind the main homestead gardens.

d) ***Jhum* farming system**: *Jhum* is the age-old traditional slash-and-burn method of cultivation. It is the oldest and the most common farming practice in the hilly regions of North-eastern states. This technique involves cultivating crops and vegetables on a plot of land for two consecutive years, followed by the harvesting of the crops, and the subsequent cutting down and burning of crop wastes so that the ash from the fire aids in soil regeneration. After a period of time, the land is left fallowed, allowing some pioneer plants to thrive and replenish the soil.

These are the few established traditional farming system of the Eastern Himalayan region through the local communities are conserving the agro biodiversity**.**

Agrobiodiversity and Climate Change

Agrobiodiversity apart from supporting the local population, it is also plays an import role in regulation of climate. Agrobiodiversity provides various services to the ecosystem such as nutrient cycling, pollination, maintains soil fertility, control of pest and diseases, regulating of climate as well as adds to food security thereby maintaining the overall ecological balance. Conserving biodiversity enhances the resilience of ecosystems, enabling them to better withstand climate pressures and continue providing essential services. But due to various anthropogenic activities it has imposed a threat and change in the global climate and with change in climate it disrupts the entire ecological cycle. In North East as, the agriculture is mostly depended on rain water and changes in climate causes erratic rainfall, drought and delays in monsoon rainfall is affecting the rice cultivation in the region thus, change is climate is a matter of concern in this region as any changes in the rainfall pattern causes serious implication to the agricultural crops and with heavy rainfall in the hilly regions there occur landslides and floods which cause hindrance in the entire food supply chain, market mechanism and even causes barrier in other agricultural activities (Jamir *et al.,* 2023) . Loss in biodiversity is due to changes in climate and climate change is a result of human activities. Thus, there is urgent need of conservation of agrobiodiversity in order to mitigate climate change effects and without minimizing the anthropogenic activities it is nearly impossible to achieve sustainable development.

Community Management of Agrobiodiversity and Food system

More than 200 ethnic tribals in north eastern region and these tribals practice tradition farming systems which are mentioned above and are dependent on forest based resources, therefore playing key role in conservation of biodiversity. Biodiversity is the main pillar of resilient food systems, offering the diversity necessary to adapt to changing conditions and sustain food production. To secure our future, management of agrobiodiversity is necessary and there is need to shift toward agricultural practices that protect and restore biodiversity, ensuring nature can continue to provide its essential services. Restoring agricultural biodiversity needs a mix of protecting nature, using sustainable farming methods, and advancing science. The traditional knowledge of the different ethnic communities plays a pivotal role in the management and conservation of agrobiodiversity in the traditional rice fields and home gardens. The design of the home gardens and the methods used to maintain the traditional farming systems of the various communities are reflections of the customary wisdom that has been passed down from generation to generation (Das and Das, 2020). In addition, on-farm conservation is essential for conserving local knowledge and agrobiodiversity and in countries such as Ethiopia and Kenya, community seed banks are established which are mainly informal institutions, locally governed and managed, plays a vital role in preserving local varieties of seeds and empowering farmers and local communities to manage and sustain crop and tree diversity, particularly of farmer and farmer-improved varieties (Elouafi, 2024 and Vernooy *et al.,* 2020). Such approaches like community should also be established in North Eastern region. Agroecological practices, such as crop rotation, intercropping, and agroforestry helps in leveraging the power of biodiversity to enhance soil health, control pests, and improve water use efficiency (Elouafi, 2024). Even, in North East the people are playing an important role in conservation of the biodiversity with their traditional framing practices and use their traditional knowledge of farming practice in to conserve and betterment of their livelihood.

Payment of Ecosystem services in conservation of agrobiodiversity

The concept of ecosystem services gained attention because of its linkages with human welfare. People depend on the ecosystems for a variety of services, and as a result, an ecosystem's health depends on its capacity to deliver the services they need. Despite being its importance there is less awareness regarding its vast benefits given by the ecosystem. The different ecosystem services such as provisioning services, regulating services, supporting services, and cultural services of Himalayan region are not adequately accounted for in economic policy and are insufficiently invested in their protection and management and due to change in climate there is continuous change in biodiversity. The Himalayan region which is mostly covered with forests and people are mostly tribals who are dependent on forest based agriculture for their livelihood and perform the practices without causing any damage to the forests or ecosystem as they are more concern towards the conservation of the ecosystem. Thus, payment for ecosystem services (PES) should therefore be implemented, which will aid in offering financial incentives to farmers and other contributors to the preservation and conservation of the biodiversity in the area. Therefore, appropriate measures are needed to preserve ecological services. Also, valuing the agroecosytsem services like supporting and cultural services which bring extensive benefits from the them and valuing agroecosystem will bring in a positive externality through creation of payment for ecosystem services (PES) schemes which will solve purpose of food security and livelihood security by incentivizing the farmers to adopt ecofriendly and conservation oriented agriculture and , thus policies should be considered taking the values or benefits provided by agroecosytems (Rath *et al.,* 2024).

Farmer's Variety registration Under PPV & FRA

It is an effective system in order to provide protection of plant varieties, the rights of farmers and plant breeders, it is essential to recognize and safeguard farmers' contributions to the conservation and enhancement of plant genetic resources. This recognition encourages the development of new plant varieties also by protecting plant breeders' rights which is crucial for fostering investment in research and development, which is necessary for agricultural advancement. Such protections are expected to stimulate the growth of the seed industry, ensuring that farmers have access to high-quality seeds and planting materials. In, North East, many farmers varieties are there and only few are registered and many are yet to be registered there is an urgent need for the registration of farmer's varieties of North Eastern Region.

Policy intervention for Management of Agrobiodiversity

The safeguarding of agro biodiversity is of utmost importance. Biodiversity should be priotrized and more focus and emphasis should be given by policy-makers, development agencies, research organizations, government, non-government organizations and the private sector as it plays an important role for food security planning. Scaling up of the small and marginal farmers who plays a very important role in conservation of biodiversity should be more focused and by incentivizing the farmers to use payments for ecosystem services can help in adding transfer of benefits to farmers which will encourage the farmers for their services to the ecosystem. With better understanding of science, ecosystem services and technologies and with their collaborative approach, agricultural productivity can be increased along with enhanced conservation measures of agro biodiversity.

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Diversity of Horticultural Crops in North Eastern Region

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The North Eastern (NE) region of India, known for its diverse agro-climatic conditions, is a hotspot of horticultural diversity. The region's distinct topography, climate and cultural practices contribute to a rich array of horticultural crops, making it a significant area for both traditional and modern horticulture. The North-Eastern (NE) region, recognized as one of the biodiversity hotspots within the Indian gene centre, is also known for its ethnic diversity and traditional culture. Many crop species in this region exhibit enhanced tolerance to various biotic and abiotic stresses, supporting sustainable production. Some indigenous vegetables and fruits are also utilized by rural communities for medicinal purposes. The diverse agro-ecosystems across the entire North Eastern (NE) region harbor a wealth of fruits and vegetable crops that remain largely unexplored. Beyond their nutritional value, many regional underutilized vegetable and fruit crops are employed for medicinal purposes, income generation and poverty alleviation. The region boasts a wide range of diversity in fruits, vegetable crops, flowers, and medicinal plants. Conservation of this diversity and effective management of bio-resources are critical issues that need to be addressed at both local and regional levels.

Horticultural diversity in the NE region

Agro-climatic diversity: The NE region encompasses varying altitudes, from plains to hills, and experiences a wide range of climatic conditions. This diversity supports the cultivation of a wide array of horticultural crops, including fruits, vegetables, spices, and medicinal plants.

1. **Fruits**
   - **Citrus fruits**: The region is known for its indigenous citrus varieties like Khasi mandarin, Assam lemon, and Sohshang.
   - **Temperate fruits**: In the higher altitudes, apples, pears, plums and peaches are commonly grown.
   - **Tropical and Subtropical fruits**: Pineapples, bananas and guavas are extensively cultivated in the lower altitudes.
2. **Vegetable crops**
   - The NEH region supports the cultivation of a variety of indigenous and exotic vegetables. Traditional leafy vegetables, tuber crops like yam, and exotic crops like broccoli and capsicum are grown.
   - **Off-Season cultivation**: The cooler climate in higher altitudes allows for off-season cultivation of vegetables, which has great economic potential.
3. **Spices and medicinal plants**
   - The region is rich in spice crops like ginger, turmeric and large cardamom.
   - A wide variety of medicinal plants are also found, such as Cinchona, Aconitum, and Taxus, which have traditional and commercial value.

4. **Ornamental plants**: The NEH region is home to numerous species of orchids and other ornamental plants. The region's biodiversity includes rare and endemic species that have high ornamental as well as medicinal values.

5. Traditional practices and Indigenous knowledge: The local tribes have developed unique horticultural practices over generations, which contribute to the sustainable management of horticultural biodiversity. Shifting cultivation, locally known as "*Jhum*" and home gardening are integral parts of the horticultural system in the region.

Diversity of Vegetable crops in the NE region

The North Eastern region of India is rich in the diversity of vegetable crops, including both major and lesser-known species, many of which exhibit remarkable tolerance to various biotic and abiotic stresses, supporting sustainable agricultural systems. The underexploited vegetable crops in this region have a long history of safe consumption, and the local communities are well aware of their nutritional and medicinal values. The diverse agro-ecosystems across the entire North Eastern region harbor a wealth of vegetable species that remain largely unexplored. In addition to their nutritional benefits, many of these underutilized vegetables are used for medicinal purposes and livelihood enhancement. The region boasts a wide range of vegetable diversity, including species such as *Solanum macrocarpon* (African eggplant), *Solanum xanthocarpum* (yellow-berried nightshade), *Cyphomandra betacea* (tree tomato), *Solanum pimpinellifolium* (currant tomato), *Capsicum frutescens* (bird pepper), *Capsicum chinense* (bonnet pepper), *Parkia roxburghii* (tree bean), *Allium schoenoprasum* (chive), *Vigna umbellata* (rice bean), *Canavalia ensiformis* (jack bean), and *Psophocarpus tetragonolobus* (winged bean), among others. Gourds also display significant variability, especially in fruit shape and size of the bottle gourd, as well as in lesser-known cucurbitaceous crops like *Cyclanthera pedata* (stuffing cucumber), *Luffa spp.*, *Cucumis hystrix* (wild cucumber), *Luffa graveolens*, *Momordica macrophylla*, *Momordica subangulata* (teasel gourd), *Trichosanthes cucumerina* (snake gourd), *Momordica cochinchinensis* (sweet gourd), *Momordica dioica* (spine gourd), and *Sechium edule* (chow chow). Additionally, indigenous leafy vegetables like *Ipomoea aquatica* (water spinach), *Chenopodium album* (Bathua), *Ipomoea reptans*, *Amaranthus viridis*, *Amaranthus lividus*, *Amaranthus spinosus*, *Basella rubra*, *Basella alba*, *Rumex vesicarius*, *Brassica juncea*, and *Malva verticillata* are occasionally used. Several species of *Dioscorea*, such as *alata*, *bulbifera*, *brevipetiolata*, *esculenta*, *hamiltonii*, *hispida* (Philippine medusa and red hot cat tail), *kamoonensis* (Kumaon Iris), *nummularia* (wild jujube), *pentaphylla* (orangeberry), *puber*, and *quinata* (five-leaf chocolate vine), are found abundantly in the region. Edible bamboo shoots, both cultivated and wild, include species like *Arundinaria callosa*, *Cephalostachyum capitatum*, *Bambusa balcooa* (female bamboo), *Dendrocalamus giganteus* (giant bamboo), and *Dendrocalamus hamiltonii*, among others. Despite the region's abundant vegetable diversity, research and development activities to harness these resources for economic development have been limited. Conservation, management and proper utilization of these bio-resources are critical issues that must be addressed at local, regional and national levels to fully realize the potential of the North Eastern region's vegetable crops.

Variability in genotypes of *Cucurbita* spp.

Table 1. Diversity of underutilized cucurbits in NE region

State	Diversity in crops/species
Assam, Nagaland, Meghalaya, Arunachal Pradesh, Mizoram, Manipur, Tripura, Sikkim	Pointed gourd*, Cucumis sativus, Cucurbita pepo, Cucurbita moschata, Cucurbita ficifolia, Cucumis callosus, Cucumis melo var momordica*, *Luffa spp., Momordica dioica, M. acutangula, Luffa spp., Momordica cochinchinensis, Trichosanthus anguina, Trichosanthus dioica, Benincasa hispida, Lagenaria siceraria*
Meghalaya, Manipur, Mizoram, Sikkim, Arunachal Pradesh	Chow-chow

Chow-chow (*Sechium edule*): Chow-chow is a very popular vegetable in the region commonly called squash and grows abundantly without much care and attention in the high hills of Meghalaya, Manipur, Mizoram, Nagaland and Sikkim. Chow-chow produces large starchy edible roots in addition to fruits. It is a vigorous, scrambling, tuberous-rooted perennial plant, grown for its starchy, edible fruit and seeds.

Fruit variability in Chow-chow

Diversity in *solanaceous* vegetables

The North Eastern region is rich in solanaceous vegetable diversity, particularly in *Solanum melongena* (eggplant), where several genotypes are known for their excellent qualities, including soft flesh, fewer seeds, and large fruit size. The region also harbors wild species such as *Solanum gilo*, *Solanum torvum*, *Solanum indicum*, *Solanum khasianum*, *Solanum macrocarpon*, and *Solanum xanthocarpum*. Among these, *Solanum khasianum* is valued for its medicinal properties, particularly its solasodine content, while *Solanum torvum* is widely used in medicine. These species have demonstrated resistance to pests and diseases, such as shoot and fruit borer and soil-borne diseases, respectively. Additionally, *Solanum pimpinellifolium*, which has become naturalized in this region, has shown resistance to late blight and tomato leaf curl virus. Chillies thrive in the warm to hot and humid climates of Arunachal Pradesh, Assam, Sikkim, Meghalaya, Manipur, Mizoram, Nagaland, and Tripura. Due to their long history of cultivation, natural out-crossing, and popularity, a vast genetic diversity has developed, resulting in numerous local landraces with significant variability in fruit shape, size, color, bearing habit, as well as semi-perennial and perennial growth habits, and levels of pungency. *Capsicum annuum*, *Capsicum frutescens*, and *Capsicum chinense* are important food crops in the region. Additionally, *Capsicum minimum*, also known as *Capsicum fastigiatum* (Bird's eye chilli), is widely cultivated across the region.

Diversity in *Solanum spp.*

Table 2. Diversity of *Solanum* species in NEH region

Arunachal Pradesh, Assam, Manipur, Meghalaya, Sikkim, Tripura, Mizoram, Nagaland	*Solanum macrocarpon, Solanum xanthcarpum, Solanum indicum, Solanum mammosum, Solanum khasianum, Solanum torvum, Solanum berbisetum, Solanum ferox, Solanum spirale, Solanum sisymbrifolium, Solanum kurzii* and *Solanum gilo*
Meghalaya, Manipur, Nagaland, Arunachal Pradesh	Tree tomato

Variability in *Capsicum spp.* in NE region

Table 3. *Capsicum* species and their characteristics

Species	**Economic traits**
Capsicum annum	Source of commercial dry and green chilli
Capsicum annum var. *avicular*	Wild type
Capsicum annum var. *grossum*	Less capsaicin
Capsicum annum var. *longum*	Used to produce condiments
Capsicum chinense	Closely related to *Capsicum frutescens*
Capsicum eximium	Wild type, pseudo self incompatible
Capsicum frutescens	Highly pungent
Capsicum minimum	Cultivated in almost all NEH region
Capsicum pubescens	Worthy of transfer of gene

Variability in fruit colour, fruit shape in chillies

Tree tomato *(Cyphomandra betaceae)*: Tree tomato is a perennial shrub, grown as a backyard crop in Meghalaya and Sikkim. It is popularly known as *Sohbainon-dieng* in Khasi. The inside pulp of the fruit is light orange and consumed as delicious chutney when raw or after roasting and peeling off the skin.

Diversity in leguminous vegetables

The North Eastern region is also known for its diverse wild forms and significant variability in rice bean (*Vigna umbellata*), characterized by profuse branching, a higher number of seeds per pod, an increased number of pods per peduncle, bold seeds, and high grain yield. Local landraces also exhibit notable polymorphism in seed colour. Additionally, *Vigna radiata* var. sublobata is known for its resistance to yellow mosaic virus. In the case of French bean, the climbing or pole type is particularly popular among tribal communities, as it is often used for mixed cropping with maize. Jack bean (*Canavalia ensiformis*) is also cultivated in the region, while winged bean (*Psophocarpus tetragonolobus*) is primarily grown in humid subtropical areas. Broad bean (*Vicia faba*) is successfully cultivated in Manipur and Arunachal Pradesh. The region is home to various legume species, including *Atylosia geonsis*, *Atylosia scarabaeoides*, *Canavalia gladiata*, *Mucuna manosperma*, *Mucuna nivea*, *Mucuna utilis*, *Dolichos biflorus*, *Bauhinia purpurea*, and *Vigna vexillata*. The tree bean (*Parkia roxburghii*), a common multipurpose tree species, is widely found in Manipur and Mizoram.

Table 4. Diversity of legume vegetables in NE region

State	Diversity in crops/species
Manipur, Assam, Arunachal Pradesh, Mizoram, Meghalaya, Tripura, Nagaland, Sikkim.	*Canavalia ensiformis, Dolichos lablab, Phaseolus vulgaris, Phaseolus coccineous, Vigna umbellata, Vigna radiata* var. sublobata, *Vigna umbellata* var. *radiata*, *Canavalia ensiformis, Psophocarpus tetragonolobus, Vicia faba, Parkia roxburghii, Canavalia gladiata, Dolichos falcatus, Dolichos bifilorus.*

Jack bean (*Canavalia ensiformis*): It is a bushy, semi-erect, annual herb, 2-3 m tall and the tips of its branches tend to twine under shade. Leaves are trifoliate and shortly hairy. Pods are 10-30 cm long and 2-2.5 cm broad. The pods are pendent, ribbed near suture and 10 to 25 seeded. Young green pods are eaten as a cooked vegetable. The young leaves may be cooked and eaten as a potherb.

Winged bean (*Psopocarpus tetragonolobus*)**:** Mainly found in Assam, Tripura and Meghalaya. A robust, climbing herbaceous perennial, flowers are of different colour, it may be blue, white or purple. The pods are four sided with characteristic wings and vary in length from 10-30 cm containing 5-15 seeds in each pod. All parts of the plant, i.e., seeds, flowers, leaves, pods and tuber-like-roots are edible. Flowers have a sweet taste because of the nectar they contain. The tuber-like-roots are eaten after boiling or frying.

Tree bean (*Parkia roxburghii*)**:** It is one of the most common multipurpose tree species of Mimosaceae family in the North eastern region, especially in Manipur and Mizoram. Locally called 'Yongchak' in Manipur and 'Yontak' in Assam, its tree commonly grows in every household of the region. The fruits in early stages are soft, tender and bright green in colour. They turn blackish when fully mature in March-April. Pods are formed in clusters of 10-15, each measuring 25-40 cm in length and 2-4 cm in breadth. Based on local preference, the pods are consumed at different stages of maturity, either fresh or processed.

Diversity in underutilized leafy vegetables in NE region

Key leafy vegetables in the region include *Lai sag* (*Brassica juncea*), *Lafa* (*Malva verticillata*) and water spinach. In addition to these, a wide variety of indigenous leafy vegetables are available, such as amaranth (*Amaranthus spp.*), *Poi* (*Basella rubra* and *Basella alba*), and sorrel (*Rumex vesicarius*). Other indigenous leafy vegetables occasionally used include *Jil milisag* (*Chenopodium album*). Important amaranth varieties grown in the region include *Amaranthus viridis*, *Amaranthus lividus*, *Amaranthus retroflexus*, and *Amaranthus spinosus*.

Diversity in *Allium spp* in NE region

***Allium ascalonicum (Shallot)*:** Usually, it has two cloves and occasionally as many as ten. Shallot bulbs grow in clusters and have a distinctive tapered shape that sets them apart from other members of the Alliaceae family. Most often these are of copper brown colour or reddish. Their flavour, is sometimes described as a blend of sweet onion and garlic. The height of plant is about 30-60 cm and have perennial growth habit. No seeds are produced, and propagate only by cloves or bullets. Its morphology resembles both the onion and garlic. The bulblet resembles garlic and its texture and colour are like the onion.

***Allium porrum* (Leek)**: Leek is found in cultivable and wild state. The wild plant is commonly known as 'wild leek' or 'broadleaf wild leek. Wild populations produce bulbs up to 3 cm across. Plants grow up to 1 m tall, bulb ovoid, 3-4 cm broad, scaly and scape arising from the centre of the bulb.

***Allium schoenoprasum* (Chives):** Bulb narrowly ovoid, up to 2 cm long, 0.5 cm broad, scaly membranous scales. Leaves 1-2 cylindrical, It looks like a tall tufts of grass. Umbels sub-globose, 3 cm across and have condensed flowers. Unequalpedicels, petals pink, 10- 12 mm long, lanceolate, acute.

Allium przewalsklanum: Used as vegetable.

***Allium tuberosum*:** Bulbs cylindrical, 4-6 cm long, light brown when dried, Umbel dense flowered sepals white rarely pink, 6-10 mm long, elliptic. Commonly known as Garlic chives, Chinese chives, Oriental garlic, Chinese leek related to garlic as it smells like garlic.

***Allium hookeri*:** A medium size herb leaves,commonly distributed in Manipur, Arunachal Pradesh and Meghalaya. Leaves and bulbs cooked as vegetables. Bulbs are used in the same way as onion.

Diversity in spices and condiments

The region is also known for its rich variability in spices, particularly *Piper nigrum* (black pepper) and turmeric varieties like Megha Turmeric-1, as well as the ginger variety Nadia. The region also boasts a diverse array of other spices, including *Tejpat* (*Cinnamomum tamala*), Bengal cardamom (*Amomum aromaticum*), camphor tree species like *Cinnamomum glanduliferum* and *Cinnamomum pauciflorum*, snap ginger (*Alpinia calcarata* and *A. malaccensis*), *Kaempferia* (*Kaempferia galangal*), long pepper (*Piper longum*), and *Piper peepuloides*. Additionally, species like *Zingiber cassumunar* and *Zingiber zerumbet* are used in indigenous folk medicine. The region is home to wild species with significant potential, including *Curcuma caesia* (black zedoary), *Curcuma angustifolia* (East Indian arrowroot), *Hedychium coronarium* (common ginger lily, *Takhellei angouba*), and *Hedychium spicatum* (spiked ginger lily, *Takhellei hangalpal*). The *Hedychium* genus, belonging to the Zingiberaceae family, includes edible underground rhizomes and features rare and threatened ornamental species such as *Hedychium luteum*, *Hedychium aureum*, *Hedychium radiatum*, *Hedychium robustum*, and *Hedychium dekianum*.

Black turmeric (*Curcuma caesia)*

Table 5. Diversity in rare *Zingiberaceae* in NE region

Species	Remarks
Zingiber cassumunar	Wild, used in indigenous folk medicines
Zingiber zerumbet	Wild, used in indigenous folk medicines
Curcuma angustifolia	Herb, wild, grows in dry deciduous forest
Curcuma caesia	Herb, wild
Hedychium marginatum	Cultivated and marketed
Hedychium coronarium	Perennial herb grows in moist tropical forest
Hedychium spicatum	Perennial herb, wild, sometimes cultivated
Alpinia galanga	A rhizomatous herb
Alpinia nigra	Cultivated and marketable rhizomatous herb
Alpinia officinarum	Introduced, wild or cultivated and marketable rhizomatous herb

Diversity in Tuber and rhizomatous crops

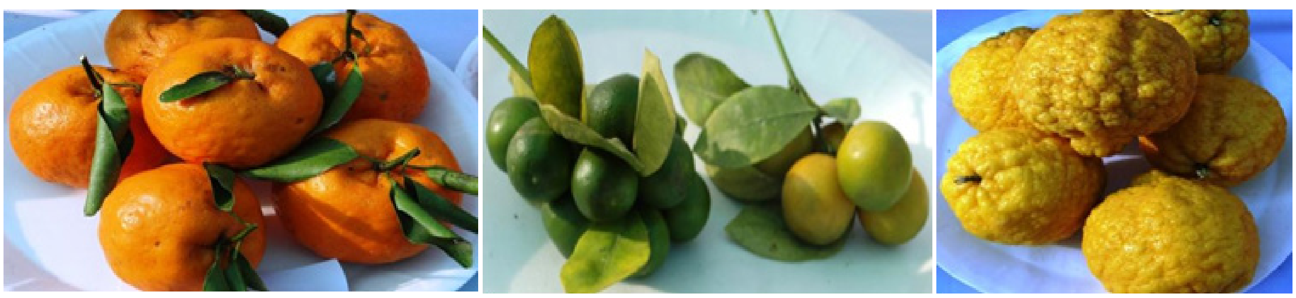
In the region, sweet potato is grown in two main varieties based on skin colour: white-skinned and red-skinned types. A diverse range of *Dioscorea* species is also found here, including *Dioscorea alata*, *bulbifera*, *brevipetiolata*, *esculenta*, *hamiltonii*, *hispida*, *kamoonensis*, *nummularia*, *pentaphylla*, *puber*, and *quinata*. *Dioscorea hamiltonii* is commonly found in the humid forests. In colocasia, there is significant variability even within a single species like *Colocasia esculenta*. Other potential species in the region include *Eleocharis dulcis*, *Sagittaria sagittifolia*, *Flemingia vestita*, and *Trapa bispinosa*. The lotus (*Nelumbo nucifera*), a rooted hydrophyte, is valued for its multiple uses, including its edibility as well as its religious and medicinal significance.

Table 6. Some other neglected vegetable crops grown in NE region

Scientific name	Family	Scientific name	Family
Abroma augusta	Malvaceae	*Centella asiatica*	Apiaceae
Allium odorum	Liliaceae	*Chenopodium album*	Chenopodiaceae
Alocasia macrorrhiza	Araceae	*Dillenia indica*	Dilleniaceae
Begonia josephii	Begoniaceae	*Diplazium esculentum*	Athyriaceae
Calamus erectus	Arecaceae	*Drymaria cordata*	Caryophyllaceae
Campylandra aurantiaca	Asparagaceae	*Eryngium foetidum*	Apiaceae
Drymaria diandra	Caryophyllaceae	*Hedychium spp*	Zingiberaceae
Houttuynia cordata	Saururaceae	*Lagerstroemia macrocarpa*	Lythraceae
Mucuna pruriens	Fabaceae	*Musa sepiatum*	Musaceae
Mussaenda roxburghii	Rubiaceae	*Oxalis corniculata*	Oxalidaceae
Physalis minima	Solanaceae	*Portulaca oleracea*	Portulacaceae
Saurauia armata	Actinidiaceae	*Saurauia roxburghii*	Actinidiaceae
Solanum nigrum	Solanaceae	*Solanum spirale*	Solanaceae
Solanum torvum	Solanaceae	*Solanum xanthocarpum*	Solanaceae
Sonchus sps.	Asteraceae	*Tacca integrifolia*	Dioscoreaceae
Trichosanthes cordata	Cucurbitaceae	*Zanthoxylum hamiltonianum*	Rutaceae

Genetic diversity of fruits in NE region

The North Eastern region is home to various tribal groups, including the Khasi, Garo, Monpas, Karbis, Jaintia, Naga, Kuki, Manipuri, Mizo, Chakma, Dufla, Adi, Mishing, Apatani, and others, who predominantly inhabit the hilly areas. These tribes traditionally practice "Jhumming" or shifting cultivation. Wild fruits play a significant role in the daily diets of the tribal people and are often sold in local markets, contributing to food diversification and nutritional security throughout the year. The region is also known as the citrus depository of India, with many citrus species originating here. Khasi mandarin (*Citrus reticulata*) is widely cultivated in Nagaland, and sweet orange (*Citrus sinensis*) is also commercially grown in some areas. In addition to these commonly cultivated species, the region is home to *Citrus indica* Tanaka (Indian wild orange), *C. latipes* (Swingle), *C. ichangensis* Swingle (Ichang Papeda), *C. medica*, *Citrus assamensis*, *Citrus macroptera*, and *C. hystrix*, which are found in the subtropical forests of the North-East and the foothills of the Eastern Himalayas. The maximum genetic variability of *Musa acuminata* and *M. balbisiana* occurs in North East India, with *M. flaviflora* localized to Manipur and Meghalaya. Other species found in the Khasi Hills require systematic collection and conservation. The region also exhibits rich diversity in genera such as *Pyrus*, *Rubus*, *Ribes*, and *Prunus*. The Shillong plateau in the Khasi Hills of Meghalaya is home to several *Prunus* species, including *P. nepalensis*, *P. undulata*, and *P. cerasoides*. *Pyrus pyrifolia* var. *cubha makai* (*P. serotina Red*) is semi-commercially grown in Meghalaya. Additionally, two species of *Elaeagnus*, namely *E. latifolia* and *E. pyriformis*, are commonly grown in the region, particularly in Sibsagar (Dikho Valley), Naga Hills, and the Khasi and Jaintia Hills. *Docynia indica* and *D. hookeriana* are also commonly found, along with *Pyrus pashia*, a medium-sized deciduous fruit tree, which is prevalent in the region.



Diversity in *Citrus* spp.

Arunachal Pradesh : *Actinidia callosa*, *Baccaurea sapida*, *Musa velutina*, *Musa ornata*, *Castanopsis indica*, *Sterculia hamiltonii*, *Nephelium lappaceum*, *Lithocarpus* spp, *Mangifera sylvatica*, *Pyrus pashia*, *Rubus niveus*, *Citrus medica*, *Livistonia jenkinsiana*, *Viburnum foetidum*, *Artocarpus chaplasha*, *Garcinia lanceifolia*, *Dillenia indica*, *Malus baccata*, *Machilus edulis*.

Mizoram : *Phyllanthus acidus*, *Garcinia lanceifolia*, *Passiflora edulis*, *Musa rosea*, *Mangifera sylvatica*.

Assam : *Citrus lemon*, *C. jambhiri*, *Citrus maxima*, *Citrus megaloxycarpa*, *C. marcroptera*, *C. assamensis*, *Artocarpus lackoocha*, *Dillenia indica*, *Averrhoea carambola*, *Phyllanthus acidus*, *Baccaurea sapida*, *Flacourtica indica*, *Elaegnus lalifolia*, *Myrica* spp.

Nagaland: *Myrica fraquhariana*, *Garcinia lanceifolia*, *Passiflora edulis*, *C. ichangensis*, *Citrus aurantium*, *Phyllanthus acidus*, *Musa magnesium*, *Juglans regia*, *Malus baccata*.

Sikkim : *Docynia indica*, *Actinidia strigosa*, *Machilus edulis*, *Bassia bytyracea*, *Musa sikkimensis*, *Spondias axillaries*, *Baccaurea sapida*, *Elaegnus latiolia*.

Tripura: *Citrus macroptera*, *Baccaurea sapida*, *Averrhoea carambola*, *Zizyphus funiculisa*, *Antidesma bunius*, *A. ghasaembilla*, *Grewia hirsuta*, *Grewia sapida, Physalis minima*, *Psidium guineens*, *Rubus ellipticus*, *Elaeocarpus floribundus*, *Citrus maxima*, *Dillenia indica*, *Carrissa carandas*.

Diverse forms of different fruits in NE region

Table 8. Underutilized fruit crops of North Eastern region

Scientific name	Common/ local name	Family	Distribution
Actinidia strigosa	Wild kiwi	Actinidaceae	Sikkim
A. callosa	Wild kiwi	Actinidaceae	Arunachal Pradesh
Baccaurea sapida (Roxb.)	Leteku	Euphorbiaceae	Sikkim, Meghalaya, Assam, Tripura
Averrhoea carambola L	Carambola (Star fruit	Oxalidaceae	Meghalaya, Assam
Docynia indica	Indian crab apple	Rosaceae	Khasi hill (Meghalaya), Sikkim
Emblica officinalis	Aonla	Euphorbiaceae	All NE States
Elaeagnus latifolia Linn.	Soh-shang (Khasi)	Elaeagnaceae	Meghalaya
Garcinia lanceaeifolia	Thekera tenga	Clusiaceae	Meghalaya, Mizoram, Nagaland,Assam
Myrica esculenta M.	nagi Soh-phie (Khasi)	Myricaceae	All North eastern hill region
Myrica fraquhariana	Soh-phie (Khasi)	Myricaceae	Assam, Nagaland, Meghalaya
Passiflora edulis	Passion fruit (Soh-rub)	Passifloraceae	Meghalaya, Mizoram, Manipur, Nagaland
Pyrus pashia	Soh-shur (Khasi)	Rosaceae	Khasi & Jaintia hills (Meghalaya)
Prunus nepalensis	Soh-iong (Khasi)	Rosaceae	Khasi and Jaintia hills (Meghalaya)
Dillenia indica	Otenga (Assamese)	Dilleniaceae	Meghalaya, Assam

Floral diversity in NE region

Commercial floral crops such as rose, anthurium, lilium, and gerbera have been introduced and are now commercially cultivated in both open fields and protected environments. The region is also known for its rich diversity of highly popular orchids. Out of the 17,000 species of orchids found worldwide, about 1,250 species occur in India, with around 700 species native to the North Eastern region alone, and approximately 324 species found in Meghalaya. The native orchid species with ornamental value and market potential typically belong to genera such as *Aerides*, *Anachnantha*, *Arundina*, *Cymbidium*, *Dendrobium*, *Paphiopedilum*, *Phaius*, *Renanthera*, *Phycostylis*, and *Vanda*. Forty orchid species from 16 genera were evaluated for their potential as cut flowers. Among the evaluated species, *Calanthe masuca*, *Cymbidium giganteum*, *Dendrobium nobile*, *Phaius tankervilleae*, *Renanthera imschootiana*, *Thunia marshalliana*, and *Vanda coerulea* showed promise as cut flowers.



Diverse floral plants in NE region

Medicinal plants

The tribal communities of the NorthEastern region possess extensive knowledge of wild plants with medicinal properties, which they have used for treating various ailments for generations. Reports indicate that 210 species from Arunachal Pradesh, 259 from Assam, 529 from Nagaland, 200 from Tripura, and 884 species from Meghalaya have medicinal value and have been traditionally used by the tribal people of this region. Among the most dominant and diverse medicinal plants in the area are *Panax pseudoginseng*, *Hydnocarpus kurzii*, *Litsea cubeba*, *Clerodendrum colebrookianum*, *Coptis teeta*, *Vitex trifolia*, *Aconitum heterophyllum*, *Alpinia galanga*, *Curcuma caesia*, *Taxus baccata*, *Acorus calamus*, *Ambrosia artemisiifolia*, *Antidesma bunius*, and *Achyranthes aspera*.



Medicinal plants of NE region

Potential of Horticultural development in NE region

Genetic resource conservation: The NE region can serve as a gene bank for various horticultural crops, with potential for breeding programmes aimed at improving crop varieties.

- **Value addition**: Developing value-added products from indigenous crops can enhance the region's economic potential.
- **Agro-Tourism**: The unique horticultural diversity and scenic beauty of the NE region can be leveraged to promote agro-tourism, providing additional income to local farmers.

Challenges

- Despite the rich biodiversity, the region faces challenges such as infrastructure constraints, limited market access and the threat of climate change.
- There is a need for conservation and sustainable utilization of the region's horticultural resources, along with the introduction of modern techniques to enhance productivity and marketability.

Status, Challenges and Use of the Genetic Diversity of Horticultural Crops in North Eastern India

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Introduction

Horticulture is a key sector in agriculture, offering significant potential for diversification and playing a vital role in ensuring food and nutritional security. Over the past three decades, it has been a major driver of economic growth. This sector allows for crop diversification and intensification, providing farmers with more opportunities for producing nutritious food and increasing their income. Horticultural production has seen a dramatic 13-fold increase, rising from 25 Mt in 1950-51 to 347 Mt in 2021-22, surpassing the production of food grains. Currently, despite occupying only 18% of the agricultural area, horticulture contributes approximately 33% of the gross value added to the country's agricultural GDP. India stands second-largest producer of horticultural crops, after China, accounting for 11.4% and 11.8% of the global fruit and vegetable supply, respectively. While discussing plant diversity, two regions of India are designated as biodiversity hotspots: the Western Ghats and the Northeastern hill regions. The Northeastern part of India, consisting of eight states Assam Arunachal Pradesh, Assam, Manipur, Meghalaya, Tripura, Mizoram, Nagaland and Sikkim located between latitudes 21˚.51 and 29˚.5 N, and longitudes 85˚.5 and 97˚.5 E. This region falls within six agro-climatic zones. The Northeast covers 7.7% of India's total geographical area but supports 50% of the country's biodiversity, 31.58% of which is endemic. The Northeastern hills are known for their varied soils, climates and topographies. This area boasts a rich diversity of fruits, vegetables, flowers (especially orchids), spices, bamboo and medicinal plants. In addition to commercial crops, many indigenous crops are highly nutritious, rich in vitamins and minerals, though they remain underutilized. The region also has the highest diversity of commercial fruits such as citrus, bananas and jackfruit. A wide variety of tropical and subtropical fruits from the genera *Garcinia*, *Artocarpus*, *Phyllanthus*, *Annona*, *Averrhoa*, *Persea*, *Aegle*, *Passiflora* and *Tamarindus* have been documented in the region. It is also rich in germplasm diversity of cucurbits, solanaceous vegetables, ginger, turmeric, bamboo and leafy greens. Among flower crops, greatest diversity is observed in orchids, ferns and other flowering shrubs. However, other horticultural crops in the area remain underutilized despite their potential to alleviate poverty and address nutritional security. The diversity of horticultural crops in this region has largely been maintained by local farmers, especially women. The region holds 16 GI (Geographical indicators) tags in horticultural crops which is an indication of stewardship in horticulture diversity.

Diversity of horticultural crops

The region is rich in biodiversity, hosting a vast array of flora and fauna. Located within the Eastern Himalayan Agro-climatic zone, the region's tropical and subtropical climate, along with the alluvial soil of the Brahmaputra and Barak valleys and the temperate climatic condition of the hilly areas with laterite and sandy soils, support a wide range of plant life. High rainfall and varied climatic conditions make this area ideal for growing a diverse selection of tropical and temperate horticultural crops. Tuber and rhizomatous crops such as sweet potato, colocasia, ginger and turmeric grow abundantly in the region, while plantation crops like cashew nut and black pepper have been introduced more recently. Additionally, underutilized crops like passion fruit, kiwi and chow-chow are cultivated in some areas. More than 300 edible plant species are found in the NE region, and some of them are worth consuming by various ethnic groups of the region (Deka *et al.,* 2012). A notable feature of Northeast India's flora is the presence of many primitive flowering plants, including *Magnolia pealiana*, *M. gustavii*, *Tetracentron sinense*, *Holboellia latifolia*, *Exbucklandia populnea*, *Manglietia* sp., *Myrica esculenta* and *Corylopsis himalayana*. Monogeneric families such as Coriariaceae, Nepenthaceae, Turneraceae, Illiciaceae, Ruppiaceae, Siphonodontaceae and Tetracentraceae are also represented in this region. Significant diversity exists among the horticultural species, showcasing variations in plant type, morphology, physiology, disease and pest resistance, adaptability and distribution. In addition to their nutritional benefits, many regional horticultural crops are valued for medicinal use and contribute to income generation and poverty alleviation programs in rural areas.

Table 1. Diversity of Horticultural crops in Northeastern India

State	Fruits	Vegetables	Spices
Arunachal Pradesh	Kiwi, Orange, Pear, Pineapple, Walnut, Apple, Banana, Guava	Cucumber, Potato, Pumpkin, Radish, Sweet Potato, Tomato, Bean, Bitter gourd, Brinjal	Large Cardamom, Ginger
Assam	Mango, Papaya, Pineapple, Sapota Banana, Guava, Jackfruit, Lemon, Litchi, Mandarin Orange	Bean, Brinjal, Broccoli, Cabbage, Capsicum, Muskmelon, Pea, Potato, Pumpkin, Radish, Carrot, Cauliflower, Colocassia, Cucumber, Gourds, Knol-khol, Spinach, Sweet potato, Onion, Tapioca, Tomato, Yam	Ginger, Turmeric, Black pepper, Chilli, Garlic
Manipur	Pineapple, Banana, Peach, Pear, Plum, Lemon, Orange, Passion fruit	Pea, Potato, Bean, Cabbage, Tomato, Onion, Cauliflower, Cucumber	Garlic, Ginger, Turmeric, Chilli
Meghalaya	Banana, Mandarin Pineapple, Plum, Guava, Lemon, Orange, Pear	Broccoli, Cabbage, Capsicum, Potato, Radish, Sweet potato, Tapioca, Turnip, Capsicum, Carrot, Cauliflower, Colocasia	Chilli, Turmeric, Black pepper, Ginger
Mizoram	Banana, Hatkora, Orange, Papaya, Passion fruit, Pineapple	Bean, Brinjal, Broccoli, Cabbage, Capsicum, Carrot, Cauliflower, Chow-chow, Cucumber, Gourds, Knol-khol, okra, Pea, Potato, Pumpkin, Radish, Tomato	Turmeric, Chill, Ginger
Nagaland	Banana, Guava, Jackfruit, Lemon, Litchi, Mandarin Orange, Mango, Papaya, Pineapple, Plum, Pomegranate	Brinjal, Cabbage, Carrot, Cauliflower, Chow-chow, Colacasia, okra, Radish, Sweet Potato, Pea, Potato, Tomato	Black pepper, Cardamom, Chilli, Garlic, Ginger, Turmeric
Sikkim	Mandarin Orange, Papaya, Passion fruit, Pear, Banana, Kiwi	Cucumber, Pea, Radish, Tomato, Turnip, Bean, Broccoli, Cabbage, Cauliflower	Large cardamom, Turmeric, Ginger
Tripura	Mango, Mosambi, Orange, Papaya, Pineapple, Banana, Ber, Guava, Jackfruit, Lemon, Litchi, Sapota	Bean, Cabbage, Capsicum, Carrot, Radish, Sweet potato, Tapioca, Tomato, Onion	Betel vine, Black Pepper, Chilli, Ginger

Table 2. State-wise area of horticultural crops ('000 ha) in 2021-22

State	Fruits	Vegetables	Plantation crops	Aromatic & Medicinal	Flowers	Spice
Arunachal Pradesh	30.09	2.62	1.60	0.24	0.00	12.33
Assam	161.98	306.23	90.48	4.62	5.30	100.14
Manipur	43.12	38.35	0.9	0.04	0.07	9.34
Meghalaya	37.38	49.61	27.73	0.00	12.47	14.52
Mizoram	66.47	40.67	21.45	0.77	0.08	27.82
Nagaland	34.41	41.51	3.41	0.08	0.04	12.03
Sikkim	20.17	22.44	0.00	0.00	0.00	42.44
Tripura	57.72	54.74	16.21	0.00	0.00	7.26
Total	431.17	533.74	161.78	5.75	17.967	183.44

Table 3. State-wise production of horticultural crops (t/ha) in 2021-22

State	Fruits	Vegetables	Plantation	Aromatic & Medicinal	Flowers		Spice	Honey
					Loose	Cut		
Arunachal Pradesh	138.00	17.41	7.05	0.16	0.00	0.00	18.59	0.15
Assam	2504.19	3747.48	163.0	0.17	35.58	57.79	317.24	1.40
Manipur	468.16	376.58	0.32	0.12	0.01	0.17	66.48	0.40
Meghalaya	378.16	520.15	35.07	0.00	0.00	0.35	72.02	0.27
Mizoram	345.36	224.64	33.64	0.78	0.00	0.80	100.93	0.30
Nagaland	316.29	455.96	7.12	0.66	0.04	0.24	40.84	0.72
Sikkim	50.78	129.37	0.00	0.00	16.50	0.09	102.95	0.53
Tripura	596.55	1179.22	37.21	0.00	0.00	0.00	27.43	0.22
Total	4746.9	6521.4	283.41	1.899	35.63	59.35	643.53	3.46

Fruit Crops

The region is home to a wealth of indigenous and wild fruits, many of which are not widely cultivated but have potential economic and ecological importance. It is mainly considered as citrus hub, as many species originated here. Khasi mandarin (*Citrus reticulata*) is extensively found, while sweet orange (*Citrus sinensis*) is also grown commercially in some parts of the region. In addition to these commonly grown species, *Citrus indica* (Indian wild orange), *C. latipes*, *C. ichangensis* (Ichang Papeda), *C. medica*, *Citrus assamensis*, *Citrus macroptera*, and *C. hystrix* are found in the subtropical forests of Northeast India and at the foothills of the Eastern Himalayas (Tanaka, 1928; Tanaka, 1937 and Mabberley, 2004). The region is also believed to be the native of several mango species, including *Mangifera* *indica* and *M. sylvatica*. Many wild mango species are found in states like Tripura, Manipur, South Assam and Mizoram. Mango species such as *Mangifera sylvatica* and *M. foetida* are native to Assam and Arunachal Pradesh, while *M. khasiana* and *M. pentandra* are indigenous to Assam. Northeastern India is a hotspot for genetic diversity in *Musa acuminata* and *M. balbisiana*, with *M. flaviflora* being specifically found in Manipur and Meghalaya. In 1986, the National Bureau of Plant Genetic Resources (NBPGR) gathered valuable banana landraces from Meghalaya, including Seeded Ladiarit, Ladison, and Rigitchi, as well as other prominent varieties like Hatigola, Eboke, Ginde, Egitchi, and Essing. The region also harbors significant biodiversity in species of *Pyrus*, *Rubus*, *Ribes* and *Prunus*. The Shillong Plateau, located in the Khasi Hills of Meghalaya, is home to several *Prunus* species, including *P. nepalensis*, *P. undulata*, and *P. cerasoides*. Additionally, *Pyrus pyrifolia* var. *cubha makai* (*P. serotina* Red) is cultivated semi-commercially in Meghalaya. A wide variety of other tropical and subtropical fruit species from the genera *Garcinia*, *Artocarpus*, *Phyllanthus*, *Annona*, *Averrhoa*, *Persea*, *Aegle*, *Passiflora* and *Tamarindus* also grow wild across the region. One of the indigenous fruits that deserve greater recognition is jackfruit, which thrives abundantly in Tripura, Assam, Nagaland and Meghalaya, with a variety of cultivars and landraces. Both cultivated jackfruit (*Artocarpus heterophyllus*) and its wild (*Artocarpus chaplasha*) are found throughout the region. Among the 300 edible plant species identified in the Northeast, many hold significant value for the ethnic communities. Two species of *Elaeagnus latifolia* and *E. pyriformis* are widely grown, particularly in regions like Sibsagar (Dikho Valley), the Naga Hills and the Khasi and Jaintia Hills. Additionally, *Docynia indica*, *D. hookeriana* and *Pyrus pashia* (a medium-sized deciduous fruit tree) are commonly found in the area. Soh-Shang (*Elaeagnus latifolia*), an underutilized fruit crop that is widely distributed across the region, is rich in bioactive compounds and contains a significant amount of essential fatty acids. Patel *et al.* (2010) reported the diversity of lesser known fruits in North Eastern States. Sankaran *et al.* (2006) gave detailed information on wild edible fruits of Tripura.

Table 4. List of Fruit Crops Diversity in North Eastern Region

Common name	Species	Distribution
Mango	*Mangifera indica* L.	Assam, Meghalaya, Mizoram, Tripura
Pineapple	*Ananas comosus* L.	Assam
Aonla	*Emblica officinalis* Gaertn	Mizoram and north east
Guava	*Psidium guajava* L.	Tropical and subtropical zone of India
Banana	*Musa acuminata* Colla. *Musa balbisiana* Colla.	Tropical and subtropical zones
Lime, lemon & oranges	*Citrus spp.*	Tropical & subtropical zone
Peach	*Prunus persica* Benth & Hook.f.	Arunachal Pradesh, Meghalaya, Nagland
Plum	*Prunus domestica* L. spp. *institia* (L)	Meghalaya, Mizoram
Strawberry	*Fragaria vesca* L.	Hills of NE region
Apple	*Malus sylvestris* (L)	Arunachal Pradesh & Nagaland

Table 5. Underutilized Fruit Crops

Scientific name	Common name	Family	Distribution
Actinidia strigosa	Wild kiwi	Actinidaceae	Sikkim
A calosa	Wild kiwi	Actinidaceae	Arunachal Pradesh
Baccaurea sapida	Leteku A.P. Tripura	Euphorbiaceae	Sikkim, Meghalaya, Assam
Averrhoea carambola L.	Carambola (Star fruit)	Oxalidaceae	Meghalaya, Assam
Docynia indica, *D. hookeriana*	Indian crab apple Soh-pho (Khasi)	Rosaceae	Khasi hill, Sikkim
Embica officinalis	Aonta	Euphorbiaceae	North eastern States
Elaeagnus latifolia Linn. *E. pyritolia*	Soh-shang (Khasi)	Elanagnacuae	Lower Assam, Meghalaya
Garcinia lanceifolia	Thekera tenga (Assamese)	Clusiaceae	Meghalaya, Mizoram, Nagaland and Assam
Myrica esculenta *M. nagi*	Soh-phie (Khasi)	Myricaceae	North eastern hill region
Myrica fraquhariana	Soh-phie (Khasi)	Myricaceae	Dikho valley Assam, Naga hills, Khasi & Jaintia hill, Meghalaya
Passifiora edulis *P. edulis* var. *flavicarpa*	Passion fruit (Soh-rub)	Passifioraceae	Meghalaya Mizoram, Manipur, Nagaland Sikkim
Pyrus pashia	Soh-shur (Khasi)	Rosaceae	Khasi & Jaintia hills (Meghalaya)
Prunus nepalensis	Soh-long (Khasi)	Rosaceae	Khasi and Jaintia hills, Meghalaya
Dillienia indica	Otenga (Assamese)	Dileniaceae	Meghalaya Assam
Machilus edulis King Syn *Persea fructifera* Kost	Pumsi (Sikkim)	Lauraceae	Sikkim Arunachal Pradesh

Vegetable crops

The region represents one of the largest groups of cultivated vegetable crops including solanaceous, cucurbitaceous, leguminous, leafy, cole, root, rhizomatous and bulbous crops. It is home to numerous solanaceous species, with an estimated 35 species from the Solanaceae family found here. Among these, the local inhabitants, especially the tribal communities, consume different species of vegetables. Notable but lesser-known edible species include tree tomato (*Cyphomandra betacea*), *Solanum torvum, S. indicum, S. macrocarpon, S. xanthocarpum, S. stramoniifolium* and *S. gilo*, with *S. gilo* being a highly valued vegetable among the Khasi and Mizo tribes. Chilli thrives in the warm, humid climate of Northeastern region. The region is home to various species of chilli, including *C. annuum* var. *aviculare*, *C. annuum* var. *grossum*, *C. annuum* var.

longum, *C. frutescens*, *C. minimum C. chinense*, *C. eximium* and *C. pubescens*. The King chilli, noted by Guinness World Records in September 2006 as the most pungent chilli in the world, originated in Northeast India, particularly in Nagaland and is widely cultivated across the region. Cucurbits, one of the largest groups of vegetable crops, are also extensively cultivated in all states of this area. The region hosts 15 genera of cucurbits, many of which are lesser known. *Momordica cochinchinensis* and *M. dioica* are commonly found in the Garo Hills of Meghalaya and Assam.

Indigenous leafy vegetables are grown, including *Amaranthus viridis*, *A. lividus*, *A. retroflexus* and *A. spinosus*, along with Puroi sag (*Basella rubra* and *B. alba*), sorrel (*Rumex vescicarius*), Jilmil sag (*Chenopodium album*) and Kalmou sag (*Ipomoea reptans*). Other commonly found leafy vegetables in the region include *Houttuynia cordata*, *Fagopyrum cymosum*, *Justicia*, *Rauvolfia*, *Rheum*, *Piper*, *Spilanthes acmella*, *Brassica*, *Bacopa monnieri*, *Commelina benghalensis*, *Colocasia esculenta*, *Oxalis corniculata*, *Centella asiatica*, *Plantago major*, *Alisma*, *Monochoria*, *Adhatoda vasica*, *Eryngium foetidum*, *Leucas aspera*, *Homalomena*, *Begonia*, *Abelmoschus*, *Mentha arvensis* and *Rumex*. These vegetables, along with other species, are mostly found in kitchen gardens and forests.

The region boasts high genetic diversity in the tuber and rhizomatous crops, including *Ipomoea batatas, Colocasia esculenta, Amorphophallus bulbiferus, A. paeoniifolius, A. campanulatus, Dioscorea alata, D. bulbifera, D. oenitophylla, D. esculenta, D. kamoonensis, D. pentaphylla, D. cylindrical, D. hamiltonii, D. oppositifolia, D. pubera, D. arachnida, D. belophylla, D. trinervia, D. wattii, D. sativa,* and *D. prazeri*. Additionally, turmeric and ginger are popular and commercially cultivated in the region.

Underutilized vegetables

In addition to the aforementioned crops, there is a significant variety of indigenous vegetable species utilized primarily by tribal populations, with the highest diversity occurring in Arunachal Pradesh. The most common multipurpose tree species in Manipur and Mizoram is the tree bean (*Parkia roxburghii* G. Don) (Kumar *et al*., 2002). In the hilly areas, tree tomato (*Cyphomandra betacea*), a perennial shrub that produces red, tomato-like fruits, is also cultivated and used. It is grown as a backyard crop in Meghalaya (Thakur *et al*., 1988). Another popular vegetable tree found in lower altitude zones is the drumstick, or horse radish, locally known as Sajina (*Moringa oleifera*). Chow-chow (*Sechium edule*), which is native to tropical America and commonly referred to as squash, grows with minimal care. *Flemingia vestita*, known locally as sohphlong, is consumed raw and is a weak climbing or trailing plant with underground tubers that occurs in the humid to subtropical regions of Northeastern India up to an elevation of 1500 meters (Sarma, 2001).

Flower crops

Northeastern region encompasses approximately 50% of India's flora, with around 8,000 species, of which 31.58% (about 2,526 species) are endemic (Hedge, 2000). This region is abundant in various plant species, including orchids, ferns, oaks (*Quercus* spp.), bamboos, rhododendrons (*Rhododendron* spp.) and magnolias (*Magnolia* spp.). Commercially cultivated crops, such as rose, anthurium, lily and gerbera, are introduced and cultivated in both open and protected environments. Orchids are popular and the Northeast is renowned for its rich diversity. Of the 17,000 orchid species worldwide, approximately 1,250 can be found in India, with about 700 species occurring in the Northeastern hilly region, including around 324 species in Meghalaya alone. More than one-fifth of the orchid species found in the region are endemic, meaning they are unique to this area and not found anywhere else in the world. Several Indian orchid species with significant ornamental value that originate from this region include *Aerides multiflorum*, *Aerides odoratum*, *Arundina graminifolia*, *Arachnis*, *Bulbophyllum*, *Calanthe masuca*, *Coelogyne elata*, *Coelogyne flavida*, *C. corymbosa*, *Cymbidium aloifolium*, *C. lowianum*, *C. devonianum*, *C. hookerianum*, *C. lancifolium*, *Dendrobium aphyllum*, *D. nobile*, *D. chrysanthum*, *D. farmeri*, *D. densiflorum*, *D. moschatum*, *D. fimbriatum*, *D. jenkinsii*, *Paphiopedilum venustum*, *P. spicerianum*, *P. hirsutissimum*, *P. insigne*, *Phaius wallichii*, *Pleione praecox*, *Renanthera imschootiana*, *Rhynchostylis retusa*, *Thunia alba*, *Vanda cristata*, *Vanda coerulea*, and *Vanda coerulescens* (Singh, 1990).

Northeast India is also known to harbor a significant number of valuable and threatened orchids, such as *Dendrobium spatella*, *Dendrobium parciflorum* and *Luisia macrotis* from Assam, *Vanda coerulea* and *Dendrobium palpebrae* from Arunachal Pradesh, *Renanthera imschootiana* and *Cymbidium tigrinum* from Nagaland, and *Anoectochilus crispus*, *Cymbidium eburneum*, *Habenaria khasiana*, *Liparis delicatulata*, *Paphiopedilum venustum*, *Taeniophyllum khasianum* and *Tainia khasiana* from Tripura. Rhododendrons are renowned for their stunning flowers and foliage. To date, 121 taxa have been recorded in India, with 117 (98%) of these distributed throughout the Northeastern states. The Shirui lily, or Shirui Kashong Timrawon (*Lilium mackliniae*), is a rare plant species native to India, found exclusively in the upper reaches of the Shirui hill range in the Ukhrul district of Manipur.

Hedychiums, part of the Zingiberaceae family, are excellent ornamental plants, of the nearly 1,000 species found in India, about 50% are located in the Northeastern states. Additionally, among non-flowering plants, various types of ferns can also be classified as ornamental. Epiphytic species such as *Lycopodium phlegmaria*, *Selaginella* spp., and *Nephrolepis* spp., including silver, golden, and walking ferns, as well as bird's nest ferns and certain tree fern species, represent cryptogamic plants that could gain popularity as ornamentals.

Spices and Medicinal crops

The Northeastern Region (NER) is rich in biodiversity, particularly concerning spice crops. Numerous unique relatives of spice crops and heirloom varieties have been identified in this area, some of which are utilized in traditional medicine and local cuisines. This valuable natural reservoir of spice germplasm presents significant potential for the spice sector in the NER and has produced distinct flavors such as Naga mircha (the world's hottest chilli), Mizo chilli (noted for its high pungency and unique flavor), Karbi Anglong ginger (characterized by low fiber and high oleoresin content), and Lakadong turmeric (known for its high curcumin content and specific profile), all of which have been awarded Geographical Indication (GI) tags. Additionally, wild relatives of large cardamom (*Amomum subulatum*) and cinnamon can be found in the region's forests.

Tribal communities possess extensive knowledge about wild plants with medicinal properties. They use these plants to treat various diseases. Reports indicate diversity of 200 medicinal plant species in Arunachal Pradesh, 256 in Assam, 526 in Nagaland, 194 in Tripura, and 834 in Meghalaya. Medicinal crops such as *Panax psuedoxinseng* (AIDS), *Litsea cubeba* (Paralysis), *Clerodendrum colebrookianum* (Heart disease), *Coptis teeta* (Malaria), *Aconitum heterophyllum* (Diabetes and rheumatism), *Vitex trifolia* (Tuberculosis), *Alpinia galanga* (Skin disease), *Curcuma caesia* (Swellings, sprains), *Taxus baccata* (Breast cancer), *Acorus calamus* (Influenza, headache, cough, cold), *Ambrosia artimisifolia* (Wounds, cuts), *Antidesma brunius*(ulcers), *Achyranthes aspera* and (Leprosy). These plants have been used by the tribal communities in the region since time immemorial.

Geographical Indication Recognized Horticulture Crops of Northeastern India

Northeastern region is home to a variety of unique horticultural species, many of which are protected by Geographical Indication (GI) tags. These tags highlight the species origins, unique characteristics and cultural significance. Efforts are underway to preserve and promote the germplasm for traditional use and breeding programs. Several GI-labeled horticultural species from this region demonstrate its rich biodiversity. This could serve as a driver for economic growth, enhancing the livelihoods of local farmers and boosting the regional economy.

Commodity and GI name	Region
Arunachal Orange	Arunachal Pradesh
Khashi Mandarin	Meghalaya
Kachai Lime	Manipur
Memong Narang	Garo Hills of Meghalaya
Kaji Nemu (Assam Lemon)	Assam
Tamenglong Orange	Tamenglong (Manipur)
Tripura Queen Pineapple	Tripura
Tezpur Litchi	Assam
Mizo Chilli	Mizoram
Elephant Chilli	Ukhrul Central Tehsil of Ukhrul (Manipur)
Naga Mircha	Nagaland
Dalle Khursani	Central hills of Sikkim
Naga Tree Tomato	Nagaland
Naga Cucumber	Nagaland
Sikkim Large Cardamom	Sikkim
Assam Karbi Anglong Ginger	Assam
Mizo Ginger	Mizoram

Conclusion

In conclusion, the northeastern region of India stands as a vibrant tapestry of horticultural crop diversity, characterized by its unique climatic conditions, rich biodiversity, and traditional agricultural practices. This region not only produces a wide array of fruits, vegetables, and medicinal plants but also holds immense potential for sustainable agricultural development. The preservation and promotion of this diversity are crucial for enhancing food security, improving livelihoods, and fostering economic growth. Additionally, the recognition of horticultural products through initiatives like Geographical Indication (GI) can further empower local communities, ensuring that the cultural heritage and ecological significance of this region are safeguarded for future generations. Emphasizing research, innovation and sustainable practices will be key to unlocking the full potential of northeastern India's horticultural crops, ultimately contributing to the region's resilience and prosperity.

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A Nutraceutical Approach to Health and Nutrition Security Combating Malnutrition through Indigenous Horticultural Crops of North East India

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Introduction

India is currently the largest country in the world in terms of population, and is projected to stay so throughout the century. Currently, India's population is estimated at 1.45 billion, representing 17.78% of the world's population (8.20 billion), which is expected to reach 1.70 billion by 2060 (UN-DESA, 2024). This rapid population growth dramatically burdens the food system of the country, which are already grappling with widespread malnutrition. Child malnutrition estimates for the indicators stunting, wasting, overweight and underweight describe the magnitude and patterns of under- and overnutrition. The world continues to face a "triple threat" of child malnutrition, which includes stunting (low height for age), wasting (low weight for height), overweight (too heavy for height) and micronutrient deficiencies, particularly among children under five (UNICEF, WHO and World Bank Group, 2023).

In 2022, approximately 390 million adults aged 18 years and older worldwide were underweight, while 2.5 billion were overweight, including 890 million who were living with obesity. Among children and adolescents aged 5-19 years, 390 million were overweight, including 160 million who were living with obesity (Mahato and Patel, 2022). Another 190 million were living with thinness. However, as per UNICEF-WHO-WB Joint Child Malnutrition Estimates – 2023 edition, in the year 2022, 148.10 million or 22.30% of children under 5 years of age were too short for their age (stunting) and nearly all children affected lived in Asia (52 per cent of the global share) and Africa (43 per cent of the global share). While, 45 million or 6.80% of children were too thin for their height (wasting), of which 13.70 million or 2.10% were suffering from severe wasting. More than three quarters of all children with severe wasting, live in Asia and another 22 per cent live in Africa. Additionally, 37.0 million children under the age of 5 were too heavy for their height (overweight). Nearly half of deaths among children under 5 years of age are linked to undernutrition. This estimate revealed insufficient progress to reach the 2025 World Health Assembly (WHA) global nutrition targets and the 2030 Sustainable Development Goal (SDG) 2 targets. Therefore, addressing such an alarming issue require more intensive efforts, if the world is to achieve the global target of reducing the number of malnourished children.

India scenario is more alarming as it topped the list of countries with the highest child-wasting rate in the world, at 18.70 per cent, whereas stunting rate is 35.50 per cent, its prevalence of undernourishment is 16.60 percent, and its under-five mortality rate is 3.10 percent, according to the Global Hunger Index (GHI), 2023 released recently. Moreover, the report also noted that among Indian women aged 15 to 24 years, the prevalence of anaemia was at a staggering 58.10 per cent.

Moreover, in North East India, malnutrition remains a significant challenge, with rising rates of stunting, wasting, and overweight children. According to National Family Health Survey-5 (IIPS and ICF, 2021), among the North Eastern states of India, Assam has the highest rates of underweight (32.80%) and wasting (21.70%), while Meghalaya has the highest stunting at 46.50%. However, Mizoram has the lowest underweight (12.70%) and wasting (9.80%) rates but the highest overweight (10.00%). The data revealed significant regional disparities in child nutrition, with some states, like Meghalaya and Assam, facing higher malnutrition challenges compared to others (Fig. 1). The double burden of malnutrition - undernutrition and rising obesity - poses serious challenges. Anaemia among children and pregnant women further complicates the region's health landscape. Despite efforts like Assam's "nutrition gardens," which encourage rural communities to grow vegetables, much more needs to be done. As all forms of malnutrition are preventable and in order to stop malnutrition before it starts, children and their families need access to nutritious diets, essential services and positive practices to set them on the path to survive and thrive. But today, these vital pathways to good nutrition are under growing threat, as many countries plunge deep into a global food and nutrition crisis fuelled by poverty, conflict, climate change and the enduring secondary effects of the COVID-19 pandemic. As the world responds to the crisis, urgent action is critical to protect maternal and child nutrition – especially in the most affected regions – and secure a future where the right to nutrition is a reality for every child

Therefore, addressing these challenges requires innovative approaches, one of which is harnessing the potential of indigenous horticultural crops from North East India, which are rich in nutraceutical resources. By focusing on nutraceuticals derived from indigenous horticultural crops, we can provide a sustainable solution to these malnutrition issues. Indigenous crops are usually neglected and derided by many in the agriculture and food industries as well as by urban consumers. Diverting the attention on such indigenous horticultural crops is an effective way to help a diverse and healthy diet and to alleviate and combat micronutrient deficiencies, the so-called 'hidden hunger' and other dietary deficiency particularly among the rural poor and the more vulnerable social groups in developing countries. In addition, these crops offer natural sources of vitamins, antioxidants, and essential micronutrients. Moreover, promoting the cultivation and consumption of these crops aligns with India's goals of food sovereignty and self-reliance, particularly in rural and tribal regions where malnutrition is most acute.

As India prepares for its population to peak, prioritizing the use of nutraceutical crops from North East India can offer a strategic pathway to achieving health and nutrition security, thereby addressing malnutrition at its roots while also preserving biodiversity and supporting local economies.

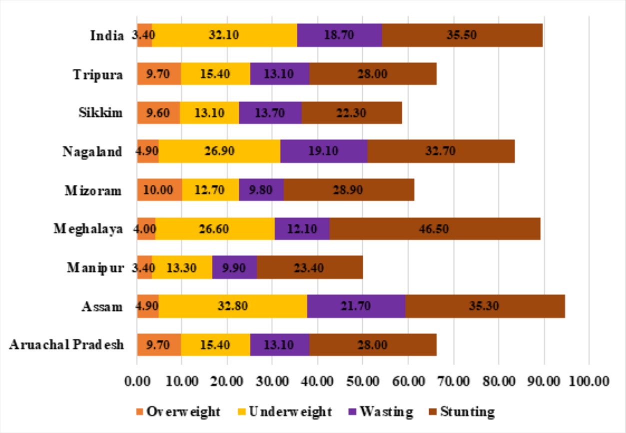

Fig. 1. Comparative Nutritional Status of Children Under Five in India and North Eastern States as per National Family Health Survey-5

A glimpse into nutraceutical rich horticultural crops of Northeast India

Northeast India, made up of the eight states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, are recognized as one of the world's most biologically diverse regions. Its distinct geography and climate, ranging from tropical to sub-temperate zones, support a remarkable range of flora and fauna. Renowned for its biodiversity, stunning landscapes, and rich cultural heritage, Northeast India is home to a wide array of nutraceutical rich horticultural crops. These crops are packed with bioactive compounds that offer numerous health benefits (Singh *et al.,* 2023). For generations, the region's inhabitants have incorporated these crops into their diets, benefiting from their therapeutic properties: an aspect that modern science is now validating. Both wild and cultivated, these crops play a vital role in the local diet and economy while offering significant potential for nutraceutical applications (Biswas *et al.,* 2022).

Northeast India's lush landscapes and favourable climatic conditions provide an ideal environment for the growth of diverse nutraceutical crops (Deka *et al.,* 2012). It not only sustains the local economy but also offer a treasure trove of health benefits, making them a vital part of the region's food and wellness culture. As the world increasingly turns to natural remedies and holistic health solutions, the horticulture crops of the Northeast stand as a testament to nature's wisdom and the region's enduring connection with it. Each state has its distinct set of crops, influenced by the local climate and soil conditions. For instance, Sikkim is known for its organic farming of fruits such as passion fruit and kiwi, while Assam is famous for its varieties of citrus fruits and the giant jackfruit.

North east is renowned as a rich hub for various horticultural crops, with fruit crops like Citrus serving as a significant repository in this region of the country. Among the *Citrus* spp., *Citrus reticulata* (Khasi Mandarin) is widely cultivated in North East and *C. sinensis* (Sweet Orange) varieties such as Kinnow and Valencia as well as Assam lemon are also commercially grown in some part of the region. In addition to these, *C. indica, C. latipes, C. ichangensis, C. medica, C. macroptera, C. assamensis, C. hystrix, C. limonia, C. limetta, C. karna, C. jambhiri, C. megaloxycarpa* are reported to grow in wild and semi-wild condition in NEH region (Kaul, 1981). On the other hand, NER is also a rich reservoir of genetic diversity, particularly for two wild *Musa* spp. such as *M. acuminata* and *M. balbisiana*. Many other wild bananas found in Meghalaya are seeded Ladiarit and Ladison, Rigitchi and other elite types, Hatigola, Eboke, Ginde, Egitchi and Essin. However, in Arunachal Pradesh, six species of *Musa* were found namely *M. argentii, M. arunachalensis, M. markkui, M. markuana, M. kamengnensis, M. puspanjalieae* and one species, *M. nagalandiana* Nagaland (Dey *et al*., 2014; Ranibala *et al*., 2018). At present, there are 27 species of wild *Musa* occurring in the region which represents 33% of the total species. The region also boasts rich diversity in *Pyrus*, *Rubus*, *Ribes*, and *Prunus*, with several *Prunus* species such as *P. nepalensis*, *P. undulata*, and *P. cerasoides* growing on the Shillong plateau. Other fruit species like *Garcinia*, *Artocarpus*, *Phyllanthus*, *Annona*, *Averrhoa*, and *Passiflora* thrive wild in the region. Jackfruit, with its numerous cultivars, grows abundantly in Tripura, Assam, Nagaland, and Meghalaya. Additionally, *Docynia indica*, *Pyrus pashia*, and tree tomatoes (*Solanum betaceum*) offer rich nutritional value. *Soh-Shang* (*Elaeagnus latifolia*) is an underutilized fruit with wide variability and bioactive compounds, playing an important role in the region's food diversity. Wild kiwi (*Actinidia callosa* and *A. stragosa*) is found growing in the natural forests of Arunachal Pradesh and Sikkim. One of the indigenous fruits that require attention is jackfruit, which grows abundantly in Tripura, Assam and Meghalaya with a large number of cultivars. Wild form of mango (*Mangifera indica*) and its allied species *M. sylvetica* occur in Arunachal Pradesh, *M. khasiana* and *M. pentandra* in Assam (Asati and Yadav, 2004). Although wild species of genus Mangifera are distributed throughout South and South-East Asia, recovery of Paleocene mango leaf fossils near Damalgiri, West Garo Hills, Meghalaya point to the origin of genus in peninsular India before joining of the Indian and Asian continental plates (Mehrotra *et al*., 1998).

In terms of vegetables, NER also has wide diversity, including solanaceous, cucurbitaceous, leguminous, leafy, cole, root, rhizomatous, and bulbous crops. Indigenous leafy vegetables such as *Amaranthus spp*., *Basella rubra*, *Chenopodium album*, *Diplazium esculentum* and *Ipomea reptans* are commonly grown, along with species like *Houttuynia cordata*, *Fagopyrum cymosum*, and *Rheum*. The region also boasts high genetic diversity in tuber and rhizomatous crops like *Ipomea batatus*, *Colocasia esculenta*, and various *Dioscorea* species. Solanaceous plants are abundant, with at least 35 species, out of which 15-16 species are consumed as vegetables and the important lesser-known species are *Cyphomandra betacea*, *Solanum torvum*, *S. indicum*, *S. macrocarpun* L., *S. xanthocarpum*, *S. straminifolium* Jacq. and *S. gilo* Raddi. Chili species, including the world-renowned King chili, which is the most pungent chili are widely cultivated in NER, especially in Nagaland. Cucurbits, another large vegetable group, are extensively grown, with 15 genera found in the region, including *Momordica cochinchinensis* (kakrol) and *M. dioica,* which are widely spread in Assam and the Garo hills of Meghalaya (Ram *et al*., 2002).

Lesser-known horticultural crops of North East India hold significant promise in addressing malnutrition due to their rich nutrient profile. These crops are not only sources of essential vitamins but also provide valuable proximate contents such as proteins, fats, and carbohydrates, along with a wealth of minerals and elements vital for human health. Furthermore, they are abundant in phytochemicals and antioxidants, which contribute to overall well-being and help in preventing various diseases. Their incorporation into local diets can greatly enhance nutritional security, especially in regions where conventional crops may fall short in meeting dietary needs. The nutrient composition including vitamins, minerals, proximate content, and antioxidants can provide further insight into their potential as functional foods. The table below illustrates these valuable attributes **(Table 1-3)**

Table 1. Nutritional composition and mineral content of some wild edible fruits and vegetables of North East India

Fruit	Crude fat (%)	Moisture (%)	Protein (%)	Crude fibre (%)	Available CHO (%)	K (mg/g)	Ca (mg/g)	Fe (mg/g)	Nutritive value (kcal/100g)
Debregeasia longifolia	2.39	65.56	11.99	1.26	68.15	20.46	19.49	3.00	342.15
Helicia erratica	1.07	82.48	3.26	3.24	88.96	2.98	2.06	0.15	378.56
Illex venulosa	1.29	67.34	3.27	4.88	87.31	11.04	9.18	0.22	374.01
Eriolobus indica	0.87	86.03	2.61	4.57	89.06	111.37	1.98	23.29	393.14
Morus indica	5.07	90.36	1.04	1.10	84.04	10.86	9.75	0.309	386.00
Myrica nagi	4.93	71.40	9.28	7.53	76.33	7.63	4.23	0.417	386.88
Myrica esculenta	4.93	72.38	9.62	5.22	78.03	7.75	4.63	0.404	395.04
Prunus nepalensis	1.36	67.34	6.00	5.22	82.57	11.75	7.30	0.213	366.57

Terminalia bellerica	3.55	56.30	8.74	4.90	78.72	7.28	5.36	0.823	381.87
Baccaurea sapida	0.73	35.59	5.58	20.40	51.90	7.30	158	75	236.50
Elaegnus latifolia	0.52	87.31	7.80	9.30	74.06	9.10	1470	180	332.10
Prunus cerasoides	0.59	83.00	3.50	7.32	84.07	470	294	211	355.60
Morus alba	0.21	84.10	5.50	2.15	87.55	-	-	-	374.10
Terminalia chebula	3.90	53.00	1.25	7.10	80.61	1270	811	31	362.50
Rhussemia lata	5.82	12.15	7.86	0.92	83.79	6.10	3.35	0.14	419.09
Spondias axillaris	7.39	62.29	1.88	9.35	77.83	10.81	6.05	0.37	385.40
Allium hooker	-	93.90	-	-	-	27.40	41.70	2.08	-
Dendrocalamus hamiltonii	-	93.20	1.63	-	1.89	1.87	5.72	0.412	-
Parkia roxburghi	-	59.10	7.40	-	12.70	5.82	1.96	0.014	-
Solanum torvum	-	74.30	3.98	-	2.45	3.14	0.722	0.011	-

Table 2. Fruits and Vegetables rich in Vitamins, Proximate and elements

Vitamins	**Fruit**	**Vegetables**
Vitamin A	Mango, papaya, carambola, wild kiwi, *Elaegnus latifolia,* loquat, dates, fig, karonda	Carrot, Sweet potato, pumpkin, red chilli, chenopodium leaves, colocoasia leaves, beet leaves, Purslane, watercress, Common leucas, horse purslane
Vitamin E	Avocado, mango, *Elaegnus latifolia*	Spinach, Kale
Vitamin C	Barbados cherry, Aonla, guava, citrus, carambola, *Garcinia cowa, Myrica spp.,* wild kiwi, *Baccaurea sapida, Elaegnus latifolia, Nephalium lappaceum,* jamun, breadfruit, bakul, *Frageria vesca*	Bitter gourd, green chilli, drumstick leaves, coriander leaves, fenugreek, brahmi, red spiderling
Vitamin B_1	Cashewnut, walnut, fig, jamun, phalsa, breadfruit, jackfruit, bakul, *Frageria vesca*	Chilli
Vitamin B_2	Bael, papaya, litchi, dates, phalsa, rose apple	Fenugreek leaves, Purslane
Vitamin B_3	Carambola, wild kiwi, breadfruit	Red spiderling, Brahmi,

Vitamin B_9	Sweet orange, mandarin	Cabbage, kale, broccoli, green leafy vegetables, Purslane
Carbohydrates	Raisins, dry apricot, dry karonda, dates, jackfruit	Tapioca, sweet potato, potato
Protein	Cashewnut, almond, *Baccaurea sapida,* fig	Lima bean, peas, cowpea, sessile joyweed, prickly amaranth, *Diplazium* fern, Indian pennywort, Chinese mellow, fenugreek, brahmi, watercress, Common leucas
Fibre	Fig, guava, almond, dates	Potato, chilli, sessile joyweed, Alligator weed, prickly amaranth, *Diplazium* fern, Indian pennywort, brahmi, red spiderling
Calorific value	Walnut, almond, cashew, dates	Tapioca, garlic, lima bean
Calcium	Litchi, dry karonda, *Pyrus pashia,* bignoy, *Baccaurea sapida,* loquat, dates, fig, jamun, phalsa, jackfruit, rose apple, bakul, *Frageria vesca*	Agathi, curry leaves, Alligator weed, red joyweed, prickly amaranth, Purslane, fenugreek, brahmi, red spiderling, marsh barbell, Common leucas, horse purslane
Phosphorus	Almond, cashewnut, walnut, carambola, wild kiwi, *Pyrus pashia, Baccaurea sapida,* loquat, dates, jamun, phalsa, breadfruit, jackfruit, rose apple, bakul, *Frageria vesca*	Amarunthus, garlic, Alligator weed, brahmi, marsh barbell, Common leucas, horse purslane
Iron	Dry karonda, date, carambola, wild kiwi, indian olive, *Pyrus pashia,* bignoy, *Baccaurea sapida,* loquat, dates, fig, jamun, phalsa, karonda, rose apple, bakul, *Frageria vesca*	Amaranthus, red joyweed, prickly amaranth, Purslane, brahmi, marsh barbell, Common leucas, horse purslane
Potassium	Carambola, wild kiwi, *Pyrus pashia, Baccaurea sapida,* dates, breadfruit, jackfruit, rose apple	Spinach, amaranthus, Alligator weed, red joyweed
Magnesium	*Pyrus pashia, Baccaurea sapida,* rose apple	Red spiderling

Table 3. Antioxidant properties of underutilized fruit crops of the NEH Region

Fruit species	Total phenolic content (GAE mg/g DM)	Total flavonoid content (mg/g DM)	Total flavonol content (mg/g DM)	Ascorbic acid equivalent (mg/g DM)	Free radical scavenging ability IC_{50} value (mg/g DM)
Eleaegnus latifolia	10.86	9.67	16.58	15.05	0.25
Eleaegnus pyrifolia	6.45	1.66	3.52	7.09	0.38
Myrica nagi	16.74	3.79	11.17	17.42	0.27
Myrica esculenta	28.56	2.25	8.87	19.33	0.16

Deka and Rymbai, (2014)

Nutraceutical Approach for Health and Nutritional Security

Horticultural crops in Northeast India have immense potential to combat malnutrition and contribute to health and nutritional security due to their rich biodiversity, nutrient content, and the region's favourable agro-climatic conditions. Here's how the key horticultural crops of the Northeast region of India, can play a pivotal role:

1. Passion Fruit (*Passiflora edulis*)

This tropical fruit, primarily grown in Manipur and Nagaland, is known for its refreshing taste and high content of antioxidants, vitamins A and C, and fiber. Passion fruit is often consumed fresh or used to make juices and desserts. Its ability to improve digestion and support immune function makes it a key nutraceutical crop in the region.

2. Pomelo (*Citrus maxima*)

A native of Assam, pomelo is the largest citrus fruit and is packed with Vitamin C, potassium, and fiber. Known for its sweet, mildly tangy taste, pomelo helps in improving heart health, regulating blood pressure, and boosting the immune system. It is also a key ingredient in traditional Northeast Indian cuisine.

3. Black Plum (*Syzygium cumini*)

Growing in abundance across Assam, Meghalaya, and Tripura, the deep purple jamun is rich in anthocyanins, iron, and vitamin C. Known for its ability to manage diabetes, improve digestion, and promote oral health, jamun is an ancient remedy in Ayurvedic practices and a beloved summer fruit.

4. Starfruit (*Averrhoa carambola*)

Starfruit, with its unique star shape when sliced, is grown abundantly in Assam and parts of Arunachal Pradesh. It is rich in Vitamin C, antioxidants, and fibre, making it a great immune booster. Its tangy flavour is a favourite in local salads and chutneys, and it also helps in managing cholesterol levels.

5. Jackfruit (*Artocarrpus heterophyllus*)

Jackfruit is a good source of magnesium, an essential mineral for bone health. It works alongside calcium to strengthen bones and may help in the prevention of osteoporosis. The fruit also contains a moderate amount of calcium, further contributing to strong bones. Due to its low-calorie content and high dietary fibre, jackfruit can help in managing weight by providing a sense of fullness, which reduces overall calorie intake. Its seeds, when boiled or roasted, are a low-fat, high-protein snack option, helping maintain muscle mass while controlling fat accumulation.

6. Blood fruit (*Haematocarpus validus*)

Natural populations of blood fruit are primarily confined in a select states/union territory, notably the Andaman and Nicobar Islands, Meghalaya, Assam, Arunachal Pradesh, Mizoram, Tripura and West Bengal. Local tribes of the Northeastern region of India incorporate this fruit into their traditional medicinal practices, harnessing its therapeutic properties such as blood purification, alleviating jaundice, anemia, itching condition, and heart-related disorder. it serves as a rich source of iron and β-carotene, addressing nutritional needs, but it also boasts low levels of anti-nutritional factors, making it a desirable dietary option. Beyond basic nutrition, blood fruit stands out for its abundance of polyphenols, anthocyanins and flavonoids, which not only contribute to its distinctive color but also confer remarkable antimicrobial, anti-inflammatory and antioxidant properties.

7. Khasi mandarin (*Citrus reticulata* Blanco)

Khasi mandarin is a nutrient-rich citrus fruit with powerful nutraceutical properties that contribute to better health and disease prevention. Its high content of vitamin C, antioxidants, flavonoids, and fiber helps in boosting immunity, promoting heart health, supporting digestion, and preventing chronic conditions like cancer, diabetes, and inflammation. By incorporating Khasi mandarin into the diet, one can harness these health benefits while enjoying its delicious taste.

8. Kiwi (*Antinidia deliciosa*)

Kiwi is a small, nutrient-dense fruit known for its unique taste and vibrant green colour. Rich in vitamins, minerals, and bioactive compounds, kiwi offers numerous nutraceutical properties that contribute to health promotion and disease prevention. Kiwi is an exceptional source of vitamin C (ascorbic acid), with a single fruit providing more than 100% of the daily recommended intake, packed with various antioxidants, Soluble fibre in kiwi helps regulate bowel movements, prevents constipation, and promotes the growth of beneficial gut bacteria, supporting overall gut health and Kiwi also contains prebiotics, which feed the good bacteria in the gut, fostering a healthy digestive environment.

9. Assam Lemon (*Citrus limon*)

Assam lemon locally known as Kaji Nemu, is a unique variety of lemon from Northeast India, particularly Assam, renowned for its large size and high juice content. It is rich in vitamin C, which boosts immunity, acts as a potent antioxidant, and aids in collagen synthesis, promoting skin health. Assam lemon also contains flavonoids and limonoids with strong antioxidant and anti-inflammatory properties, helping to combat oxidative stress and reduce inflammation. Additionally, its dietary fibre supports digestion, while its citric acid content promotes kidney health by preventing the formation of kidney stones. Regular consumption of Assam lemon can improve heart health, aid in detoxification, and help in managing weight due to its low calorie and high nutrient profile.

10. Dragon Fruit (*Hylocereus undatus*)

Rich in vitamin C, it strengthens the immune system and acts as a potent antioxidant, helping to fight free radicals and reduce inflammation. Dragon fruit is also high in fiber, promoting healthy digestion, supporting gut health, and aiding in weight management. It contains betalains, powerful antioxidants that have anti-cancer and anti-inflammatory properties. Additionally, dragon fruit provides essential minerals like magnesium and iron, which support muscle function and energy production. Its low-calorie content, combined with these bioactive compounds, makes dragon fruit an excellent functional food for overall health and wellness.

11. Andro Pineapple (*Ananas comosus*)

The Andro pineapple, a special variety from Manipur, is prized for its unique sweetness and rich nutraceutical properties. High in vitamin C, it boosts immune function, promotes skin health, and serves as a strong antioxidant, protecting cells from damage caused by free radicals. The pineapple contains bromelain, a powerful enzyme with anti-inflammatory, digestive, and potential anticancer properties. This enzyme aids in protein digestion, reduces inflammation, and may help alleviate symptoms of arthritis. The fruit is also rich in fiber, which supports digestive health and weight management, and contains essential minerals like manganese, important for bone health and metabolism.

12. Bay berry/ Box myrtle (*Myrica esculenta*)

The fruits are consumed raw or used in pickling, and they can also be dried, canned, or fermented to produce alcoholic beverages. The bark serves multiple purposes, functioning as a tanning agent and a source of yellow dye. Medicinally, the bark is astringent and antiseptic, with its decoction traditionally used to treat asthma, fever, chronic bronchitis, lung infections, and toothaches. The fruit extract is recognized as a rich source of natural antioxidants, while powdered stem bark is taken as a remedy for dysentery. Additionally, the bark is applied externally as a stimulant to relieve rheumatism.

13. Malabar tamarind *(Garcinia cowa)*

The fruit, rich in vitamin C with a sour taste, is commonly consumed, while its young leaves are used as food additives. A gum from the tree trunk is employed in the production of yellow varnish. Medicinally, boiled leaves are consumed (50 ml twice daily) to treat dysentery and diarrhea. Ethnomedicinally, the plant is known for improving blood circulation, acting as an expectorant, antipyretic, and laxative, and aiding in digestion. It is also used to treat dysentery. Its fruits possess pharmacological properties, including anti-inflammatory, antioxidant, antimutagenic, antiplatelet, anticancer, antimicrobial, and antidiabetic activities. Phytochemical analysis has identified various compounds, such as despidones, flavonoids, phloroglucinol, terpenes, steroids, xanthones, palmitic acid, and hydrobenzoic acid, in the fruits, stems, and leaves (Paudel *et al*., 2023).

14. Assam apple (*Docynia indica*)

Fruits are edible and eaten fresh or processed into pickles or jelly. Fruit extract is made into a semi solid gel locally known as "chuk" in Sikkim, which is a good medicine for stomach disorder. It is used as a natural remedy for treatment of infectious diseases, digestive aid and also show hypoglycaemic and hypo lipidemic effect. This fruit holds significant nutraceutical value, being rich in antioxidants, vitamins, and essential minerals. Its high moisture content (80-85%) along with potassium, calcium, and magnesium contributes to its strong antioxidant properties, making it beneficial for reducing risks of chronic diseases like cardiovascular issues and cancer. It is also a good source of Vitamin C (14.8-17.5 mg/100g), vital for immune function and skin health. Phytochemicals such as flavonoids, terpenoids, and carotenoids further enhance its role in human health, offering anti-inflammatory, anti-microbial, and anti-carcinogenic benefits. The nutritional profile and its bioactive compounds make it an important nutraceutical with potential therapeutic benefits.

15. Jalpai (*Elaeocarpus floribundus*)

Elaeocarpus floribundus is a sour-tasting fruit known for its high iron content and medicinal properties. It contains 0.69% protein, 19.50% carbohydrates, and 0.59% minerals. The fruit is used to treat ulcers, biliousness, and women's diseases, and is considered a tonic. It is also effective for dysentery and diarrhea. Ripe fruits are edible, commonly used in pickles, while the leaves serve as remedies for rheumatism and as an antidote for poisoning. Medicinally, various parts of the plant are used globally for treating diabetes, hypertension, inflamed gums, and ulcers. The leaves contain vitamin C, myricetin, ellagic acid, and tannins, while the fruit's acidity is due to citric acid. The fruit's fiber comprises rhamnose, arabinose, galactose, and uronic acid. Notably, it also exhibits strong antioxidant properties.

16. Indian wild Pear/ Himalayan Pear (*Pyrus pashia*)

The fruit of *Pyrus pashia* is rich in essential minerals such as phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and iron (Fe). Edible and soft when ripe, the fruit has an astringent quality and is suitable for dehydration. Its juice is particularly beneficial in curing eye disorders. Traditionally, the fruit is consumed to quench thirst and relieve constipation. It has diuretic and astringent properties and is used to treat various ailments, including anemia, ocular issues, digestive disorders, sore throats, irritability, abdominal pain, dysentery, and leishmaniasis. Additionally, the fruit is often mixed with cattle feed to increase milk production. The Monpa community in Tawang, Arunachal Pradesh, brews tea from the leaves. The flowers, soaked for 24 hours and then cooked with beef, chicken, or eggs, are used to treat coughs, emesis, and diarrhea, as well as to reduce cholesterol levels. The bark, known for its tonic and astringent qualities, is used to treat fever, peptic and stomach ulcers, sore throats, and typhoid fever.

17. Bignoy (*Antidesma bunius*)

Antidesma bunius is a valuable fruit rich in calcium and iron, commonly consumed raw or used to make jam, jelly, wine, and sauce. The ripe fruits exhibit astringent, anti-dysenteric properties and help quench thirst while stimulating salivation. is rich in various bioactive compounds, including terpenes, saponins, tannins, flavonoids, and acids such as gallic, ellagic, and ascorbic acid. Traditionally, its leaves are used to treat skin disorders, syphilis, snakebites, and indigestion, while the fruits are consumed as a healthy alcoholic drink or cooked and also used as a remedy for diabetes, hypertension, and gastrointestinal issues with its anti-toxins properties. The roots possess anthelmintic properties and help alleviate coughs and stomach aches. The bark is recognized for its antidiabetic effects, and the seeds are effective against intestinal worms. This diverse medicinal use underscores the valuable potential of *A. bunius* in traditional healthcare.

18. Meghalayan Cherry (*Prunus nepalensis*)

It is locally known as Sohiong in the Khasi Hills of Meghalaya, and bears edible fruits that are commonly used to make fruit juice. The fruits are astringent, while the leaves serve as a diuretic and are utilized in the treatment of dropsy. The pulp of the fruit is also employed in the preparation of squash, jam, ready-to-serve (RTS) beverages, and cherry wine, showcasing its versatility in culinary applications.

19. *Elaegnus latifolia*

Elaeagnus latifolia is a nutrient-dense fruit rich in vitamins, particularly A, C, and E, as well as essential minerals, flavonoids, and other bioactive compounds. It provides beneficial fatty acids and exhibits anti-carcinogenic properties. Additionally, this species has the unique ability to fix atmospheric nitrogen in the soil, enhancing soil fertility. The fruits are commonly consumed raw with salt and can be processed into various products, including pickles, jam, and jelly. It is rich in polysaccharides, proteins, and fats, containing bioactive compounds such as flavonoids, phenolics, and indole alkaloids. The fruit serves as a vital source of potassium, phosphorus, magnesium, and calcium, helping to prevent mineral deficiencies. Additionally, it provides trace minerals like iron, zinc, copper, and manganese, essential for metabolic reactions. Notably, *E. latifolia* fruits possess potent antimicrobial properties that inhibit bacterial and fungal pathogens, highlighting their importance in traditional medicine and nutrition.

20. Sessile Joyweed/Sanchi saag (*Alternanthera sessilis*)

It is a rich source of proteins, dietary fiber, and sterol compounds, including alpha spinasterol, beta sitosterol, beta sitosterol glucoside, campesterol, oleanolic acid, saponins, and stigmasterol. It is particularly effective in treating various skin diseases, as well as conditions such as acne, asthma, diarrhea, dizziness, and digestive disorders. Additionally, the plant exhibits a range of medicinal properties, including being an abortifacient, antiulcer, cholegogue, diuretic, febrifuge, galactagogue, memory enhancer, and antihyperglycemic agent. The stems and leaves are beneficial for eye troubles, while a decoction made with a pinch of salt is used to alleviate vomiting of blood. The shoots can be combined with other ingredients to help restore virility, and poultices made from the plant are effective in treating boils. This edible medicinal weed consists of two cultivars such as green and red. The green cultivar is commonly used to alleviate pain, promote wound healing, and treat conditions such as dysentery, asthma, and hypertension, while the red cultivar is recognized for its potential in preventing cardiovascular and liver diseases.

21. Alligator weed (*Alternenthera philoxeriodes*)

This plant is a valuable source of essential minerals, including calcium, iron, and potassium, as well as dietary fiber. It contains bioactive compounds such as 7α-L-rhamnosyl-6-methoxy-luteolin, oleanolic acid, alternanthin, β-sitosterol, stearic acid, and oleanolic acid-3-O-β-D-glucoside. Known for its antiviral, antibacterial, and hepatoprotective properties, it is effective in clearing heat, cooling the blood, detoxifying, and promoting urine excretion. The plant is particularly beneficial for conditions such as coughing up blood, hematuria, cold and fever, measles, encephalitis B, stranguria with turbid urine, eczema, anthrax, furunculosis, and venomous snake bites.

22. Red Joyweed (*Alternenthera polygonoides*)

It is a rich source of essential minerals, including iron, calcium, and potassium, as well as dietary fiber and various sterol compounds, including anthocyanins. Primarily consumed as a leafy vegetable, it holds significant value among tribal communities. Medicinally, the plant is recognized for its hepatoprotective and anticancer properties, as well as its ability to cleanse the blood.

23. Prickly amaranth/Spiny amaranth (*Amaranthus spinosus*)

This plant is an excellent source of antioxidants, protein, calcium, iron, and vitamins. Its high dietary fiber content promotes digestive health and alleviates constipation. Additionally, it helps lower bad cholesterol levels in the blood, reducing the risk of cardiovascular diseases and osteoporosis.

24. Diplazium fern/Dheki/Lingru/Pako (*Diplazium esculentum*)

Diplazium is an exceptional source of proteins, essential minerals, dietary fiber, vitamins, and potent antioxidants. Its remarkable health benefits stem from the presence of glycosides, phenols, terpenoids, and saponins, which collectively contribute to its powerful antimicrobial, anti-inflammatory, anthelmintic, and anti-diarrheal properties. Furthermore, this plant is renowned for its positive effects on liver health, making it a valuable addition to both traditional and contemporary herbal medicine.

25. Indian pennywort (*Hydrocotyle sibthorpioides*)

This plant is an excellent source of essential minerals and vitamins, boasting a diverse array of beneficial compounds, including stigmasterol, daucosterol, hibalactone, genistein, daidzein, methyl-3,4-dihydroxybenzoate, protocatechuic acid, caffeic acid, isorhamnetin, quercetin, and hyperin. Notably, the juice extracted from this plant exhibits emetic properties, making it effective for certain therapeutic applications. Its multifaceted medicinal uses include acting as a depurative, febrifuge, expectorant, antitussive, antifebrile, diuretic, and anticancer agent. Additionally, its significant antimicrobial properties enhance its value as a natural remedy, underscoring the plant's potential in traditional and modern medicine.

26. Chinese Mallow (*Malva verticillate*)

This plant is an excellent source of essential minerals and vitamins, enriched with a diverse range of beneficial compounds, including stigmasterol, daucosterol, hibalactone, genistein, daidzein, methyl-3,4-dihydroxybenzoate, protocatechuic acid, caffeic acid, isorhamnetin, quercetin, and hyperin. Notably, the juice extracted from this plant exhibits emetic properties, making it effective for certain therapeutic applications. Its multifaceted medicinal uses include acting as a depurative, febrifuge, expectorant, antitussive, antifebrile, diuretic, and anticancer agent. Additionally, its significant antimicrobial properties enhance its value as a natural remedy, underscoring the plant's potential in traditional and modern medicine.

27. Creeping wood sorrel (*Oxalis corniculate*)

Oxalis is an excellent source of flavonoids, tannins, phytosterols, phenolic compounds, glycosides, fatty acids, galacto-glycerolipid, and volatile oil, with its leaves rich in various antioxidants. This plant is abundant in essential fatty acids, including palmitic, oleic, linoleic, linolenic, and stearic acids. It is also known for its significant medicinal properties, exhibiting anticancer, anthelmintic, anti-inflammatory, analgesic, steroidogenic, antimicrobial, astringent, depurative, diuretic, emmenagogue, febrifuge, cardio-relaxant, stomachic, and styptic activities.

28. Purslane/Nunia saag (*Portulaca oleracea*)

It contains significant amount of iron, calcium, zinc, vitamin A, riboflavin, folic acid, and flavonoids. It is known for its diuretic, sedative, analgesic, cardiotonic properties. Additionally, it has been utilized in the treatment of rheumatism, gynecological disorders, as well as renal and colorectal diseases.

29. Red Spiderling/Punarnava (*Boerhavia diffusa*)

The plant is good source of sodium, magnesium, calcium, vitamin C, vitamin B_3, dietary fiber, antioxidants, and therapeutic compounds such as boeravinone and punarnavarin. Widely recognized in Ayurveda, this is known for its anti-inflammatory and analgesic properties. The roots are particularly beneficial for hepatic disorders and functions as an effective diuretic. Furthermore, it can inhibit the proliferation of immune cells. The anti-proliferative, anti-cancer, and anti-diabetic effects of this plant are attributed to the isolated bioactive compound punarnavarine.

30. Water Cress/Helencha (*Enhydra fluctuans*)

Helencha is rich in protein, β-carotene, and antioxidants, as well as contains a variety of beneficial compounds, including saponins, myricyl alcohol, kaurol, cholesterol, sitosterol, glucosides, and sesquiterpene lactones such as germacranolide, enhydrin, fluctuanin, and fluctuandin. Additionally, it contains several diterpenoid acids along with their isovalerate and angelate derivatives, as well as other steroids like stigmasterol. Renowned for its diverse medicinal properties, the plant is considered antidiabetic, antimicrobial, anti-inflammatory, anticancerous, hepatoprotective, neuroprotective, and analgesic. Its leaves possess laxative and anti-bilious properties and are effective in treating inflammation, leukoderma, bronchitis, and biliousness, making them useful for skin and nervous disorders, as well as for addressing liver torpidity.

Indigenous and widely grown horticultural crops of Northeast India are vital not only for sustenance but also for their nutraceutical properties. Nutraceuticals are bioactive compounds found in food that provide health benefits beyond basic nutrition, offering preventive and therapeutic advantages. The crops of this region are a rich source of vitamins, minerals, antioxidants, and other phytochemicals that promote overall health and well-being. Regular consumption of these crops can help prevent diseases that are increasingly common in India, such as diabetes, hypertension, and heart disease. The antioxidants, fibre, and healthy sugars present in these crops help regulate blood sugar levels, improve digestion, and protect against chronic disease. They form an essential part of the diet in Northeast India, contributing to the region's traditional health systems and food security.

Challenges and Future Prospects

Despite its rich potential, horticulture sector in Northeast India faces several challenges. Poor infrastructure, limited access to modern technology, and inadequate marketing channels often hinder farmers from fully benefiting their produce. Perishable crops are prone to post-harvest losses due to inadequate storage and transport facilities.

However, with the growing global demand for nutraceutical products, there is tremendous opportunity for Northeast India to emerge as a leader in indigenous horticulture production. Government initiatives to promote horticulture, improve cold storage, and establish processing units are steps in the right direction. Investments in research, value addition, and marketing will help unlock the full potential of the region's crops.

Conclusion

Northeast India's rich and diverse array of fruit crops represents a blend of nature's bounty and cultural heritage. These crops, prized for their unique flavours and health benefits, have sustained generations of people in the region and hold great promise for the future. With proper support, this sector in Northeast India can contribute significantly to both combating malnutrition and the regional economy for nutraceutical products. By embracing its natural strengths and preserving its biodiversity, the region has the potential to become a powerhouse in sustainable and health-oriented crop production.

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Conservation and Utilization of Orchid Genetic Resources of North East Region of India

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The Orchidaceae family, often celebrated as the most diverse in the plant kingdom, showcases an extraordinary array of species with remarkable adaptations and ecological roles. Encompassing approximately 28,000 species across 763 genera, along with over 100,000 cultivated hybrids, orchids are a testament to nature's evolutionary ingenuity. These plants have successfully colonized a vast range of habitats, growing as epiphytes on trees, lithophytes on rocks, or terrestrials rooted in the soil. Their flowers, ranging in shape, size, fragrance, and colour, reflect this diversity—from minute blossoms just 0.083 inches wide to the colossal 34-inch blooms of *Paphiopedilum sanderianum 'Rapunzel'*, the world's largest orchid flower. Orchids are found in over 200 countries, inhabiting every continent except Antarctica. Figure 1 depicts the distribution of orchids across the globe.

Orchids' adaptability and aesthetic appeal have made them a focal point in both horticulture and conservation biology. However, their complex life histories are marked by dependencies on specific mycorrhizal fungi, pollinators, and substrates which also render them vulnerable to environmental changes and human activities. The over-collection of orchids, driven by the demand for ornamental plants and traditional medicine, has led to significant declines in wild populations. In recognition of these threats, all wild orchid species are protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

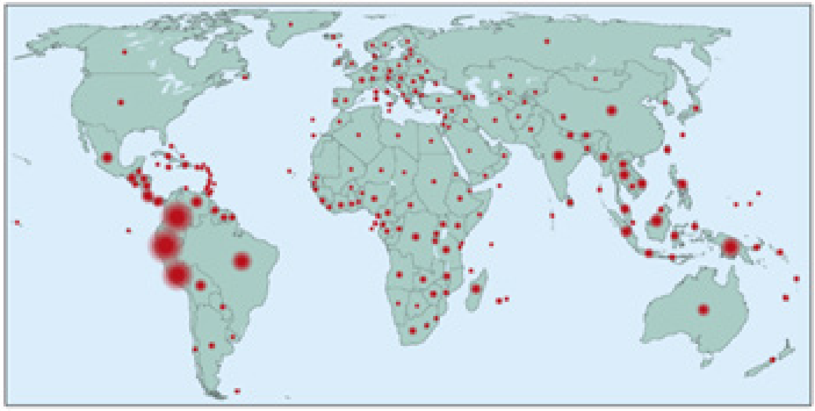


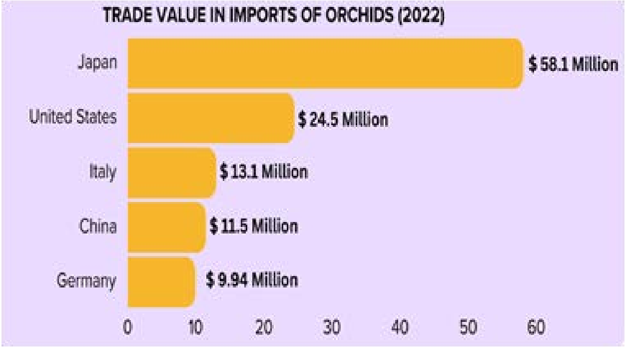
Fig.1. Country-level distribution of orchids around the world (map data courtesy of Michael Harrington via ArcGIS) ©Botanic Gardens Conservation

Recent advancements in DNA sequencing have further deepened our understanding of orchid evolution and biogeography, revealing that orchids likely originated in the northern hemisphere around 83 million years ago, rather than in Australia as previously hypothesized. These findings underscore the dynamic evolutionary history of orchids, with most extant species having emerged within the last 5 million years.

Given the ecological significance of orchids and their precarious conservation status, it is imperative to develop and implement effective strategies for their protection. This concept note aims to explore the current status, challenges, and opportunities in orchid conservation, with a particular focus on the unique biodiversity of Indian orchids. By fostering collaboration between research institutions, conservationists, and local communities, we can ensure the survival of these extraordinary plants for future generations.

Global Outlook in Orchids

Fig. 2. Pictorial depiction of Global Orchid Market



The global orchid market is a specialized segment within the broader ornamental plant industry, characterized by a dynamic interplay of production, trade, and consumption. This market is driven by a blend of traditional horticultural practices and modern advancements, offering a wide array of orchid varieties and hybrids that are highly sought after by hobbyists, collectors, and the commercial flower industry. Figure 2 illustrates an outlook of the Global orchid Market.

The Asia-Pacific region, with countries like Thailand, Taiwan, and China leading the way, dominates the global orchid market as major producers and exporters. **In Europe,** the Netherlands plays a pivotal role as a key producer and re-exporter, particularly in the segments of potted and cut orchids.

- **Thailand**: A global leader in the orchid market, has a well-established industry with a strong focus on exporting popular species like *Dendrobium.*
- **Netherlands**: Serving as a central hub for the orchid trade in Europe
- **Taiwan and Malaysia**: These countries are key contributors to the global supply of potted and cut orchids, catering to diverse markets worldwide.

Consumer trends indicate a growing interest in rare and exotic orchid species. The market is poised for continued growth, fuelled by ongoing innovations in tissue culture and hybridization techniques, which are expanding the range of commercially available orchid varieties.

Orchid Diversity in India:

India boasts a rich orchid flora, with 1,256 species or taxa distributed across 155 genera, as identified by the Botanical Survey of India's comprehensive census titled 'Orchids of India: A Pictorial Guide'. These orchids are not only diverse in their morphology and ecological adaptations but also play a critical role in maintaining the ecological balance of their habitats.

Orchids of the North-East Region

The North-East region of India, which covers 7.9% of the country's geographical area and supports 3.75% of its population, is a hotspot for orchid diversity. The region's diverse agro-climatic conditions, ranging from tropical rainforests to alpine scrubs, create an ideal environment for the growth of many orchid species. Of the 1,256 orchid species recorded in India, a significant number are found in this region:

- Arunachal Pradesh: 612 species
- Sikkim: 560 species
- West Bengal (Darjeeling Himalayas): 479 species

The region's total cultivable area spans 4.0 million hectares, with 0.82 million hectares dedicated to horticultural crops, making floriculture, including orchid cultivation, a vital economic activity.

Orchids beyond the North-East

While the North-East is a primary hub for orchids, India's orchid diversity extends beyond this region. The Northwestern Himalayas and the Western Ghats are also rich in orchid species. Notably, 388 orchid species are endemic to India, with a substantial number found in the Western Ghats:

Western Ghats: 128 endemic species

Kerala: 111 endemic species

Tamil Nadu: 92 endemic species

This wide distribution highlights the ecological significance of orchids across various Indian ecosystems, from tropical forests to temperate regions.

Production & Economic growth:

Orchids have emerged as valuable assets in the horticultural industry, recognized as low-volume, high-value crops that offer substantial economic opportunities, particularly for local communities in the North-East region of India. The growing medicinal orchid market further underscores their potential, especially in areas like Sikkim and Northeast India, where orchids have long been integral to traditional medicine. These regions are rich in native orchid species, many of which possess unique medicinal properties. As interest in the exploration and commercialization of these species increases, it is essential to balance these activities with sustainable practices and conservation efforts to safeguard the region's biodiversity.

In India, the liberalization of industrial and trade policies has spurred increased demand for orchids, both for cut flowers and potted plant production. The area under orchid cultivation has expanded dramatically, growing from 10 hectares in 2012-2013 to 3,040 hectares in 2022-2023. Correspondingly, the total production of orchid cut flowers has surged from 180 metric tons (MT) in 2012-2013 to 10,730 MT in 2022-2023.

Initially, during 2013-2014, orchid cultivation was concentrated in a few North-East states, including Assam, Mizoram, Meghalaya, and Sikkim, with an area of 43 hectares and a production of 5,480 MT of cut flowers. However, orchid cultivation has since expanded to other regions such as Karnataka, Kerala, Madhya Pradesh, Telangana, Goa, and West Bengal, where orchids are now cultivated for both cut and loose flower production.

Endemic orchid species of India:

The Indian subcontinent, especially the northeastern region, is renowned for its rich diversity of endemic orchid species. The geographical isolation caused by the Himalayas in the north and the surrounding seas in the south has significantly influenced the evolution of unique endemic taxa. It is to be noted that there are some orchid species which are endemic not only to this region but also to the home states in which they are distributed in Sikkim and Arunachal Pradesh Himalayas, the Naga and Manipur hills, the Lusai - Mizo hills and Khasi – Jaintia hills.

Notable endemic orchids found in various regions are given below:

State	***Orchid species***
Assam	*Dendrobium spatella, Dendrobium parciflorum, Luisia macrotis, Bulbophyllum obrienianum, Calanthe odora, Eria pumila, Eulophia candida, Liparis plantaginea, Phalaenopsis mastersii, Tainia barbata*
Arunachal Pradesh	*Vanda coerulea, Dendrobium palpebrae*
Nagaland	*Renanthera imschootiana, Cymbidium tigrinum*

Meghalaya	*Anoectochilus crispus, Cymbidium eburneum, Habenaria khasiana, Liparis delicatula, Paphiopedilum venustum, Taeniophyllum khasianum, Tainia khasiana*
Tripura	*Renanthera imschootiana*
Mizoram	*Dendrobium palpebrae*
Manipur	*Ascocentrum ampullaceum var. auranticum, Epidendrum radicans, Vanda stangeana*
Sikkim	*Calanthe whiteana, Cymbidium whiteae, Vanda pumila*
Western ghats	*Coelogyne flaccida, Cymbidium iridioides, Oberonia robusta*
Himalayan regions	*Habenaria radiata, Paphiopedilum insigne*

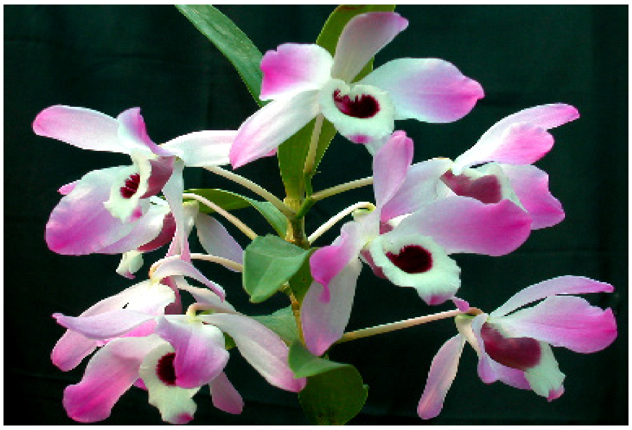
Apart from the aforementioned species, other notable endemic orchids in India include *Vanda testacea* (Testacea Vanda), *Amitostigma mosesianum* (Moses' Amitostigma), *Phaius tankervilleae* (Tankerville Orchid), *Zeuxine longifolia.*

Monotypic Orchid Genera of North-East India: *Anthogonium* Wall. ex Lindl., *Arundina* Bl. *Acrochaene* Lindl., *Bulleyia* Schltr. *Cremastra* Lindl., *Cleisocentron* Bruhl, *Dickasonia* L.O. Williams, *Diglyphosa* Bl., *Eriodes* Rolfe, *Herpysma* Lindl., *Jejosephia* A.N. Rao & Mani, *Mischobulbum* Schltr., *Myrmechis* (Lindl.) Bl., *Neogyne* Reichb.f., *Ornithochilus* (Lindl.) Wall. Ex Benth., *Risleya* King & Pantl. *Renanthera* Lour. and *Tipularia* Nutt.

Paphiopedilum venustum (Wall.) Pfitz

Arundina graminifolia (Don) Hochr.

Coelogyne cristata Lindl.



Dendrobium nobile Lindl.

Significance of Orchids from ancient medicine to cultural heritage:

Orchids hold a significant place in India's biodiversity, culture, and traditional medicine. Notably, species like ***Vanda tessellata*** and ***Flickingeria macraei*** have been recognized for their medicinal properties, as referenced in classical texts like the *Sushruta Samhita* and *Charaka Samhita*. These orchids are integral to Ayurvedic medicine, highlighting the deep-rooted connection between orchids and India's ancient healing practices.

Beyond their medicinal value, orchids also possess cultural and religious importance across various regions. The **Fox-tail orchid (*Rhynchostylis retusa*)**, known locally as Kopohphool in Assam, plays a crucial role in the Bihu festival. The fragrant, rose-purple inflorescences of this orchid are traditionally worn by women during the celebrations. Similarly, the bright golden flowers of ***Dendrobium hookerianum*** are considered sacred in Buddhist traditions and are commonly used to adorn Gompas (pagodas) in worship of Lord Buddha (Ninawe & Swapna, 2017).

Arundina graminifolia, known as the bamboo orchid, is significant in traditional Indian medicine, where it is used for its emollient and antibacterial properties. Notable for its short vegetative phase and continuous flowering, this orchid holds potential for drug development. Recent studies have identified the presence of medicinal compounds like bibenzyl, flavonoids, and phenylpropanoids across various plant parts, highlighting its potential as a valuable resource for phytochemical research and medicinal applications in India (Singh *et al.,* 2022).

In Sikkim, ***Dendrobium nobile* Lindl.** is celebrated as the state flower, reflecting its deep cultural and medicinal significance. This orchid species have been traditionally used in Asia for treating eye infections, burns, and various ailments, including ageing, antimicrobial issues, and pain relief. A global study of ***Dendrobium*** species identified 100 phytochemical compounds, highlighting the presence of bioactive compounds such as Vitamin A aldehyde and longifolene. These compounds underscore the medicinal potential of ***Dendrobium nobile***, inviting further exploration in modern medicine (Meitei *et al.,* 2019).

Aerides odorata contains a variety of compounds, including polyphenols, flavonoids, and alkaloids, which may have antimicrobial, antioxidant, anti-inflammatory, and anticancer properties. The root paste is used for curing joint pain and swelling.

Among the orchid species of North-Eastern India, four orchids—**Jeevak (*Malaxis muscifera*)**, **Rishabhak (*Malaxis acuminata*)**, **Riddhi (*Habenaria intermedia* and *Eulophia nuda*)**, and **Vriddhi (*Habenaria edgeworthii*)**—are used in the 'Astavarga' group of drugs in the Ayurvedic system of medicine.

IUCN Red List Classification and Conservation Challenges globally

Up to 45 per cent of all known flowering plant species across the globe could be under threat of extinction with the plant family *Orchidaceae* (orchids) among the most threatened. Approximately 20% of orchid species are at risk of extinction due to habitat loss, climate change, and invasive species. The vulnerability of orchids to environmental changes, coupled with the over-collection of wild plants, exacerbates their decline. The Convention on International Trade of Endangered Species (CITES) oversees international orchid trade to safeguard these species. With the rapid decline of orchid habitats and pollinators, ex-situ conservation in botanic gardens is increasingly vital for maintaining species survival and preserving genetic diversity.

International Union for Conservation of Nature's Red List of Threatened Species (Fig.3)

According to the IUCN Red List, three orchid species are classified as possibly extinct in the wild globally. These include ***Aeranthes parkesii***, ***Aeranthes africana***, and ***Vanda lombokensis***. Additionally, there are 48 orchid species considered critically endangered and

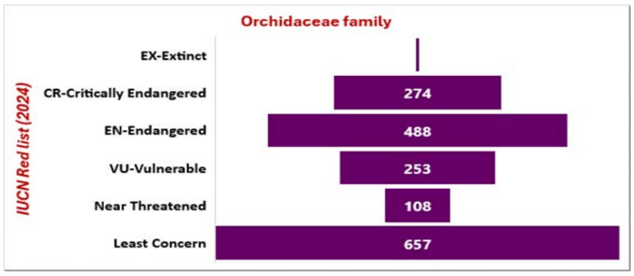


Fig. 3. Number of Orchidaceae Species Listed on the IUCN Red List

possibly extinct. IUCN also identifies 1,304 species as endemic and recognized ***Ophrys insectifera*** (Fly Orchid) and ***Cypripedium himalaicum*** (Himalayan Cypripedium) as amazing species *(IUCN, 2024).* A 2023 study by Nature identified 278 species that need immediate conservation action, but more than 70% of these species are not protected in botanical gardens and do not have an IUCN conservation assessment (Vitt *et al.,* 2023)

Threats to Orchids in India

Despite their ecological and economic importance, orchids in India face several threats, including habitat destruction, over-collection, climate change, and the loss of pollinators and mycorrhizal partners. The high level of endemism among Indian orchids, particularly in biodiversity hotspots like the Western Ghats and the North-East, underscores the urgent need for targeted conservation efforts.

Habitat Loss and Fragmentation: Deforestation and habitat fragmentation disrupt the connectivity of orchid populations, impairing genetic diversity and hindering pollinator movement and seed dispersal. The degradation of natural habitats makes it challenging for orchids to thrive and for pollinators to access their food sources.

Climate change in Northeast India: is accelerating biodiversity loss by altering habitats, increasing species vulnerability, and shifting species distribution. Changes in temperature and precipitation disrupt the delicate ecological balance required for orchids to survive. Extreme weather events, such as floods and landslides, alongside rising temperatures, have negatively impacted orchid habitats, pollinator populations, and essential microclimates, leading to significant declines in biodiversity. The noticeable rise in average annual temperatures and severe flooding in the region underscores the urgent need for targeted conservation efforts.

Mycorrhizal Fungi Disruption: Orchids depend on mycorrhizal fungi for seed germination and growth. Soil disturbances from deforestation, agricultural expansion, and pollution can disrupt these critical fungal networks, leading to failed germination and the establishment of new plants. This disruption threatens the regeneration and survival of orchid populations.

Cultural Shifts and Loss of Traditional Knowledge: Traditional knowledge about the sustainable use and conservation of orchids is gradually being lost due to modernization leading to decline in community-led conservation efforts. This cultural shift impacts the preservation of valuable traditional practices and knowledge vital for orchid conservation.

Illegal Trade: Despite being listed under CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora), illegal trade in wild orchids continues. This illicit activity exacerbates the decline of vulnerable orchid species, threatening their survival.

The high level of endemism among Indian orchids, particularly in biodiversity hotspots like the Western Ghats and the Northeast, highlights the urgent need for targeted and effective conservation measures to address these threats.

Research Priorities

Orchid Conservation:

- **Assessment of Conservation Status and Extinction Risk:** Development of a systematic framework to evaluate the conservation status and extinction risk of native orchid species by developing a mobile application to streamline data collection during field surveys and for accurate species identification.

- **Biodiversity, Distribution, and Population Dynamics:** Documentation and studies on the distribution of orchid species and further analysis of population dynamics with a focus on identifying and prioritization of endangered species for conservation action.
- **Identification of critical habitats** within biosphere reserves, National parks and wildlife sanctuaries by GIS or remote sensing technologies for orchid habitat mapping, understanding the habitat changes and predicting the future risks. This data-driven approach supports targeted conservation efforts and the identification of potential new habitats for relocation or restoration.
- **Investigation on the ecological role of mycorrhizal fungi and pollinators** in orchid pollination biology to enhance reintroduction efforts. Further, studies on mycorrhizal specificity of orchid species with special emphasis on early developmental stages
- ***Ex situ* conservation** with a special focus on the propagation and preservation of critically endangered orchid species
- **Orchid tourism and orchidariums**: significantly aid in conservation and research. They support the preservation of endangered species through controlled cultivation and ex-situ conservation, raising public awareness and fostering conservation efforts. In research, these facilities provide controlled environments for studying orchid physiology, reproduction, and genetics. They facilitate advancements in cultivation techniques and biotechnological methods, such as tissue culture and genetic engineering, contributing to the development of new cultivars and improved conservation strategies.

Advancing orchid breeding:

Trait-specific Cross breeding: Prioritize the development of targeted crossbreeding programs to combine desirable traits such as disease resistance, stress tolerance, and enhanced floral characteristics (e.g., colour, fragrance, and size) in commercially important orchid species.

Enhancing Mutational Breeding Approaches: Investigation of the effects of various mutagens (e.g., colchicine, radiation) on different orchid species to determine optimal doses, exposure times, and the most responsive genotypes

Molecular marker-assisted breeding: Developing molecular markers for specific traits in key orchid species focussing on trait mapping, genetic diversity assessment, and hybrid selection to improve the efficiency and accuracy of breeding programs.

Trait Mapping and QTL Analysis: Prioritize the identification and mapping of quantitative trait loci (QTL) associated with key traits such as flowering time, drought tolerance, and pest resistance in orchids like *Dendrobium* and *Phalaenopsis.*

Breeding for Resilience: Focus on breeding orchids with enhanced resilience to environmental stresses, such as drought, temperature extremes, and pest pressures. This research will contribute to the long-term sustainability of orchid cultivation in the face of climate change.

Medicinal Compound Identification: Prioritize the identification and characterization of bioactive compounds in orchids with medicinal value. Research should aim to link specific genetic traits with the production of these compounds, facilitating the breeding of orchids with enhanced medicinal properties.

Biotechnological Interventions for addressing Climate Change-Induced Biodiversity Loss in Northeast India

Molecular Breeding: Utilization of molecular markers to identify and select orchid species or genotypes with traits such as drought tolerance, heat resistance, and adaptability to changing environmental conditions to develop climate-resilient orchid varieties better suited to withstand shifts in temperature and precipitation.

Cryopreservation: Cryopreservation is a vital long-term conservation method for orchids, preserving seeds and pollen at −196 °C to prevent extinction. It surpasses short-term storage methods by halting all metabolic processes, ensuring effective preservation. Techniques like vitrification, which uses cryoprotectants to reduce intracellular water and prevent ice formation, and desiccation, which involves drying seeds before storage, are crucial for maintaining viability. These methods have been successfully applied to orchids such as *Bletilla*, *Dendrobium*, and *Paphiopedilum*. Despite their effectiveness, there is a need to develop and standardize protocols for cryopreservation, including for associated fungi and *in vitro* propagation. Further research is essential to refine these protocols and enhance ex-situ conservation efforts for diverse orchid species.

Omic technologies: Studies on omic technologies, such as genomics, transcriptomics, and proteomics, to study and manipulate the mycorrhizal associations of orchids that can lead to the identification of fungal strains and confer greater resilience to climate-induced stress. Genomic studies reveal large and variable genome sizes, with methods like flow cytometry helping estimate DNA content in species like *Phalaenopsis.* Transcriptomics provides insights into gene expression and regulatory mechanisms, such as the roles of miRNAs in floral development and gene function. Proteomics elucidates protein functions related to flower development and symbiotic germination. Databases like Orchidstra 2.0 consolidate extensive gene expression data across orchid species. Omics approaches are crucial for advancing breeding, conservation, and commercial production of orchids.

Genetic engineering: Genetic engineering advances the enhancement of key orchid traits such as flowering time, fragrance, colour, and vase life through techniques like Agrobacterium-mediated transformation and CRISPR/Cas9 genome editing. These methods are applied across various orchid genera, including *Phalaenopsis, Cattleya, Cymbidium, Dendrobium, Oncidium, Paphiopedilum, and Vanda.* MADS-box genes, crucial for regulating flowering, have been studied in both model plants and orchids. In *Arabidopsis*, genes like SOC1, FLC, SVP, and AGL24 manage flowering mechanisms, while their orthologous counterparts in orchids, including SOC1, AGL6, SVP, and AP1, play similar roles.

Recent developments include the use of complete orchid genomes for precise genetic modifications, with CRISPR/Cas9 technology enabling high-efficiency gene editing. Advances such as multiplex genome editing and protoplast-based screening are refining breeding techniques. Future research should focus on improving transformation protocols, enhancing gene delivery methods, and expanding genome editing applications to overcome current challenges and facilitate the development of new orchid varieties.

In vitro propagation

Mass Multiplication through Bioreactors based tissue culture techniques:

Bioreactor technology has emerged as a transformative tool for the large-scale multiplication of orchids, offering a controlled and sterile environment that significantly enhances the efficiency and scalability of micropropagation. Particularly, Temporary Immersion Bioreactor Systems (TIBs) have demonstrated their effectiveness in improving nutrient uptake, reducing contamination risks, and ensuring uniform growth, thereby producing high-quality plantlets with greater consistency and faster turnaround times. This technology not only accelerates the production of market-ready plantlets but also reduces labor costs and overall production inefficiencies. Moving forward, research should prioritize optimizing bioreactor parameters specific to different orchid species, such as nutrient composition, immersion cycles, and aeration. Developing tailored, species-specific protocols will further enhance the benefits of bioreactor systems, supporting both commercial cultivation and conservation efforts.

Developing customized culture media for specific orchid species is essential, focusing on optimizing nutrient composition and growth regulators to improve seed germination and propagation.

Protocols need to be created to address the challenges of propagating recalcitrant species, concentrating on enhancing explant survival and genotype-specific responses.

Tailored regeneration and transformation protocols should be developed to facilitate successful genetic transformation, with a focus on techniques like somatic embryogenesis and PLB formation.

Sustainability through Precision Techniques

In commercial orchid production, precision and digital farming technologies are pivotal for enhancing both efficiency and sustainability.

Real-time environmental monitoring through remote sensing and drones enables optimal management of temperature, humidity, and light, thereby improving orchid health and yield.

Precision irrigation systems, supported by soil moisture sensors, ensure water is used efficiently, delivering the precise amount needed for plant growth.

Automated climate control systems maintain stable growing conditions, reducing labour costs and minimizing plant stress.

AI-driven data analytics optimize breeding and resource management decisions, while GIS-based mapping supports strategic planning for expansion and conservation. Prioritizing research in these areas, assessing their economic benefits, and addressing adoption challenges can significantly advance sustainability and profitability in commercial orchid production.

Conclusion

In conclusion, the SWOT analysis of the orchid industry highlights key areas for attention. The strengths include a rich diversity of orchids and advancements in biotechnology and precision farming, which offer significant potential for growth. However, the industry also faces weaknesses such as reliance on specific environmental conditions and high costs for technology. Opportunities for growth exist in market expansion, new biotechnological developments, and orchid tourism. Nonetheless, threats like habitat loss, climate change, and illegal trade pose serious risks. To maintain and improve orchid conservation and cultivation, it is essential to develop effective conservation strategies, use technology wisely, and promote international collaboration. Addressing these challenges while seizing opportunities will be crucial for preserving orchid diversity and ensuring the industry's long-term success.

Keeping in view of the above background, priorities for orchid research and promotion in India in general and in north eastern region in specific are listed below.

- Collection of all available orchids of India at National Active Germplasm Site, ICAR-NRCO
- Characterization, evaluation and documentation of the collected orchid resources.
- Promotion of suitable indigenous species into trade (Cut flower/Potted plant/Value added products).
- Identification of genera and species for making new generation hybrids.
- Hybridization, embryo culture, hardening and selection of noble and superior hybrids for orchid cut flower and potted plant trade.
- Micro-propagation of important orchids. Collaborative research on active bioactive compounds for therapeutic, medicinal and other useful properties of orchids.
- Standardization of primary and secondary hardening of micro-propagated orchids.
- Deep research on reduction of gestation period of orchids.
- Application of advance genomic tools, genome editing in targeted breeding to develop superior hybrids / clones for commercial use.
- Standardization of cost-effective production technology. Weather management, Growing media, nutrient and watering schedule.

- Studies on manipulation of light and weather parameters for early, regular and higher flower production. Multi tier production
- Standardization of high tech, precision and aeroponic cultivation of orchids including application of AI and digital technologies.
- Standardization of organic production technology of orchids .
- Pest and disease management practices keeping in mind the regulatory requirements of targeted markets.
- Research on solar and wind power for the energy needs in production chain.
- Standardization of post harvest handling practices, packaging boxes, value added display boxes for single floret or multiple florets, and dry flowers.
- Solar-powered cool carts for vendors/ Orchid carts. Orchid rentals. Orchid decorations for corporate and social events. Orchids in plug trays /plug panels.
- Working with state govts / stake holders/ private partners for the promotion of orchid clusters augmented with cool chain, marketing channels and value addition chains.
- Orchid being a unique and special commodity, to harness its full potential for economic utilization of the immense genetic resources and vast potential there is a need for Orchid Mission in the country, at least for the North Eastern Region.

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Diversity and Flagging the Issues with Farmers Related to Medicinal & Aromatic Crops

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Biodiversity refers to the variability of living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems, as well as the ecological complexes they form. It encompasses genetic diversity within and between species, as well as across ecosystems, ultimately representing all forms of life. India is recognized as one of the world's mega biodiversity centers, housing two of the planet's 18 biodiversity hotspots in the Western Ghats and the Eastern Himalayas. The country is also renowned for its rich heritage of natural and medicinal knowledge, with many ethnic groups and tribal communities in remote regions continuing to rely on traditional systems of medicine. Biodiversity is vital for maintaining ecological balance, sustaining ecosystem services, promoting economic stability and growth, and supporting human well-being. It enhances resilience to climate change, natural disasters, and disease outbreaks.

The North-Eastern region, which houses about 50% of the country's plant diversity is made up of 8 states, including Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Nagaland, Tripura, and Sikkim, and is known for its rich repository of medicinal and aromatic plants (MAPs). The region is home to numerous species that are endemic and of high medicinal value, making it a critical area for the cultivation of these plants. Northeast India, encompassing the states of Arunachal Pradesh, Assam, Mizoram, Manipur, Meghalaya, Nagaland, Tripura, and Sikkim, covers a geographical area of 262,180 km^2 representing about 8% of India's total area and home to approximately 40 million people. The region is divided into distinct physiographic zones: the Eastern Himalayas, the Northeast hills, and the Brahmaputra and Barak valley plains. During summer, temperatures average around 30°C, while in winter, they range from 16 to 20°C. Northeast India is recognized as one of the world's biodiversity hotspots but faces significant threats from human activities and climate change. The region boasts over 7,000 plant species and valuable medicinal plants, it plays a key role in India's ecological and economic landscape, offering opportunities for sustainable agriculture and conservation.

Over 500 species of medicinal plants have been documented in Arunachal Pradesh. In Assam, 952 plant species have been identified with applications in various medical practices (ENVIS Centre: Assam, Status of Environment and Related Issues). Manipur has recorded approximately 1,500 species of medicinal and aromatic plants to date. Meghalaya has reported 834 medicinal plant species. In Tripura, a total of 892 species of medicinal plants have been recorded by FRLHT, Bengaluru, with support from the State Forest Department and the State Medicinal Plant Board. Sikkim is home to about 420 species of medicinal and aromatic plants, while Nagaland has 650 indigenous species of medicinal and aromatic plants. The Northeast India possesses 14 species of the Geraniaceae family and more than 35 species of Solanaceae. Out of the 2,416 plants recorded for ethnomedicinal purposes in India, approximately 1,953 species are used by different ethnic groups in the Northeast. This area is also notable for its high concentration of Zingiberaceae, with 19 genera and about 88 species documented.

Owing to geographical and climatic diversity aspect, MAPs are found across diverse habitats, from tropical rainforests to alpine regions, deserts to wetlands. The variation in climate, altitude, and soil conditions in these regions contributes to the rich diversity of MAPs. For example: MAPs species rich in **tropical regions** like *Curcuma longa* (turmeric), *Aloe vera*, and *Catharanthus roseus* (Madagascar periwinkle), which are known for their medicinal properties. **Temperate Regions p**roduce plants like *Lavandula angustifolia* (lavender), *Rosmarinus officinalis* (rosemary), and *Mentha piperita* (peppermint), widely used for their aromatic oils and **Alpine and Mountainous Regions** which include the Himalayan and Andean regions are home to unique MAPs like *Nardostachys jatamansi* (spikenard) and *Artemisia spp.* which thrive in high altitudes. Another aspect is species richness and endemism where MAPs are represented by thousands of species, spread across different families of plants, with many being endemic to specific regions. Endemic species, which are found only in particular regions, contribute to the diversity and uniqueness of MAPs. For instance, the Mediterranean region is home to many aromatic plants like thyme (*Thymus vulgaris*), oregano (*Origanum vulgare*), and sage (*Salvia officinalis*) and the Eastern Himalayas and Western Ghats of India have high levels of endemism in MAPs, with plants like *Saussurea costus* and *Aconitum heterophyllum.* MAPs are also an essential component of medicinal and therapeutic medicine systems like Ayurveda, Traditional Chinese Medicine (TCM), and Native American medicine. The bioactive compounds derived from MAPs such as *Camellia sinensis, Papaver somniferum, Artemisia annua, Mentha spp.*, *Ginkgo biloba* contain alkaloids, flavonoids, terpenes, and glycosides which have therapeutic properties including anti-inflammatory, antimicrobial, antioxidant, and anticancer effects. Aromatic diversity in plants produces essential oils which are used in perfumes, cosmetics, and aromatherapy. These oils are complex mixtures of volatile compounds such as terpenes, alcohols, and esters. Some globally significant aromatic MAPs include: **Lavender** (*Lavandula angustifolia*) which is known for its soothing fragrance and use in stress relief. **Rosemary** (*Rosmarinus officinalis*) is used in culinary applications for its invigorating aroma in cosmetics. **Sandalwood** (*Santalum album*) which is prized for its aromatic wood and oil, widely used in perfumes and incense. On **Cultural and Traditional Knowledge predominance,** MAPs have been integral to indigenous and local knowledge systems for centuries. Traditional knowledge about the medicinal and aromatic properties of plants has been passed down through generations, playing a vital role in the health and well-being of communities. This cultural diversity enhances the overall understanding of MAPs, contributing to diverse approaches in using plants for healing. As the diversity of Medicinal and Aromatic Plants is vast, sustainable use and conservation are vital to ensure that this diversity continues to benefit future generations.

CSIR-NEIST has been working in the MAP sector since a long time back. CSIR-NEIST boasts a state-of-the-art germplasm bank, conserving medicinal and aromatic plant genetic diversity. The germplasm bank ensures long-term preservation of valuable genetic resources. CSIR NEIST, Jorhat has more than 4000 germplasm (Figure 1) of different MAPs including Lemongrass, Java Citronella, Patchouli, *Kaempferia galanga, Kaempferia parviflora, Clerodendrum colebrookianum, Hibiscus sabdariffa, Hibiscus acetocella,* Arrowroot, *Bixa orellena, Ocimum sp., Capsicum chinense*, *Solanum khasianum*, *Acorus calamus*, *Curcuma longa, Curcuma caesia, Curcuma amada, Curcuma zedoaria*, *Homalomena aromatica*, *Zingiber officinale* and *Zingiber zerumbet.*

Many of the elite MAPs varieties have been developed including Jor Lab C-5, Jor Lab L-8, Jor Lab L-9, Jor Lab L-10, Jor Lab L-11, Jor Lab -14, Jor Lab L-15, Jor Lab P-1, Jor Lab SM-2, Jor Lab ZB-103, Jor Lab AC-1, Jor Lab K-1 by CSIR-NEIST, Jorhat, Assam. More than 50 technology transfers have been made for the developed varieties. The varieties of MAPs have been distributed throughout India and were cultivated in many of the regions. The elite varieties possess enhanced adaptability to diverse climates and soils. The elite varieties can enhance India's global competitiveness in the medicinal and aromatic plant market.

Figure 1: MAPs diversity conserved at CSIR-NEIST, Jorhat

In addition to that, all 27 developed germplasm have been registered with the Indian Council of Agricultural Research (ICAR), featuring enhanced characteristics such as improved herbage and rhizome yields, higher essential oil content and richer compound profiles. These advancements elevate market value and provide significant advantages over traditional varieties. Additionally, more than 110 farmer training programs have been conducted, facilitating buyer-seller meetings for 10,000 farmers and establishing direct linkages between them and industries, bypassing intermediaries. Approximately 4,500 hectares in the northeastern region have been successfully converted to commercially cultivated MAP varieties. This effort has enhanced agricultural productivity, fostered local economic development, and increased the availability of valuable raw materials.

The northeast region has a bounty of biodiversity, however, it is faced with a series of challenges in the sector of MAPs cultivation. Some of the major issues faced by MAPs cultivators from this region have been briefly described below:

- **Lack of adequate Infrastructure and Technology**: Farmers in the Northeastern region often lack access to advanced agricultural technologies and infrastructure. This includes poor irrigation facilities, lack of access to quality planting materials, and inadequate storage and processing facilities. Absence of the proper infrastructure, farmers fail to produce high-quality crops and hence cannot increase their income potential.
- **Lack of proper market chain and absence of minimum support price (MSP)**: Farmers are mostly dependent on the middlemen to get returns for their produce. This often results in reduction in their net profit. Also, no fixed prices are prevalent for medicinal and aromatic plants (MAPs) and their sale mostly depends on demand in the local and international market. This is one of the major reasons for discouragement among the farmers cultivating medicinal and aromatic plants. As per reports, in 2020, despite the high demand for medicinal plants, many farmers were unable to get fair prices for their produce due to market inefficiencies.
- **Climatic instabilities and lack of proper connectivity**: Most of the regions in the Northeast are hilly or with terrains. These terrains impact the connectivity of the farmers with the traders and *mandis* due to the lack of proper roads and vehicles. Poor connectivity results in a hike in transport fares, further resulting in less interest among farmers in cultivation of MAPs. These factors can significantly impact the yield and quality of medicinal and aromatic plants. The slope regions limit the utilization of modern agricultural tools, leading to the utilization of a huge workforce, further increasing the establishing investment. Also, recurrent floods in the plains and instances of landslide and soil erosion further add to the woes of cultivators.
- **Lack of Research and Development (R & D) centres on MAPs**: Sticking to traditional methods of cultivation and lack of research institutes for carrying out scientific studies for the development of optimal cultivation practices, for management of pests and diseases and also for dissemination of knowledge on post-harvest management specific to the region, further adds up to the issues faced by farmers.

Accordingly, the probable solutions for the development of the cultivation of MAPs in North East India include **the adoption of rainwater harvesting, non-tillage farming, awareness of the local weather updates, use of improved varieties of MAPs, adoption of organic farming, reduction of livestock emissions, and most importantly crop rotation.**

To make Northeast India self-sufficient in all aspects, a holistic plan is essential, with a strong focus on biodiversity conservation and entrepreneurship development. These two factors will play a crucial role in transforming the socio-economic conditions of the local population. Currently, crop production in the region is largely subsistence-based, aimed at fulfilling the needs of the farmers themselves. Several challenges hinder agricultural productivity, including the reliance on local crop varieties, limited use of fertilizers and pesticides, low moisture retention in upland soils, etc Additional factors such as low temperatures, poor drainage in valley lands during the monsoon, insufficient irrigation in the winter months, limited sunshine hours, and traditional farming practices contribute to low productivity and cropping intensity. However, by adopting improved agricultural techniques and modern agro-technologies, crop productivity in the region can be significantly enhanced. This would not only boost food security but also create opportunities for economic growth, ensuring that both conservation and development go hand in hand.

Government on the positive front has been playing a very significant role by providing necessary support through numerous schemes, programme, and policy implementation. Ministry of Ayush, Government of India had implemented a centrally sponsored scheme of National Ayush Mission (NAM) to promote the cultivation of prioritized medicinal plants on farmer's land. Some of the efforts include the establishment of nurseries with backward linkages for raising and supply of quality planting material (QPM), post-harvest management with forwarding linkages, primary processing, marketing infrastructure etc. National Medicinal Plants Board (NMPB), Ministry of Ayush facilitates to create market linkage for medicinal plants raw materials. NMPB has also launched "e-CHARAK", a mobile application serving as a platform to enable information exchange between various stakeholders, mainly farmers, involved in the medicinal plants sector across the country. It also provides a fortnightly market price of 100 medicinal plants from 25 herbal markets across India. Different missions like the CSIR- Aroma Mission conducted in different phases, along with RCFC (NER) have been able to create a profound impact on the development of the cultivation sector of MAPs by mediating a consistent supply of QPMs throughout North East. CSIR- NEIST, Jorhat, a frontier runner in the development of MAPs sector in the entire North East, has been consistently acting as a knowledge house for creating awareness among the cultivators for high margin gains from MAPs cultivation. The Indian government has launched several other initiatives like the National Horticulture Mission (NHM), Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Pradhan Mantri Krishi Sinchai Yojana (PMKSY), etc., which directly or indirectly work towards the cultivation of medicinal and aromatic plants. However, the implementation of these policies at the grassroots level has been inconsistent. Farmers have to undergo numerous bureaucratic hurdles in accessing government schemes due to bureaucratic issues and a lack of awareness. Many R & D institutions namely Department of Science & Technology (DST), Indian Council of Medical Research (ICMR), Department of Biotechnology (DBT), National Horticulture Board (NHB), Council of Scientific and Industrial Research (CSIR), etc., have been significantly involved towards providing research grants, essential scientific interventions, techniques, capacity building training programs, and also access to modern technologies, trying to alleviate the issues faced by the farmers and stakeholders in the North East region. The economic returns from cultivating medicinal and aromatic plants can be significant, provided the challenges mentioned above are addressed. Studies have shown that the cultivation of certain high-value medicinal plants can yield returns up to three times higher than traditional crops. Hence sincere approach towards solving the issues outlined will help many farmers in the North-Eastern region to fully capitalize on the cultivation sector of MAPs.

Indian Knowledge on Traditional Rice Cultivars: Collection, Conservation and its Successful Utilization

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Indian knowledge in rice cultivation is longstanding. In Ramayana, it is mentioned that Vishnu had sent a messenger to the king, Dasharath with payasam (a sweet made of milk and rice) saying that it is a boon that will bring sons if it is eaten by the king's wives. Mahabharat also mentioned payasam. Yudhishthira, had a love for payasam. Still today, it is fed to young babies as their first meal in many parts of the country.

The primary centre of origin of rice is the Indian sub-continent and a huge number of traditional cultivars are available in present India. Germplasm is the basis of all plant improvement programmes. The collected traditional rice cultivars possessed a high probability of useful genes for efficient applications in rice improvement to develop high yielding varieties with resistance to biotic and abiotic stresses. Those traditional rice cultivars need to be conserved *ex situ* or *in situ*.

In the rice repository of Uttar Banga Krishi Viswavidyalaya, Pundibari has about 200 traditional cultivars collected from West Bengal, Assam and Manipur. Basic information about Farmers' Varieties of traditional cultivars was gathered from the particular individual farmers who are conserving the cultivars. To obtain complete distinctive features of individual cultivar, the traditional cultivars were *ex-situ* characterized following the Table of Characteristics in the "Guidelines for Conduct of Test for Distinctiveness, Uniformity and Stability on Rice (*Oryza sativa* L.)" published by PPV&FRA (2007), Government of India. The collected traditional cultivars were grown in the University Research Farm, Pundibari, situated at 26°19′N latitude and 99°23′E longitude and a height of 43 MSL following the standard package of practices as described by Roy (2023).

Every *Kharif* season, the traditional cultivars are cultivated and seeds are collected individually to conserve them. All the traditional cultivars were DUS characterized (Surje *et al*., 2022). Some special characteristics also have been identified during characterization (Roy and Surje, 2016). Few special characters were identified in the collected germplasm, such as clustered panicle, multi-kernelled spikelets, long sterile lemma, dark purpled kernel, purple leaf and leaf sheath and floating rice.

Clustered Panicle: Commonly one spikelet is found on a pedicel. Thuri and Narkeldari showed multiple spikelets per pedicel (Surje *et al*., 2019). The number of spikelets per pedicel in Thuri varied from 1-4 and from 1 to 6 in Narkeldari. This feature resulted in high grain density in a panicle.

Multiple Kerneled Spikelet: Rice is single seeded fruit and in generally, rice bears one kernel per spikelet. However, Jugal showed 2-3 kernels per spikelet (Roy *et al.*, 2013). The single-grained spikelet varied from 0.00 to 46.26% per panicle. Single pistillated-spikelet was first reported on the 8th day before flowering and it was 2.63%. The number of spikelets bearing single ovary/kernel gradually increased till the panicle emergence and then till the physiological maturity of grains. Maximum single kernelled-spikelet was recorded on the 30th day after panicle emergence (46.26%). The double ovary/kernelled-spikelet per panicle varied from 53.74% to 95.39%. The high percentage of double pistillated-spikelet per panicle was recorded before heading and it was more than 90% or very near to 90%. Gradually, the double pistillated-spikelet per panicle decreased with the advancement of the developmental course of the panicle and continued to decrease till grain maturity. The lowest percentage (53.74%) of double kernelled-spikelet per panicle was observed on the 30th day after panicle emergence and it almost remained static till harvest of the crop. Triple pistillated-spikelet was 4.33% per on 10th day before panicle emergence. On the 9th day before panicle emergence it was 2.33% and on 8th day before panicle it was 1.00% only and subsequently, no triple pistillated-spikelet was observed till grain maturity.

Long Sterile Lemma: The sterile lemma of rice is much smaller in size than the fertile lemma. The sterile lemma of Rami Gelee is longer than the lemma and palea (Roy *et al.*, 2013). Around 100 breeding lines have been isolated from a cross between Nilachal and Swarna. Those breeding lines have been characterized and are being maintained in the Rice Repository of Uttar Banga Krishi Viswavidyalaya, Pundibari.

Dark Purple Kernel: The kernels of Sadabhatkalo, Chakhao Amubbi, Kalawati were found to have dark purple coloured kernels (Roy *et al.*, 2013) and commonly they are known as 'black rice'. Coloured rice is reported to be a potent sources of antioxidants and their consumption is encouraged. Black rice contains relatively high anthocyanin (primarily cyaniding-3-O-glucoside and peonidin 3-O-glucoside) in the pericarp layer which gives the dark purple color. Anthocyanin is known for its bioactive properties and is recognized as a health-enhancing substances due to its antioxidant activities, anti-inflammatory, anticancer, anti-atherogenic, and anti-hypoglycemic effects.

Floating Rice: Shri Bhupen Barman, a farmer of Alipurduar-II (Alipurduar district, West Bengal, India) conserves *in situ* four genotypes of floating rice. Earlier, floating rice was popular among the farmers of that area because of the stagnation of water during the rainy season for 4-5 months. Due to the introduction of new high-yielding varieties of rice and crop diversification most of the Farmers' Varieties of rice have disappeared. But, Shri Bhupen Barman purposefully is conserving four traditional landraces, namely Singara, Betho, Kauka and Khama. Those four varieties have been characterized (Roy *et al.*, 2022) and have been registered under PPV&FR Act (2001). These cultivars have some unique characteristic features, such as they grow along with the rise in water level during the rainy season. It may reach even up to 3.0 m in height. When the water level goes down and gradually dries up by the end of rainy season, the rice plant falls down on the soil surface and gives rise to branches from each node of the plant.

Lodging Tolerance: Lodging status of rice is an important consideration for determination of grain yield and acceptability of the genotype among the rice farming community. Fifty nine traditional cultivars of rice were screened for lodging tolerance under three different cultivation environments. Boichi and Seshaphal were found to be highly lodging tolerant under all the three situations (Debbarma and Roy, 2017). Majority of the local genotypes were reported to be susceptible to lodging.

The important traditional cultivars were used as donor for rice improvement, such as, Tulaipanji used in mutation breeding, Kalonunia used in cross combination with Pusa Basmati to develop blast tolerant recombinant lines. Kalonunia was also used for development of somaclonal variation, Nilachal, Kalonunia, Bhog Jeera-1 were used for development of recombinants, etc. A number of desirable mutants and recombinant lines were developed which are in different stages of yield trials. Some pure lines also have been isolated from the collected traditional cultivars. One aromatic pure line of Kalonunia has been isolated and released by State Variety Release Committee (West Bengal) and named as Uttar Sugandhi. Another variety, namely Uttar Ganga has been developed using Nilachal (a traditional cultivar) as one the parent and has been released by Central Variety Release Committee. Another recombinant line, named as *Uttar Bijoy* (IET 28102) was developed by crossing between Bhog Jeera (a traditional cultivar) and Gontra Bidhan-1. A mutant, namely Uttar-Tromay Subas (IET 28104) was developed from Tulaipanji. Uttat Bijoy and Uttar-Trombay Subas have already been submitted to State Variety Release Committee for release in West Bengal. In nutshell, it is important to conserve the Indian traditional cultivars and simultaneously they may be used for rice improvement.

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Flagging the Issue of Farmers for Adopting Agrobiodiversity in Local Food System

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Abstract

India, one of the world's largest countries, relies heavily on agriculture, a major occupation for most people. It directly and indirectly provides 60% of the country's employment. The North Eastern Region part of India, a hotspot for agricultural biodiversity and cultural and geographical diversity, is home to at least 166 food crops species and 320 wild relatives of crops. These include cereal crops like rice, pulses like pigeon peas, peas, and horticultural crops like turmeric, banana, jackfruit, mango, etc. The agrobiodiversity in North-East India is primarily maintained by local communities in traditional farming systems—home gardens, kitchen gardens, shifting cultivation, and rice fields. The majority of the agrobiodiversity analysis has been focused on these important traditional farming systems. Agrobiodiversity, a cornerstone for developing resilient and productive agro-food systems, is rapidly declining due to deforestation, unsustainable agricultural practices, and developmental projects. This study briefs on the basic understanding of the current state of knowledge and initiatives that support agrobiodiversity in the North Eastern Region of India and major flagship issues of local food systems of this region with special reference to Manipur, Mizoram and Meghalaya. Many institutes, including ICAR, CAU-Imphal, and other state departments, provide ideas on how to increase biodiversity in local agri-food systems. Agrobiodiversity can make local agri-food systems more effective and resilient, and contribute to healthier, diversified and culturally appropriate diets for local residents of North Eastern Region of India. To prevent further agrobiodiversity loss, there is a need for stronger partnerships and collaborations between local communities and knowledge institutes like ICAR, CAU-Imphal, NEHU-Shillong, and state departments to fill knowledge and innovation gaps, aiming for agrobiodiversity to be embedded in local food systems and leveraged as a tool for transformation.

Keywords: Biodiversity, Agrobiodiversity, Local food system, and North-East India.

Introduction:

The North Eastern Region of India located within the Eastern Himalayan zone and encompassing two global biodiversity hotspots, is renowned for its abundant flora, fauna, cultural diversity, and traditional knowledge systems (Mylliemngap, 2021). In the North Eastern Region of India, agriculture is the primary occupation of local communities. The sustainable use of valuable wild species and various forest products from adjacent forested areas complements this agricultural activity. This region comprises eight states: Sikkim, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura (Fig. 1). The region includes an area of approximately 255,000 km^2, accounting for 8% of the country's overall land area. Its physiographic structure is classified into three distinct divisions: the Meghalaya Plateau, the North Eastern Region hills and basin, and the Brahmaputra Valley. The North Eastern Region Hills and Basin constitute approximately 65% of the total land area, with the Brahmaputra Valley and the Meghalaya Plateau covering 22% and 13%, respectively. The region experiences rainfall predominantly between May and November, with annual precipitation ranging from 2,000 to 4,000 mm. Agriculture is the primary livelihood source for nearly 90% of the population. Within the workforce, 60.1% are cultivated, 9.3% work as agricultural labourers, and 7.3% are involved in livestock, forestry, fisheries, and other related activities (Das *et al*., 2012).

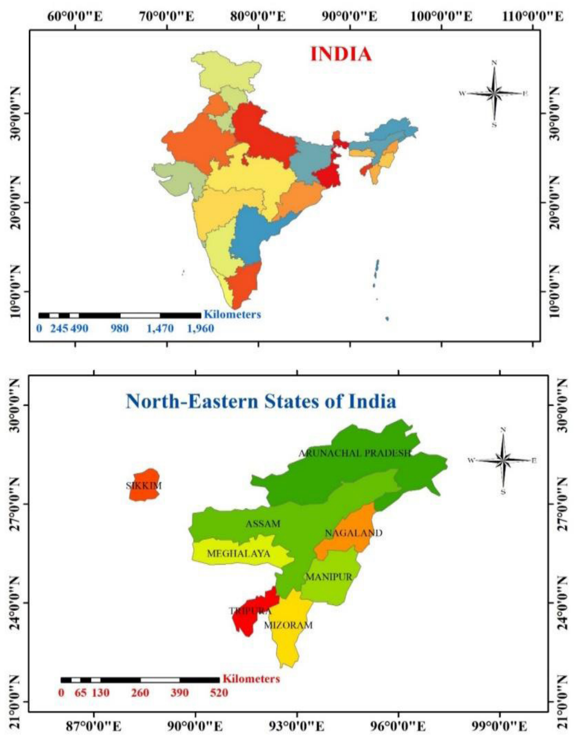
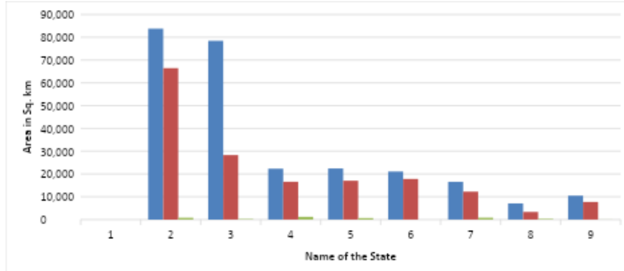


Fig. 1. The upper map depicts India and the below map depicts the North Eastern states of India

Forest coverage in the country: The Forest Survey of India (FSI), headquartered in Dehradun and operating under the Ministry, has conducted biennial assessments of forest cover since 1987. These findings are systematically documented in the India State of Forest Report (ISFR). According to the most recent ISFR 2021, India's total forest cover is 713,789 square kilometers, accounting for 21.71% of the nation's geographical area. Between the ISFR 2019 and ISFR 2021 assessments, forest cover increased by 1,540 km^2. In North-East India maximum total forest cover was shared by Arunachal Pradesh, followed by Assam, Mizoram, Meghalaya, Manipur, Tripura, and Sikkim (Fig 2).



Source: Ministry of Environment, Forest and Climate Change, Report. 2023

Fig. 2. Forest coverage in the North-East India

Introduction to North Eastern India and its biodiversity significance:

The North Eastern India, which includes the states of Arunachal Pradesh, Assam, Meghalaya, Manipur, Tripura, Mizoram, Nagaland, and Sikkim (Fig.1). The NE region, located at the unique intersection of the Indian-Malayan, Indo-Chinese, and Indian biogeographical realms, is remarkable in that it offers a diversified biota with a high level of endemism. The region is also home to around 135 of India's 450 tribes, the culture and customs of which play a crucial part in determining the fundamental concerns pertaining to biodiversity protection.

The north-eastern region has received global attention due to its great biodiversity, and it has been designated as a priority for investment by the world's largest conservation organizations (Singh *et al.,* 2023). The region's lowland and montane moist to wet tropical evergreen woods are thought to be the world's northernmost authentic tropical rainforests (Proctor *et al.,* 1998). The Indian Council of Agricultural Research (ICAR) classified it as a rice germplasm center, while the National Bureau of Plant Genetic Resources (NBPGR), India, reportedly highlighted the region as being rich in wild relatives of agricultural plants, making it a key player in global conservation efforts.

Forest types found in the region are broadly classified as six major forest types: Tropical moist deciduous, tropical semi-evergreen, tropical wet evergreen, subtropical, temperate, and Alpine forests. Out of the nine important vegetation types of India, six are found in the North Eastern Region (Hegde, 2000). These forests harbor 80000 out of 15,000 species of flowering plants, 40 out of 54 species of gymnosperms, 500 out of 1012 species of Pteridophytes, 825 out of 1145 species of orchids, 80 out of 90 species of rhododendrons, 60 out of 110 species of bamboo, 25 out of 56 species of canes, In the table-1, the species richness our diversity explained by (Chakravarty *et al.,* 2012).

Table 1: Flowering plants in terms of species richness

State	Species richness (flowering plants)
Arunachal Pradesh	5000
Sikkim	4500
Meghalaya	3500
Assam	3010
Manipur	2500
Nagaland	2250
Mizoram	2200
Tripura	1600

Status of Agrobiodiversity of North-East India:

Rice is the primary crop in the country's North Eastern Region, where about 6,000 of the 12,000 known rice landraces are grown. This region shows vast variability in rice germplasm, with glutinous and japonica types being dominant. Many rice cultivars are resistant to diseases, pests, drought, and cold. The region is also home to diverse, economically important flora and is considered a zone of active speciation. The region's rich biodiversity, including 17 species of citrus fruits, over 600 species of orchids, 63 bamboo species, and a variety of mushrooms and medicinal plants, is a testament to the region's natural wealth. Table 2 also showed the biological diversity of the North Eastern region.

Table 2. Distribution of wild relatives of cultivated crops in the NE Indian Himalayan & India

Crop	Number of species		Remarks
	NE Himalayas	India	
Cereals	16	60	
Legumes	6	33	
Fruits	51	109	
Vegetables	27	64	
Oilseeds	1	12	
Fibre crops	5	24	
Spices and condiments	13	27	
Miscellaneous	13	26	
Rice (landraces)	6000	12,000	
Citrus	17 (Assam Only)	37	
Bamboo	63	136	100 landraces collected by ICAR
Orchids	600	1,300	450 in Sikkim alone,225 rare, 12 endangered and 16 vulnerable

Sources: Upadhyay and Sundriyal (1998), Dubey *et al.*, (2002) Numerous horticulture products of North-East India were given the G.I. tag, such as Arunachal orange, Khasi mandarin, Tezpur litchi, Kachai lemon, Indian wild orange 'Memangnarang,' Tripura queen pineapple, Naga tree tomato, Assam Karbi Anglong ginger, Mizo Chilli, and Sikkim large cardamom, etc. During 2021-22, the total area in Northeast region under fruits, vegetables and spices is 431.17 thousand ha, 533.74 thousand ha and 183.44 thousand hectares, respectively. Depending on the climate, altitude, and physiographic difference of land, the major fruits, vegetables and spices are cultivated in different N.E. states. The mandarin, pineapple, turmeric, ginger, litchi, Lemon, banana, chilli, cucurbits, large cardamom etc., are traditional crops grown in the regions. Recently Kiwi fruit, Apple, Guava, Pear, Walnut, Broccoli, Cabbage, Capsicum, Carrot, Cauliflower, Knol-khol, Muskmelon, Pea, Potato, Pumpkin, Radish, Spinach, Sweet potato, Onion, Tapioca, Tomato are gaining popularity in some areas. In the NEH states, Assam is the largest producer of fruits, vegetables and spices in the region contributing almost 50% of the total area. The table-3 showed production was highest (6826.87 thousand M tonnes) in Assam which contributes more than 50% of total horticultural production in the region. Tripura and Meghalaya states are the second and third-largest producers of horticultural products in the region (Patel and Tripathi, 2023). The North Eastern region is home to many spice crops, including black turmeric, Lakadong turmeric, King Chilli, Bird's Eye chilli, Assam lemon, etc., with high market demand for their unique features. The higher production of spices from the region could significantly improve the livelihood of the residents and contribute to the economic growth of the NEH region as well as the country(Ralte and Ekhe, 2022).

Table 3. State-wise production of horticultural crops ('000 mt) in 2021-22

State	Fruits	Vegetables	Plantation	Aromatic & Medicinal	Flowers		Spices	Honey	Total
					Loose	Cut			
Arunachal Pradesh	138.16	17.41	7.05	0.16	0.00	0.00	18.59	0.15	181.52
Assam	2504.19	3747.48	163.0	0.17	35.58	57.79	317.24	1.40	6826.87
Manipur	468.16	376.58	0.32	0.12	0.01	0.17	66.48	0.40	912.23
Meghalaya	378.16	520.15	35.07	0.00	0.00	0.35	72.02	0.27	1006.03
Mizoram	345.36	224.64	33.64	0.78	0.00	0.80	100.93	0.30	706.45
Nagaland	316.29	455.96	7.12	0.66	0.04	0.24	40.84	0.72	821.87
Sikkim	50.78	129.37	0.00	0.00	16.50	0.09	102.95	0.53	300.22
Tripura	596.55	1179.22	37.21	0.00	0.00	0.00	27.43	0.22	1840.62
Total	**4746.9**	**6521.4**	**283.41**	**1.899**	**35.63**	**59.35**	**643.53**	**3.46**	**12296.00**

Source: Ralte and Ekhe, 2022

Institutes involved in protection of biodiversity in relation to North East India:

A. Protected Areas and National Parks: North-East India has several protected areas and national parks, which play a vital role in preserving wildlife. Among these, Kaziranga and Manas National Parks in Assam, which are recognized as UNESCO World Heritage Sites, have significantly contributed to protecting the endangered Indian rhinoceros and various other species: Nameri, Dibru-Saikhowa, Pobitora sanctuary, Lawkhowa sanctuary, Nameri NP. Burachapori, Sonai Rupai, and Barnadi are other important protected areas in North-East India (Chatterjee, 2008).

B. Community-Based Conservation: In Northeast India, the spirit of community-based conservation is thriving, with local groups actively participating in biodiversity preservation efforts. The Khasi Hills Community REDD Project is a shining example of this, demonstrating how a group of forest-dependent communities can develop a successful REDD-type project to finance conservation and restoration activities (Poffenberger, 2015). These initiatives help local communities manage their natural resources and encourage sustainable practices. The active involvement of these local communities in preserving their natural heritage is a source of inspiration and a testament to the power of collective action in conservation efforts.

C. Biodiversity Research and Documentation: Several research institutions in Northeast India, such as the **Botanical Survey of India** and **Zoological Survey of India**, play a key role in documenting and studying the unique biodiversity of the NEH region. Their work, including species surveys and monitoring biodiversity changes, is essential for understanding ecosystems and guiding conservation efforts.

D. Some other Institutes related to biodiversity in North Eastern region:

- ICAR-NEH region, Umiam, Meghalaya
- Central Agricultural University, Imphal, Manipur
- Bioinformatics Center at NEHU, Shillong
- ICAR-NBPGR, Shillong station, Meghalaya
- Institute of Bioresources and Sustainable Development (IBSD) at Imphal, Manipur
- Govind Ballabh Pant 'National Institute of Himalayan Environment'(NIHE)- Itanagar - 791113 Arunachal Pradesh, India
- Biodiversity Research Centre Mizoram University-Aizawl
- CEE North-East, Guwahati 781 003, Assam, India
- Centre with Potential for Excellence in Biodiversity, Rajiv Gandhi University, Arunachal Pradesh, India

Agricultural practices of North Eastern region:

Shifting (*Jhum*) farming, bamboo-drip irrigation, paddy-cum-fish cultivation, and traditional agroforestry systems are examples of traditional practices used by several Indigenous communities in various states of North-East India. These practices were established by local communities to adjust to the local climate, geography, ecology, and socio-cultural importance to the affected Indigenous communities.

Shifting cultivation, also known as slash-and-burn, swidden, or rotational bush fallow agriculture, is one of the most ancient farming systems believed to have originated in the Neolithic period, 8,000 B.C. (van Vliet *et al*., 2012).

Terrace or Bun cultivation: Bun cultivation on hill slopes and valleys is a settled cultivation system that has been practiced for the last three decades to provide an improved production system, conserve soil moisture, and prevent land degradation and soil erosion (Jeeva *et al.,* 2006).

Rice-fish farming: The rice-fish farming is carried out as a co-culture. Rice-fish co-culture involves introducing juvenile fish for simultaneous farming during rice cultivation and generally harvesting the adult fish after the rice is harvested. In contrast, rice-fish rotations involve harvesting adult fish before cultivation or introducing juvenile fish after the rice has matured. Freshly, this farming has expanded widely in many countries because of its apparent advantages (Sollows & Tongpan, 1986, Purba, 1998).

Bamboo drip irrigation system: Irrigation for plantation crops poses a severe problem of soil erosion. The tribal farmers of Meghalaya have developed the indigenous technique of bamboo drip irrigation. Betel vines planted with areca nut as the supporting tree are irrigated with this system, in which water trickles or drips at the base of the crop (ICAR-NEH region Umiam website).

ZABO system: The Zabo system is an indigenous farming practice from Nagaland. The term "Zabo" translates to "impounding of water." This system integrates forest management, agriculture, and animal husbandry, all built on a solid soil and water conservation foundation. It features protected forest areas at the hilltops, water harvesting tanks positioned mid-slope, cattle yards, and paddy fields at the lower levels, serving as crop storage and irrigation sources during the growing season (ICAR-NEH Region, Umiam).

Traditional food system of North-East India:

The North-East part of India is known for its cultural, traditional, and diverse food system. The method of diverse food preparation in Tribal cultures has been passed down from generation to generation and is still practiced by every family today. The products are commercially supplied and sold locally but not nationally or globally. This part is generally known for its local food system diversity in terms of vegetarian and non-vegetarian food. The region's residents generally for food directly and indirectly depend on agrobiodiversity. North-East India is known for the availability of tasty food. Fig. 3 shows a higher diversity level in Manipur state's local food system, while Fig. 4 shows Mizoram state and Fig. 5 indicates Meghalaya state food diversity. Through this diverse food system, the local peoples of North Eastern Region states feel connected with nature and serve their role in agrobiodiversity conservation in the region. Different kitchen gardening models in the North Eastern Region's different states also showed their richness concerning agrobiodiversity. Some literature below discusses the diversity of local food systems in the states of North-East India, including Manipur, Mizoram, and Meghalaya.

Manipur: The Manipuri's' traditional meals include Iromba, Champhut, Kangshoi, Hawaichar, Soibum, Ngaree, Paknam, Chagem pomba, Kangshu, Hentak, Khazing, Heikak, sticky rice chapatti/bread, and so on. Alcoholic beverages produced from Rice are widely used at all of Manipur's tribal celebrations, which are known locally as Yu. The people of Manipur tend to eat a variety of leafy vegetables, which are abundant in the forest area of Manipur state (Devi & Suresh Kumar, 2012). This state shares an international border with Myanmar. If not adequately protected, sometimes, it is not suitable for the health of the state's agrobiodiversity or the local food system of the Manipur State.

Fig. 3. Diversity in the local food system of Manipur state.

Mizoram: Mizoram is also a state of North-East India, sharing a national border with three states of North-East India, including Tripura, Assam, and Manipur. It also shared an international border with Bangladesh and Myanmar. Mizoram is also known for its extraordinary richness in terms of local food systems or traditional food systems. Rice is the leading food of the tribal groups in Mizoram, often eaten with vegetables, salads, and meat. Traditional farming in Mizoram uses shifting cultivation, which is still practiced in the highlands (Sati *et al.,* 2014). Besides Rice, people commonly eat boiled fish, stinky beans chutney, chilli chutney, fried vegetables like bok choy with soy chunks, mustard rice porridge, fermented pork fat chutney, and boiled chicken with dry roselle leaves (Fig 4). In Mizoram, some reports show that wild vegetables play an important role in improving nutrition and food security.

Fig. 4. Showes Diversity in local food system of Mizoram state

Meghalaya: Meghalaya is the third largest state among the North Eastern Region states of India. This state came into existence on 21st January 1972 by carving out two districts from the Assam state: the United Khasi Hills, Jaintia Hills, and the Garo Hills. The different tribes of Meghalaya have a unique dietary pattern that reflects their diverse cultural identity. Adequate nutrition is essential for growth, development, and a healthy lifestyle (Blah & Joshi, 2013). The local food system of Meghalaya consists of many veg. And non-veg. Dishes along with many vegetables including tomato and Chameleon root chutney, fermented soybean foods, Pork soup with cauliflower and mustard, Smoked beef in different recipes, Fried smoked beef and fried pork dishes, Pork in sesame, and beef curry, Rice cooked in bamboo pipe and Colocasia salad, Pork with pumpkin leaves and Fish curry, Dry Fish with sesame and Pork with mushroom, Smoked beef with Cho-Cho, Chicken and egg, Pork pulao and fish pulao, Dry fish curry, and dry fish curry, Plantain fried and with Pork, Common sowthistle and plantain flower salad, Plain Rice and sweet rice fritters, Dry and Fermented fish chutney, Pulse curry and Pork with onion, Rice in white sesame and black sesame. Eating and promoting these diverse local foods of Meghalaya residents ensures the preservation of their diverse cultural heritage and local food system in the era of climate change. Fig. 4 shows the diverse food of Meghalaya state.

Fig. 5. Diversity in local food system of Meghalaya state

Kitchen gardening: A kitchen garden is an extensive cultivation of various kinds of vegetables, spices, medicinal plants, fruits, and other domestic articles around the residence or within walking distance from the place of residence (Fig 6). Such gardens may meet the family's demand for vegetables and fruits, known as kitchen or home gardens (Kohima *et al*., 2021). The kitchen garden is an essential component of the local food system of the North Eastern Region states of India. The crucial benefits of kitchen gardens include

- the availability of pure and fresh vegetables at minimum cost,
- proper use of space around the household,
- good source of food and nutritional security, and
- increased women's employment in the North Eastern Region.

A diversified model of kitchens or home gardens improves the livelihood of the people in the North Eastern Region regarding their local food system and helps improve local economics. A diversified kitchen garden model showed the region's beauty and richness of agrobiodiversity. Some literature discusses the different kitchen gardens in North-East India, including Manipur, Mizoram, and Meghalaya. Kitchen or home gardens are used as a gene bank in North-East India because hundreds of vegetables, fruits, ornamental plants, and medicinal plants are grown and conserved in the region's Kitchen gardens or home gardens.

Manipur: In Manipur, different tribes grow kitchen gardens for the fulfilment of daily requirements of the family like - The Tangkhul tribe, which is the largest tribe among the Naga tribes in Manipur, traditionally cultivate a variety of crops in their home gardens, called yamkui for daily use and local market sales. They grow winter crops, such as mustard, cabbage, radish, beans, and spinach, and summer crops, like pumpkin, cucumber, brinjal, gourd, and carrot. This longstanding practice helps preserve local biodiversity and sustains the community with seasonal produce (Salam *et al.,* 2011). In Manipur, its contribution to state economics is very high and has continuously increased for the last decade. In the fiscal year 2021, kitchen gardens in Manipur generated approximately 154 million Indian rupees for the state economy, showing a slight growth compared to the previous year. (Anonymous, 2023).

Fig. 6. Model of kitchen garden of Manipur state

Mizoram: In the fiscal year 2021, kitchen gardens in Mizoram contributed over 41 million Indian rupees to the Indian economy, nearly doubling their value from 2012, accounting for 22.3 million rupees (Fig 7)—Mizoram state govt. Promoting kitchen gardening in the state, which started developing school space for kitchen gardens called 'Kan Sikul, 76 Kan Huan' or My School, My Farm, to improve the nutritional content of meals served to children. Generally, in the Mizoram state, numerous vegetables, fruits, and medicinal plants are grown in kitchen gardening. Mizoram is also very well known for its cultural and traditional heritage of kitchen gardens or home gardens, which play essential roles in agrobiodiversity conservation and are a good source for the local food system of the local tribes of Mizoram.

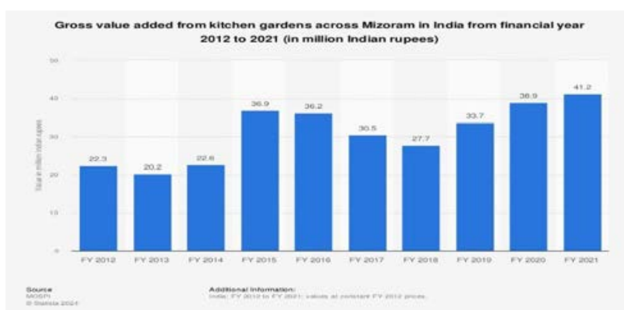


Fig. 7. Gross value added from kitchen gardens across Mizoram in India from financial year 2012 to 2021 (in million Indian rupees)

Meghalaya: In the fiscal year 2021, kitchen gardens in Meghalaya generated approximately 57 million Indian rupees for the state economy, slightly lower than the previous year. The slight decrease in the kitchen garden economy of Meghalaya is a severe concern for related state departments and residents. Among the three states of Nort-Easte, including Manipur, Mizoram, and Meghalaya, this state has the second position after Manipur regarding the economy of kitchen gardens. Many schools in Meghalaya have set up their own kitchen gardens to promote kitchen gardens in the state. These kitchen gardens help children learn how to grow their vegetables and fruits at school and at home. They improve nutrition in schools and encourage healthy habits in children. It is a great way to teach school kids where their food comes from and to get them excited about eating fresh vegetables. In Meghalaya, kitchen gardens have a great diversity with respect to vegetables because there is a diversity of vegetables present there, like leafy vegetables, beans, potatoes, chillies, Solanaceae vegetables, etc. These kitchen gardens also have good space for fruit crops like Khasi mandarins, pineapples, and many others. In Meghalaya, many medicinal plants are commonly found in home gardens, especially kitchen gardens. Some of the most grown medicinal plants include *Calamus floribundas, Centella asiatica, Fagopyrum cymosum, Hemidesmus indicus, Kaempferia rotunda, Mussaenda roxburghii, Merremia hedereaca, Piper peepuloides, Smilax*sp. and *Trichosanthes palmata.* At the same time, large numbers of ornamental plants are also grown in the kitchen gardens, like - *Cassia tora, Dracaena fragrans, Luculia pinceana, Morinda angustifolia, Raphidophora calophyllum* and a variety of orchids (Tynsong & Tiwari, 2010).

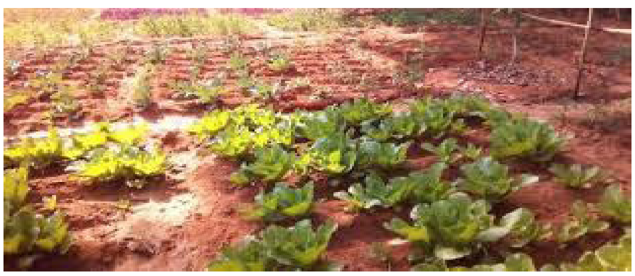


Fig. 8. the Kitchen garden of Meghalaya

Advantage of Agrobiodiversity: Fig. 9 shows numerous advantages of agrobiodiversity. It includes economic, environmental, and socio-cultural dimensions essential in ensuring food and nutritional security. Its management involves the domestication of crops and animals alongside efforts to enhance productivity despite various environmental and societal changes. As the foundation of agriculture, agrobiodiversity has driven the evolution of farming systems. Agrobiodiversity plays an essential role in the development of climate-resilient crops. The interdependence between agriculture and biodiversity is a critical factor in its importance. Biodiversity is vital for agricultural systems, and when practiced sustainably, agriculture can actively conserve and promote biodiversity. Thus, sustainable agricultural practices benefit from and contribute to biodiversity conservation.

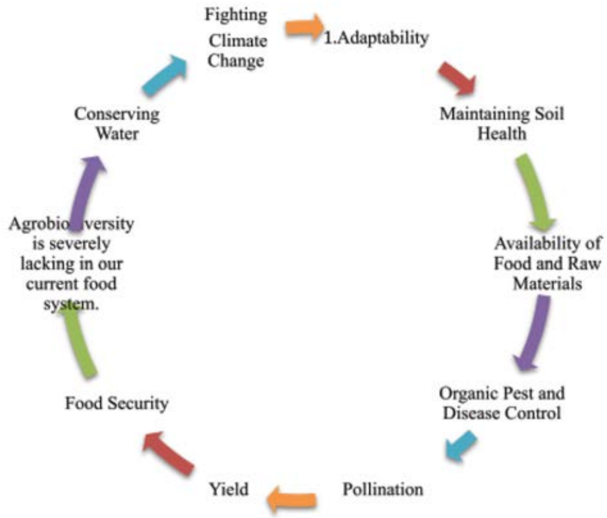


Fig. 9. Some major advantages of Agrobiodiversity

Flagging issues of local communities:

Farmers in Northeast India face several challenges when adopting agrobiodiversity in the local food system. These issues are complex and often interrelated, including socio-economic, environmental, and policy-based factors. The biodiversity conservation challenges in Northeast India are complex, reflecting the diverse issues its constituent states face. The region is not a uniform geographical unit, so conservation concerns differ across states. These challenges are influenced by demographic composition, governance, and the sociopolitical context. The relatively intact forest cover in the region is primarily due to its remoteness, limited accessibility, and low population density. However, significant portions of the primary vegetation have been disrupted by natural processes— frequent landslides, soil erosion, and seismic activity—and human activities (Chatterjee, 2008). Here are the key issues:

Lack of Knowledge and Awareness:

Limited understanding of the benefits of agrobiodiversity: Farmers often need more awareness of the benefits of agrobiodiversity, including its potential to enhance resilience to climate change, improve soil health, and provide economic benefits through diversified crop genetic resources.

Traditional knowledge erosion: The new generation, now day by day, is losing touch with indigenous agricultural practices that naturally encourage agrobiodiversity erosion in the local food system.

Encroachment:

The encroachment of forestland poses a significant threat to biodiversity and conservation efforts, especially in parts of the NEH region. The issue is politically sensitive, making it challenging to determine the exact extent of the encroachments. Addressing the problem requires strong political will.

Climate Change and Environmental Pressures:

Unpredictable weather patterns: Climate change has also affected cropping patterns, making it difficult for farmers to adopt agrobiodiverse practices, which may require more specific environmental conditions for quality grain and other agricultural production.

Land degradation is also a big challenge for local communities. Agricultural practices like Shifting cultivation (jhum) and deforestation have led to soil degradation and soil erosion, reducing the land's capacity in terms of fertility to support diversified cropping patterns.

Forest fires:

Forest fires at the end of winter are common, often caused by villagers who deliberately burn the forest floor, which is covered with dry, flammable leaves and twigs. In Arunachal Pradesh, the Sherdukpen and Mompa tribal communities set fires to create fresh grass for their cattle to graze. Unfortunately, this practice harms both the natural and artificial regeneration of the forest and negatively impacts wildlife. (Semwal *et al.* 2003).

Limitations of **Market:**

Low market demand for diverse crops: The market regularly prioritizes staple food crops like rice (*Oryza sativa* L.), wheat (*Triticum aestivum*), and maize (*Zea maize* L.), making it difficult for farmers to profit from cultivating diverse species like small millets.

Poor market access: Farmers in remote areas always need help accessing good market facilities to sell non-traditional or diverse crops like millet.

Lack of value chains: In North Eastern Region states, there is still an absence of organized value chains that support the sale of locally grown, biodiverse crops.

Introduction to exotics genetic resources and immigrations:

New varieties of genetic resources for mass propagation and higher production acc, identical introductions, and cross-breeding will have obvious ecological impacts. In Tripura, more than 280 species of plants have been introduced. The state has reported exotic aquatic insects like *Notonecta* sp., *Ranatra*sp., *Geris* sp., *Nepa* sp., *Lithocerus* sp., and dragonfly nymph that are causing management problems (SBSAP 2005–2006 Tripura). The North Eastern Region part of the country shares an international border with China (1395 km), Bhutan (455 km), Myanmar (1640 km), Bangladesh (1596 km), and Nepal (97 km). So, these states had many potentials for the introduction of exotics spp. In addition to immigration, it is very harmful to agrobiodiversity conservation.

Policy and Institutional Barriers:

Lack of supportive policies: Agricultural policies in India, including the Northeast, often focus on high-yielding varieties that lead to monoculture farming and cannot provide appropriate support for agrobiodiverse conservation.

Absence of proper extension services: In this region, Agricultural extension services often focus on conventional farming practices rather than promoting agrobiodiversity.

Seed Availability and Access:

Limited availability of diverse seeds: Farmers may find it difficult to access seeds for new crops that promote agrobiodiversity.

New crop seeds and their importance in the local community are less available.

Cultural and Traditional Factors:

- *Loss of traditional crop varieties:* The introduction of high-yielding varieties has led to a reduction in the cultivation of traditional crop varieties, which is reducing agrobiodiversity.
- *Dietary pattern changes:* Under the influence of urbanization, changing food preferences lead to a decline in the consumption of diverse food crop products.

Socio-Economic Limitations:

- *Low-income levels:* Most of the farmers in the region are smallholders with limited financial resources, making them hesitant to take risks with adopting diverse cropping patterns that may have uncertain markets or yields in the region.
- *Cultural preferences:* There often needs to be more cultural bias toward growing staple crops traditionally cultivated in the region, reducing the inclination to experiment with diverse agricultural or horticultural crops.
- *Labor shortages:* The labor-intensive nature of agrobiodiversity practices and diverse agricultural crop practices can be challenging due to the migration of young people from rural areas to big cities for better economic opportunities.

Land Tenure Issues:

- *Land ownership disputes:* In some regions of Northeast India, land tenure systems are complex, and disputes over ownership or access can restrict farmers from diversifying their crops.

Addressing these issues would require a multifaceted and multi-institutional approach that includes government policy reform, market development, education, and infrastructure improvements, all necessary to enable farmers to adopt and benefit from agrobiodiversity in the North Eastern States of India.

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Animal Genetic Resources Management in India: With Special Reference to NEH Region

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Genetic Resources for Food and Agriculture include Plant Genetic Resources (PGR), Animal Genetic Resources (AnGR, including fish & aquatic) and Microbial and Fungal genetic resources. This agrobiodiversity contributes to the various ecosystem services (ESS) including provisioning, regulating, supporting, habitat and cultural. India, one of the mega-biodiversity centres, possesses large and diverse AnGR distributed over a large range of geographical, ecological and climatic regions. Around 20 livestock and poultry species, including zebu cattle, riverine buffalo, swamp buffalo, sheep, goat, pig, horse, donkey, camel, yak, mithun, chicken, duck and geese, distributed over a large range of geographical and ecological regions. The country possesses 536.8 million livestock and 851.8 million poultry (20th Livestock Census, 2019), registering continuous increase in population over the years. . A large number of breeds of the farm animal have been generated through natural adaptation to the climate as well as planned breeding by livestock keepers, playing a vital role for food and agricultural support to the society.

AnGR is not only the great source of food but also provide agricultural and transport power, manure as bio-fertilizer and energy fuel etc. In India, AnGR contributes significantly to the national economy, apart from providing food and social security to the people. The country, being the top producer in the world has produced 230.6 million tonnes milk during 2022-23, recording substantial growth during last five decades. Among total milk production, cattle are contributing about 52 percent, buffalo 45 percent and goat and camel producing about 3 percent of the milk. Egg production, mainly by the fowl has reached to 138.4 billion during 2022-23, with 40 billion increase during last seven years, only. About 85% of the total eggs are produced by the commercial layers and rest from backyard poultry. Meat is another important provisioning services by the livestock and poultry species. In year 2022-23, total meat production in country was 9.77 million tonnes, to which poultry contributed about 51 percent. Buffalo is second major species contributing 17.6 percent of total meat production. Goat and sheep contributed about 25 percent of the meat production in the country. AnGR also contribute for fibre production. Total 33.61 million Kg wool was produced in country, during year 2022-23, however a decline in the wool production has been observed in recent time. Revenue amounting Rs. 8683 crore has been estimated through production of animal hide and skin. Hair and bristle has also generated about Rs.196 crore. Growth of AnGR based product is also significant, ranging from 4 to 10 percent annual in recent years. This progress has also largely contributed in improving food and nutritional security in the country. The contribution of animal sector has been increased from about 15 percent to almost 30 percent in total agricultural economy in country during last four decades. AnGR also contributes to the various ecosystem services (ESS) including provisioning, regulating, supporting, habitat and cultural, benefitting within as well as out of the production system through interactions of other components of biodiversity and natural resources. The direct gain from AnGR is estimated to be around five percent of National Gross Value Added (GVA) and around 30 percent of Agriculture GVA during 2023-24.

AnGR status in India

At present, the country possesses 536.82 million livestock and 851.81 million poultry, with the count in 20th Livestock Census, 2019 (Table 1). The species wise proportion of total livestock is 36.04% cattle, 20.47% buffalo, 27.74% goat, 13.83% sheep, 1.69% pig and rest 0.23% represented by mithun, yak, horses and ponies, mule, donkey and camel. As compared to the year 1956, the population of cattle, buffalo, sheep, goat, pig, mule, yak and poultry has increased and horses & ponies, camel and donkey have declined, may be due to faster adoption of mechanization in agriculture.

Table 1: Livestock and poultry population (in million) over the years in India

Species	1956	1961	1972	1982	1992	2003	2012	2019
Cattle	158.70	175.60	178.30	192.45	204.58	185.18	190.90	193.46
Buffaloes	44.90	51.20	57.40	69.78	84.21	97.92	108.70	109.85
Sheep	39.30	40.20	40.00	48.76	50.78	61.47	65.07	74.26
Goats	55.40	60.90	67.50	95.25	115.28	124.36	135.171	148.88
Horses	1.50	1.30	0.90	0.90	0.82	0.75	0.63	0.34
Camels	0.80	0.90	1.10	1.08	1.03	0.63	0.40	0.25
Pigs	4.90	5.20	6.90	10.07	12.79	13.52	10.29	9.00
Mules	0.04	0.05	0.08	0.13	0.19	0.18	0.20	0.08
Donkeys	1.10	1.10	1.00	1.02	0.97	0.65	0.32	0.12
Yaks	NC	0.02	0.04	0.13	0.06	0.06	0.08	0.06
Total livestock	***306.60***	***335.40***	***353.60***	***419.59***	***470.85***	***485.00***	***512.06***	***535.82***
Poultry	94.80	114.20	138.50	207.74	307.07	489.01	729.21	851.81

During last seven decades, livestock population has increased by more than 80 percent, in the country. Poultry population showed tremendous increase, burgeoning around 10 times during same phase. Among livestock, cattle population, constituting the highest proportion, has been increased nearly by quarter since independence, however, the share among the total livestock population deceased from 53 to 36 percent. On other side, buffalo population increased by almost one and half times, increasing its share in total livestock. Further, spread of buffalo country wide may be unequal as around two-third of the population is concentrated in the north and western states, where most of the milch breeds of buffaloes are found. Most obvious change observed in Indian livestock is emergence of crossbred cattle population during last four decades, after adopting crossbreeding programmes in the country. The more rapid trend has been seen in recent years. During year 2012-2019, population of crossbred cattle has been increased around 30 percent, against the decrease of 6 percent for indigenous cattle.

The populations of goat and sheep have shown continuous increase, apart few exceptions. Pig population has almost doubled since independence, however, the population is showing declining trend during last two decades. There is a rapid decline in some of the species like horse, donkey and camel.

AnGR status in NEH region

The north eastern hill (NEH) region of eight states comprises around four percent of country's livestock and around eight percent of poultry. However, the ratio for per capita livestock /poultry is much higher than the country's average. AnGR diversity is much higher, with availability of 11 livestock and 3 poultry species in the region. Among these, 11 species are contributing towards food. The region is rich in bovine diversity comprising cattle, buffalo, yak & mithun along with wild relatives like wild cattle, gaur, wild yak. Total livestock in the NER is 24.3 million, which is about 4.5 percent of total livestock population of the country. Overall, livestock population in NER states has declined by 8.4 percent during 2012 to 2019. Decline in livestock population has been observed in Nagaland (39%), Tripura (32%), Arunachal Pradesh (18%) and Assam (5%). Region is rich in poultry genetic resources, with around 69 million population, comprising 8.1 percent of the total poultry population in the country. The region has witnessed significant increase in poultry population, with overall increase of 59 percent during 2012 to 2019 period. Very high increase in poultry populations have been observed in Assam, Manipur, Meghalaya and Mizoram. In contrary, Arunachal Pradesh and Tripura showed the decline in the poultry population in their states.

Table 2: Livestock and poultry population (in thousand) in NEH states during different years

State	*Livestock*			*Poultry*		
	2007	*2012*	*2019*	*2007*	*2012*	*2019*
Arunachal Pradesh	1412.65	1412.67	1161.4	1348.4	2244.2	1599.6
Assam	17226.6	19082.2	18092.2	29060.3	27216.2	46712.3
Manipur	788.5	695.8	550.7	2403.3	2499.5	5897.6
Meghalaya	1822.6	1957.6	2039.1	3092.9	3400	5379.5
Mizoram	328.1	311.9	359.7	1239.2	1271.4	2047.8
Nagaland	1418.6	911.2	553.8	3155.9	2178.5	2838.9
Sikkim	270.1	291.6	274.3	157.5	451.97	580.9
Tripura	1869	1936.2	1317.9	3700.95	4272.7	4168.2
Total NEH	**25136.2**	**26599.2**	**24349.1**	**44158.45**	**43534.47**	**69224.8**
India	**529697.6**	**512057.3**	**535838.9**	**648829.6**	**729209.3**	**851809.9**

Species-wise, cattle is the highest in number, comprising 55 percent of the total livestock in the region. Goat (22%) and pig (17%) are second and third largest livestock species. The NER possesses all mithun, and nearly half of the pig and yak population of the country. Mithun and yak populations have been increased, whereas, pig and cattle population have declined in the NER during last two censuses.

Table 3: Species-wise livestock population (in million) in NEH region

Species	*NEH*	*India*	*% population*
Cattle	13.4	193.5	6.93
Buffalo	0.5	109.9	0.45
Mithun	0.39	0.39	100.00
Yak	0.03	0.06	50.00
Sheep	0.37	74.26	0.50
Goat	5.4	148.89	3.63
Pig	4.24	9.06	46.80
Horse	0.02	0.34	5.88
Donkey	0	0.12	0.00
Livestock	**24.3**	**536.8**	**4.53**
Poultry	**69.2**	**851.8**	**8.12**

Global initiatives for AnGR management

Global initiatives for preserving the AnGR diversity and their sustainable utilization may be traced back to the commencement of the Convention on Biological Diversity (CBD) in 1992. Under the aegis of CBD, the Commission on Genetic Resources for Food and Agriculture (CGRFA) in 1999, worldwide initiated the process to identify the national priorities for the management of AnGR for its sustainable use and preserving biodiversity. Further, National sovereignty over its genetic resources, including animals of the country has been endorsed under CBD. It has necessitated to protect the animal genetic resources through developing appropriate policies specifically describing and cataloguing valuable livestock and poultry breeds available in the country.

Global Plan of Action (GPA) for AnGR management

United Nation's Food and Agriculture Organization (FAO) initiated its sincere efforts for AnGR biodiversity preservation through the Global Plan of Action (GPA) for Animal Genetic Resources in 2007. Also known as 'Interlaken declaration', it is the first internationally accepted framework for the management of AnGR. Further, the FAO's Global Plan of Action (GPA) for AnGR has been adopted in form of Interlaken Declaration by the international community in 2007. Among four ***Strategic Priority Areas (SPAs),*** the Characterization, inventory and monitoring of trends and associated risks, and the Conservation of AnGR are main focus for implementation of the GPA, at global level. After its adoption, the countries have realized the necessity of inventory of native germplasm and most of the countries initiated the process to inventories such populations.

In recent time, United Nations (UN) also appealed for management of all genetic resources globally specifically to promote sustainable agriculture and achieving food security through their Sustainable Development Goals (SDGs). SDG Goal 2 (Zero Hunger), Target 2.5 (Indicator 2.5.1: Number of plant and animal genetic resources for food and agriculture secured in either medium or long-term conservation facilities, for Indicator 2.5.2: Proportion of local breeds classified as being at risk of extinction) are well related to the farm animal biodiversity. A new dimension on 'locally adapted breeds' has also been added under Indicator 2.4.1, recently. The FAO is also responsible for global monitoring of these Indicators, through an online database Domestic Animal Diversity Information System (DAD-IS, http://www.fao.org/dad-is/en/).

Further, in light of our commitment towards Aichi targets of CBD, Global Plan of Action by FAO, Sustainable Development Goal of UN, the management of AnGR biodiversity has been largely felt which come in form of 'Delhi Declaration' in 2016. It signifies the progress made towards the documentation, collection, conservation and use of agrobiodiversity related genetic resources, and further felt the need towards their sustainable use, greater exchange and knowledge and technology transfer. Through conserving and using it sustainably, it could make an important contribution towards resolving problems of hunger, food insecurity, malnutrition and climate change and helping in attaining the SDGs and the Aichi Targets of the Convention on Biological Diversity.

Characterization and inventorization of Farm AnGR

In India, there are 219 registered indigenous AnGR breeds, which includes 53 of cattle, 20 of buffalo, 39 of goat, 45 of sheep, 8 of horses and ponies, 9 of camel, 14 of pig, 3 of donkey and one of yak in livestock and 20 of chicken, one of geese and 3 of duck in poultry and 3 breeds of dog. One synthetic cattle breed "Frieswal" has also been registered, recently. The proportion of animal breeds in India is very less in comparison to number of breeds in the world. Initially, the known breeds of livestock and poultry were registered as extant breeds, and simultaneously process for registration of new breeds was initiated. First time in the year 2008, all 129 extant breeds of livestock and poultry were registered by the NBAGR. Further 91 breeds were newly added and by 2023, the number reached 220.

Table 4: Number of AnGR breeds in India *vis-à-vis* Asia and world

Species	*India*			*Asia*	*World*
	Extant breeds	*New breeds*	*Total*		
Asses	0	3	3	42	170
Bactrian camel	0	0	0	9	14
Buffalo	10	10	20	107	128
Cattle	30	24	54	261	1224
Dromedarian camel	8	1	9	14	89
Goat	21	18	39	195	662
Horse	6	2	8	148	818
Pig	0	14	14	216	602
Sheep	39	6	45	276	1382
Yak	0	1	1	25	28
Others	0	3	3	33	457
Total mammals	*114*	*82*	*196*	*1318*	*5584*
Chicken	15	5	20	308	1669
Duck	0	3	3	94	279
Geese	0	1	1	46	205
Other avian	0			77	390
Total avian	*15*	*9*	*24*	*525*	*2543*
Total breeds	***129***	***91***	***220***	***1853***	***8127***

Several new breeds have also been reported from the remote regions of the country. Importantly, many of breeds were registered from remote areas like NEH and also for the minor species, which are although less in population but contributes significantly to the society. Many of the new breeds have been added in breed inventory by the states like Gujarat, Odisha and Tamil Nadu, mainly because of active participation of local agencies and NGOs in these states. Registration of new breeds during last decade has put more than 25 million livestock and poultry into the descript category in the country.

In NEH region, despite of low population density of the AnGR, the region is rich in farm animal species, their specialized populations and breeds. The region comprises 24 indigenous animal breeds almost 11% of total breeds of the country, which is almost three times higher than national average (almost 1 breed in 1 million livestock in comparison to 1 breed in 3 million in country).

Table 5: States (in country and NEH) with highest number of animal breeds

State	Total breeds			State	Total breeds		
	Pr.	*Sec.*	*Total*		*Pr.*	*Sec.*	*Total*
Rajasthan	28	5	33	Assam	7	0	7
Gujarat	24	4	28	Meghalaya	4	1	5
Tamil Nadu	21	0	21	Manipur	3	1	4
Maharashtra	16	2	18	Arunachal Pradesh	2	1	3
Karnataka	12	3	15	Nagaland	3	0	3
Uttar Pradesh	11	3	14	Sikkim	3	0	3
Odisha	12	1	13	Tripura	1	1	2
Jammu & Kashmir	11	0	11	Mizoram	1	0	1
Andhra Pradesh	8	2	10				

Pr. - Primary home tract, Sec. - Secondary home tract

Non-descript AnGR in India

India possesses nearly 10 percent of the global livestock population, however, the breed proportion is only about 4 percent of the total number of breeds of the globe. There is one breed per 3 million livestock population in India, which is lower than the world average (one breed per 0.9 million animals), about 4 to 6.5 million for cattle, buffalo and goat, the three most populous species in India. Around 54% percent of population of different species falls under the non-descript category. As per 20th Livestock Census (2019) species-wise non-descript population included 51.8 per cent of cattle, 45.4 per cent of buffaloes, 50.6 per cent of sheep, 63.5 per cent of goat and 70.9 per cent of pigs. The descript and non-descript populations of different livestock also widely vary across the states. There is also possibility to have large number of mixed populations in different states.

Table 6: Total population (in thousands) and proportion of non-descript population of major livestock species in Indian states (20th Livestock Census, 2019)

States	Cattle		Buffalo		Sheep		Goat		Pig		Total Livestock	
	Total population	*% Non-descript*	*Total population*	*% Non-descript*	*Total population*	*% Non-descript*	*Total population*	*% Non-descript*	*Total population*	*% Non-descript*	*Total population*	*% Non-descript*
Andhra Pradesh	4600	41.7	6219	36.0	17626	48.2	5522	91.7	91	90.1	34067	52.2
Bihar	15397	60.9	7719	69.3	213	80.8	12821	55.3	343	92.4	36540	61.2
Chhattisgarh	9983	71.5	1174	78.0	180	99.4	4005	95.6	526	98.1	15872	79.2
Goa	60	51.7	27	96.3			9	100.0	35	91.4	132	74.2
Gujarat	9633	27.4	10543	30.2	1787	19.9	4867	60.9			26893	34.0
Haryana	1928	10.4	4368	11.9	288	57.3	334	56.3	108	39.8	7046	16.0
Himachal Pradesh	1828	40.8	646	39.8	791	28.1	1108	60.6	2	100.0	4412	43.3
Jammu & Kashmir	2539	42.9	690	72.2	3247	40.2	1730	77.9	1	100.0	8325	52.0
Jharkhand	11223	57.6	1350	47.9	641	47.6	9121	23.6	1276	79.6	23614	44.8
Karnataka	8469	23.4	2984	57.1	11050	42.7	6169	80.2	323	78.0	29013	46.9
Kerala	1341	4.7	101	68.3	1	100.0	1359	21.0	103	2.9	2908	14.5
Madhya Pradesh	18750	76.7	10307	67.5	324	98.8	11064	88.2	164	97.0	40637	77.8
Maharashtra	13992	57.3	5603	58.6	2680	78.5	10604	78.0	161	91.3	33079	66.1
Odisha	9903	79.5	458	89.7	1279	87.6	6393	63.1	135	99.3	18170	74.7
Punjab	2531	7.5	4015	3.6	85	61.2	347	19.6	52	17.3	7050	6.7
Rajasthan	13937	56.6	13693	42.6	7903	48.1	20840	63.4	154	96.8	56800	54.6
Tamil Nadu	9518	15.9	518	76.1	4500	43.1	9888	76.3	66	75.8	24500	46.7
Telangana	4232	77.4	4226	60.1	19063	53.7	4934	92.3	177	96.0	32640	63.7
Uttar Pradesh	19019	47.9	33016	41.3	984	82.6	14480	64.0	408	88.5	68012	48.9
Uttarakhand	1852	9.5	866	42.6	284	32.7	1371	78.4	17	58.8	4427	39.1
West Bengal	19077	55.8	630	61.1	952	82.6	16279	21.1	540	72.6	37483	41.7
NEH states												
Arunachal Pradesh	339	97.9	6	100.0	7	100.0	159	100.0	271	95.2	1161	98.1
Assam	10909	30.2	421	89.8	332	97.9	4315	88.2	2099	60.9	18092	50.3
Manipur	224	92.4	36	97.2	6	100.0	38	94.7	235	88.5	550	91.1
Meghalaya	903	96.3	15	100.0	15	100.0	397	100.0	706	57.8	2039	83.7
Mizoram	45	53.3	2	100.0	0.4	0.0	14	100.0	292	100.0	359	20.6
Nagaland	78	76.9	15	100.0	0.3	0.0	31	96.8	404	47.8	553	58.0
Sikkim	148	18.2	1	100.0	2	50.0	90	100.0	27	55.6	274	50.7
Tripura	739	82.5	7	100.0	5	100.0	360	25.8	206	48.5	1318	61.8
INDIA	193462	51.8	109851	45.4	74260	50.6	148884	63.5	9055	70.9	536761	53.9

It is obvious that there is still a sizable Non-descript (undefined) population in the country. The non-descript population of different species definitely have large number of unique/ homogenous population of different species and also large number of mixed populations those neither falls in registered breeds nor a unique population. The country still possesses a sizeable proportion of livestock and poultry undocumented, which includes several homogenous/unique populations those may have potential to be breeds. Further, there are large proportion of mixed populations that do not conform to any of the breed due to non-homogeneity in population, and/or cross breeding and other demographic factors. Admixture analysis including population and diversity studies of such admixed population vis-à-vis established breeds can aide in drawing a diversity representation of the native breeds of major livestock species adapted to their geographical and ecological niche. Besides, it can further facilitate in cataloguing, characterization and documentation of the native populations. In recent times, the genome wide analysis has been advocated to provide better resolution of population structure as well as admixture status. The task was highly demanding, surely it needed a larger collaboration with various central and state agencies including AHD of all States, SAU/SVUs, other ICAR institutes, NGOs etc.

Mission towards Zero Non-descript AnGR

ICAR- NBAGR has undertaken the characterization and documentation of entire native livestock and poultry in the country in Mission mode. "Mission towards Zero Non-Descript AnGR of India' was initiated on 11th August, 2021 by ICAR-NBAGR. The Mission is aimed to lowering down of proportion of non-descript livestock and poultry, significantly, along with identification of potential breeds in the country as well as to understand the architecture of mixed populations of livestock species. Since its launch, the Mission received a great momentum across the country, and has been prioritized by the ICAR/GoI.

Since, the task was enormous and it was difficult to cover all the AnGR of the country for exploration of potential populations, further characterization of these populations and leading to their registration as established breeds. To tackle this, Bureau created a new framework through creating State and Functional Groups. All of the states were covered under these groups. These groups were made responsible for all kinds of mission activities for their respective states. The primary work was to explore the potential populations in the states in collaboration with state agencies and further coordinate for their characterization and registration of new germplasm by the state agencies in these states. New approach of state/ region wise exploration was adopted and projects were initiated in this direction.

For sensitization of the stakeholders the institute organized State Interface Meets and after the launch of the mission, interface meets with 19 state/UT have been completed. These states/ UTs are (Ladakh (UT), Chhattisgarh, Maharashtra, Rajasthan, Uttar Pradesh, Jharkhand, Telangana, Punjab, Haryana, Madhya Pradesh, West Bengal, Himachal Pradesh, Bihar, Arunachal Pradesh, Andaman & Nicobar, Kerala, Lakshadweep, Goa and Odisha.

After launch of the Mission, institutional projects were initiated for survey and documentation of AnGR in 22 states and two Union Territories in collaboration with SAHD, KVKs, SAUs/SVUs. After launch of the Mission, Bureau has surveyed 24 states & 2 UTs to explore and identify new potential populations of indigenous livestock, poultry and dog. Since the task of the Mission is enormous and can only be completed through country-wide networking with the larger participation of the stakeholders at local levels, 33 Network Centres involving State AHDs, SAUs/ SVUs, ICAR institutions NGOs of 25 states/UTs, were initiated during the year 2022 and 2024. All with explorations under the Mission has resulted in identification more than 50 new populations from various states in the country.

Newly identified populations are being characterized by the Bureau in collaboration with state agencies specifically State Animal Husbandry Departments and State Agricultural/Veterinary Universities. Among 54 potential populations explored country-wide under institutional projects, characterization following systematic survey with standardized questionnaires was initiated for 43 populations by 27 State Network Centres. About 30 populations have already been characterized since the launch of the mission, country-wide. Many of the populations were from the remote regions of the North-Eastern states, Ladakh, Vidarbh region of Maharashtra, Bihar etc. Efforts for the registration of indigenous animal breeds were also enhanced. During last three years, 20 new breeds were added in the inventory. Many of the applications for registration of new breeds are in process at the Bureau.

Conservation of farm AnGR

Monitoring of breed diversity

Based on Breed-wise Livestock Census during 2013 and 2019, Bureau has developed a 'Breed Watchlist 2022' for indigenous animal breeds. Risk status has been assessed for 164 breeds of various species including cattle, buffalo, sheep, goat, camel, horse, pig and chicken in country. Based on population trend, breeding animals and effective population size, the breeds have been assessed for either 'at risk' or 'not at risk' categories, as per the criteria laid down by the FAO. Its further categories the breeds at risk with its severity - vulnerable, endangered and critical. Total 38 breeds were identified with various threatened status. Total 14 breeds are under 'vulnerable', 19 breeds are under 'endangered' and 5 breeds are under 'critical', category, as per the Watchlist.

Table 7: Breeds at risk in NEH region

Attributes	Arunachal Pradesh	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Sikkim	Tripura
Registered Breeds	**3**	**7**	4	**5**	**1**	**3**	**3**	**2**
	Tibetan sheep Bhutia horse Arunachali yak	Lakhimi cattle Luit buffalo Assam Hill goat Doom pig Daothigir chicken Miri chicken Pati duck	Luit buffalo Kaunayen chicken Manipuri Black pig Manipuri horse	Assam Hill Goat Niang Megha pig Chitagong chicken Masilum cattle Wak Chambil pig	Zovawk pig	Thuthu cattle Sumi Ne goat Tenyo Vo pig	Siri cattle Bonpala sheep Bhutia horse	Mali pig Chittagong chicken
Breeds at risk	Tibetan sheep Bhutia horse		Manipuri horse			Sumi Ne Goat Tenyi Vo pig	Siri cattle	
Germplasm Cryopreserved	Arunachali yak	Luit buffalo Assam Hill goat Doom pig	Manipuri horse	Wak Chambil pig Niang Megha pig			Siri cattle Bonpala sheep	Mali pig

Germplasm cryopreservation

India has a unique sui generis system of breed registration and Gazette notification for documenting the AnGR diversity in the country. It is also important to claim sovereignty over native germplasm. Under, Indicator 2.5.1, germplasm of AnGR, specially native breeds/populations are being cryopreserved at National Genebank at ICAR-NBAGR for medium and long time conservation. At present, 63 breeds/populations of seven species have been cryopreserved in form of semen and 71 native breeds/populations in form of somatic cells. Cryopreservation of oocytes (vitrified) and DNA is also being done in ICAR-NBAGR.

The Bureau has cryopreserved the germplasm of the 25 indigenous breeds 'at risk' (66 percent of breeds at risk), in form of semen/somatic cells/ova in its National Gene bank. After development of the Breed Watchlist-2022, Bureau has given much impetus on conservation of threatened indigenous breeds in form of germplasm cryopreservation as well creating Conservation Units under Network Program on AnGR. Overall, germplasm- Semen of 63 indigenous breeds/populations, and Somatic cell of 71 breeds/populations have been cryopreserved at the National Gene Bank of the Bureau.

Further, *In situ* conservation program for five endangered breeds (Tibetan & Karnah sheep, Zanskari horse, Halari donkey and Mewari camel) have been initiated at five Network Centres during 2023-24. First conservation unit of Teressa goat was established at ICAR-Central Island Agriculture Research Institute (CIARI) with technical support of ICAR-NBAGR. Teressa goat is one of the threatened indigenous breeds as per Breed Watchlist 2022. To strengthen the stakeholders and for the promotion of Ladakhi cattle, Ladakhi Cattle Breed Society was established in in Ladakh during 2023.

Policies, legislation, Institutions and Capacity Building

Breed registration framework

ICAR initiated "Registration of Animal Germplasm" specifically indigenous livestock and poultry breeds in the country in the year 2007. In the year, 2008, NBAGR was given the temporary authority for the registration of germplasm related to livestock and poultry in the country. Subsequently, in 2008, ICAR constituted a Breed Registration Committee (BRC) under the chairmanship of Deputy Director General (Animal Science), ICAR for the registration of new breeds. Process of Registration of strains and varieties of livestock and poultry species has been also initiated in year 2020.

Registration of breeds of native livestock and poultry has broader impact through modulating various policies and programmes and affecting all stakeholders of livestock sector in the country. Most importantly, it enabled to conduct breed wise livestock census by the Govt. of India which could ensure the precise population of each of the breed in the country. This has come to be much useful for suitable policy formulation for their conservation and development, if the breed is endangered. In 20th Livestock Census (2019), total 164 breeds were included for breed wise survey. Farmers are best benefitted by the registration process.

Gazette notification of indigenous breeds

Further, to provide legal safeguards for protection of indigenous breeds being registered by ICAR-NBAGR have been notified in the year 2019 and 2020 under relevant Official Gazette of Government of India and, now have legal support as far as any IPRs or benefit sharing are concerned. First Gazette Notification for 184 breeds (No 3364 (S.O. 3699(E)) was published in October, 2019 as the notified breeds of the concerned States as well as of whole of India to be kept and reared for purposes of animal husbandry, production, breeding, conservation, utilization, consumption and trade. Till date six gazette notifications for 212 indigenous animal breeds (5 notifications) and 2 chicken lines (1 notification) have been published. The Gazette Notification provided legal support to Intellectual Property Rights (IPRs) of the registered breeds and for developing mechanism for sharing benefits among the animal keepers. In era of globalization, there remains a constant threat of germplasm piracy as well as forged patenting and IP rights to the inherent characteristics. Registration and notification would keep the proper check to such spurious activities related to precious native germplasm.

Policy issues related to Access to germplasm

Access to any biological material including Animal Genetic Resources is regulated under Biological Diversity Act (BDA, 2002). Under Section 3 to 5 of the BDA Act "No person shall without previous approval of the National Biodiversity Authority, obtain any biological resource occurring in India. However, Sections 3 and 4 shall not apply to collaborative research projects involving transfer or exchange of biological resources between institutions, including Government sponsored institutions of India, and such institutions in other countries, if such collaborative research projects satisfy the certain conditions as specified by BDA in sub-section (3) of Section 5". Guidelines for export and import of the any type of germplasm (live animals, semen, ova, embryo and gonads) of livestock species have been laid down by department of animal husbandry & dairying, MoFAHD. Guidelines regarding the Exchange of Genetic Resources for Research have been prepared by the ICAR, which also covers the Exchange of animal genetic resources viz. a) Live animal- Normal/ GMO. b) Cryopreserved germplasm-Semen, Embryos, Oocytes, Somatic cells, DNA.

Biosecurity as well as biosafety measures related to AnGR are undertaken by the central agencies including Department of Animal Husbandry and Dairying, Ministry of Fisheries, Animal Husbandry and Dairying and also to the some extent by DBT, Ministry of Science of Government of India.

Public awareness and Capacity Building

Bureau has also organized 50 national/ international training programmes/workshop, Brain storming, interactive meet for different categories of stakeholders for the management of AnGR. NBAGR has developed effective linkages with DAHDF, National Biodiversity Authority, all ICAR-Animal Science institutions, and majority number of State Animal Husbandry Departments, SAUs, Livestock Development Boards, Non-Government organizations/Gaushalas. Sensitization meetings have been held with all NE states for zero non-descript mission. Farmers Awareness Programmes for Conservation of Indigenous livestock and Poultry were organized in field areas of Arunachal Pradesh, Tripura and Assam.

Breed Conservation Award has been institutionalized, since 2017, to felicitate breeders/ organizations in order to conserve and promote the native livestock and poultry breeds on the occasion of *Kisan Divas*. During the years, ICAR-NBAGR awarded around 40 Livestock owners/ organizations for the promotion and conservation of more than 20 indigenous animal breeds since inception. NBAGR has also helped in formation of breed societies in different states.

The Institute is providing karyotyping and DNA testing services (genetic diseases and A1-A2 allele) for screening of breeding bull's cattle / buffalo to the government agencies in the country. More than three thousand samples of 18 states were processed during last 10 years.

Conclusion and way forward

The country has taken important steps in developing new strategies for effective management of its overall biological diversity. For conservation of AnGR, various strategies and approaches have been evolved by Government, Non-Government institutions and local communities, time to time. Nevertheless, the world is now have a greater need of the germplasm possessing traits like heat tolerance, disease resistance and better thriving ability in scarce situation. Certainly, this most valued AnGR is much needed for its effective management and conservation, particularly when they are facing serious threat in view of pressure of high production demand. Hence, a strong National Plan of Action is required for conserving, managing and sustainably using farm animal genetic resources by developing linkage among various stake holders including R&D organizations, NGOs and livestock keepers for effective implementation of various strategies. It is obvious that the conservation programs are difficult to be implemented at farmer's level, therefore, it should be a national and states responsibility.

As a need for complete identification and documentation of all available germplasm in the country, NBAGR has to undertake the documentation of entire native livestock and poultry covering all states in next 3-5 years. Keeping a target towards zero non-descript AnGR with respect to information, the policy intervention would result in complete description, distribution, physical traits, production potential, adaptability and uniqueness of the native populations of all livestock and poultry species. A statutory procedure needs to be developed to provide legal protection to Animal Genetic Resources/ Germplasm, specifically with commercial value, in form of varieties/lines/strains developed under NARS system, at par to the plant varieties protected under PPV &FR Act. Only after legal protection, the commercialization of newly developed forms of Animal Genetic Resources may be done. Conservation of germplasm through various means including cryopreservation for all the registered breeds should be priority. In situ conservation in participatory approach would also be focus area. Valuation of AnGR, through modeling is another facet for future work to known the true value of the native germplasm. Similarly, contribution of AnGR in overall management of Agrobiodiversity should be assessed.

A consortium of many players including ICAR-NBAGR, ICAR Research Institutes/SAUs/SVUs, KVKs, DAHD&F and SAHDs, Livestock Development Boards, Ministry of Environment & Forests, Breed Societies/ Livestock Keeping Communities/NGOs is needed for achieving these goals. There is a need for National level authority for management of AnGR which could take overall responsibility for formulating, coordinating and monitoring the strategies and action plans. National Focal Point on Farm AnGR is also needed for effectively planning and implementing the action plan for management of AnGR.

Actions under GPA	Implementing agencies	Time line
SPA1: Characterization and Inventory of Farm AnGR		
Identification of potential breeds	ICAR, SAU/SVU, DAHD&F, State A.H. Deptt., NGOs	3 Years
Characterizing, documenting and registering the identified populations	ICAR, SAU/SVU, DAHD&F, State A.H., NGOs	3-5 Years
Strengthening national database on AnGR	DAHD&F, ICAR, State A.H. Deptt., SAU/SVU	Continued
SPA2: Conservation of Farm AnGR		
Conducting breed-wise livestock census for monitoring breeds	DAHD&F, State A.H. Deptt.	Every 5 years
Identifying breeds under threat	ICAR, National Focal Point, DAHD &F, SAU/SVU, State A.H.	Every 5 years
Prioritizing the breeds for conservation	ICAR, National Focal Point, DAHD&F, ICAR, State A.H. Deptt., SAU/SVU	Every 5 years
Implementing conservation programmes for breeds at risk	DAHD&F, ICAR, State A.H. Deptt., SAU/SVU, NGO	Continued

Strengthening National Gene Bank as germplasm repository	ICAR, DAHD&F, State A.H. Deptt., SAU/SVU	Continued
Establishing Regional Gene Bank in NEH	ICAR, DAHD&F, State A.H. Deptt., SAU/SVU	5 years
SPA3: Improvement and Sustainable Utilization of Farm AnGR		
Formulating and periodically review breed-wise breeding policies	DAHD&F, State A.H. Deptt., SAU/SVU, ICAR,	Every 5 years
Genomic selection and Producing genetically superior germplasm for genetic improvement and conservation.	DAHD&F, ICAR, State A.H. Deptt., SAU/SVU	Continued
Formation of breed societies for each breed.	DAHD&F, ICAR, State A.H. Deptt., SAU/SVU	Continued
Value addition of indigenous breeds for enhanced economic worth and creating niche markets	DAHD&F, ICAR, State A.H. Deptt., SAU/SVU	Continued
SPA4: Policies, Legislation, Institutions and Capacity Building		
Formulating/reviewing National and State Livestock Policies	DAHD&F, State A.H. Deptt.	Every 5 years
Developing legal framework for protection of Livestock Keepers' Rights	DAHD&F, ICAR, State A.H. Deptt., SAU/SVU	Urgent
Capacity building to support management and conservation of AnGR	ICAR, DAHD&F, State A.H. Deptt., SAU/SVU	Continued
Creating national and state fund for conservation of AnGR	DAHD&F, State A.H. Deptt.	Urgent

Biodiversity for Climate Resilient Livestock Production in North-Eastern India

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Introduction

North-East region of India constitutes 5.2 per cent of the total geographical area endowed with rich biodiversity. This region depicts the faunistic and floristic resemblance of Indo-Malayan and Indo-Chinese bio-geographical regions. The North-Eastern region of India stands out as a biodiversity hotspot, renowned for its rich natural resources, varied ecosystems, and unique agro-climatic conditions. This blend of biodiversity and environmental complexity is crucial for sustaining the livelihoods of local communities, especially those engaged in livestock farming. With the growing challenges posed by climate change, the region's biodiversity is becoming increasingly important in enhancing the resilience of livestock systems to these changes. Incorporating biodiversity into livestock production not only sustains productivity but also promotes environmental sustainability, mitigates vulnerability to climate-induced stress, and strengthens the adaptive capacity of local farming practices. This article examines the significance of biodiversity in fostering climate-resilient livestock systems in North-Eastern India. It focuses on the role of indigenous livestock breeds, a variety of fodder resources, ecosystem services, and traditional knowledge in building resilience. Additionally, the article addresses the threats facing biodiversity in the region and outlines strategies for conservation to ensure sustainable livestock production amidst climate change.

Importance of Biodiversity in North-Eastern India

The North East India being one of the most remarkable hearths of biodiversity is the home of more than a thousand different species of flora and fauna widespread across the states of Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Tripura. The region is part of both "Himalaya" and "Indo-Burma" biodiversity hotspots. The region boasts a vast array of ecosystems, from tropical rainforests and alpine meadows to grasslands, wetlands, and river valleys. This rich ecological diversity creates ideal conditions for a wide range of plant and animal species, including native livestock breeds that have adapted to the region's diverse and often challenging climate. Biodiversity in this area plays a crucial role in supporting the livelihoods of its largely rural population which depend heavily on agriculture, forestry and livestock farming as key sources of income.

A. Indigenous Livestock Breeds

A key element of biodiversity in Northeast India is the presence of indigenous livestock breeds that have adapted exceptionally well to the local environment. These breeds have developed traits over time that enhance their resilience to the region's fluctuating and often harsh climate. Prominent examples include the Mithun *(Bos frontalis)*, Yak, and native breeds of cattle, buffalo, pig and poultry. These species have evolved in response to the area's unique geographical and climatic challenges, making them invaluable for sustainable livestock production in the face of climate change. For instance, the Mithun, native to the hilly terrains of Arunachal Pradesh, Nagaland, Manipur, Mizoram, and more recently spotted in Assam's Dima Hasao district, is renowned for its ability to navigate steep, rugged landscapes and graze on a variety of vegetation. In the face of climate change in the Eastern Himalaya, Mithun conservation could be an innovative alternative for the adaptation and resilience-building of rural people. Similarly, the Yak, found in the high-altitude zones of Sikkim and Arunachal Pradesh, thrives in extreme cold and low oxygen levels, making it a critical resource for communities in the Himalayan regions. These animals provide essential resources like meat, milk, hides, hairs, dung and the most needed transportation in the high hills contributing significantly to the socio-economic well-being of local communities. Indigenous poultry breeds such as the Miri, Daothagir and local duck varieties (Pati, Nageshwari) also exhibit higher resistance to diseases and thrive on minimal feed, reducing reliance on commercial farming inputs (Singh *et al.,* 2020).

The Lakhimi cattle, renowned for their resilience and ability to withstand the climatic and environmental challenges of Assam, are particularly important for local milk production. The Luit buffalo, another Indigenous breed, plays a dual role in Assam's agricultural economy by providing draught power for ploughing fields and offering milk for household consumption and local markets. Adapted to the waterlogged conditions of Assam's wetlands and flood-prone areas, this buffalo breed is highly valued for its ability to work efficiently in challenging terrains that would hinder other breeds. Similarly, the Wak Chambil pig of Meghalaya and the Manipuri black pig are integral to the livelihoods of indigenous communities, playing an essential role in household economies and traditional farming systems. The Wak Chambil pig, known for its disease resistance and adaptability, is raised under low-input systems, making it highly sustainable in Meghalaya's rural landscapes. It can thrive on locally available feed resources such as kitchen waste, wild roots, and foraged plants, which reduces the dependence on commercial feeds and lowers the cost of pig farming. This breed is highly prized for its ability to convert low-quality feed into quality pork, a staple protein source for many rural families in the region. The Manipuri black pig, thrives in Manipur's hilly terrains, feeding on local vegetation and waste, making it an environmentally sustainable choice for pig farmers. In addition to their economic value, both the Wak Chambil and Manipuri black pigs contribute to biodiversity by maintaining genetic diversity within livestock populations, which is crucial for building resilience against the threats posed by climate change and emerging diseases.

The grazing habits of Lakhimi cattle and Luit buffalo, for instance, help maintain grassland ecosystems and prevent the encroachment of invasive species. Similarly, the scavenging behavior of indigenous pigs helps manage underbrush in forested areas, reducing the risk of forest fires and contributing to the health of forest ecosystems. By maintaining these diverse livestock populations, Northeast India can protect the ecological services that are vital for both agriculture and environmental resilience. The loss of these indigenous breeds would not only diminish the genetic diversity of livestock in the region but also threaten the sustainability of local agricultural systems. In recent years, there has been a growing trend of replacing indigenous breeds with exotic ones in pursuit of higher productivity. However, this approach often leads to greater dependency on external inputs, such as expensive feed and veterinary care, and increases the vulnerability of livestock systems to climate variability. The introduction of exotic breeds also risks diluting the genetic traits that make indigenous breeds so valuable in terms of their adaptability to local conditions. Therefore, there is an urgent need to promote and support the conservation of these indigenous breeds through policies that encourage their breeding, sustainable management, and integration into modern farming systems.

B. Fodder Resources and Ecosystem Services

In addition to livestock diversity, the rich plant biodiversity of Northeast India plays a crucial role in supporting livestock production, especially through the provision of fodder. The region's forests, grasslands, and agroforestry systems are home to numerous native fodder plants, grasses, shrubs, and trees that are vital for livestock nutrition. Indigenous species such as broom grass *(Thysanolaena maxima)*, bamboo, and various legumes are especially important during lean seasons when conventional feed sources are scarce. These native plants are generally more resilient to the region's climatic conditions and require fewer inputs like water, fertilizers, and pesticides, making them highly valuable in the face of climate change. Extreme weather events such as droughts, floods, and irregular rainfall patterns can severely disrupt the availability of conventional fodder crops, but species like bamboo, which is abundant in the region, offer a sustainable and cost-effective feed alternative during dry periods (Patra & Lalhriatpuii, 2017).

The region's diverse ecosystems also provide essential ecosystem services that support sustainable livestock production. Healthy ecosystems regulate water cycles, prevent soil erosion, maintain pastureland quality, and contribute to carbon sequestration. These functions are particularly important in a region prone to heavy rainfall and landslides, where maintaining biodiversity helps stabilize soils, reduce runoff, and prevent land degradation. Wetlands and forested areas act as natural water reservoirs, ensuring a reliable water supply for livestock during droughts or periods of water scarcity (Das & Deka, 2014). These ecosystem services enhance the resilience of livestock systems to climate-related challenges and contribute to the long-term sustainability of agriculture in the region.

Role of Traditional Knowledge

Traditional knowledge, especially in biodiversity and livestock management, plays a crucial role in fostering climate-resilient livestock production in North-Eastern India. Indigenous communities in the region have developed sophisticated livestock management systems grounded in a deep understanding of their environment. These systems incorporate the use of indigenous livestock breeds, rotational grazing, and integrating livestock with crop farming, all of which promote sustainable resource use and environmental preservation. For instance, the Apatani tribe of Arunachal Pradesh practices a unique integrated farming system that combines rice cultivation with fish and livestock farming, maximizing resource use and enhancing resilience to climatic variability (Gogoi & Hazarika, 2018). Similarly, many indigenous groups use locally sourced medicinal plants to treat livestock diseases, minimizing the need for chemical inputs like antibiotics and pesticides. The reliance on local resources and the low-input nature of these traditional practices make them naturally resilient to climate change. Traditional knowledge of livestock management is invaluable in adapting farming systems to evolving environmental conditions. By merging this indigenous knowledge with modern scientific methods, farmers in North-Eastern India can create more sustainable and resilient livestock systems capable of withstanding the challenges of climate change.

Challenges to Biodiversity and Livestock Production in North-Eastern India

Despite the critical importance of biodiversity for climate-resilient livestock production in North-Eastern India, several challenges threaten the sustainability of these systems. These challenges include habitat loss, deforestation, land-use changes, the introduction of exotic breeds and fodder crops, and the impacts of climate change itself.

A. Habitat Loss and Deforestation

Deforestation and habitat loss pose significant threats to biodiversity in this region. The forests in the region, which offer critical fodder resources and ecosystem services, are being cleared at an alarming rate due to agricultural expansion, infrastructure projects, and urbanization. This not only diminishes the availability of essential fodder but also disturbs the fragile ecological balance that underpins livestock production. Furthermore, the reduction in forest cover worsens the effects of climate change by decreasing the area's ability to absorb carbon dioxide and maintain local climate stability (Lalrinsanga *et al.,* 2019).

B. Introduction of Exotic Breeds and Fodder Crops

The introduction of exotic livestock breeds and fodder crops is another significant threat to biodiversity in the region. While exotic breeds such as Holstein-Friesian cattle and commercial poultry may offer higher productivity in terms of milk or meat, they are often poorly adapted to the local environment and require intensive management, including higher feed inputs, veterinary care, and climate control. These breeds are also more vulnerable to diseases and climatic stresses, making them less suitable for climate-resilient farming systems. Similarly, the cultivation of exotic fodder crops such as hybrid grasses and maize for silage has led to a reduction in the cultivation of indigenous fodder species. This not only erodes the region's plant biodiversity but also increases the dependency on external inputs such as fertilizers, pesticides, and irrigation, which can be unsustainable in the long term (Das & Deka, 2014). In contrast, indigenous livestock breeds and fodder plants are better suited to the local environment and require fewer external inputs, making them more sustainable options for climate-resilient livestock production.

C. Climate Change

Climate change presents a significant threat to livestock production in North-Eastern India. The region is experiencing rising temperatures, unpredictable rainfall, and an increase in extreme weather events such as floods, droughts, and landslides. These climate changes directly affect livestock production by reducing water and fodder availability, increasing disease outbreaks, and negatively impacting the reproductive health of animals. For example, higher temperatures can cause heat stress in livestock, leading to decreased feed intake, slower growth rates, and lower milk production. Heat stress also compromises the immune systems of animals, making them more vulnerable to diseases. Additionally, irregular rainfall and prolonged droughts contribute to water shortages and a decline in fodder supply, often forcing farmers to depend on costly commercial feeds (Singh *et al.,* 2020). These challenges are especially difficult for smallholder farmers who have limited resources to adapt to these climate-related pressures.

Challenges in biodiversity conservation and policy implementation

Biodiversity conservation is critical for ensuring climate-resilient livestock production in this region, where diverse ecosystems and indigenous livestock breeds contribute to the region's ability to withstand climatic changes. However, the region faces numerous challenges in conserving biodiversity and effectively implementing policies that promote climate-resilient livestock systems. Below are some key challenges:

1. Fragmented Policy Implementation

Despite existing policies and programs aimed at conserving biodiversity and promoting climate-resilient agriculture, implementation on the ground is often weak and inconsistent. There is a significant gap between policy formulation at the national or state level and actual on-ground execution, especially in remote areas of Northeast India. Local communities may not be aware of or actively engaged in these initiatives, leading to reduced impact.

2. Insufficient Integration of Traditional Knowledge

Indigenous communities possess deep knowledge of local breeds and sustainable livestock-rearing practices, which have evolved to cope with the region's challenging climatic conditions. However, policies often fail to incorporate this traditional knowledge into modern conservation and livestock development programs, resulting in the loss of practices that promote biodiversity and resilience.

3. Lack of Focus on Indigenous Breeds

Indigenous livestock breeds, such as the Mithun (*Bos frontalis*), are well-adapted to the region's unique climatic conditions. These breeds play a vital role in maintaining biodiversity and ensuring livestock resilience. However, there is often more focus on introducing high-yield exotic breeds that may not be well-suited to local conditions. This shift can lead to the erosion of genetic diversity and reduce the adaptability of livestock systems to climate stressors.

4. Deforestation and Habitat Loss

Livestock production often depends on forest ecosystems, which provide grazing areas, fodder, and water resources. However, deforestation driven by agriculture expansion, infrastructure development, and illegal logging reduces the availability of these resources. Habitat loss also directly impacts wild biodiversity, which supports ecosystem services essential for livestock production, such as pollination and soil health.

5. Overgrazing and Land Degradation

Overgrazing by livestock can lead to land degradation, loss of vegetation cover, and reduced soil fertility. In Northeast India, where pastoral systems are common, unsustainable grazing practices reduce the resilience of ecosystems. Degraded lands are less capable of supporting biodiversity and are more vulnerable to climatic changes such as droughts or heavy rains, further affecting livestock production.

6. Inadequate Conservation of Pastureland

A significant proportion of livestock in the region depends on common pasturelands for grazing. However, these grazing lands are often poorly managed, with limited investments in their conservation or improvement. The degradation of pastureland reduces the availability of high-quality fodder, which is essential for livestock productivity and biodiversity conservation.

7. Climate Change

Changes in rainfall patterns, increasing temperatures, and more frequent extreme weather events impact forage availability, water resources, and the health of livestock. Climate-induced changes in ecosystems also affect the distribution of diseases and pests, which can devastate livestock populations. Current policies often do not sufficiently address the need for climate-adaptive strategies that integrate biodiversity conservation and livestock production.

8. Weak Institutional Capacity

Effective biodiversity conservation and the promotion of climate-resilient livestock production require strong institutions that can coordinate between government agencies, local communities, NGOs, and research institutions. In many parts of Northeast India, institutional capacity is weak, leading to poor enforcement of biodiversity protection laws and inadequate support for sustainable livestock farming practices. Additionally, the region's remote and difficult terrain makes it challenging to implement and monitor conservation programs.

9. Limited Research and Data

The lack of comprehensive research and data on biodiversity in Northeast India, especially related to livestock production, is a major challenge. The region's unique ecosystems and diverse species are under-researched, making it difficult to develop evidence-based conservation strategies. Similarly, there is insufficient data on the performance of indigenous livestock breeds under changing climatic conditions, which hampers efforts to promote climate-resilient livestock production.

10. Socio-economic Pressures

High levels of poverty and dependence on agriculture and livestock for livelihoods in rural areas create pressure on natural resources. Local communities often prioritize short-term economic gains over long-term sustainability, leading to over-exploitation of forests, overgrazing, and poaching. Policies aimed at biodiversity conservation must balance the need for conservation with the economic needs of local populations, which is often a complex and challenging task.

11. Market-Driven Challenges

Market demands for high-yield livestock products can push farmers to adopt intensive livestock rearing practices, which often rely on non-native species and feed that are not sustainable in the long term. This can lead to a reduction in the use of indigenous breeds, loss of biodiversity, and increased vulnerability to climate change.

12. Transboundary Issues

Northeast India shares international borders with several countries, including Bhutan, Bangladesh, and Myanmar. Biodiversity conservation and livestock management efforts often face challenges due to several issues such as illegal wildlife trade, deforestation, and movement of livestock, which can introduce diseases and invasive species. These challenges require international cooperation, which is often difficult to achieve.

Moving Forward: Strategies for Overcoming Challenges and Conservational Strategies

- **Conservation of Indigenous Livestock Breeds**: Prioritizing the preservation and promotion of indigenous livestock breeds, which are naturally adapted to the local climate and environmental conditions. Breed conservation programs, gene banks, and community-level breeding initiatives can enhance climate resilience and reduce the need for external inputs.
- **Sustainable Land Use and Agroforestry Systems**: Implementing agroforestry and integrated land-use systems that combine livestock farming with forest conservation. This can promote biodiversity while providing shade, reducing soil erosion, and enhancing forage availability for livestock, especially in hilly terrains.
- **Integration of Traditional Knowledge**: Leverage the traditional ecological knowledge of indigenous communities regarding biodiversity, natural resource management, and livestock care. Supporting community-led conservation programs that incorporate these practices to create sustainable, resilient livestock farming systems.
- **Climate-Smart Agricultural Practices**: Promoting climate-smart livestock farming techniques, such as rotational grazing, zero-grazing systems, and the use of climate-resilient fodder crops.
- **Enhanced Policy Support and Institutional Framework**: Strengthening the policy framework to support biodiversity conservation in livestock production. Providing incentives for farmers practicing sustainable methods, improving access to resources, and promoting cross-sectoral collaboration between government agencies, research institutions, and local communities for effective conservation strategies.

Conclusions

Climate-resilient livestock production in North-Eastern India is gaining importance. The region's indigenous livestock breeds, diverse fodder resources, ecosystem services, and traditional knowledge provide the foundation for farming systems that are more adaptable to the changing climate. However, the biodiversity of the region is under threat from habitat loss, the introduction of exotic species, and the impacts of climate change itself. To ensure the sustainability of livestock production in the region, it is essential to implement conservation strategies that protect and enhance biodiversity. These strategies should focus on the conservation of indigenous livestock breeds, the sustainable management of natural resources, and the integration of traditional knowledge with modern scientific practices. By adopting these approaches, North-Eastern India can continue to support climate-resilient livestock production that sustains the livelihoods of its people while protecting its rich natural heritage.

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Management of Livestock Biodiversity in Northeastern Region of India: Participatory and Partnership Approach

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North Eastern Region of India is the homeland of biodiversity in animal genetic resources and representing a unique agro-ecosystem with integrated subsistence low input tribal production system where farm animals play a role in improving the socio-economic status and livelihood of the people. The North-Eastern region of India is one of the major biodiversity hotspot in the world. This region is not only contributing plant diversity but also represent a huge diversity in animal genetic resources. The unique domestic species like Yak, Mithun and wild species like one-horn Rhino and Pigmy hog are the heartthrob of this region and well known globally. The Region of India lies between 21.5^{0}N to 29.5^{0} N latitude and 85.5^{0} E to 97.5^{0} E longitude and comprising the states of Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. It occupies about 8% of total land area and 4% of total population of the country (Census of India 2011). This region has a unique agroecosystem such as high annual rainfall (2500-3000 mm), subtropical to alpine climate, undulated and hilly terrain with the altitude ranges from 1000 to 3000 meters above the mean sea level. About 65.59 per cent of the geographical area covered by forest which mostly under private or community ownership. This unique geographical location leads to diversity in animal genetic resources and its production system. By and large, this region practices integrated subsistence low input tribal production system where livestock and poultry play a complementary and vital role in improving the socio-economic status and livelihood of the people.

North Eastern Region of India is the homeland of diverse animal genetic resources including cattle and buffalo, sheep and goat, pigs, horse, ponies, yaks, mithun and poultry. The total livestock and poultry population of this region is about 70.13 million, which includes13.29 million cattle, 0.58 million buffalo, 0.57 million sheep, 7.85 million goat, 3.95 million pig, 23 thousands horse and pony,1 thousand mule, 2 thousands donkey ,18 thousands yak, 0.30 million mithun and 43.53 million poultry. Among them, 92.76 % are indigenous population and remaining is crossbred population (Table 1). Although there are 169 registered breeds of livestock and poultry in India. This region has only 15 registered breed which include two cattle, one goat, four pig, two horse and ponies, one yak, four chicken and one duck breed (NBAGR, 2024). Besides many uncharacterized farm animal breeds/populations are reared by tribal farmers in the region, which described as indigenous local. The diversity of domesticated livestock and poultry breeds was developed due to years of evolution within a specific niche as a result of adaptation and selection. These indigenous animal genetics resources are playing vital role in food and livelihood security of the people and maintaining genetic diversity in the ecosystem. These indigenous animals are able to survive and perform reproduce in adverse agro climatic condition even in low or and zero input production system. The objective of this review is to enumerate the farm animal genetic resources of region and their descriptions, unique features, utility and importance which will be an important aspect for conservation strategies and breeding policy issues in the region of India.

Table 1 :Share of major Indigenous livestock and poultry population in NE region in India

Species	National Level				NE Region		
	Total (million)	Indigenous (million)	% of share		Total (million)	Indigenous million)	% of share
Cattle	190.90	151.17	79.19		13.29.	12.39.	93.24
Sheep	65.06	61.28	94.19		0.57	0.55	96.82
Pig	10.29	7.83	76.14		3.95	2.15	54.43
Poultry	511.71	217.49	42.51		43.53	41.17	94.58
Buffalo	-	108.70	100		-	0.57	100
Goat	-	135.17	100		-	7.85	100
Horse & pony	-	0.62	100		-	0.023	100
Total	**1023.37**	**683.18**	**66.76**		**70.13**	**65.05**	**92.76**

(including yak, mithun, donkey)

Source : 19th Livestock census 2012

Conservation of for indigenous animals

The indigenous farm animals are the result of long evolutionary processes. However, their population size is declining because of genetic dilution due to crossbreeding and facing degeneration. Some of the indigenous breeds or populations like Bonpala sheep, Manipuri pony, Doom pig and all the indigenous poultry breeds of this region are under risk of extinction. So conservation program for protection of this indigenous animal become urgently needed in this region of India.

Conservation policy

The government of India as well as all the state government of North-Eastern state has been implemented many scheme and policy for conservation of indigenous animals. For example National Programme for Bovine Breeding (NPBB) initiated in 2014 to conserve, develop and proliferate selected indigenous bovine breeds of high socio-economic importance. The Assam Livestock Development Agency (ALDA) is a state implementing agency of NPBB launch programme for local Swamp Buffalo improvement and conservation with the establishment of a nucleus farm at Barhampur(Assam). Similarly National Livestock Mission was launched in the year 2014-15 for piggery development in North Eastern region of India. The government of India sanctioned a project in 2011 for conservation Banapala sheep. Accordingly a nucleus farm was established in west for propagation of this threatened germplasm. The government of Manipur implemented conservation policy for Manipuri Pony in 2016. This policy includes development of a breeding tract for Manipuri pony and complete banned of cross breeding of Manipuri Ponies till the population stabilized with the participation of local community. This policy also facilitates cryo-preservation of semen of good pedigree stallions for *ex-situ* conservation. In poultry, Rural Backyard Poultry Development (RBPD) Programme was launched in NE states in 1999-2000 for conservation of local indigenous birds by increasing hatching, brooding and strengthen the poultry farms. However, the conservation scheme or policies implemented for only a few indigenous breed/population of this region. So it is very much essential to established suitable breeding policy and conservation strategies for each indigenous animal breed/population to protect the indigenous animal biodiversity of North Eastern region of India.

Conservation strategies

The conservation of indigenous farm animals should be done by two way viz., in-situ conservation and ex-situ conservation. For In-situ conservation each state department of NE region should work in joint hand in collaboration with central agencies for identification, documentation and registration of each indigenous breed available in this region. The proposed strategy of conservation of indigenous animals of NE region of India is given in Fig 1. The state department should establish organized/nucleus breeding farm for each indigenous breed/ populations at different places with in their breeding habitat. Community participation plays a key role in in-situ conservation of indigenous animals of this region as because majority of the land of this region are community based and most of the indigenous breeds are associated with particular community. The state and central agencies should facilitate community-based conservation with sustainable and valuable use of indigenous animal in this region. This could be done by creating awareness and capacity building of the local community of this region through technical and institutional supports mechanism.

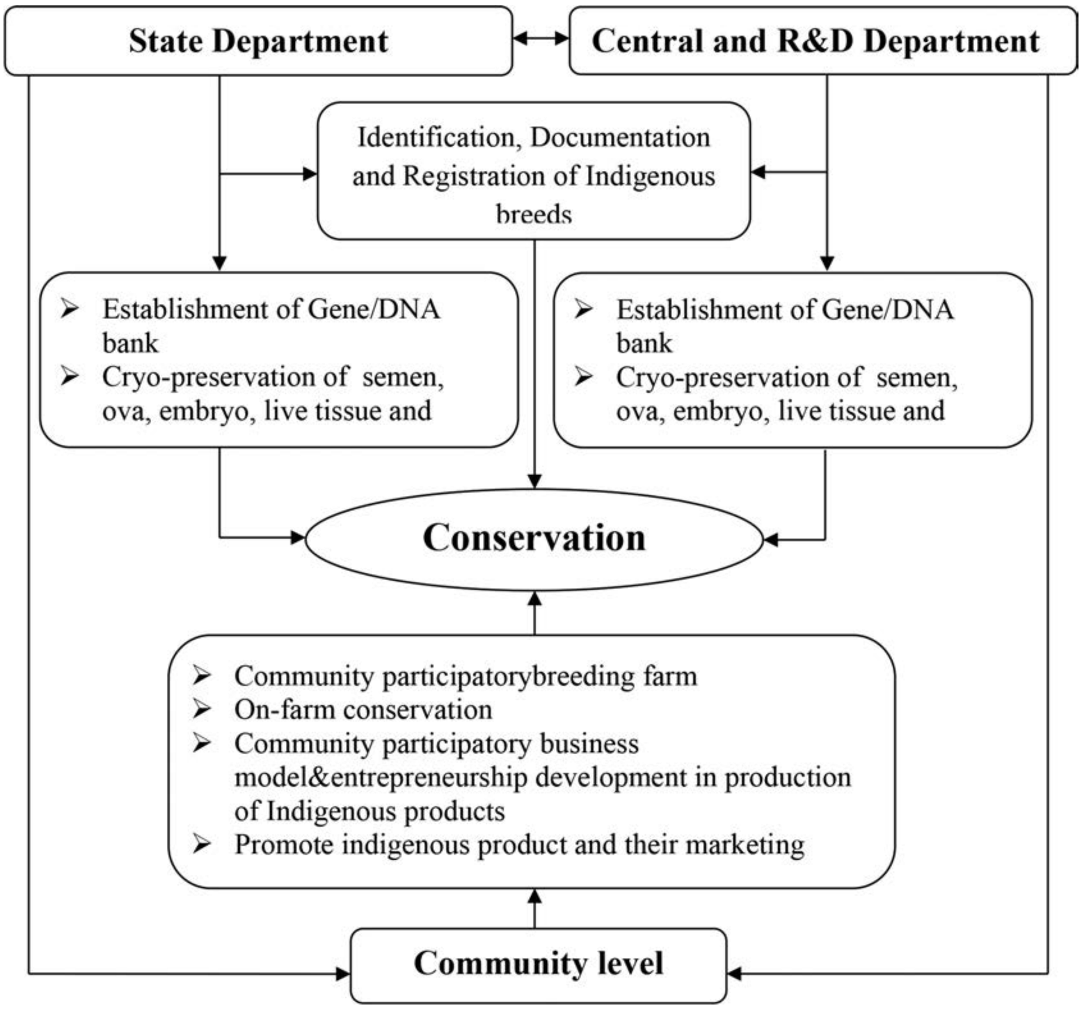

Fig. 1 : Strategies for conservation of Indigenous animal (Kadirvel *et al.,* 2019)

The farmer/community of this region should be provided incentives to enhance their attention and interest in rearing of indigenous animals. Establishment of community breeding farm and supply of pure germplasm at village level for propagation of indigenous animals, development of community participatory business model to promote indigenous animals product and entrepreneurship development through training on value addition in indigenous animal product, their packaging, leveling, branding and marketing will be prerequisite for community based conservation in this region. This community participation will provide long term benefit for conservation of indigenous animals of NE region of India.

For ex-situ conservation the R&D institute of this region in collaboration with state and central agencies should established organized animal research stations for each indigenous animal breeds at different location for scientific study. In vitro conservation of genetic material such as cryopreservation of semen, oocytes, embryo, stem cell, live tissue, cells *etc*. for each indigenous breed of this region and their periodic evaluation is warranted. The R&D institute of this region such as Assam Agricultural University, Central Agricultural University-Manipur, ICAR-RC for NEH region should create gene/DNA bank for indigenous livestock and poultry breed of this region for future purpose. The R&D institute should also conduct extensive research through application of modern biotechnology to regeneration the endangered breed endangered breed of this region.

The farm animal genetic resources of this region possess few unique features that are important in the aspect of socio-cultural significance of the local people that distinguished themselves from the farm animals in others parts of the country. Although, these farm animals play a major and significant role in the in income and livelihood of local people, but these indigenous animals are poor productive when compared to the crossbred animals. Thus the farmers motivated to rear crossbred animals. The introduction of exotic germplasm and unrestricted crossbreeding become a threat for the many indigenous germplasm resulting decline of their population. Therefore precise and reliable estimation and evaluation of different important economic and climate resilient traits of indigenous germplasm and their genetic characterization, documentation and registration is necessary. Control breeding strategies to be adopted to restrict the genetic dilution through indiscriminate crossbreeding of native breed and implementation of strict policy from central & state agency and institutional support mechanism to facilitate *in-situ* conservation and promote community participation in the conservation measures. The farmer/community should be provided incentives to enhance their attention in rearing of indigenous animal as the awareness and interest of the farmers/community. Application of conventional and modern biotechnological tool in *ex-situ* conservation of sperm cell, ova, embryo and stem cell in collaboration with research institutes, central and agencies are essential for conservation of indigenous livestock and poultry in the north-east region of India.

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Sheep and Goat Genetic Resources of North-Eastern India

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North-East India comprising eight states shares international borders of 5182 km with Bhutan, Nepal, Myanmar, China and Bangladesh. The region is covered by eastern Himalayan and Patkai range of mountain and the mighty Brahmaputra and Barah river system. The altitude varies from less than 100 feet from mean sea level to over 23000 feet above mean sea level. The altitudinal differences coupled with varied physiography contribute to climatic variation in the region, which varies from sub-tropical to Alpine. The region due to heavy rainfall has very high humidity varying from 42 to 92 per cent in different seasons.

The entire North-East region of India possesses a large variety of livestock genetic resources and is maintained mostly in the rural and semi-urban areas with small land holdings and the animal husbandry sector plays a vital role in the income generation of both rural and semi-urban economy. The native goat and sheep dwell in the natural environment and have not so significant history of selection for their genetic improvement. They thrive well in low input systems and under existing management system their productivity can not be considered inefficient. They are capable of withstanding harsh climatic conditions as well as scarcity of feeds and fodder. Sheep are raised by communities in Sikkim and Arunachal Pradesh mostly on nomadic management system throughout the year in search of grazing. However, in Assam and Meghalaya, sheep are reared for mutton by economically weaker section of people and other communities involved in agriculture.

Genetic diversity is necessary for the long-term survival of the populations for adaptation and evolution, when environmental conditions have changes. Though the region is rich repository of goat and sheep genetic resources, till date only two goat and two sheep breeds have been registered. A good number of non-descript populations are yet to be characterized. Identification and characterization of livestock genetic resources is essential as the genetic diversity has been providing the material for successful breed conservation and improvement programme.

According to 20th Livestock census (2019), the North eastern region possesses of 0.4 million sheep and 148.88 million goat. Assam is the parent state amongst the states of north eastern region to have the highest sheep (0.03 million) and goat population (4.31 million). The ratio of sheep and goat owned by the populace of north eastern India is one sheep against 13 goats.

A. Sheep breeds: There are two registered sheep breeds in North eastern India.

i) Bonpala: Bonpala a dual purpose sheep breed native to Sikkim (Vij *et al.,* 2011). It is registered at ICAR-NBAGR, Karnal with accession number INDIA_SHEEP_2200_BONPALA_14034. It got its name from *Bon* means forest and *Pala* means home. They are reared as migratory animal under an extensive management system. Generally, they are reared in zero input system. Usually, they thrive by eating jungle vegetation. Proper housing is not common. They are provided only supplement that is salt. Bonpala are found to be completely white to completely black and have generally mixed colour of black and white. Bonpala tall, leggy, well–built animals. Their nose is typically of roman type, which is more prominent in males. Ears are small and tabular. Belly and legs are devoid of wool. Male animals are endowed with thick horn, usually curved backwards, twisted forward and outward.

The breed is popular for excellent reproductive performance with age at puberty occurring around 6 months and first lambing occurring around 11–12 months. Lambing size varies from single to triplets. The wool quality is coarse and carpet type. (https://www.leafconagro.com). The average fibre diameter, fibre length and medullation percentage are 54 ±1.28 micron, 9.86 ±0.95 cm and 90.87 ±2.8 % respectively. The adult body weight (1-3 years) in male and female is 51.6 ±0.76 and 44.1±0.37kg (Bhutia *et al.* 2006)

Fig. 1. Female Bonpala sheep

Fig. 2. Male Bonpala sheep

Fig. 3. Flock of Bonpala (Salt feeding)

Courtesy: ICAR, NBAGR database

i) Tibetan: The Tibetan sheep breed is native to North Sikkim and Arunachal Pradesh (Tawang district). It was registered at ICAR-NBAGR, Karnal in the year 2019 with accession number INDIA_SHEEP_2300_TIBETAN_14038. They are locally known as "*Luk*" meaning Goddess Laxmi (Goddess of wealth) by the nomadic highland herdsmen in North Sikkim (Kumar *et al.,* 2016). They are well adapted to harsh agro-climatic conditions like complete snow-bound pasture land. Tibetan sheep play a key role in sustaining the production system and maintaining balance in high altitude agro-ecology along with yak (Kumar *et al.* 2015). They are medium sized animals, mostly white with black or brown faces and brown and white spots on the body. Males are horned having medium sized spiral horns running upward, downward and upward with a sharp tip. The nose line is convex, giving a typical Roman nose. The ears are small, broad and drooping. The belly, legs and face are devoid of wool. They are reared for meat and wool. Carpets made of Tibetan sheep are one of the best quality in the world. Lambing occurs mostly from February to March and the Dokpas shear lambs at the age of 6 months (Kumar *et al.,* 2017). Animals are shorn twice a year (April/May and October/November) with average greasy fleece weight per clip ranging from 400 to 900 gm. The average staple length of wool is 7.24 ± 0.11(cm), Medullation (%) is 19.30 ± 0.64 and the average fibre diameter (μ) is 13.22 ± 1.25. Adult sheep weight goes to an average of 26.20 ± 0.45 kg (ICAR-NBAGR database).

Fig. 4. Female Tibetan sheep

Fig.5. Male Tibetan sheep

Fig. 6. Flock of Tibetan sheep

Courtesy : ICAR, NBAGR database

iii) Indigenous sheep of Assam : Indigenous sheep of Assam are distributed predominantly in Dhubri, Barpeta, Darrang, Kamrup, Bongaigaon and Goalpara districts of Assam. It is mainly reared for meat. The males are generally horned and the females are polled. The predominant coat colour of the sheep is light brown (52.94 per cent) followed by brown (31.28 per cent) and mixed colour (15.78 per cent) with the combinations of brown, black, white, and light brown, brown, black and white. The average adult body weight is 13.457 ± 0.27 kg. Horns are thick at the base, curved backward and downward with tapering ends. They are very prolific. The mean lamb size is 2.3 with type of lambing observed to be 25.79% singlet , 67.98% twin , 4.96% triplet and 1.27 % quadruplet (Nath, 2018).

Fig.7. Indigenous sheep of Assam

B. Goat breeds: There are two registered goat breeds in North eastern India.

i) Assam Hill Goat: Assam hill goat is native to the hill agro-climatic region of Assam and adjoining areas of Meghalaya. It was registered at ICAR-NBAGR, Karnal with accession number INDIA_GOAT_0213_ ASSAMHILL _06031. It is considered as one of the most prolific, small sized and meat type goat breed. It is very popular among the rural farmers due to its ability to adopt wide range of environmental conditions with lower disease incidence and better meat quality. They are usually white with occasional black patches on backline and legs. These goats are short legged with small body size. Both buck and does are bearded. Ears are medium in size, horizontally placed with pointed tips. Tail is short and hairy. The body weight at birth is 1.19+0.24 kg and adult weight is 15-26 kg. Age at first kidding ranged from 13.34 months. The average litter size is 1.56. Kidding interval is 7.63 months. Twinning and triplets are high. Litter Size ranged from 1 to 4 (ICAR , NBAGR database) The percentage of single, twin and triplets were 60.76, 34.93 and 4.31 respectively. (Bora *et al.*2014).

Fig. 8. Female Assam Hill goat

Fig. 8. Male Assam Hill goat

ii) Sumi-Ne: Sume Ne is native to Zunheboto district of Nagaland. It has been registered at ICAR-NBAGR, Karnal with accession number 'INDIA_GOAT_1400_SUMINE_06028 in the year 2017. *Sumi* is a tribe in Nagaland and *'ne'* means goat in Sumi dialect. Hence, goats reared by Sumi people are known as 'Sumi-ne.' These goats are mostly reared in extensive and semi-extensive management system. Long silky fibers obtained from these goats are used by local people for making traditional items with socio-cultural significance. The goats are reared by tribal people mainly for meat, coarse fiber and skin. These goats are predominantly black (head and neck) and white (remaining parts) colour. Animals with brown coat mixed with gray hair also exists. Average adult body weight is 16.18 kg in male and 13.5 kg in female. Average fleece weight (kg/year) is 0.197, Staple length(cm) is 15.55 , Fibre diameter(μ) is 225.56 and dressing percentage is 47. An adult goat can yield fibre ranging from 187 to 207 g with mean 197.33 g (Sheetal 2016).

Fig.9. Female Sumi-Ne goat

Fig.10. Male Sumi-Ne goat

iii) Shinghari: Shinghari is a native goat of Sikkim, these goats are medium-sized with compact body predominantly brown/light brown. The distinct feature is white to whitish brown stripes on face extending from the bone of the horn to the muzzle. As per the 19th livestock census, the goat population was 90,500 all over the state, further the 20th Livestock Census revealed 20.16 % decline in their population. The sad state of affairs is that amongst this recorded goat population of Sikkim, the strength of Shinghari goats is still not known.

Fig.11 Shinghari goat

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Genomics and Conservation of Indigenous Animal Breeds

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Introduction

Livestock resources play a crucial role in human survival and the development of civilization. In addition to providing milk, meat, eggs and fuel, around two billion people (one third of the global population) depend on farm animals for their livelihoods (Eusebi *et al.,* 2020). It is a vital component of our agricultural system, providing nutritional sustenance and additional income to the country's population. The contribution of livestock to the total GVA (gross value added) in agriculture and allied sectors increased from 24.32 per cent in 2014-15 to 30.38 per cent in 2022-23. The livestock sector contributed 4.66 percent of total GVA in 2022-23 (https://pib.gov.in). It is worth mentioning that India possesses vast animal genetic resources which include 536.36 million livestock and 851.81 million poultry. There are 220 registered indigenous livestock and poultry breeds including 53 for cattle, 1 for synthetic cattle, 20 for buffalo, 39 for goat, 45 for sheep, 8 for horses & ponies, 9 for camel, 14 for pig, 3 for donkey, 3 for dog, 1 for yak, 20 for chicken, 3 for duck and 1 for geese. The species-wise population and registered breeds of different species are summarised in Table 1.

Table 1. Species wise population and registered breeds of animals in India

Sr. No.	Species	No. of breeds registered till now	Total Population (million)
1	Cattle (including synthetic)	54	193.46
2	Buffalo	20	109.85
3	Sheep	45	74.26
4	Goat	39	148.88
5	Pig	14	9.06
6	Camel	09	0.25
7	Horse	08	0.34
8	Chicken	20	851.81
9	Donkey	03	0.12
10	Yak	01	0.058

The significance of conserving animal genetic resources has long been recognized and remains a priority at the national and international level. Livestock breeds have evolved through a combination of mutation, genetic drift, and selective pressures imposed by local environments, endemic diseases, available feed resources and human selection. These factors have shaped unique genetic architectures, making them crucial for preservation. India is known for its rich diversity in livestock genetic resources, and boasts traits like disease resistance, adaptability to local climates, and sustainability in low-input systems. The recent changes in socio-economic status, low production levels in native breeds, and the introduction of exotic germplasm have further heightened the risk of genetic erosion among indigenous livestock breeds of India. These factors may affect the long-term sustainability of livestock production systems.

During the last few decades, there has been a significant and alarming decline in livestock species, with roughly 200 uniquely adapted breeds becoming extinct. Currently, an estimated 30% of the world's livestock breeds, approximately 1,200 to 1,500, are in endangered risk status (FAO, 2015). Further, it is necessary to highlight that *if sufficient within-species genetic diversity is not conserved, the ecological and economic effects will be widespread and catastrophic* (Hoban *et al.,* 2013). Therefore, it is essential to conserve animal genetic resources with a focus on prioritizing selection strategies that meet current needs, such as adapting to changing environments, improving immune responses, and aligning with evolving consumer preferences. In addition, conserving animal genetic diversity in livestock populations is to safeguard against the loss of valuable genetic traits in locally adapted populations, which hold significant socio-economic, cultural, historical, and ecological importance.

Genomic tools for conservation of Animal Genetic Resources

The recent advancements in molecular genetics have enabled the direct analysis and measurement of genomic diversity, moving beyond reliance on statistical estimates from pedigree data. This is achievable even in populations or breeds lacking detailed records at the field level. *A marker is defined as stable and inherited variation that can be detected by suitable technique and subsequently can be used to identify specific genotype other than itself which is otherwise difficult to detect.* These markers nowadays not only for assessing a population's genetic diversity but also for exploring genetic relationships between different populations. In addition, molecular genetic markers are considered as powerful tool for genome analysis and facilitating the investigation of how heritable traits are linked to underlying genomic variations. Presently, genetic diversity parameters can now be directly estimated from DNA, providing precise insights into the genetic variations that exist between and within breeds, populations, and individuals.

In the past years, microsatellite markers have been extensively used for population genetic parameters estimation, parentage verification, individual identification, and breed assignment in domestic animals (Ginja *et al.,* 2019). The microsatellite analysis led to a significant advancement in the analysis of genetic diversity. However, in the past decades, modern genetic analysis has significantly advanced with the introduction of high-throughput sequencing technologies and SNP genotyping platforms, enabling the generation of genomic data such as single nucleotide polymorphisms (SNPs). SNPs are single-base mutations in the genome sequence found in both coding and non-coding regions, allowing for the study of both neutral and functional genetic variation. Their widespread use in livestock genetics is attributed to their affordability, automation, and high prevalence in domestic animal genomes. Presently, commercial SNP arrays are available for most of the livestock species, providing genome-wide coverage of genetic variants.

Whole Genome Sequencing

Whole genome sequencing (WGS) is revolutionizing the conservation of animal genetic resources by providing comprehensive insights into the genetic diversity of the population. It enables the detailed analysis of genetic variation within and between populations, aiding in the identification of unique genetic traits and evolutionary lineages. This information is crucial for developing targeted conservation strategies, such as managing breeding programs to avoid inbreeding and preserving genetic diversity. Overall, WGS supports informed decision-making, enhancing the effectiveness of conservation efforts and safeguarding animal biodiversity.

SNP Genotyping

SNP genotyping plays a vital role in conserving animal genetic resources by providing a high-resolution tool to assess genetic diversity and population structuring. Single nucleotide polymorphisms (SNPs) are genetic markers that help identify variations across populations, allowing conservationists to monitor genetic health and detect signs of inbreeding or loss of diversity. SNP genotyping also facilitates the tracking of genetic changes over time, ensuring that conservation efforts adapt to evolving challenges and support long-term species survival. For SNP genotyping, commercial SNP arrays are available for various livestock species for assessing the genomic diversity in the population. A commercially available platform such as Illumina and ThermoFisher provides a robust tool for SNP genotyping

ddRAD sequencing

ddRAD sequencing (double digest Restriction-site Associated DNA sequencing) is a powerful tool for SNP discovery and genotyping. It helps in conserving animal genetic resources by providing detailed insights into genetic diversity and population structure. This method targets specific regions of the genome using restriction enzymes, generating a comprehensive snapshot of genetic variation across populations. Additionally, ddRAD sequencing is a low-cost methodology and covers less portion of genome as compared to WGS Further, ddRAD sequencing aids in designing targeted conservation strategies, such as optimizing breeding programs and protecting genetic resources against threats and environmental changes.

Epigenome sequencing

Epigenome sequencing is a cutting-edge approach that enhances the conservation of animal genetic resources by mapping epigenetic modifications, such as DNA methylation and histone modifications. These modifications influence gene expression without altering the underlying DNA sequence and can provide insights into how animals adapt to environmental changes and stressors. By analyzing the epigenomic data, conservationists can identify epigenetic markers associated with adaptive traits and environmental resilience. This information helps in understanding how genetic expression is regulated in response to conservation challenges. Ultimately, epigenome sequencing supports more informed and dynamic conservation strategies, ensuring that both genetic and epigenetic diversity are preserved for future generations.

Microsatellite genotyping

Microsatellite genotyping is a robust technology and instrumental in conserving animal genetic resources by providing detailed insights into genetic variation and population structure. Microsatellites are short, repetitive DNA sequences, that serve as highly informative markers for assessing genetic diversity, gene flow, and population dynamics. Microsatellite genotyping allows researchers to identify genetic bottlenecks, inbreeding levels, and population fragmentation. By tracking these genetic parameters, microsatellite genotyping aids in designing effective management strategies, such as establishing conservation priorities and facilitating gene flow between isolated populations. This approach enhances the ability to maintain or restore genetic diversity, crucial for the long-term survival and adaptability of animal species. Recently, genetic diversity of conserved cattle and buffalo bulls at National Gene Bank, ICAR- National Bureau of Animal Genetic Resources, Karnal was evaluated. This study revealed that excessive genetic diversity is being stored in the National Gene Bank (Kumar *et al.,* 2024)

Estimators of genetic diversity and inbreeding

The measures of genetic diversity and inbreeding from molecular data include key parameters such as observed and expected heterozygosity, allelic diversity or the number of polymorphic alleles per locus, and runs of homozygosity.

1. Genetic diversity

The most commonly used indicator of diversity is the expected heterozygosity (*He*) (Nei, 1973). It is defined as the probability that two alleles chosen at random from a population are different. In addition, it may also be defined as the proportion of heterozygous individuals in a population at HW equilibrium with the same allelic frequencies as observed in the actual population (Mäki-Tanila *et al.,* 2010). Further, Observed Heterozygosity (H_0) is also estimated along with the expected heterozygosity. Observed heterozygosity (HO) is defined as the proportion of heterozygous individuals within a population. It is negatively correlated with inbreeding depression, which refers to the reduction in trait performance caused by the expression of harmful recessive alleles in homozygous individuals. Previously, genetic diversity was assessed using pedigree records to calculate the coefficient of inbreeding and kinship, which estimate the proportion of the genome expected to be identical by descent (IBD) within and between individuals. Individuals with the lowest pedigree relatedness were chosen for conservation efforts. This widely used approach is known as the optimal contribution method (Grundy *et al.,* 1998). However, the advent of high-throughput genome sequencing technologies and SNP arrays has enabled more precise estimates of genome-wide diversity, providing detailed insights into genomic regions. A key distinction between pedigree-based and molecular-marker-based diversity assessments lies in their treatment of founder populations.

A key difference between pedigree-based and molecular-marker-based diversity assessments concerns founder populations. Pedigree records assume that all alleles are not identical by descent (IBD), whereas molecular markers consider alleles that are identical by state (IBS) as identical by descent. As a result, pedigree-based and marker-based diversity are measured on different scales, with pedigree-based diversity reflecting only the diversity resulting from recent and documented ancestry.

i. Runs of Homozygosity

Previously, inbreeding coefficient (F) has been estimated using pedigree data, but estimates derived from SNP markers are significantly more accurate and less biased than those from pedigree data, even when large pedigrees are involved. As a result, runs of homozygosity (ROH) have been suggested as an effective method for estimating F (F_{ROH}), which is defined as the proportion of the genome contained within these segments. It is important to note that F_{ROH} values are derived from molecular data, reflecting observed homozygosity, whereas F_{PED} values are based on probabilities from pedigree information.

The formula for calculating F_{ROH} (the proportion of the genome in runs of homozygosity) is:

F_{ROH} = Total length of ROH segments/ Total length of the genome

Total length of ROH segments: the sum of all the lengths of the runs of homozygosity detected in the genome.

Total length of the genome: the entire length of the genome

The inheritance of identical haplotypes from a common ancestor results in long stretches of homozygous genotypes known as runs of homozygosity (ROH). ROH are widespread across livestock populations and are correlated with pedigree inbreeding. They are not randomly distributed across the genome, more common in regions of low recombination and are concentrated in small areas known as ROH islands. In outbred populations, the number of ROH is linked to effective population size, with smaller populations generally having more ROH and larger populations having fewer. In contrast, populations with high inbreeding rates exhibit much longer ROH segments due to the deep relatedness of their parental lines. Further, the large populations exhibit fewer and shorter ROH, however, small or bottlenecked populations show more and comparatively longer ROH. It is worthy mentioning that admixed populations have the fewest ROH, while consanguineous populations have long ROH. ROH can be identified using SNP arrays or genome sequencing data using available suitable software such as PLINK, detectRUNS etc.

Several studies have examined the distribution pattern of ROH across the genome in livestock populations to elucidate their demographic history and offer insights for developing conservation management strategies (Peripolli *et al.,* 2018). Herrero-Medrano *et al.,* (2013) performed a comprehensive analysis of high-density SNP data and provided an overview of population structure, demographic history, and inbreeding patterns of minority breeds and wild pig populations from the Iberian Peninsula. Their findings would be helped in designing and implementing strategies for the future management of endangered minority pig breeds and wild populations. It is worth mentioning that ROH provide valuable insights for managing inbreeding and designing effective breeding programs for farm animals.

Conclusion

In conclusion, livestock resources are essential for human survival and the development of civilizations, providing food, fuel, and livelihoods for billions. India, with its rich animal genetic diversity, plays a crucial role in sustaining agricultural systems. However, the growing risk of genetic erosion, driven by socio-economic changes and the introduction of exotic breeds, threatens the long-term sustainability of indigenous livestock. Conservation of these genetic resources is vital, both for preserving unique traits such as disease resistance and for maintaining biodiversity. Genomic tools, such as SNP genotyping and whole-genome sequencing, offer powerful methods to assess genetic diversity and inform conservation strategies. By utilizing these modern technologies, effective management of inbreeding and the preservation of valuable traits can be achieved, ensuring the survival and adaptability of livestock populations for future generations.

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Semen Technology for Conservation of Indigenous Livestock

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Biodiversity can be preserved by employing two types of methods; they are *in situ* conservation and *ex-situ* conservation. Indigenous livestock are also preserved following both the methods. *In situ* conservation is defined as the conservation of species within their natural habitat, where the natural ecosystem is protected and maintained. It has many advantages like, it preserves species as well as their natural habitat, ensures protection to a large number of populations, economic and a convenient method of conservation and it doesn't require species to adjust to a new habitat. On the other hand, conservation of biodiversity outside of their natural environments or ecosystems is known as *ex-situ* conservation. It mainly involves conservation of wild and cultivated species as well as genetic resources. One of the ways of ex-situ conservation is by establishing gene banks, where sperm, ova, and seeds are stored at controlled temperatures and humidity.

Indigenous livestock germplasm of India:

Indigenous livestock breeds have long played a crucial role in the livelihood and food security of rural communities, particularly in developing regions. These breeds, adapted to the local environment and climatic conditions, possess unique characteristics that make them valuable assets for sustainable agricultural practices (Mapiye *et al.*, 2019). Despite their importance, indigenous livestock breeds are often underutilized, with their productivity remaining low and populations facing the threat of extinction (Mapiye *et al.*, 2019). To address this issue, it is vital to explore strategies for the sustainable use of these genetic resources, which can provide significant benefits to both local communities and national economies, one of the key advantages of indigenous livestock is their ability to adapt to harsh environments and thrive in areas with limited resources. (Shaheen *et al.*, 2020) This resilience is particularly important in the face of climate change, which is posing increasing challenges to livestock production. As climate change continues to impact agricultural systems, the development of indigenous livestock breeds can play a crucial role in ensuring food security and the sustainability of livestock production (Mapiye *et al.*, 2019; Magiri *et al.*, 2020). India, a land of remarkable diversity, is home to an array of indigenous livestock breeds that have adapted to the unique climatic conditions and cultural traditions of the region over centuries. These resilient animals not only play a pivotal role in the livelihoods of smallholder farmers but also contribute to the rich cultural heritage of the country. The indigenous livestock population in India is presented in the table below:

Table 1: Indigenous Livestock Population of India (20th Livestock Census, 2019; GoI)

Species	Total Population (In million)	Indigenous Population (In million)	Percent Indigenous Population
Cattle	193.46	142.11	73.46
Buffalo	109.85	-	100.00
Sheep	74.26	70.17	94.49
Goat	148.88	-	100.00
Pig	9.06	7.16	79.03
Poultry	851.81	317.07	37.22

In the country, 53 cattle, 20 buffalo, 1 yak, 44 sheep, 37 goat, 13 pig and 19 chicken breeds are registered as breeds. Indigenous breeds of India are well adapted to Indian agro-climatic conditions and are resistant to many tropical diseases and can survive and produce milk on poor feed and fodder resources.

Semen technology for conservation of livestock:

Semen Preservation and Artificial Insemination:

Preserving the genetic diversity of indigenous livestock populations is of paramount importance in maintaining sustainable agricultural practices and ensuring long-term food security. One critical aspect of this preservation effort is the cryopreservation of semen, which enables the storage and distribution of valuable genetic material without the need to maintain live animal populations. Cryopreservation of semen, particularly in buffalo and other small ruminant species, has presented significant challenges due to the inherent sensitivity of their sperm to the freezing and thawing process (Mittal *et al*., 2019). The high susceptibility of these sperm to oxidative damage and cold shock during cryopreservation has resulted in suboptimal post-thaw survival rates, which has been a major obstacle in the widespread adoption of artificial insemination techniques using frozen-thawed semen (Mittal *et al*., 2019). Recent research has shed light on the factors that influence the success of semen cryopreservation in indigenous livestock. Factors such as freezing rate, cryoprotectant selection, and the use of antioxidants have been identified as critical determinants of post-thaw sperm quality and viability. For instance, studies have shown that optimizing the freezing rate can significantly improve the post-thaw motility and acrosome integrity of buffalo bull spermatozoa. Similarly, the use of appropriate cryoprotectants and antioxidants can help mitigate the damaging effects of oxidative stress and cold shock, thereby enhancing the cryosurvival of small ruminants, yak as well as in boar semen. Sperm cryopreservation is one of the most important procedures in the development of biotechnologies for assisted reproduction. In some farm animals, the use of cryopreserved sperm has so many benefits for which relevance has become more evident in recent decades. Values for post-thaw sperm quality, however, are variable among species and within individuals of the same species. There is no standardized methodology for each of the stages of the cryopreservation procedure (andrological examination, semen collection, dilution, centrifugation, resuspension of the pellet with the freezing medium, packaging, freezing and post-thaw sperm evaluation), which also contributes to differences among studies. Cryotolerance markers of sperm and seminal plasma (SP) have been evaluated for prediction of ejaculate freezability.

Sperm Selection Techniques:

There are different methods for selection of sperm (reviewed by Morrell and Rodriguez-Martinez, 2011). They classified the methods into those that result in removal of seminal plasma only (washing), and methods that select spermatozoa on the basis of some characteristics like sperm migration (based on sperm motility), filtration (based on membrane integrity), and colloid centrifugation (based on sperm motility, morphology, viability and chromatin integrity). They further classified colloid centrifugation into density gradient centrifugation (DGC) and Single layer centrifugation (SLC).

Sperm selection on the basis of colloid centrifugation is based on sperm motility, morphology, viability and chromatin integrity. Therefore, this method has advantage over other techniques in selecting sperm for higher fertility. The major applications of the SLC based selection is to improve the sperm cryosurvival by removing dead and dying sperm cells prior to cryopreservation and to select morphologically normal sperm cells for AI, ICSI or IVF (Morrell and Rodriguez-Martinez, 2011). The sperm selected can be assessed for morphology, membrane integrity, acrosome integrity, mitochondrial membrane potential, production of reactive oxygen species, chromatin integrity, protamine deficiency, presence of free thiols etc.

Techniques such as micro-fluidic sperm sorting, Magnetic-Activated Cell Sorting (MACS) electrophoretic sperm selection, Intra-cytoplasmic Morphologically Selected Sperm Injection (IMSI), and sperm DNA fragmentation analysis are pivotal in reshaping the ART landscape.

They address essential aspects of gamete quality evaluation and selection.

Sperm Sexing:

Sperm sexing is an assisted reproductive technology that involves the sorting "X" and "Y" chromosome-bearing live sperm cells of semen samples. Insemination of sexed semen would help to produce animals of predetermined sex, and the use of sexed semen is an essential solution for the animals with sex-linked diseases. Animals of the desired sex are of great interest for animal farmers to increase the economic benefits. Furthermore, production of genetically superior quality animals could be possible by the use of sexed semen. Use of sexed semen is a feasible solution to maintain the optimum sex ratio of the animals. The use of sexed semen in dairy and beef farms ensures the production of animals of the desired sex, resulting in a reduction of costs and an improvement of environmental sustainability. Several methods have been developed over the years, but most of them were abandoned due to their limited efficacy. Currently, the only commercially available method for the separation of X- and Y-chromosome-bearing sperm is fluorescence-activated cell sorting. However, this technique is expensive and has limited usefulness for the industry, considering that it cannot produce doses of sexed semen with the desired number of sperm for artificial insemination. Immunological methods have emerged as an attractive alternative to flow cytometry and proteomic knowledge of X- and Y-sperm could be useful to the development of a new method.

Sex-sorted semen is a recently introduced technology gaining more attention from researchers particularly, in the conservation programs. Preselection of semen based on the sex chromosomes (X- and or Y-bearing chromosomes) is of paramount importance to obtain desired sex of the offspring and avoid animal wastage as much as possible.

Conclusions

The different indigenous breeds of farm animals are as a result of evolutionary processes, they have adapted to the harsh climatic conditions with low management inputs in terms of feeds, fodder and healthcare, capable to convert low quality feeds and fodder more efficiently into animal products and better adapted to withstand tropical diseases. They are integral part of agriculture. These breeds are now subject to fast genetic degradation and dilution because of unplanned breeding and introduction of exotic germplasm through crossbreeding. Application of different advanced biotechnological tools like semen preservation, selection and sexing may effectively be used to conserve this important germplasm.

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Poultry Biodiversity of Northeast India and its Conservation

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I. Introduction

India is home to a diverse range of indigenous poultry germplasm, which includes various breeds of chickens, ducks, geese, turkeys, and other domesticated birds. These breeds have been developed over centuries through selective breeding and adaptation to local environments, making them well-suited to India's climate and cultural practices. Poultry is the world's primary source of animal protein. India has emerged as the 3rd and 5th largest egg and poultry meat producer respectively in the world. The total poultry population of India is 851.81 million, increased by 16.8% over previous census. The total backyard poultry in the country is 317.07 million, increased by 45.8% over previous census and the total commercial poultry in the country is 534.74 million, increased by 4.5% over previous census.

The northeastern region of India is also considered as one of the original homeland in Asia for evolution of modern poultry from the Red Jungle Fowl, which is still found in the forest of the region. As per 20th Livestock Census, the total poultry population in North Eastern Region (NER) of India is 69.22 million out of which more than 94 percent birds are located in rural areas. Among the North Eastern states, Assam has the largest poultry population (67.48%) followed by Manipur (8.52%), Meghalaya (7.77%), Tripura (6.02%), Nagaland (4.10%), Mizoram (2.96%), Arunachal Pradesh (2.31%) and Sikkim (0.84%). The growth rate of poultry resources in the region as per the last Livestock Census was +59.01 percent, which was more than the national poultry growth rate of +16.81 percent. The share of NER to the country's total poultry population during the period was 8.13 percent.

II. Poultry Biodiversity of NER of India

Total of twenty one native breeds of fowl and six indigenous ducks and one geese breed registered so far in India. Among these Miri, Daothigir, Chittagong, Kaunayen, Naked Neck, Frizzle fowls etc. and Nageswari, Sylhet mete, Chinahanh (Muscovy), Pati ducks etc. are found in the region. Brief information about native poultry breeds or varieties found in the region is as follows.

1. **Miri:** This breed of fowl is originally found in the Sibsagar, North Lakhimpur and Dibrugarh districts of Assam, mostly reared by the Mishing tribe. The majorities of these birds are white and mixed light brown in colour. The birds are small in body size, alert, hardy and also good in fighting. The colour of egg is light brown and females are good sitters and are efficient mother too.
2. **Daothigir:** This breed of fowl is scattered in the northern and southern bank of river Brahmaputra. It is reared particularly in the Bodo tribe dominated areas. This is fairly a heavy breed with good juvenile growth rate. The males are mostly yellowish brown in colour and females are barred with black and white stripes.
3. **Chittagong fowl:** Chittagong fowls are found to be distributed in Meghalaya and Tripura bordering Bangladesh. These birds are said to be native of Chittagong region of Bangladesh. Chittagong birds are dual-purpose type reared for both meat and egg. However, these birds are found to have reduced in number to a large extent.
4. **Kaunayen:** Kaunayen is fighting type of indigenous chicken found in the Imphal Valley comprising of Thaubal, Imphal West, Imphal East and Bishnupur districts of Manipur. These birds are highly energetic, alert and

have endurance for longer duration fights. Kaunayen birds are mainly used for cock fighting. Birds have elongated body with long neck and long legs. The prominent plumage colour is black followed by brown (or red) with or without patches of white, black, brown or golden feathers on neck, back and wings especially in males. Body weight of an adult cocks ranged from 2.4 to 3.8 kg and that of an adult hen ranged from 1.0 to 2.9 kg. In a year a hen undergoes at least three laying cycles laying around 35 eggs per year.

5. **Naked Neck:** These birds are found in hot and humid coastal regions and northeastern region of India. It is a medium sized, dual purpose bird having rectangular shaped body with single or pea comb. Plumage colour is variable with red and black tends to dominate. As the name indicates, neck of the birds is fully naked or only tufts of feathers are seen in front of the neck just above the crop. Particularly in males as they approach sexual maturity, the resulting bare skin becomes reddish.

6. **Frizzle fowl:** These birds are also found in hot and humid coastal regions and northeastern region of India. This is a dual purpose breed. The plumage colour varies from red to black and white. The rachus of feather is curved due to presence of dominant frizzle gene (F).

7. **Nageswari duck:** This breed is distributed in the Barak Valley of Assam and in certain places of Bangladesh. The original homeland of this variety of duck is believed to be the erstwhile Sylhet district of Assam, which is now in Bangladesh. This is white breasted duck and they lay 140-150 light bluish colour eggs annually (Islam, 2001). The Nageswari ducks are locally called as "Nagi" or "White breasted Nageswari". The average age at first egg of Nageswari duck is around 188 days with a range of 174 to 198 days. The average annual egg production in Nageswari ducks is about 140 to 150.

8. **Sylhet mete duck:** This breed is found in the Sylhet district of Bangladesh and also barak Valley of Assam. The plumage colour of this breed is grayish with black spots on the feather tip. The beak is yellow and with bluish neck and head in drake. They lay 80-150 eggs annually under farm condition.

9. **Cinahanh (Muscovy duck):** This type of indigenous duck is found throughout the state of Assam. They have the tendency of grazing on the field. They start laying at 300 to 315 days of age. The annual egg production is 50 to 60 numbers per duck and they are mostly reared for meat production. Matured average body weight in males is 4.0 to 4.5 and in females 2.25 to 2.5 kg.

10. **Pati duck:** Pati is the non-descript indigenous duck variety of Assam with wide phenotypic variations which constitute about 85.6% of the total duck population in Assam (Islam *et al.,* 2002). The average annual egg production is 80 to 90 eggs per duck. The farmers of Assam mainly rear Desi ducks under natural conditions and they lay about 60 to 70 eggs annually. The average age at maturity of Pati duck is 229.28±10.06 days while the average weight at 20 and 40 weeks are 969.95±24.41 gm and 1225.20±34.72 gm respectively.

11. **Other poultry species:** Other poultry genetic resources like turkey, quail, guinea fowl, geese, pigeon *etc.*, which represent only 1 per cent of the total poultry population of the region have not yet been fully exploited. Turkey, geese and guinea fowls which are mainly reared for meat purpose can thrive well under sub-optimal conditions of nutrition, housing and management and can be raised effectively in villages and tribal areas. Pigeon is another poultry species commonly reared by the peoples of the region. Particularly in Assam, on an average every rural household rears 3-4 pairs of pigeon to partly fulfil their required level of animal protein for the family. Japanese quail farming, because of their several attributes like small space and feed requirement, less initial investment, easy to handle, more resistant to diseases etc. has a bright scope to promote rural poultry production in the region. This will not only

provide gainful employment to a large number of rural families but also will help to provide supplemental income and valuable animal protein in the form of egg and meat.

III. Conservation and Uses of Native Poultry Biodiversity

The importance of native breeds of poultry birds for rural economy in developing and underdeveloped countries is very high. They play a major role for the rural poor and marginalized section of the people with respect to their subsidiary income and also provide them with nutritious chicken egg and meat for their own consumption. One of the most important positive characters of native chicken is their hardiness to tolerate the harsh environmental condition and poor husbandry practices without much loss in production. The native chicken breeds are the reservoir of genomes and major genes for improvement of high yielding exotic germplasm for tropical adaptability and disease resistance. The low production performance of native breeds of chickens may be improved through improvement in husbandry practices, better healthcare, and supplementary feeds during lean season and also through selection and crossbreeding. Crossbreeding with exotic germplasm showed the improvement quickly, however, selection in native breeds can bring the improvement permanently. Upgradation of the native breeds of chickens through different breeding technique helps to increase the productivity of the germplasm and also their conservation in their natural habitat as the rural people will be very happy to rear them for their adoptability to harsh environment.

IV. Strategy for Conservation of Poultry Biodiversity in Northeast India

A number of species of poultry *viz*. chicken, duck, guinea fowl and quail, make important contribution to food and income of the farmers in the region. There is large genetic variation in these species, which are required to be characterised and utilized for improvement and their conservation. The conservation initiatives in Northeast India should demonstrate the collective efforts of government bodies, NGOs, local communities and research institutions to protect the region's rich poultry biodiversity. By combining scientific research, community involvement, sustainable practices, and policy measures, these initiatives aim to preserve the natural heritage of Northeast India for future generations.

A number of methods have been used for conservation of livestock and poultry genetic resources. These include *in-situ* conservation of the breeds/populations and *ex-situ* conservation through cryopreservation of semen, ova, embryos, skin, blood, DNA fragments, etc. These methods are relevant when the breed is rare or near extinction. Special emphasis should be laid on resistance to various diseases, resistance to harmful endo- and ectoparasites, tolerance to large fluctuations in quantity and quality of feed, tolerance to non-availability of adequate quantity and quality of drinking water, tolerance to extreme temperature, humidity and other adverse climatic factors, adaptation to low capacity management conditions, ability to survive, regularly reproduce and produce for long periods of time. The viability of a livestock and poultry genetic resource programme is enhanced when it focuses on traits that increase the economic value of the breed to the communities involved. It is imperative that extensive surveys be undertaken in the home tracts of the known breeds for their description and evaluation and identifying the need and approach to their conservation and improvement. Where the numbers are extremely small, immediate efforts should be made to conserve those breeds, preferably *in-situ*. Some strategies and policies for conserving poultry biodiversity in India include:

1. Breeding programs

States can develop region-specific breeding strategies to conserve indigenous poultry breeds and identify their suitable breeding programmes.

2. *In-situ* conservation

Breeders can maintain genetic diversity by promoting indigenous germplasm. This can be done by associating breeds with products that have geographical indications or traditional importance.

3. Incentives

The government can provide incentives or subsidies to keep at-risk breeds. Breeders who contribute to conservation can be recognized with awards or honors.

4. Awareness generation

Public awareness can be created about the unique traits of indigenous birds and their importance.

5. Community-based conservation

Local people can be made the primary stakeholders in the development and conservation of indigenous poultry germplasm.

V. Factors Accelerating Erosion of Poultry Biodiversity

1. **Development interventions:** Preference is given to high-input, high-output poultry breeds developed for benign environments. Commercial interests in donor countries promote use of relatively temperate-adapted breeds and create unrealistic expectations in developing countries.
2. **Specialization:** Emphasis on a single productive trait, e.g. egg production, leading to exclusion of multi-purpose birds.
3. **Genetic introgression:** Crossbreeding and accidental introgression leading to loss of indigenous breeds.
4. **Technology:** Modern technologies and machinery replace work livestock and poultry.
5. **Biotechnology:** Cryopreservation equipment inadequate to store germplasm of threatened breeds. Artificial insemination and embryo transfer rapidly displace indigenous breeds.
6. **Economic change:** Market for typical outputs is outcompeted by subsidised imports or replaced by synthetics.
7. **Environmental change:** Climate or vegetation change makes a breed unviable in a particular habitat.
8. **Political instability:** Eliminates local breeds owned by vulnerable populations.
9. **Natural disaster:** Floods, drought and epizootics preferentially affect remote or isolated human, livestock and poultry populations.

VI. Government Initiatives on Poultry Germplasm Conservation and Improvement in India

The poultry development programs in India are virtually eliminating local birds in most of the schemes because the high producing synthetics, developed by research institutes and private sector, are distributed in rural areas to increase the egg and meat production. Supply of strains/hybrids or synthetic chicks developed from exotic breeds of poultry with high genetic merit on egg production and higher growth rate, considered as the only or the main development intervention. The results under these programmes are not encouraging

1. Poultry Venture Capital Fund (PVCF-EDEG-Entrepreneurship Development and Employment Generation):

PVCF a sub component under National Livestock Mission was initiated with the following objectives:

i. To encourage entrepreneurship in various poultry activities and provide capacity building for employment opportunities

ii. To improve production of poultry products and productivity of processing units through technology upgradation and also encourage introduction of innovative technology.

iii. To encourage rearing of other poultry species like quails, ducks, and turkeys etc. which have good potential. This programme mainly focus on the hybrid poultry rearing with also emphasis on the rearing of Poultry like low input technology variety of chicken and other alternative species like turkey, ducks, Japanese quails, guinea fowl and geese.

2. Central Poultry Development Organization (CPDO):

Under the CPDO four centres at Hessaraghatta, Chandigarh, Mumbai and Gurgaon were established with the following objectives:

i. To meet all requirements of Poultry Sector exclusively in the un-organized backward sector (which still contribute to about 40% of total egg production of the country), through single window approach i.e. training, monitoring of feed quality, availability of quality chicks, project preparation and other related extension activities including diversification of poultry production programme which so far has been concentrated on chicken.

ii. To maintain G.P./Parent stock of both layer and broiler which are suitable for low -input technology for distribution of their Parent/ Commercial chicks to meet the requirement of unorganized sector and also to be used for in house training programme.

iii. To adopt 5 to 10 villages by CPDO for providing full package of inputs on cost basis.

iv. Farmers training programme on regional basis in the farm or in real field situation.

v. Monitoring of feed quality, compiling inventory of raw materials and formulation of least cost poultry feed using locally available feed ingredients.

vi. Production of Quail/turkey/Guinea Fowl/ Emu etc. under diversification programme.

Apart from these other government organisations viz. National Bureau of Animal Genetic Resources (NBAGR), Indian Council of Agricultural Research (ICAR), State Animal Husbandry and Veterinary departments and also some Non-governmental organizations (NGOs) are engaged in conservation of native poultry germplasm in the country.

VII. Conclusion

The importance of poultry birds for rural economy in NER of India is very high which play a major role for the rural poor and marginalized section of the people with respect to their subsidiary income and also provide them with nutritious chicken egg and meat for their own consumption. The region is endowed with varieties of native poultry germplasm. The native poultry breeds are the reservoir of genomes and major genes for improvement of high yielding exotic germplasm for tropical adaptability and disease resistance. Upgradation of the native breeds of poultry through different breeding technique helps to increase the productivity of the germplasm and also their conservation in their natural habitat as the rural people will be very happy to rear them for their adoptability to harsh environment. The conservation initiatives in Northeast India should demonstrate the collective efforts of government bodies, NGOs, local communities and research institutions to protect the region's rich poultry biodiversity. By combining scientific research, community involvement, sustainable practices, and policy measures, these initiatives should aim to preserve the overall natural heritage of Northeast India for future generations.

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Role of Animal Production with Special Reference to Yak Farming in Sustainable Development of NE Region of India

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Abstract

Livestock is an imperative part of Indian agricultural sector and according to Central Statistics Office (CSO) about 45% of the gross value added in the agriculture sector was contributed by livestock, forestry and fisheries, which registered a combined growth rate of 8.1% in the first quarter of 2018-19. The North-Eastern region of India with its eight states comprising of the seven sisters- Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, and Tripura and their one brother state Sikkim has its definite unique identity due to its peculiar physical, economic, and socio-cultural characteristics. The NE region of India is home to diverse animal genetic resources including cattle, buffalo, sheep, goat, pigs, equines *etc.* Apart from these traditional livestock species, NEH region also possess Yak in good numbers. Therefore, the main emphasis of this manuscript will be the role of animal production with special reference to Yak farming in sustainable development of NE Region of India.

Introduction

The Northeast region of India occupies 7% of total land area and is also one of the world's most bio-diverse regions, reflecting ecological and cultural contrasts between the hills and the plains. Arunachal Pradesh, Meghalaya, Mizoram, Sikkim, and Nagaland are almost entirely covered by hilly areas, 40 -50 % of Assam by plains, whereas Manipur and Tripura have both plains and hilly regions. The region has diverse hill ecosystems covering more than two-third of total geographical area. The region has 3.73% of the total population of the country and contributes 2.6% to the Net Domestic Product. It has a forest cover of more than 66.1% against the national average of 21.1% and most of the area is under private or community ownership. Agriculture is the prime source of livelihood for the majority of the rural population in this region, followed by animal husbandry. Livestock production in the North East is pre-dominantly the endeavour of small holders. Almost 90% of the rural households keep livestock of one species or the other. The importance of the livestock of NE India is more pronounced owing to limited arable land, a high proportion of the meat-eating population, and rapid urbanization. Animal production plays a significant role in the sustainable development of North-East India by economic contribution, employment generation, and nutritional security.

Livestock Resource in the NER

The region supports a variety of livestock, including cattle, pigs, goats and poultry adapted to local conditions. Yak is a unique bovine species of the NER reared beside other livestock. The distribution of the livestock inhabiting the NER is given in Table 1. In this study, data were collected from various published and unpublished sources. A wide range of primary and secondary data was collected data on Net State Domestic Product (NSDP), Agricultural GDP (AgGDP), and value of outputs from livestock and crops were collected from various issues of National Accounts Statistics of the Central Statistical Organization (CSO), Ministry of Statistics and Program Implementation, Government of India. The data on livestock population were compiled from different livestock censuses.

Table 1: Livestock Population in NER

State	Cattle	Buffaloes	Sheep	Goat	Pig	Horses & Ponies	Yak	Mithun	Total Livestock (in Thousands)
Assam	10853.26	421.72	332.1	4315.17	2099	12.78	0	0	18034.03
Arunachal Pradesh	338.7	6.38	7.35	159.74	271.46	3.05	24.08	350.15	1160.91
Manipur	224.21	36.23	5.92	38.7	235.26	1.08	0	9.06	550.46
Meghalaya	902.03	15.71	15.68	397.5	706.36	0.27	0	0	2037.55
Mizoram	43.93	2.11	0.49	14.82	292.47	0.16	0	3.96	357.94
Nagaland	76.87	15.65	0.36	31.6	404.7	0.07	0	23.12	552.37
Sikkim	146.91	1.14	2.02	90.51	27.32	0.12	5.22	0.002	273.242
Tripura	724.44	7.13	5.46	360.2	206.04	0.02	0	0	1303.29
NER Total	13310.35	506.07	369.38	5408.24	4242.61	17.55	29.3	386.292	24269.792
All India	192523.4	109851.7	74260.62	148884.8	9055.49	342.23	57.72	386.31	535362.2
Share of NER in India (%)	6.91	0.46	0.50	3.63	46.85	5.13	50.76	100.00	4.53

Source: Livestock Census 2019, Ministry of Agriculture, GOI

1. Livestock Production Trends in NER

The livestock population composition is shifting in North East India, where overall livestock population growth fell by 2.6% between 2012 and 2019 compared to 1.5% between 2007 and 2012, while poultry population growth significantly increased by 6.3% between 2012 and 2019 compared to -0.3% during 2007-2012 (Sharma and Omena, 2024). Nutrition, health, the environment, and marketing are all being impacted by the demand-driven revolution in livestock production and consumption that is occurring in many emerging nations, including India (Khan & Bidabadi, 2004). According to Chand and Raju (2008), livestock products can be generically classified into five categories: (a) milk, (b) meat, (c) poultry, (d) manure, and (e) wool and hair. The milk production in Assam was reported to be the highest with 882.76 thousand tonnes among the other states of the NER in the year 2018-19 followed by Tripura with 185.27 thousand tonnes, Meghalaya with 86.61 thousand tonnes, Manipur with 85.75 thousand tonnes, Nagaland with 72.57 thousand tonnes, Sikkim with 60.85 thousand tonnes, Arunachal Pradesh with 55.1 thousand tonnes and Mizoram with the least milk production of 25.75 thousand tonnes. Hence, the NER contributes 0.77% with 1454.66 thousand tonnes of milk production to the 187749.5 thousand tonnes of the India as a whole (Livestock Census 2019, Ministry of Agriculture, GoI). Milk production in NER has increased from 1141.43 thousand tonnes in 2008-09 to 1454.7 thousand tonnes in 2018-19. However, the percentage of NER in country's annual milk production declined 1.02% in 2008-09 to 0.77% in 2018-19. Similarly, the percentage of NER in country's annual meat production declined 4.93% in 2008-09 to 3.03% in 2018-19. The total NER meat production comprising of Cattle, buffaloes, goats, pigs and poultry accounts for 245.5 thousand tones whereas 8114.46 thousand tonnes of meat is being produced throughout the country as of Livestock Census 2019. In the same way, wool production in the NER, it is only 42.63 thousand kilograms and that is also contributed by Arunachal Pradesh accounts for the only 0.11 % share in the country's total produce of 40420 thousand kilograms.

2. Contribution of Livestock to agricultural economy of NER

Livestock plays a significant role in the economy of the Northeast Region of India by providing a vital source of income for many rural households. It contributes to livelihoods through dairy, meat and egg production. Livestock also contributes to food security and nutrition and thereby supplying essential proteins through dairy products, meat and eggs crucial for the local population. Also, the contribution of livestock in the agricultural GDP for the country increased from 24% in TE 1992-93 to 28% in TE 2002-03. Whereas, the share of livestock in agriculture of NER had in fact declined from 20% to 18% during the period (Table 2).

Table 2: Livestock share in agriculture of NER

States	TE 1992-93			TE 2002-03		
	Share of agric-ulture in SDP (%)	Share of livestock in agricu-ltural VOP (%)	Per capita income (Rs)	Share of agric-ulture in SDP (%)	Share of livestock in agricu-ltural VOP (%)	Per capita income (Rs)
Arunachal Pradesh	32.8	13.2	8809	25.3	20.1	9564
Assam	37.4	17.8	5737	31.7	15.0	6736
Manipur	32.3	32.9	5668	25.4	31.0	8678
Meghalaya	23.9	33.1	7123	22.8	37.2	11204
Mizoram	25.9	27.3	8319	22.2	27.6	11489
Nagaland	19.9	30.8	9395	32.8	20.7	12087
Sikkim	32.0	15.4	8500	20.4	17.3	12374
Tripura	32.8	16.1	5535	22.4	16.5	11118
NER	34.2	19.5	6073	28.8	18.1	7900
India	29.2	24.1	8222	21.4	27.6	11977

Source: National Accounts Statistics (various years), CSO, Government of India.

4. Yak-the unique bovid of NER

Despite Yaks having a negligible share of total NER livestock population, they play significant role in the socio-economy of the ethnic communities of NER. In Northeast India, Yak is quite significant animal both culturally and economically. Yaks (*Peophagus grunniens*) are regarded as the "almighty livestock" by the herding communities since they are deeply ingrained in the customs, socio-economic processes, and culture. Yaks are well adapted to the harsh climate and hypoxia occurring under high altitude grazing conditions >3000 m above mean sea level, of the Himalayan Mountains. Yaks are the largest animals of the cold areas and survive in extreme cold upto -40 °C.

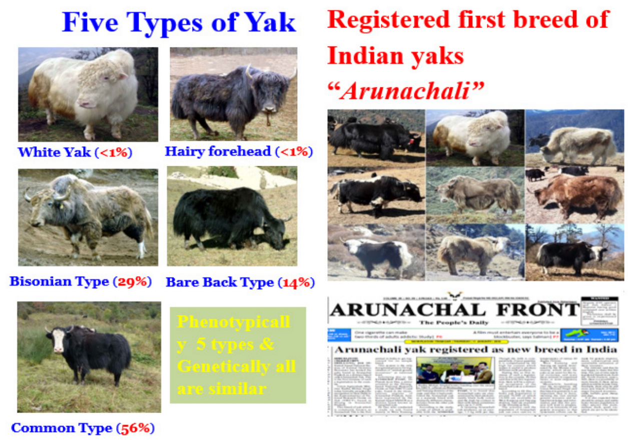
Yak (*Peophagus grunniens*)

ICAR-NRC on Yak farm

The native high-altitude yak has evolved multiple unique adaptations, including morphological, physiological, biochemical, and genetic changes due to long-term selection. Yaks require only 33 % of the feed as consumed by the cattle and does not compete with any livestock. Yak is regarded as the multi-purpose bovid as they provide livelihood and nutritional security to the communities rearing them. Yak is a multi-purpose animal as it is primarily raised for milk, meat, fibre, and draft purpose. Yaks are also used as Pack animals for transportation. Yak wool is also used to make traditional clothing and handicrafts.

4.1 Distribution of Yaks

In India, around 58 thousand Yaks are reared under transhumance by various pastoral nomads of UT of Ladakh and J & K, Arunachal Pradesh, Sikkim, Himachal Pradesh and West Bengal for their livelihood and nutritional security. The pastoral nomads are known by different names in the respective regions namely, Brokpas in Arunachal Pradesh, Dokpas in Sikkim and Changpas in Ladakh. Yaks primarily inhabit higher altitudes of the Himalayas especially states like Arunachal Pradesh and Sikkim. Yak is also somewhat responsible for the National Security as it is reared across the high-altitude international borders *vis-a-vis* Indo-China, Indo-Bhutan, Nepal and Pakistan. Therefore, Yak is also a very strategic animal for keeping vigilance on the borders in the States of Ladakh, J&K, Arunachal Pradesh, Sikkim and Himachal Pradesh. Yaks are also integral to the livelihood of pastoral communities and feature in local traditions and festivities. Therefore, Yaks are inherently associated with the religion, culture, sentiment and social life of the pastoral nomads & ethnic communities. Indian yaks have been phenotypically categorized in to five types White, Bare Back, Bisonian, Hairy Forehead and common type. However, based on genetic characterisation all the types were similar. Yak population of Arunachal Pradesh was characterized for its production and physical traits for breed registration and subsequentially based on unique characters the first breed named “Arunachali” was registered in year 2018.



Traditionally, Yaks are raised under Transhumance system of rearing on highland pastures and during summers the Yaks have the availability of Lush green pastures whereas during winters only dry pastures and tree fodder is feasible. As far as the population of the yaks is concerned in the NER, there are around 24,075 yaks in the Tawang and West Kameng districts of Arunachal Pradesh and 5,219 in the North, East and Western districts of Sikkim according to the Livestock Census 2019.

4.2 Constraints and Challanges of yak production

- Yak production face several constraints and issues as a lot of hard-work is required in hostile geo-climatic conditions.
- There is inadequate nutrition during lean period due to the reduction in grazing areas and reduced forest covers.
- Limited genetic variation leads to inbreeding and reduced resilience to diseases.
- Changing weather patterns affects grazing lands and water availability and thereby impacting livestock health and productivity.
- Seasonal availability of quality forage limits livestock nutrition and overall health.
- Diseases like brucellosis and infestation by parasites significantly affect yak and population leading to reduced productivity and increased mortality.

- Traditional grazing and husbandry practices may also hinder modern and improved production techniques.
- Lack of infrastructure such as veterinary services and transportation can impede growth and productivity.
- Predators attack is also another major concern for the livestock herders along with inadequate government policies and support systems hindering the development of sustainable yak farming.
- Remote areas often have limited access to markets making it difficult for producers to sell their animal products and hence get refrained from the well-deserved economic returns.

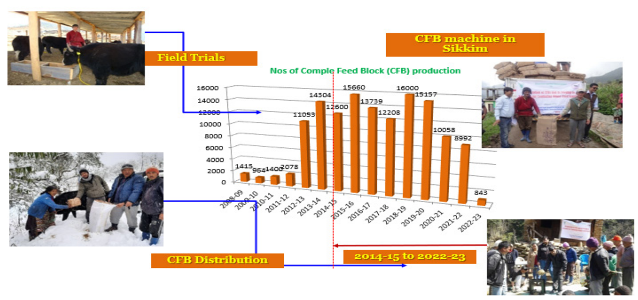
4.3 Technological Support for Yak farmers by ICAR-NRC on Yak in collaboration with other government organizations

Technological support for Yak farmers can significantly enhance productivity and sustainability by utilizing artificial insemination and genetic selection to improve herd quality and disease resistance, by implementing digital health tracking systems for early disease detection and management. There are other key areas where improvements can lead to further enhancement in the productivity of the Yak farming and these include:

1. Sustainability and improvement of yak farming
2. Genetic improvement of Yak
3. Conservation and multiplication of yak germplasm
4. Value addition of yak products and developing market linkages
5. Livelihood security improvement of yak farmers

4.3.1. Sustainability and improvement of livestock farming

- **Cultivation and propagation of the fodder:** In order to ameliorate the degraded high altitude pasture suitable grasses & legumes have been propagated. Further, to mitigate the winter fodder scarcity complete feed block (CFB) technology has been implemented in Parts of Arunachal Pradesh and Sikkim complemented with conservation of the green foliage through ensiling in poly-bags especially maize and salix.
- **Animal Health Care:** Effective healthcare for Yak is essential for their productivity and well-being which has been achieved up to some extent by the timely vaccinations against common diseases like brucellosis, FMD, Lumpy skin disease, Haemorrhagic septicaemia (HS) and Black quarter (BQ) to reduce the disease incidences. Besides this, deworming programs has also been implemented along with regular health check-ups for signs of illness enabling early detection and treatment of the various health issues.
- **Preparedness for winter:** Preparing feed for yak is extremely crucial for their health and survival in the harsh cold conditions for the peak winters.



Complete Feed Block technology has been extensively popularized among the yak rearers. For the maintaining the continuous supply of feed, 6 manual CFB making machines & around 35000 CFBs were distributed among the tribal farmers of Arunachal Pradesh and Sikkim.

4.3.2. Genetic Improvement & Conservation and Multiplication of Germplasm:

Yak germplasm exchange with Sikkim is being done. Yak semen straws conservation & distribution to AHD of different yak tracts is also a regular practice.

4.3.3. Breed characterization of yak population of NER:

Yak population faces challenges due to climate change, habitat loss and changing agricultural practices. Therefore, conservation efforts are crucial to ensure sustainability of this species. Hence, supply or exchange of superior Yak bulls to farmer of NER for breeding purpose is being done, breeding programs are implemented and awareness about these species is inculcated among the herders from time to time in the rearing regions.

Germplasm conservation and upgradation through biotechnological tools:

Biotechnological tools play a significant role in these efforts, providing advanced methods for genetic conservation, breeding and enhancement. Therefore, various biotechnological interventions have been done for germplasm conservation and upgradation including:

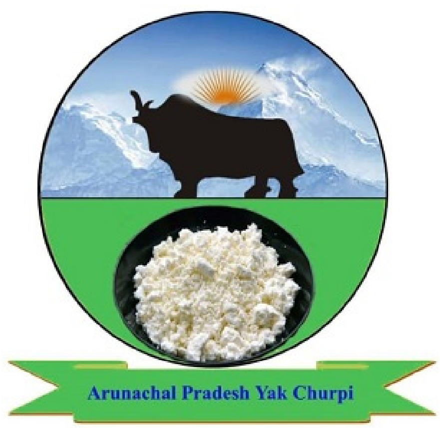
- Frozen semen technology and artificial insemination
- Estrus synchronization and timed artificial insemination (TAI)
- Multiple ovulation and Embryo transfer (MOET) and *in–vitro* Embryo production (OPU-IVF).
- First IVF yak calf "NORGYAL" was born on 15th July, 2013 using OPU, IVF and Embryo transfer technology.

4.3.4. Value addition of Yak & Mithun products

Yak-milk and its products:

Yak milk and dairy products such butter (Mar), ghee, curd, wet cheese (*chhurpi*) and hard cheese (*Churkam*) gives the pastoral nomads an essential source of vitamins and nutrients (Li *et al.,* 2011). Therefore, various value-addition strategies have been incorporated to the Yak milk and its products for enhancing its market-value such as:

- Yak milk whey beverages incorporated with Kiwi fruit pulp
- Flavored Churkam
- Technology has been developed for health-conscious consumers to develop low fat dietary fibre enriched paneer from yak milk. The technology has additional benefit of utilizing the separated milk cream for Ghee making. ICAR-NRC on Yak is further developing processed cheese from yak milk.
- For their constant efforts for working on the yak and to enhance the yak milk production along with its value-addition, ICAR-National Research Centre on Yak, Dirang could secure the first ever yak milk product – "**Arunachal Pradesh Yak Churpi**" with the **Geographical Indicator Tag** with the collaboration of the yak herders.



Yak fibre: A boon to the *brokpas*

Yak fibre also known as yak wool is a natural textile derived from the coat of the yak. This unique fibre is highly valued for its warmth, softness and durability making it an important resource for local communities and the textile industry. Yak produces three types of fibre: coarse outer hair, a mid-type and a fine down fibre, which grows prior to the onset of winter as additional protection for the yak against cold (Table 4). The amount of fibre produced by individuals and the proportions of coarse hair and down varies with the region where the yaks are kept and the associated climate, and with breed, sex, age and the season and method of harvesting the fibre. The average age of clipping is 12-18 months. A mature yak can produce 250-750g fine/down fibre & 1.5-5.0Kg coarse fibre

Table 4: Fibre types -Down, mid-type & coarse fibre.

Characteristics	Fibre types		
	Down fine fibre	Mid-type fibre	Coarse fibre
Fibre diameter (μ)	< 25	25 – 52.5	>52.5
Length (cm)	3.7 – 4.1	5.3 – 13.0	8.9 – 21.1
Medulla	unmedullated	Latticed	medullated
Lustre	Soft	Good	Strong
Crimp	Irregular	A few large	No crimps

Value addition of Yak fibre: Yak fibres open up new possibilities to help and improve the economic conditions of herdsmen through value addition. Value addition of yak fibre is very crucial to achieve 3 to 4 times better economic returns and for this yak fibres can be blended with other natural fibres like wool (sheep and angora wool) and jute to form yarn and fabric with different designs.

Keeping all these aspects in mind, **ICAR-National Research Centre on Yak** has come up with various yak fibre value-added products like yak fine fibre-sheep wool blended products and yak-jute blended garments and products such as *Chitpa Jaamu, Phachung (bags), knitted caps, mats, charmar, coats etc.*

Yak as a Pack animal: Yak are the exclusive beast of burden in the high Himalaya due to their high-altitude adaptations, legendary strength and endurance, and sure footedness. Male yaks can carry a load up-to 35% of its live body weight and walk 14 km, with a speed of 4-6 km per hour.

4.3.5. Recent initiatives taken for promotion of yak farming:

In recent years, various initiatives have been undertaken in India to promote yak focusing on their conservation, breeding and utilization such as:

1. **Government Schemes and programs:**

- **National Livestock Mission (NLM)** launched by the Indian government aims to promote sustainable development of the livestock sector by focusing on the conservation and development of indigenous species like yak and Mithun.
- **Integrated Livestock Development schemes:** States like Arunachal Pradesh and Sikkim have implemented integrated livestock development schemes that include provisions for the promotion of yak through financial assistance, veterinary care and access to improved breeding policies.

2. **Research and Development:**

- **ICAR initiatives:** The Indian Council of Agricultural Research has undertaken various research programs focused on Yak and Mithun.
- **ICAR-NRCY:** ICAR-National Research Centre on Yak, Dirang focusses on Yak breeding, conservation and research and conducts various awareness and training programs for farmers.

3. **Training and Capacity building:**

- **Skill development programs:** Various organizations conduct training programs for farmers and herders and covers practices in yak and Mithun management, veterinary care, feed management and marketing of product.

4. **Promotion of Yak products through value addition:**

   Initiatives have been introduced to promote the processing of yak and Mithun products including meat, milk and fibre.

5. **Promotion of Semi-Intensive farming:** Sedentarization of yak to bypass trans-humance migration grazing patterns keeping in m the climate change and lesser availability of the grazing grounds. Following the semi-intensive system, the daily body weight gain in yaks has increased from 95-120 g/day to 400-550 g/day. Similarly, age of attaining puberty has decreased from 3.5-4.5 years to 2.0-2.5 years, calf production by a yak has increased from 1 calf per 3 years to 1 calf per year, yaks have started to come into estrus regularly throughout the year and milk yield has increased from 400-500 g/day t0 1.5-2.5 kg/day. Additionally, after nutritional interventions the adult body weight has drastically increased from 200-300 kg for male to 450-550 kg and from 150-200 kg to 250-350 kg for female.

6. **Developing bankable scheme for yak farming**

7. **Yak insurance policy:** The National Insurance Company Ltd has approved an insurance policy for yaks, following relentless efforts by the National Research Centre on Yak (NRCY) here in West Kameng district. The insurance policy will shield yak owners against the risks posed by weather calamities, diseases, in-transit mishaps, surgical operations and strike or riots.

8. **Creating awareness about the diversified use of these unique bovines:** Formation of herder's cooperative society and self-help groups.

9. **Extension & Other STC activities:**

- **ICAR-NRC on Yak, Dirang** in collaboration with Department of Animal Husbandry, Livestock, Fisheries and Veterinary Services conducts various awareness and training programmes under the Scheduled Tribe Component (STC) as well as the NEH schemes of ICAR. Table 5 shows various STC programs conducted during the financial year 2021-22 to Oct, 2023.

Table 5: STC Activities conducted during 2021-22 to Oct 2023

FY	Arunachal Pradesh		Sikkim		Ladakh		Total	
	Beneficiaries	Prog.	Beneficiaries	Prog.	Beneficiaries	Prog.	Beneficiaries	Prog.
2021-22	187	6	64	1	203	2	454	9
2022-23	427	6	121	3	0	0	548	9
2023-24	526	6	286	4	0	0	812	10
Total	1140	18	471	8	203	2	1814	28

In collaboration of Govt. of Sikkim also supported yak farmers by providing immediate remedial support to recover the health of surviving starved yaks due to unprecedented continuous and heavy snow during Dec 2018 to March 2019.

10. **Recognition to Yak pastoralists:** Yak pastoralists have rich cultural traditions tied to their livestock. Their practices include unique herding techniques, seasonal migrations, and rituals that honour their animals.

Here are some of the awards to honour the hardships and challenges faced by the pastoralists to sustain yak and Mithun rearing:

- Breed Saviour Award 2021-**Mr. Lobsang Tsewang**
- Pastoralists and Rangeland Award
- 2021 Dungkharpa Welfare Society

Conclusion

Yak is the livestock species specifically reared by the various ethnic communities of NER for their livelihood and nutritional security. Although, livestock sector has slower growth in NER than at national level, but a significant proportion of landless, small & marginal farmers has access to livestock, which offer opportunities for household income augmentation and employment generation. In a nutshell, the scientific raising of yak will enable their impoverished rearers to make ends meet by providing additional money to meet their basic amenities. Therefore, in the states where yak raising is a long-standing custom, it is imperative to promote scientific farming by providing supportive technical, institutional and policy initiatives for improvement of breeds, feed availability, disease control, food safety and private investments in NER. The latest advancements in artificial insemination, oestrus synchronisation, timed AI and embryo transfer technologies along with other extension activities will undoubtedly contribute significantly to the goal of generating high-quality germplasm in farmers' fields. Overall, recognizing yak pastoralists is also imperative for safeguarding their way of life, supporting biodiversity and fostering sustainable development.

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Fish Germplasm of Northeast India

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Introduction

Northeast India, coming under two Biodiversity Hostpots, the Himalaya and the Indo-Burma Hostpost, is known for its rich biodiversity, particularly in its aquatic ecosystems, which are home to a wide array of fish species (Myers *et al.,* 2000; Kottelat and Whitten,1996; CEPF, 2005; Roach, 2005). Recent geological events, such as the collision of the Indian, Chinese, and Burmese plates, are thought to be responsible for the diversity, and the Himalayan orogeny was crucial to the diversification and evolution of the species that live in mountain streams (Kottelat, 1989). This region is characterized by its unique topography, ranging from the high altitudes of the Himalayas to fertile river basins, creating a variety of habitats that support both indigenous and migratory fish populations. The region comprises the eight landlocked states Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim, and Tripura in terms of fish diversity and natural resources. Reservoirs, tanks, ponds, beels, oxbow lakes, and other abandoned waterways make up the region's extensive and diverse fishing resources, which span 4.18 lakh hectares of water-spread land (excluding rivers and streams, which are estimated to be 20,875 km).

The distribution of fish species in the region is closely linked to the types of water bodies present, which include rivers, lakes, ponds, wetlands and also caves. Each of these aquatic environments supports distinct fish communities adapted to their specific conditions. For instance, fast-flowing stream and rivers are home to species such as Glyptosternoids, Mahseers, Garras, small torrent Minnows and various endemics which thrive in high-oxygenated waters. In contrast, slower-moving waters and floodplains are often rich in species like Labeos, Carps, which prefer warmer, stiller environments. Lakes and wetlands, such as those found in Manipur and Mizoram, harbor diverse fish populations, including endemic species that are adapted to these unique ecosystems. This variation in aquatic habitats leads to a rich tapestry of fish diversity across the region, with each habitat supporting its own set of ecological interactions and distribution patterns. The genetic resources of these fish species are invaluable, not only for their ecological roles but also for their significance in supporting the livelihoods of local communities (Allen *et al.,* 2010). The fish genetic resources in Northeast India encompass diverse species, including both economically important and endemic varieties. Common species such as Indian Major carps (*Labeo catla*, *Labeo rohita*, and *Cirrhinus mrigala*) dominate aquaculture practices, while indigenous species like Mahseer and various endemic species highlight the region's ecological uniqueness. These fish are not only vital for local diets but also hold cultural significance and contribute to recreational fishing. The genetic diversity within these populations enables them to adapt to changing environmental conditions, making it essential to conserve this genetic heritage for the resilience of local ecosystems. In recent years, there has been growing recognition of the importance of fish genetic resources in Northeast India.

However, the genetic resources of Northeast India's fish populations face several threats. Five interrelated categories can be used to classify the threats to freshwater biodiversity worldwide: overexploitation, water pollution, flow alteration, habitat destruction or degradation, and exotic species invasion (Dudgeon *et al.,* 2006). Climate change is now a more significant threat to cold-blooded creatures. These factors can lead to genetic erosion, reducing the adaptive potential of fish populations and compromising their long-term viability. To address these challenges, comprehensive management strategies that incorporate genetic research, conservation planning, and community involvement are necessary. By prioritizing the conservation of fish genetic resources, Northeast India can ensure the sustainability of its fisheries while preserving the ecological integrity of its aquatic ecosystems for future generation. Conservation efforts are increasingly focused on preserving the genetic diversity of both wild and cultured fish species. Initiatives such as habitat restoration, community-based conservation programs, and sustainable aquaculture practices are essential to safeguard these genetic resources. Moreover, scientific research on fish genetics, fish biology, breeding programs, and the impact of environmental changes is crucial for developing strategies that enhance the sustainability of fisheries and aquaculture in the region.

River Basins in Northeast India

Northeast India is home to several significant river basins that are crucial for the region's ecology, economy, and cultural heritage. The Brahmaputra River Basin is the most prominent, originating from Tibet and flowing through Arunachal Pradesh before entering Assam and ultimately Bangladesh. This river is not only one of the largest in the world but also supports diverse ecosystems and provides vital water resources for agriculture, fishing, and hydroelectric power generation. The basin is characterized by rich alluvial plains, which contribute to its high agricultural productivity, and it is also home to numerous fish species that are integral to the local livelihoods.

In addition to the Brahmaputra, is the Barak-Meghna-Surma River Basin and its tributaries, which flow through the states of Manipur, Mizoram, and Assam. The Barak-Meghna-Surma River Basin plays a crucial role in supporting local communities with water for irrigation and fishing. Smaller river systems, such as the Teesta in Sikkim and West Bengal, and the Dhansiri and Dikhou in Assam, also contribute to the region's hydrology and biodiversity.

Furthermore, the Chindwin River Basin, primarily located in Myanmar but extending into northeastern India, is an essential hydrological region that plays a crucial role in the ecology and economy of the area. Originating from the northern hills of Myanmar, the Chindwin River flows southward, joining the Irrawaddy River. While much of the basin lies outside India, its headwaters and northern tributaries are in Manipur and Nagaland. The basin is characterized by diverse ecosystems, including wetlands and forests, which provide habitats for various aquatic and terrestrial species. The Chindwin River itself is significant for local communities, supporting fishing activities and agriculture along its banks.

The Kaladan Basin, encompassing parts of northeastern India and Myanmar, is another vital waterway that influences regional ecology and socio-economic activities. Originating from the Arakan Mountains in Myanmar, the Kaladan River flows into the Bay of Bengal, traversing through Mizoram before reaching its delta. This basin is known for its rich biodiversity, supporting numerous endemic fish species as the basin is neither connected to the Brahmaputra nor to the Chindwin Basins. The Kaladan River also serves as a crucial trade route, enhancing connectivity between India and Southeast Asia. Conservation efforts in the Kaladan Basin are essential to protect its diverse ecosystems from the impacts of development, deforestation, and climate change, ensuring sustainable use of its natural resources for future generations.

These river basins not only provide essential resources for the people but also sustain rich habitats for various aquatic and terrestrial species, making them vital for conservation and sustainable development efforts in the region.

Fish Genetic Resource of Northeast India

Vishwanath *et al.,* (2014) reported the presence of 357 fish species belonging to 120 genera and 35 families in Northeast India. However, many new species are discovered in the last 10 years. About 422 fish species from northeast India, belonging to 133 genera and 38 families, including indigenous and exotic species, have been reported (Munilkumar *et al.,* 2023). Maximum diversity is observed in the family Cyprinidae with 154 species followed by Sisoridae. Many of these species are endemic to the region, but they face threats from various anthropogenic activities and environmental changes. The most recent IUCN assessment of fish species in the Eastern Himalaya was conducted in 2010, revealing that approximately 50% of the assessed species were classified as Data Deficient (DD). The assessment indicated that the highest number of threatened species is found in the Chindwin basin of Manipur, particularly within the Imphal River and its tributaries that drain the central valley and surrounding hills, extending into adjacent areas of Myanmar. The fishes genera endemic to the region includes *Tariquilabeo, Semiplotus, Poropuntius, Bangana, Psilorhynchus, Neonoemachilus, Physochistura, Rhycoschistura, Mustura, Aborichthys, Olyra, Akysis, Oreoglanis, Exostoma, Pareuchiloglanis, Creteuchiloglanis, Parachiloglanis, Myersglanis, Erethistes, Erethistoides, Hara, Pseudolaguvia, Chaca, Badis, Pillaia, Cantophyrs.* Many of the genera are monotypic represented by only a single species like *Chitala, Notopterus, Anguilla, Gudusia*, *Hypsibarbus, Acantopsis, Cantophyrs, Homalopteroides, Ailia, Pachypterus, Rama, Microphis*, *Leiodon.* They are significant for conservation and biodiversity studies because they may indicate specialized evolutionary adaptations or niche occupancy. The conservation of monotypic genera is particularly important, as the loss of their sole species would result in the complete extinction of that genus.

Northeast India is one of two hotspots for subterranean fish diversity in the Indian subcontinent. The region is home to several underground fish species, including three nemacheilid loaches and one of the Mahseer species: *Schistura sijuensis, S. papulifera S. larketensis* and *Neolissochilus pnar* (the largest subterranean fish described so far). According to Hora (1944), several fish species exhibiting exceptional adaptations to a hill stream lifestyle are found in this region. These include: *Psilorhynchus, Balitora, Hemimyzon, Homalopteroides, Garra, Glyptothorax, Pseudocheineis, Pseudolaguvia, Myerglanis, Exostoma, Erethistes, Hara, Erethistoides Creteuchiloglanis, Parachiloglanis***,** and *Pareuchiloglanis.*

Distribution of fishes

The distribution of freshwater fishes in Northeast India is influenced by various environmental factors, including altitude, substratum nature, habitat type, and flow velocity. In Northeast India, fish diversity varies significantly with altitude. At lower elevations, such as the fertile floodplains, species like carps, are abundant due to the warmer temperatures and abundant food sources. As the altitude increases, particularly in hilly and mountainous regions, the fish community shifts to include species adapted to cooler, faster-flowing waters. For example, species such as *Schizothorax, Glyptothorax* and other hill stream fishes thrive in the colder streams and rivers found in higher altitudes, exhibiting specific adaptations that enable them to survive in these environments. The nature of the substratum also plays a crucial role in fish distribution. Soft, sediment-rich substrates found in slow-moving waters often support species that prefer such environments, including various types of catfish, minnows and sometimes loaches. In contrast, rocky or gravelly bottoms typical of fast-flowing streams provide suitable habitats for species that require strong anchorage, such as loaches and hill stream fish. The substrate influences not only the types of fish present but also their feeding behaviours and breeding sites. Different habitats, such as rivers, lakes, wetlands and caves, further delineate fish distribution. Rivers support migratory species that rely on current for breeding and feeding, while lakes often harbor sedentary species adapted to still waters. Wetlands, with their rich biodiversity, serve as nurseries for juvenile fish and provide critical feeding grounds. Caves support the optimal environment for subterranean species as in the cases of species like *Schistura sijuensis, S. papulifera S. larketensis* and *Neolissochilus pnar*. Each habitat type offers unique ecological niches that cater to specific fish communities. Flow velocity is another critical factor affecting fish distribution. In high-velocity waters, fish species such as *Schizothorax, Tor, Glyptothorax, Garra* and other fishes with adaptations that allow them to maintain their position and navigate the currents effectively occurs. Conversely, in low-velocity environments, species such as *Barilius, Loaches* and *Labeos* thrive, as they can exploit the abundant resources available in calmer waters. The ability of fish to adapt to varying flow conditions influences their distribution patterns across the diverse aquatic landscapes of Northeast India. In summary, the distribution of freshwater fishes in Northeast India is shaped by a complex interplay of altitude, substratum, habitat type, and flow velocity, resulting in rich biodiversity and specialized adaptations among fish species in this ecologically significant region.

The distribution of fish species in the Northeast streams is closely linked to their anatomical traits, which have evolved to adapt to the challenging conditions of torrential waters. Many fishes, such as those from the genera *Schizothorax* and *Garra*, possess streamlined bodies that reduce drag while swimming against strong currents. Their robust fins, particularly the pectoral and pelvic fins, are often well-developed, allowing for precise maneuverability in turbulent waters. Additionally, some species have specialized adaptations, such as sucker-like mouths, which enable them to cling to rocky substrates, preventing displacement by fast-flowing water. These anatomical features not only enhance their survival in harsh environments but also dictate their distribution patterns along various stream gradients. Moreover, the presence of specific anatomical traits influences the ecological niches that the freshwater fish occupy within these streams. Fish with stronger, more muscular bodies tend to thrive in the swiftest currents, where competition is fierce and food resources may be abundant. Conversely, species with adaptations for slower-moving waters may be found in eddies and pools, where they can exploit different food sources and habitats. This specialization creates a mosaic of fish distribution across the diverse aquatic landscapes of the northeast water bodies, highlighting the intricate relationship between anatomical adaptations and environmental conditions. Menon (1962) linked the anatomical traits that allow fish to live in torrential streams to their distribution. He identified six major groups of fish: (a) *Labeo, Tor, Barilius,* and *Puntius,* which live in shallow, clear, cold water in the foothills without any noticeable changes to the current, (b) Schizothoracines and the introduced trout, which live in bottom water layers in deep fast current and have strong, muscular cylindrical bodies, (c) *Crossocheilus spp,* which hides among pebbles and stones to fend off the strong current, (d) loaches *Nemacheilus, Botia, and Amblyceps*, which have special attachment devices, (e) fish with adhesive organs on their ventral surface that allow them to attach to bare rock surfaces in lower current, such as *Garra, Glyptothorax*, and Glyptosternum, and (f) fish with limpet-shaped bodies and mouths, gills, and fins that are highly adapted to their environment, such as *Balitora.*

Within a single water system, water temperature is always a significant limiting factor that affects local occurrence and global distribution. Water temperature affects the metabolic rates of organisms, their reproductive cycles, and their overall survival. For instance, many fish species have optimal temperature ranges for growth and reproduction, temperatures outside these ranges can lead to stress, reduced fertility, and increased mortality. Additionally, temperature influences the solubility of oxygen in water, which is vital for the survival of aerobic organisms. In warmer waters, oxygen levels can drop, leading to hypoxic conditions that can limit the presence of sensitive species. Globally, water temperature plays a pivotal role in determining the distribution of species across different ecosystems. As temperatures vary in freshwater and marine environments, organisms have adapted to thrive within specific thermal ranges

Aquaculture in Northeast India

Northeast India boasts a rich diversity of fish species, making it a unique region for aquaculture development. The region's varied ecosystems, including rivers, lakes, and wetlands, support both indigenous and exotic fish species. Traditionally, local aquaculture practices have centered around species such as Inadian Major Carps (*Labeo catla*, *L. rohita*, and *Cirrhinus mrigala*) which are well-suited to the region's environmental conditions. The recognition of the region's biodiversity has led to an increasing focus on promoting aquaculture practices that utilize local species, enhancing both ecological sustainability and food security. In recent years, there has been a growing emphasis on integrating indigenous fish species into aquaculture systems. Species such as the endangered Mahseer and various endemics local species into aquaculture, farmers can contribute to conservation efforts while also benefiting from their unique market value. This approach not only preserves the genetic diversity of fish populations but also aligns with sustainable practices that respect local ecosystems. Efforts to breed and cultivate indigenous species are gaining traction, further enriching the aquaculture landscape of Northeast India.

Despite the promising developments, the aquaculture sector faces challenges that impact fish diversity and sustainability. Over-reliance on a few commercially popular species can lead to genetic erosion and threaten the survival of indigenous fish populations. Additionally, environmental factors such as habitat degradation, pollution, and climate change pose risks to both wild and cultured fish species. To mitigate these challenges, it is essential to adopt integrated aquaculture practices that prioritize biodiversity, ensuring that a variety of species are cultivated and maintained within local ecosystems.

The future of aquaculture in Northeast India lies in balancing the economic potential of fish farming with the preservation of the region's rich fish diversity. Promoting awareness among farmers about the importance of using diverse species in aquaculture can enhance resilience and productivity. Government and community initiatives focused on sustainable aquaculture practices, along with research into breeding and management of indigenous fish, can create a more diverse and sustainable aquaculture sector. By leveraging its unique fish diversity, Northeast India can not only boost its aquaculture industry but also play a vital role in conserving its aquatic biodiversity for future generations.

Threats

Despite the diversity in the region, fish species are threatened due to habitat loss, over-exploitation, flow modification, invasive species and climate change. Conservation programs which aim to preserve genetic diversity, such as establishing gene banks or breeding programs are vital for sustainable aquaculture practices, improving stock quality, growth rates, and disease resistance in the freshwater fisheries of the region.

The aquatic environments are experiencing such serious threats to both biodiversity and ecosystem stability due to anthropogenic interference and climate change, requiring several strategies and priorities to address this crisis (Jena and Gopalakrishnan, 2012; Singh *et al.,* 2014). Fish biodiversity is central to ecosystems, but all species face different risks, including habitat alterations, resource shrinkage, and germplasm loss due to factors like water discharge, siltation, overfishing, and climatic changes. The major threats to the fish diversity are:

1. Floods, environmental changes, and extreme climatic events have a profound impact on fish diversity in Northeast India. The region's complex hydrology is influenced by seasonal monsoons, which can lead to both beneficial and detrimental effects on aquatic ecosystems. These events can alter habitats, disrupt breeding patterns, and affect water quality, threatening the survival of sensitive species. While floods can temporarily enhance habitats and create new spawning grounds, they can also result in habitat destruction, sedimentation, and the introduction of

pollutants, disrupting established fish populations. Additionally, environmental changes such as deforestation, urbanization, and climate change exacerbate these impacts by altering water quality and flow patterns. Extreme climatic events, including erratic rainfall and rising temperatures, further threaten the delicate balance of these ecosystems, potentially leading to declines in native fish species and reduced biodiversity. Consequently, the resilience of fish populations is challenged, necessitating urgent conservation efforts to protect and sustain the region's rich aquatic biodiversity. For effective conservation, it is essential to develop adaptive management strategies that account for these unpredictable changes. This includes monitoring ecosystems to assess vulnerabilities and implementing habitat restoration projects to enhance resilience against flooding and other extreme events. Furthermore, raising awareness among local communities about the effects of climate change on aquatic ecosystems can foster collective action towards conservation efforts.

2. Over-exploitation and overfishing practices in Northeast India have significantly contributed to the decline in fish diversity in the region. With a growing population and increasing demand for fish as a dietary staple, local communities often resort to traditional fishing methods, often unregulated, combined with increasing commercial pressures, have led to the depletion of key fish species, particularly those that are already vulnerable or endemic. The high demand for popular species, has resulted in unsustainable harvesting practices, including the use of destructive gear and techniques such as fine mesh nets and electric fishing, not only depletes target species but also captures non-target fish and disrupts breeding grounds. The consequences of these overfishing practices extend beyond the immediate loss of fish species. The decline in fish diversity can disrupt aquatic ecosystems, as various species play crucial roles in maintaining ecological balance. For instance, the reduction of certain fish populations can lead to an increase in algal blooms, affecting water quality and harming other aquatic organisms. Furthermore, the socio-economic impact on local communities is profound, as fishers struggle to sustain their livelihoods in a diminishing resource landscape. This situation underscores the urgent need for effective management strategies, including community-based regulations and sustainable fishing practices, to safeguard the region's aquatic biodiversity and ensure the long-term viability of its fisheries.

3. The introduction of exotic species for commercial aquaculture in Northeast India has led to significant concerns regarding the decline of native fish diversity. As the demand for fish has surged, aquaculture practices have increasingly turned to non-native species such as *Tilapia, Pangasius,* and Common Carp, which are favored for their fast growth rates and high market value. While these exotic species can enhance production in the short term, their introduction often disrupts local ecosystems. They may out compete indigenous species for resources, alter habitat structures, and introduce diseases, thereby putting native fish populations at risk. This competition can lead to declines in native species, particularly those already vulnerable to environmental changes and habitat degradation. Moreover, the reliance on exotic species can undermine the traditional practices and cultural significance of indigenous fish species among local communities. Many native fish hold ecological and cultural importance, playing vital roles in local diets and livelihoods. The shift towards exotic species not only threatens the genetic diversity of fish populations but also impacts the resilience of local ecosystems. As native species decline, the associated biodiversity, including plants

and other aquatic organisms that depend on these fish, is also at risk. To mitigate these impacts, it is essential to develop sustainable aquaculture practices that prioritize the conservation of local fish diversity, integrate community knowledge, and promote the use of indigenous species that are well-adapted to the region's unique ecological conditions.

4. Climate change poses a significant threat to fish diversity in Northeast India, impacting aquatic ecosystems through alterations in temperature, precipitation patterns, and water quality. Rising temperatures can affect fish metabolism, reproductive cycles, and habitat suitability, particularly for cold-water species found in higher altitudes. Changes in rainfall patterns can lead to flooding and droughts, disrupting spawning grounds and altering the availability of critical habitats. Additionally, increased runoff from heavy rainfall can introduce sediments and pollutants into rivers and lakes, further degrading water quality and negatively affecting fish populations. As a result, many indigenous species struggle to adapt to these rapidly changing conditions, leading to declines in their populations and overall biodiversity. The combined effects of climate change threaten not only the ecological balance of aquatic environments but also the livelihoods of communities that rely on fish for food and income, highlighting the urgent need for adaptive management and conservation strategies in the region.

5. Rapid urbanization in Northeast India has led to significant habitat loss, posing a critical threat to fish diversity in the region. As townshed and cities expand with infrastructural development, natural water bodies such as rivers, lakes, and wetlands are increasingly encroached upon, resulting in habitat degradation and fragmentation. This loss of aquatic habitats disrupts the breeding and feeding grounds essential for many fish species, particularly those that are indigenous to the area. Urban runoff and pollution further exacerbate the problem, deteriorating water quality and reducing the ecological integrity of remaining habitats. Consequently, native fish populations face increased pressures, leading to declines in biodiversity and the potential extinction of vulnerable species. The transformation of natural landscapes into urban environments underscores the urgent need for sustainable urban planning that prioritizes the preservation of aquatic ecosystems and their associated biodiversity.

6. The increasing construction of dams in Northeast India has significantly modified natural flow patterns, adversely affecting fish diversity in the region. Dams alter the hydrology of rivers, creating artificial reservoirs while disrupting the natural seasonal flow regimes that many fish species rely on for spawning and migration. As water levels fluctuate and sediment transport is hindered, essential habitats such as gravel beds and floodplains become degraded, leading to a decline in fish populations. Species that depend on free-flowing rivers, such as migratory fish like the Mahseer, are particularly vulnerable to these changes, as their spawning routes are obstructed. Additionally, altered water temperatures and reduced oxygen levels in stagnant reservoirs further stress aquatic life. The cumulative impact of these flow modifications highlights the need for careful planning and management of dam projects to mitigate their ecological consequences and preserve the region's rich fish diversity.

Sustainable Utilization of Fishery Resources-Recommendations and Strategies

To preserve threatened ecosystems and species, integrated biodiversity conservation strategies are crucial. These strategies should support sustainable development by protecting biological resources, preserving habitats and ecosystems. Effective fish diversity conservation requires broad-based management measures.

1. **Ranching:** Captive breeding or hatchery programs are used to replenish declining natural stocks by removing juvenile fish from their natural habitats and allowing them to reach sexual maturity. These programs are used to compensate for declining fish populations, supplement, and enhance wild fishery yields, making them a major tool in conservation efforts.
2. **Conservation aquaculture:** It is increasingly crucial in rehabilitation programs for endangered or threatened fishes. It involves using captive propagation to preserve imperilled species and local characteristics in the face of severe decline, increasing effective population size of the threatened species, as seen in the restoration of white sturgeon populations (Schreier *et al.,* 2012).
3. **Habitat restoration** is a crucial method for repairing ecological degradations in damaged aquatic areas. In recent years, rivers and lakes have seen a significant decrease in the original wild stock of precious fish species due to recurrent floods. Management practices like riparian buffer zones are essential.
4. **The Indian Fisheries Act of 1897**, amended in 1956, is crucial for fish conservation. It regulates gears, mesh size, fishing seasons, and prohibits using explosives or poisons. However, enforcement in northeastern states is minimal. The Act needs amendment to conserve fish germplasm resources.
5. **Recreational fishery and ecotourism:** These play a pivotal role in the conservation of fish diversity by promoting sustainable practices that benefit both local economies and aquatic ecosystems. Engaging anglers and nature enthusiasts in fishing activities encourages a deeper appreciation for wild, endemic species and their habitats. This awareness can lead to increased support for conservation initiatives, as local communities recognize the economic value of preserving healthy fish populations and pristine environments. Many recreational fisheries are managed through catch-and-release programs, which help maintain fish stocks while allowing enthusiasts to enjoy the sport. By creating a demand for healthy ecosystems, recreational fishing can serve as a powerful incentive for habitat protection and restoration efforts. Moreover, ecotourism centered on coldwater fisheries can provide substantial economic benefits to local communities, further motivating them to engage in conservation practices. Eco-friendly lodges, guided fishing tours, and educational programs not only attract visitors but also generate revenue that can be reinvested in conservation initiatives. By fostering a sustainable tourism model, communities can create jobs while ensuring the long-term health of their natural resources. This symbiotic relationship between recreational fishing, ecotourism, and conservation efforts highlights the importance of integrating economic incentives into biodiversity protection strategies. Ultimately, by valuing fish diversity through sustainable recreational practices, we can enhance conservation outcomes and promote a more resilient aquatic ecosystem for future generations.

Therefore, to ensure the long-term viability of fishery resources in the region, it is crucial to adopt sustainable utilization practices that balance ecological health with economic development. One key recommendation is the implementation of integrated management practices that consider the entire aquatic ecosystem. This involves monitoring fish populations, habitat conditions, and water quality to make informed decisions about fishing quotas and seasons. Additionally, promoting community-based management can empower local stakeholders to participate in conservation efforts, fostering a sense of ownership and responsibility towards their resources. Education and awareness programs can also be instrumental in informing communities about sustainable practices and the importance of biodiversity, encouraging responsible fishing techniques and habitat protection.

Another vital strategy is the promotion of aquaculture practices that reduce pressure on wild fish populations. Developing sustainable fish farming systems for high-value endemic species can help meet market demand while preserving natural habitats. Techniques such as recirculating aquaculture systems (RAS) for commercial fishery, can minimize water use and waste, ensuring that fish farming is environmentally friendly and exotics are not escaped in the wild. Furthermore, restoring degraded habitats and enhancing riparian zones can improve overall ecosystem health, benefiting both wild and farmed fish. Collaborative efforts among government agencies, NGOs, academicians, scientists and local communities are essential to creating comprehensive policies that support sustainable utilization and conservation of fishery resources in Northeast India, ensuring their availability for future generations.

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Empowering Conservation: The Role of Krishi Vigyan Kendras in Preserving Genetic Resources in Northeast India

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Introduction:

A diverse array of plant species vital for human consumption, livestock feed, and cultural practices are preserved in the fields and homestead gardens of traditional farmers in the Northeastern (NE) region of India. The comprehensive tasks of collecting, characterizing, and raising awareness for the conservation of these species, as well as safeguarding the rights of farmers, who are the custodians of this biodiversity, require a strong grassroots organization supported by experts. In India, the National Agricultural Research System (NARES) primarily addresses the needs of the agricultural germplasm sector. Serving as the grassroots representatives of NARES, KVKs play a crucial role in the collection, in situ conservation, evaluation, and multiplication of economically significant germplasm. Moreover, KVKs contribute significantly to raising awareness and protecting the rights of farmers. The following sections will provide an overview of the vital contributions made by KVKs in the collection, utilization, and protection of the germplasm wealth in Northeast India.

1. KVKs' role in ongoing genetic resource programmes:

Local landraces of various crops are regarded as valuable repositories of our unique biodiversity. Krishi Vigyan Kendras (KVKs) act as essential grassroots farm science centers within the National Agricultural Research System (NARS), bringing together a diverse team of experts specializing in different areas of agriculture. In the Northeastern (NE) region, KVKs have actively engaged rural communities, uniting them around agricultural and related issues to improve their livelihoods. A key focus of their work is the conservation and promotion of local landraces. These indigenous crop varieties are vital for smallholder farmers in remote areas, providing essential nutrition for their families and fodder for their livestock.

With the increasing impacts of climate change and rising demand for nutritious food, it is essential to systematically explore and legally protect the vast gene pool found in local landraces. However, many of these landraces face challenges in expressing their unique traits outside their native environments. In the Northeastern (NE) region, KVKs have been quietly yet actively collaborating with organizations such as the ICAR-National Bureau of Plant Genetic Resources (NBPGR), the Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA), and various Agricultural Universities (AUs) to collect germplasm, conduct evaluations, and promote these resources while upholding farmers' rights. Although their efforts to mobilize communities for germplasm conservation and to raise awareness about the importance of preserving genetic diversity are well recognized, they remain under-documented. Almost all KVKs in the NE region play a significant role in genetic resource initiatives by collecting, purifying, and advocating for indigenous landraces. Additionally, they serve as valuable knowledge and logistical support hubs for various agencies involved in germplasm collection and in situ conservation. Many KVKs have dedicated specific areas of their farms to preserve important landraces and farmers' varieties.

Recently, the Agricultural Technology Application Research Institute (ATARI), Umiam, Meghalaya, compiled a report detailing the activities of the KVKs under its jurisdiction, particularly focusing on germplasm-related initiatives such as registration and legal protection. In the last five years, they collected 222 germplasm, and submitted 201 of them to NBPGR. Fifteen unique germplasm were identified by them and eight of them were promoted through front-line demonstrations. This summary highlights the wide range of activities KVKs are engaged in, including collecting, registering, characterizing, and promoting landraces and farmers' varieties. Many KVKs also run awareness programs funded by the PPVFRA. Currently, the PPVFRA supports KVKs in states like Arunachal Pradesh, Assam, Manipur, Mizoram, and Tripura to conduct these awareness-building activities.

The promotion of unique landraces is a vital agricultural and economic service provided by KVKs in the rural areas of Northeast India. These centers have played a significant role in promoting local varieties such as 'Kachai Lemon,' 'Kalikhasa,' 'Chokua,' and several types of rice, including 'Kakching Phou,' 'Mairang Phou,' and 'Hegwang Mei.' They have also supported the cultivation of 'Meitei Morok' chili, 'Chako Youh,' and 'Ongso Youh' jhum rice, as well as 'Nyakmok Onglek' purple and sticky maize.

One noteworthy example is the 'Chako Youh' jhum rice variety, which is exceptionally viable, maintaining its quality over approximately five years between jhum cycles. This is impressive because most small grain rice varieties typically have a viability period of just 1 to 2 years. The identification and promotion of such unique landraces highlight the importance of collaboration between KVK specialists and traditional conservators, emphasizing the broader implications for conservation efforts.

2. Optimizing KVK Activities to Boost Leadership in Genetic Resource Programs

An analysis of the accessions stored in the National Gene Bank, along with existing literature, indicates that there are significant gaps in the collection of certain crops from Northeast India. Specifically, there is a shortage of maize from Tripura, soybean from Assam, Nagaland, and Tripura, and sesame from Sikkim. In this context, KVKs are well-positioned to play a vital role in addressing these gaps. With their extensive expertise, knowledge, and outreach capabilities in rural areas, KVKs can provide crucial support for collecting specific traits, especially those related to stress tolerance and quality.

To tackle the ongoing challenge of obtaining quality seeds for indigenous varieties, KVKs can engage in various activities. These include purifying farmers' seeds, identifying local seed growers, offering training on seed production and storage techniques, and promoting the creation of community seed banks. Such initiatives will not only help improve access to quality seeds but also strengthen the conservation and cultivation of native plant varieties.

The PPVFRA has outlined several essential measures for the conservation and development of landraces and farmers' varieties, in which KVKs can play a pivotal role. These roles include documenting traditional knowledge to preserve local agricultural practices, supporting traditional growers in promoting in situ conservation, and engaging in participatory crop improvement alongside local conservators. KVKs can also conduct training sessions focused on preventing genetic erosion and establish community seed banks to safeguard traditional varieties. Through these efforts, KVKs can significantly enhance the sustainability and preservation of local plant genetic resources, contributing to agricultural diversity and community resilience.

The Northeast (NE) region is rich in diverse genetic resources, featuring numerous agricultural and horticultural crop varieties that have been granted protection through Geographical Indication (GI). KVKs have played an active role in advancing the GI process for several of these varieties, including the Kachai Lemon. Looking forward, KVKs will continue to be essential in generating the scientific information necessary for effective GI protection. While GI status is expected to help secure the economic interests of local communities, it does not automatically lead to direct financial benefits. To realize these economic advantages, secondary agricultural and marketing initiatives are critical, such as forming Farmer Producer Organizations (FPOs). KVKs are vital to these efforts, as they serve as the most reliable scientific support for rural communities. These initiatives not only enhance the value of local landraces but also help maintain the interest of traditional conservators in preserving their heirloom varieties.

It is a well-acknowledged fact that modern landraces have been shaped by farmers through selection in traditional farming settings. In these environments, the interaction between plant genotypes and soil microflora plays a vital role, reflecting the principles of contemporary natural farming. Therefore, assessing landraces based on their responses to the unique microclimatic conditions found in natural farming systems is a promising approach. With their expertise and access to various microclimates, KVKs are well-positioned to enhance the advantages of natural farming by leveraging local landraces and germplasm effectively.

3. **Empowering KVKs: Leadership roles through organizational support**

With the right organizational backing, KVKs can significantly enhance their leadership roles in genetic resource conservation. By leveraging institutional resources and support systems, KVKs can implement innovative strategies that foster collaboration and drive impactful community engagement in genetic resource management. Some possible areas are:

a) **Collaborative networks and partnerships:** By enhancing their role as community knowledge hubs, KVKs can strengthen partnerships with schools, universities, Farmer Producer Organizations (FPOs), private businesses, NGOs, and government agencies to raise localized awareness about the value of plant germplasm. These collaborations will aid in collecting and sharing data on indigenous varieties, thus promoting the preservation and sustainable commercialization of local landraces. Moreover, a structured approach to data collection from community members—such as elders, traditional practitioners, and vendors—will contribute to developing indexes that assess use value, cultural significance, population trends, threat levels, commercial demand, perceived vulnerabilities, and harvesting intensity. This comprehensive data can ultimately inform conservation priorities at a local level, ensuring that efforts are effectively targeted and relevant to the community's needs.

b) **Financial and corporate engagement:** Tapping crowdfunding platforms and Corporate Social Responsibility (CSR) programs to secure funds for their conservation efforts. A "Germplasm for Good" campaign, for instance, could encourage businesses to fund germplasm conservation projects, with an emphasis on co-branding and sustainability.

c) **Adopt a germplasm program:** KVKs can initiate an "Adopt a Germplasm" program targeting urban consumers, corporations, and NGOs, where sponsors fund the conservation of unique indigenous landraces. This sponsorship model allows businesses and individuals to be directly involved in germplasm preservation, receiving updates and building personal connections with rural farming communities.

d) **Cultural and culinary tourism:** By developing agricultural and culinary tourism around indigenous crops (may be as a part of their Kisan Mela), KVKs can engage tourists, food enthusiasts, and local businesses. Organizing "Germplasm Trails" or "Culinary Tours" would showcase traditional farming practices, highlight local landraces, and create economic benefits for rural farmers while promoting conservation awareness.

e) **VR experiences:** Some selected KVKs, with the help of ICAR-NBPGR or their host institute/university, could create virtual reality (VR) experiences that simulate the farming of indigenous crops, targeting schools, universities, and public outreach events to educate a broader audience about the value of plant germplasm.

f) **Genetic heritage park**s: Converting germplasm section in the existing farm to 'Genetic Heritage Parks' in different regions could serve as educational and conservation hubs for local biodiversity. Targeting tourists, students, and researchers, these parks would showcase live demonstrations of traditional farming, seed preservation, and plant breeding practices, raising public awareness and supporting tourism-related income for rural areas.

g) **Biodiversity ambassadors program:** KVKs could create a Biodiversity Ambassadors initiative by enlisting celebrities, chefs, influencers, and public figures to advocate for plant germplasm conservation. These ambassadors would raise awareness about indigenous crops and promote the consumption of traditional varieties, leveraging their influence to reach wider audiences.

i) **Plant germplasm crowdfunding and demand forecasting:** Using crowdfunding platforms, KVKs could directly involve the public in conservation efforts, targeting urban consumers, sustainability advocates, and agriculture enthusiasts. Additionally, employing demand forecasting tools would help predict market trends for indigenous crops, allowing KVKs to better advice farmers on the crops with the highest commercial potential, ensuring sustainable income streams.

4. Conclusion

By embracing collaborative partnerships, innovative initiatives, and targeted community involvement, KVKs can substantially expand their role in conserving and commercializing plant germplasm. The Northeast region of India, known for its diverse genetic resources, faces challenges like collection gaps and the underutilization of many local landraces. As the popularity of natural farming and traditional flavours grows, the economic potential of these native varieties is set to increase. KVKs are uniquely positioned to lead efforts in the identification, collection, evaluation, and conservation of germplasm, blending scientific expertise with indigenous knowledge from traditional farmers.

Creative strategies—such as crowdfunding, culinary tourism, and educational outreach—can raise awareness, conserve biodiversity, and foster sustainable economic opportunities for rural communities. Leveraging modern technologies and engaging youth through schools and gamified platforms can ensure the survival and success of indigenous plant varieties in both rural and urban markets, while complementing national initiatives aimed at preserving genetic diversity.

However, to enhance KVKs' participation in managing genetic resources, it is crucial to recognize that they are currently operating at near-maximum capacity. Expanding their involvement would require substantial organizational support, including additional contractual manpower, funding, mobility, and training resources, as well as covering publication costs. With proper support, KVKs could play an even more pivotal role in ensuring the sustainability and resilience of India's plant genetic resources.

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Integrating Research and Indigenous Knowledge: Enhancing Agriculture in Arunachal Pradesh

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Abstract

Agriculture in Arunachal Pradesh, a northeastern state in India, is deeply rooted in Indigenous Technical Knowledge (ITKs) developed by local communities over generations. These traditional practices are adapted to the local environment and culture, offering sustainable solutions that are often overlooked by modern agricultural research. This paper explores the importance of ITKs in enhancing agricultural sustainability, resilience, and productivity, while also addressing the challenges and strategies for integrating these practices with scientific research. ITKs in Arunachal Pradesh include practices such as shifting cultivation (Jhum farming), Apatani wet rice cultivation, and bamboo drip irrigation. Shifting cultivation, despite criticism for deforestation, incorporates fallow periods that maintain soil fertility and biodiversity.

Challenges in integrating ITKs with modern research include the lack of documentation, perceived inferiority of traditional methods, limited access to research for remote farmers, and insufficient policy support. To bridge this gap, the paper proposes several strategies: participatory research involving local farmers, knowledge exchange programs, comprehensive documentation and dissemination of ITKs, policy advocacy for the recognition and support of traditional knowledge, and capacity building for farmers and extension workers. Participatory action research (Chambers, 1994) and the Farmer Field School (FFS) approach (van den Berg & Jiggins, 2007) have shown success in increasing the acceptance and adaptation of sustainable practices. The Traditional Knowledge Digital Library (TKDL) in India demonstrates the importance of documenting traditional knowledge (Patwardhan & Mashelkar, 2009), while the Protection of Plant Varieties and Farmers' Rights Act (PPVFR Act) provides legal recognition and protection for farmer innovations (Sahai, 2003). Capacity-building programs by ICAR – Krishi Vigyan Kendra have positively impacted rural livelihoods and productivity.

Integrating ITKs with modern research can create a more sustainable, resilient, and productive agricultural system in Arunachal Pradesh. Valuing and building upon traditional practices support local farmers' livelihoods, cultural heritage, and environmental health.

Keywords: Indigenous Technical Knowledge (ITK), Sustainable Agriculture, Arunachal Pradesh, Participatory Research, Traditional Farming Practices.

Introduction

Arunachal Pradesh, a state situated in the northeastern corner of India, represents a rich tapestry of diverse ecosystems, cultures, and agricultural practices. The region's agricultural landscape is intricately intertwined with Indigenous Technical Knowledge (ITKs) that have been developed and refined by local communities over centuries. These traditional practices, deeply rooted in local environments and cultural contexts, provide a unique perspective on sustainable agriculture that modern scientific research often overlooks.

Significance of Indigenous Technical Knowledge

Indigenous Technical Knowledge encompasses a wide array of traditional practices that have been shaped by intimate knowledge of local conditions. In Arunachal Pradesh, these practices include shifting cultivation (Jhum farming), integrated rice-fish farming by the Apatani tribe, and bamboo drip irrigation. Each of these methods reflects an advanced understanding of the region's ecology and demonstrates the potential for sustainable agricultural practices that align closely with environmental stewardship.

- **Shifting Cultivation (Jhum Farming):** Shifting cultivation is a practice where plots of land are cultivated for a few years and then left fallow to regenerate. Despite facing criticism for its impact on deforestation, studies such as those by Tripathi and Barik (2003) and Ramakrishnan (1992) highlight the ecological benefits of this method. The fallow periods support soil fertility and biodiversity, contributing to the overall health of the ecosystem.
- **Apatani Wet Rice Cultivation:** The Apatani tribe employs an integrated system of rice and fish farming, which is a testament to their sophisticated knowledge of water management and resource use. Research by Singh and Singh (2006) has shown that this system significantly enhances productivity and sustainability, achieving rice yields of 4-5 tons per hectare compared to the regional average of 2-3 tons per hectare.
- **Bamboo Drip Irrigation:** Bamboo drip irrigation is an indigenous technique that utilizes bamboo pipes to channel water efficiently to crops. Singh *et al.,* (2010) have documented its effectiveness in reducing water wastage and improving crop yields, making it a valuable low-cost irrigation method, particularly in areas with scarce water resources.

The need for integration with modern research

While ITKs offer substantial benefits, their integration with modern agricultural research presents several challenges. These include the lack of formal documentation of traditional practices, biases towards modern scientific methods, limited access to contemporary research for remote farmers, and insufficient policy support for integrating traditional knowledge into mainstream agricultural systems.

Opportunities for integration

Integrating ITKs with modern research holds the promise of creating a more resilient and sustainable agricultural system in Arunachal Pradesh. This integration can be achieved through several strategies:

- **Participatory Research:** Engaging local communities in research activities can help validate and refine ITKs, ensuring that they are aligned with contemporary scientific principles. Participatory action research (Chambers, 1994) and the Farmer Field School (FFS) approach (van den Berg & Jiggins, 2007) are effective methods for fostering collaboration between researchers and farmers.
- **Knowledge Exchange Programs:** Facilitating knowledge exchange between traditional knowledge holders and modern scientists can enhance the applicability and acceptance of ITKs. Establishing platforms for dialogue and demonstration can help bridge the gap between traditional and scientific knowledge.
- **Documentation and Dissemination:** Comprehensive documentation of ITKs is essential for preserving and sharing traditional knowledge. The Traditional Knowledge Digital Library (TKDL) in India serves as an example of how such documentation can be effectively managed and utilized (Patwardhan & Mashelkar, 2009).
- **Policy Advocacy:** Advocating for supportive policies that recognize and integrate ITKs into agricultural development programs is crucial. The Protection of Plant Varieties and Farmers' Rights Act (PPV&FR Act) provides a legal framework for protecting traditional knowledge and innovations (Sahai, 2003).

- **Capacity Building:** Training programs for farmers and extension workers can enhance their ability to apply both traditional and modern practices. Capacity-building initiatives by organizations such as the International Fund for Agricultural Development (IFAD) have demonstrated positive impacts on agricultural productivity and rural livelihoods (IFAD, 2013).
- Research by Tripathi and Barik (2003) and Ramakrishnan (1992) highlights the ecological benefits of Jhum cultivation. The Apatani tribe's integrated rice-fish farming system, studied by Singh and Singh (2006), demonstrates high productivity and resource efficiency due to traditional water management techniques. Bamboo drip irrigation, documented by Singh *et al.* (2010), showcases a low-cost, sustainable method for reducing water wastage and improving crop yield.

An African proverb says "When an old knowledgeable person dies, a whole library dies" indicating the importance of ITKs.

Importance of indigenous technical knowledge

Environmental Adaptation

ITKs are specifically adapted to the local climates, soil types, and ecosystems of Arunachal Pradesh. They incorporate extensive knowledge of local flora and fauna, weather patterns, and water resources, ensuring that agricultural practices are well-suited to the region's unique environmental conditions.

Sustainability

Many ITKs involve organic practices, crop rotation, and natural pest control methods that reduce dependence on chemical inputs, promoting sustainable agriculture. For example, shifting cultivation, despite criticisms for deforestation, includes fallow periods that allow the land to recover, maintaining soil fertility and biodiversity.

Cultural Relevance

ITKs are integral to the cultural identity of local communities. Practices such as the Apatani tribe's wet rice cultivation are not just agricultural methods but also a part of cultural heritage. Preserving these practices supports cultural cohesion and community identity.

Resource Efficiency

Traditional agricultural practices often make efficient use of available resources, minimizing waste and maximizing productivity. Bamboo drip irrigation, for instance, is a low-cost method that efficiently channels water to crops, reducing wastage and improving yields.

Impact of Indigenous Technical Knowledge (ITK) in agriculture

Water Management: In Sri Lanka, traditional methods of forecasting rain and managing water have been passed down through generations. Farmers utilize these methods to conserve water and make informed decisions about crop planting. Techniques such as constructing cascading tanks and utilizing canals for water distribution have been effective in ensuring water availability for agriculture. Additionally, farmers have developed practices for efficient water use, such as selecting drought-resistant seed varieties and timing ploughing to optimize rainwater utilization.

Soil Conservation: Farmers in various regions have implemented ITK practices for soil conservation. For instance, the use of Vetiver grass as a vegetative barrier helps prevent soil erosion and stabilizes slopes. This method is cost-effective and adaptable to different environmental conditions. Additionally, traditional practices like contour ploughing and planting between stabilized hedges have proven effective in controlling erosion, improving soil structure, and enhancing water infiltration.

Nutrient Management: Traditional knowledge includes methods for nutrient management that rely on natural resources and minimize reliance on artificial inputs. Techniques such as using botanical extracts like Bilb Rasyan and Gaajar Ghaas Svaras, as well as incorporating organic materials like cow urine and plant residues, help enrich the soil with essential nutrients. These practices promote sustainable agriculture by maintaining soil fertility and reducing dependence on chemical fertilizers.

Pest Management: Farmers have long employed ITKs for pest management, utilizing natural substances like neem leaves, tobacco, and cow urine to repel or control pests. These methods are eco-friendly and help minimize the use of synthetic pesticides, reducing environmental pollution and protecting beneficial insects. Additionally, practices like intercropping and crop rotation help disrupt pest cycles and maintain a balance in agroecosystems.

Crop Disease Control: Traditional practices for crop disease control involve the use of herbal extracts, ash, and cultural methods to prevent and manage diseases. Techniques such as applying ash and turmeric powder to plant leaves, using herbal solutions for seed treatment, and incorporating botanical extracts into crop management help mitigate disease incidence. These methods are safe, cost-effective, and contribute to sustainable crop production.

Integrated Pest Management (IPM): ITKs play a crucial role in integrated pest management by combining various techniques such as cultural, mechanical, and biological controls. Practices like attracting birds to paddy fields, using botanical formulations for pest suppression, and employing natural predators and traps help maintain pest populations below damaging levels. IPM strategies promote biodiversity, reduce pesticide dependence, and enhance ecosystem resilience.

Fisheries Management: In fisheries, traditional knowledge is utilized for fish preservation, pond management, and boat maintenance. Techniques such as salting and sun drying fish, using natural materials for boat construction and repair, and employing herbal extracts for water treatment contribute to sustainable fisheries management. Traditional practices ensure resource conservation, maintain fish quality, and support livelihoods in fishing communities.

Crop Husbandry and Animal Husbandry: ITKs are applied in crop and animal husbandry for soil fertility enhancement, pest and disease management, and animal health care. Practices such as burning stubbles for pest control, using natural remedies for animal ailments, and incorporating organic materials into soil contribute to sustainable agriculture. Traditional knowledge promotes ecosystem health, resilience, and the well-being of farming communities.

Indigenous Technical Knowledge plays a crucial role in sustainable agriculture by providing effective, low-cost solutions for water management, soil conservation, nutrient management, pest control, disease management, and fisheries management. By integrating traditional practices with modern agricultural techniques, farmers can enhance productivity, minimize environmental impact, and ensure food security for future generations.

The challenge of grain storage loss persists, impacting farmers nationwide. However, indigenous storage techniques, rooted in local wisdom, offer eco-friendly, cost-effective solutions to this dilemma. These methods not only safeguard grains from pests and environmental hazards but also ensure longevity without compromising quality. Two such indigenous storage structures, Kulumai and Underground Grain Storage Pit, epitomize the fusion of tradition and practicality, embodying centuries-old practices adapted to contemporary needs.

Case studies of ITKS in Arunachal Pradesh

Shifting Cultivation (Jhum Farming)

Shifting cultivation, or Jhum farming, is a traditional method where land is cleared, cultivated for a few years, and then left fallow to recover. A study by Tripathi and Barik (2003) in Arunachal Pradesh showed that the organic matter input during the cultivation period and the subsequent fallow periods-maintained soil fertility and biodiversity. This system also supports a diverse range of plant and animal species, contributing to the ecological health of the region. The United Nations University study by Ramakrishnan (1992) emphasized the ecological benefits of Jhum cultivation, including the maintenance of soil structure and prevention of soil erosion.

Apatani Wet Rice Cultivation

The Apatani tribe practices an integrated rice-fish farming system, which Singh and Singh (2006) found to be highly productive and sustainable. Their study highlighted the tribe's sophisticated water management techniques, which include the construction of intricate irrigation canals and the use of natural water bodies for fish farming. This integrated system enhances resource use efficiency and biodiversity. The average yield of rice in the Apatani fields is reported to be around 4-5 tons per hectare, significantly higher than the regional average of 2-3 tons per hectare for rainfed rice systems.

Bamboo Drip Irrigation

Bamboo drip irrigation is an indigenous method where bamboo pipes channel water from streams to fields. A study by Singh *et al.,* (2010) documented this practice and demonstrated its effectiveness in reducing water wastage and improving crop yields. This system, which can deliver 18-20 litres of water per minute to the fields, is particularly useful in areas with limited water resources. The study found that fields using bamboo drip irrigation had up to 25% higher yields compared to those using conventional irrigation methods.

Challenges in integrating itks with modern research

Lack of Documentation

Many ITKs are passed down orally and are not well-documented. This makes it challenging to validate and disseminate these practices scientifically, limiting their potential integration with modern agricultural research.

Perceived Inferiority

There is often a bias towards modern scientific methods, leading to the undervaluing of traditional knowledge. This perception hinders the acceptance and integration of ITKs into mainstream agricultural practices.

Limited Access to Research

Farmers in remote areas of Arunachal Pradesh may have limited access to scientific research and modern agricultural advancements. This gap restricts the exchange of knowledge and the adoption of improved practices.

Policy and Support

There is insufficient policy support and funding for integrating ITKs with modern practices. Policies that recognize and protect traditional knowledge and farmer innovations are crucial for supporting this integration.

Strategies for Bridging the Gap

Participatory Research

Engaging local farmers in research projects can validate and improve ITKs. Participatory action research (PAR) models, as described by Chambers (1994), have been successful in increasing the acceptance and adaptation of sustainable practices. This approach involves farmers directly in the research process, ensuring that the findings are relevant and applicable to their needs. For example, the Northeastern Region Community Resource Management Project (NERCRMP) has implemented participatory research to enhance the application of ITKs, resulting in increased crop yields and farmer income.

Knowledge exchange programs

Establishing platforms for knowledge exchange between researchers and farmers is essential. The Farmer Field School (FFS) approach, implemented by the Food and Agriculture Organization (FAO), has shown significant success in enhancing farmers' knowledge and adoption of integrated pest management practices (van den Berg & Jiggins, 2007). Workshops, field schools, and demonstration plots can facilitate this exchange.

In Arunachal Pradesh, Krishi Vigyan Kendra's have been instrumental in bridging the gap between scientific research and traditional farming practices, thereby enhancing the adoption of sustainable agricultural practices among local farmers. Here is a detailed overview of their activities and impact in the region:

1. **Training Programs:**

a. **Capacity Building:** KVKs in Arunachal Pradesh organize a range of training programs aimed at enhancing the technical skills and knowledge of farmers. These programs cover various aspects of agriculture, including crop management, pest control, soil health, and water conservation. By equipping farmers with updated knowledge and techniques, KVKs help them improve productivity and sustainability.

b. **Hands-On Training:** Practical, hands-on training sessions are conducted to demonstrate modern agricultural techniques and tools. This approach allows farmers to gain practical experience and see the benefits of adopting new practices in their own fields. Training often includes workshops on seed production, organic farming, and integrated pest management.

c. **Farmer Field Schools (FFS):** KVKs implement Farmer Field Schools, which provide a platform for farmers to learn and discuss agricultural practices in a collaborative environment. FFS encourages experiential learning and peer-to-peer knowledge exchange, enhancing the adoption of sustainable practices.

2. **Field Demonstrations:**

a. **On-Farm Trials:** KVKs conduct on-farm trials to demonstrate the efficacy of new technologies and practices. These trials involve setting up demonstration plots where farmers can observe the performance of new crop varieties, irrigation methods, and pest management techniques under local conditions.

b. **Technology Dissemination:** Field demonstrations showcase modern agricultural technologies and innovations, such as improved seed varieties, drip irrigation systems, and bio-pesticides. By observing these technologies in action, farmers are more likely to adopt them in their fields.

c. **Success Stories:** KVKs highlight successful case studies and success stories from field demonstrations to inspire and motivate other farmers. These stories often involve increased yields, reduced costs, and improved environmental outcomes, showcasing the tangible benefits of adopting new practices.

3. **Extension Services:**

a. **Advisory Services:** KVKs provide advisory services to farmers on various aspects of agriculture, including crop selection, soil health management, and market linkages. These services help farmers make informed decisions and address specific challenges in their farming practices.

b. **Personalized Support:** Extension officers from KVKs offer personalized support to farmers, including one-on-one consultations and site visits. This personalized approach ensures that farmers receive tailored advice and assistance based on their unique needs and conditions.

4. **Collaboration and Partnerships:**

a. **Research Institutions:** KVKs collaborate with research institutions and universities to bring the latest scientific advancements to farmers. These partnerships facilitate the transfer of cutting-edge technologies and practices from research labs to the field.

b. **Government and NGOs:** KVKs work with government agencies and non-governmental organizations (NGOs) to implement agricultural development programs and initiatives. These collaborations help in the effective implementation of policies and schemes designed to support farmers.

c. **Community Engagement:** KVKs engage with local communities to understand their needs and challenges. This community-driven approach ensures that the training programs and demonstrations are relevant and address the specific issues faced by farmers in the region.

5. **Impact and Outcomes:**

a. **Increased Adoption:** KVK initiatives have led to increased adoption of sustainable agricultural practices among farmers in Arunachal Pradesh. Practices such as organic farming, water-saving irrigation methods, and improved crop management have been successfully implemented in many areas.

b. **Improved Productivity:** Farmers who have participated in KVK programs have reported improvements in crop yields and overall productivity. The adoption of new technologies and practices has helped increase agricultural output and income.

c. **Environmental Benefits:** The promotion of sustainable practices by KVKs has contributed to environmental conservation. Techniques such as soil conservation, water management, and integrated pest management have reduced the environmental impact of farming activities.

d. **Enhanced Knowledge:** KVK programs have significantly enhanced the knowledge and skills of farmers, empowering them to make informed decisions and adopt practices that improve their livelihoods and sustainability.

Documentation and Dissemination

Creating accessible databases and publications documenting ITKs is vital. The Traditional Knowledge Digital Library (TKDL) in India, for instance, has demonstrated the importance of documenting and protecting traditional knowledge (Patwardhan & Mashelkar, 2009). Ensuring that this information is available in local languages can enhance its accessibility and utility. A collaborative effort between local universities and community organizations in Arunachal Pradesh could create a comprehensive database of ITKs, ensuring their preservation and wider dissemination.

Policy Advocacy

Advocating for policies that recognize and support the integration of ITKs into mainstream agricultural research and extension services is crucial. The Protection of Plant Varieties and Farmers' Rights Act (PPVFR Act) in India provides legal recognition and protection for traditional knowledge and farmer innovations (Sahai, 2003). Such policies can incentivize the adoption of ITKs and support sustainable agricultural development. The National Mission for Sustainable Agriculture (NMSA) can include specific programs aimed at integrating ITKs into its framework, providing funding and support for traditional practices.

Capacity Building

Providing training and resources to farmers and extension workers can enhance their understanding and application of both ITKs and modern scientific methods. Capacity-building programs by organizations like the International Fund for Agricultural Development (IFAD) have demonstrated positive impacts on rural livelihoods and agricultural productivity (IFAD, 2013). In Arunachal Pradesh, capacity-building initiatives can include training on sustainable farming practices, water management, and crop diversification, enhancing the overall resilience of the agricultural system.

Conclusion

Integrating Indigenous Technical Knowledge with modern agricultural research in Arunachal Pradesh offers a holistic approach to developing a sustainable, resilient, and productive agricultural system. This integration acknowledges the value of traditional practices that have been refined over generations, aligning them with modern innovations to address contemporary challenges. By fostering collaboration among local farmers, indigenous communities, researchers, and policymakers, it is possible to develop agricultural practices that enhance biodiversity, improve climate resilience, and promote sustainable resource management. Documenting and sharing traditional knowledge ensures its preservation and transmission, while participatory extension services and inclusive educational programs can empower communities.

Policy support is crucial for recognizing and protecting indigenous knowledge, providing the necessary legal and financial backing to integrate it with modern practices. Through case studies, pilot projects, and community initiatives, successful examples of this integration can be demonstrated, inspiring broader adoption.Ultimately, the synthesis of Indigenous Technical Knowledge and modern agricultural research not only supports the livelihoods of local farmers but also contributes to environmental health and cultural preservation. This approach holds the promise of a more sustainable and prosperous future for Arunachal Pradesh and can serve as an inspiring model for other regions seeking to harmonize tradition with innovation.

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NATIVE BASKET- *Your Ethnic Taste*: The Value Chain Development, Brand Creation, Brand Promotion and Market Linkage Initiative of Native Crops of Assam

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Prologue

It is said that when *CHAO-LUNG-CHUKAPHA* the first Ahom King crossed Patkai Hills and entered Assam in 12th Century AD, he was charmed by the abundant rice, other crops, vegetables, other plant resources and called it *MON-DUM-CHUNG* i.e. "Land of Plenty" and the Ahoms ruled Assam for 600 years till the advent of imperial British after the Indo-Burmese war of 1826 AD. During their reign of 600 years in Assam (also in parts of the neighbouring states) the heydays of agriculture, primarily the cultivation along with the diversity of rice reached its peaks. Even after Assam was taken over by the British, the trend of the traditional agriculture system using the native crop varieties somewhat continued, but sadly its gradual decline started in Independent India and by 80's, owing to diverse factors, the decline accelerated alarmingly and noticeable genetic erosion has occurred in the native crop varieties of Assam.

The North East India is a confluence theatre, of diverse anthropological types. More so in the state of Assam, where the dynamics of convergence and divergence are, in a continuous state of flux. There are various historical and anthropological records available that hints at linkages of the people of this region to those of East and of South East Asia and to that of India.

The North Eastern Region of India is one of the 18 hot spots of Indian Mega diversity center. The region is endowed with various crop plants diversities together with the occurrence of their wild relatives where 43% floristic element of total Indian flora are available. Hardly 20 crops, many underutilized crops are utilized as daily food by the people of this region and rice is used as the primary stapple food and to make processed products. Among the states of the region, Assam is the richest in diversity of rice and its wild relatives, but sadly due to indiscriminate introduction of improved / HYVs rice varieties have threatened the survival and thus made many or most of the invaluable genetic resources of the heirloom native rice varieties critically endangered.

The Story of the brand "NATIVE BASKET- Your Ethnic Taste" to promote and market the heirloom varieties of native crops of the North Eastern Region of India

The endeavour has been initiated from November 1998 under the NATP-PB Project implemented by ICAR with the concept of survey, exploration, documentation (along with the documentation of the associated ITK / TK), collection of the native genetic resources of North East India, *ex-situ* conservation of the germplasm in the ICAR-NBPGR National Gene Bank and organizing awareness generation campaign in the grassroots level for motivating / encouraging the farmers for conserving the native crop varieties. Since the inception of NATP-PB Project in N.E. India, lot of dedicated effort has been exerted towards the conservation of the native varieties of crops and irrespective of whatever has been done, still it has been noticed that the diversity of these invaluable genetic resources has been depleting alarmingly by the invasion of HYVs. Since the farmers are getting more production from HYVs and thus value out of their produce, they are deserting the native varieties and as a result widespread genetic erosion of native varieties have occurred. Hence, it has been bitterly realized that, without creating a market prospect for the native crops varieties and assuring a lucrative financial return to the farmers, in reality, the effort of conservation of these invaluable native genetic resources is going to yield no positive result.

Table 1. In the following table the present status of the native rice varieties and Associated Traditional Knowledge Native Rice Varieties of Assam has been displayed

Season with Native Term	Character with Native Term	% of Land Coverage	Status of Existence	Specific Information / Special Traits and Associated Traditional Knowledge
Ahu (Autumn-Summer)	Non-Glutinous	<0.5%	Critically Endangered	Low yield. Not susceptible to normal short duration flood and are used for making processed products.
	Glutinous (Bora Dhan)	<0.25%	Critically Endangered	Low yield. Not susceptible to normal short duration flood. All varieties are used for making processed products
	Aromatic (Joha Dhan)	<0.25%	Critically Endangered	Low yield. Not susceptible to normal short duration flood. Has socio-cultural and socio-religious use.
Shali (Kharif 1)	Non-Glutinous	2-3%	Critically Endangered	Low to Moderate yield. Not susceptible to normal short duration flood and stagnant water and are used for making processed products.
	Glutinous (Bora Dhan)	1%	Critically Endangered	Low yield. Not susceptible to normal short duration flood. All varieties are used for making processed products. Has socio-cultural and socio-religious use.
	Semi-Glutinous (Chakowa Dhan & Lahi Dhan)	<0.5%	Critically Endangered	Low yield. Not susceptible to normal short duration flood. All varieties are used for making processed products. Few selected varieties are used for making Soft Rice (Komal Chaul) which has received GI. Has socio-cultural and socio-religious use.
	Aromatic (Joha Dhan)	<0.5%	Critically Endangered	Low yield. Not susceptible to normal short duration flood. Has socio-cultural and socio-religious use.
Bao or Deep Water Rice (Kharif 2)	Non-Glutinous	<0.5%	Critically Endangered	Low yield. Not susceptible to flood and stagnant water and can be used for making processed products.

Though a sizable chunk of the native crop varieties got extinct, the UN Environment implemented GEF funded project which was launched in 2016 brought great hope for rescuing the precious genetic resources of the heirloom varieties of native crops as therein the “value chain development, brand creation & market linkages of the native crop varieties selected as target crops" is one of the primary & focused objectives of the project. Taking advantage of this focused objective and its guidelines under the project, a target oriented applied module has been designed and initiated the work towards,

- In-depth market study and research
- *In-situ* (on-farm) conservation and nutritional profiling of available genetic diversity of the targeted native crop
- Identification and selection of the heirloom native varieties and its processed products of the targeted crops having market prospect
- Seed multiplication of the heirloom varieties of the targeted native crops
- Creation of FPOs with business oriented mindset
- Identification and selection of beneficiary champion farmers
- Properly organized cultivation and storage systems
- Community managed seed system
- Appropriate processing, value addition, quality control
- Value chain development and market linkage
- Brand development and aesthetic packaging penetrative brand promotion and propaganda planning
- Robust marketing strategy for the holistic conservation of the rich diversity of the native crop varieties and safeguarding the rich traditional agricultural heritage through value chain development and market linkages of the native heirloom crop varieties.

As it has been well understood and realized that, only lucrative earning from the native crop varieties would encourage the farmers to cultivate those varieties and thus the primary objective of conservation of the invaluable native crop genetic resources could be successfully attained.

Based on the prospect, with an in-depth focus on conservation, a holistic strategy and effort has been initiated since the start of 2018 under the project towards creating a product brand for the native crop varieties of the project sites of Assam and accordingly a plan was devised to create FPO's and identify and select farmers, existing SHGs and FMCs in consonance with the stagey.

According to the strategy the brand "NATIVE BASKET" has been created and promoted by Foundation for Development Integration (FDI) with its logo registered as a Trademark under the Bureau of Patents and Trademarks, Govt. of India, with a FSSAI licence from the Ministry of Health and Family Welfare, Govt. of India and an aesthetic design for packaging the brand has also been designed. FDI has entered into entered into a collaborative agreement with the firms: M/s RED RIVER (as Primary Stuckist, Distributor & Marketing Firm), M/s NILACHAL AGROTECH (as Supporting Marketing Firm) and M/s BANSAR (as Online Marketing Firm).

The tag line for the brand is, "**NATIVE BASKET- *Your Ethnic Taste***", *A Trademark Registered Brand of Organically Produced Nutrient Rich Heirloom Crops Varieties of North East*

As of now, 24 native heirloom rice varieties for wholegrain and 9 native heirloom rice varieties for processed products have been identified and selected from across the project sites of Assam based on the Field Trial & Seed Multiplication, preference of the farmers & consumers, in-depth market study & research, market prospect analysis undertaken during 2017, 2018 and 2019 and nutritional profiling of the rice varieties done at ICAR-NBPGR. In this process native heirloom varieties of Pigeon Pea, Black Gram, Green Gram, Sesame, Mustard and some more rice varieties were also included under the brand.

A network of farmers and selected SHGs have been sensitized, made aware and engaged across the project sites of Assam to cultivate the selected heirloom native rice varieties (for whole grain and processed products) in large scale for the value chain development and market linkages through the FPOs under the brand "NATIVE BASKET".

The members of the 3 FPOs across the project sites of Assam have been trained develop and maintain forward & backward communication & linkages with the network of farmers and selected SHGs for keeping them interested and remain engaged in cultivation of the selected heirloom native rice varieties (for whole grain and processed products) and purchase the produce at a justified and competitive price to keep them within the network, and also to attract new farmers to the network and supply to the marketing agency, Red River which has been connected with the FPOs through Foundation for Development Integration (FDI).

The brand has been launched with 4 native rice varieties of Assam and an outlet opened for the same at the Kamakhya Temples' Complex, Guwahati, Assam on December 30, 2020.

Till date, under the brand "**NATIVE BASKET**", wholegrain of 5 Non-glutinous Deep Water Rice (Bao Dhan), 3 Non-glutinous Kharif Rice (Shali Dhan), 5 Aromatic Rice (Joha Dhan), 3 regular Komal Chaul (Soft Rice or Zero Cooking Rice), 3 roasted Komal Chaul (Soft Rice or Zero Cooking Rice), 2 Sticky Rice (Bora Chaul), 1 Sticky Roasted Rice (Bhaja Chaul), 1 Roasted Rice Powder (made from Sticky Rice), and 6 Flattened Rice (Cheera), and wholegrain of 1 Black Gram (Mati Mah), 1 Green Gram (Mogu Mah), 1 Sesame (Kola Til) have been launched in the market.

It has been observed that, since the first launch products under the brand "NATIVE BASKET" on December 30, 2020 till date, good response, and demand for launched have been received from public at the in display and sale in the outlet opened at the Kamakhya Temples' Complex.

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Entrepreneurial Ecosystem Creation with Wild Edible Fruits using Fermentation Technology in the State of Meghalaya

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Abstract

This paper explores the creation of an entrepreneurial ecosystem in Meghalaya centered around the utilization of wild edible fruits through fermentation technology. Meghalaya's rich biodiversity, coupled with a tradition of local agriculture, provides a fertile ground for harnessing these indigenous resources to establish new business ventures. Fermentation technology, specifically in the production of fruit wines, distilled spirits, and other fermented products, offers significant economic opportunities. This paper examines the potential for building a sustainable entrepreneurial ecosystem, the role of indigenous fruits, technological advancements, challenges, and policy recommendations for enhancing local livelihoods.

1. Introduction

1.1 Background

Meghalaya, known for its lush green hills, diverse flora, and indigenous fruit varieties, holds untapped potential in the realm of Agri-entrepreneurship. Many fruits such as Sohiong (*Prunus nepalensis*), Te'Gism (*Prunus jenkinsii*), Blood Fruit (*Haematocarpus validus*), Sohlang (*Viburnum*), Soh Phoh Khasi (*Docynia indica*), Plums, Soh Niamtra (Khasi mandarin), passion fruit, banana, jackfruit and pineapple grow abundantly in the region. Despite this biodiversity, the state's fruit market remains largely underdeveloped, with limited value addition and poor connectivity to larger markets.

1.2 The Role of Fermentation Technology

Fermentation is one of the most ancient and efficient methods of food preservation and product development. In recent years, fermentation has expanded beyond traditional uses, transforming into a technology that supports the production of value-added products such as fruit wines, vinegars, brandies, and other beverages. Leveraging fermentation technology to process wild fruits into marketable products offers an avenue for entrepreneurship and rural development in Meghalaya.

2. Potential of Wild Edible Fruits of Meghalaya

2.1 Overview of Wild Edible Fruits

The wild edible fruits of Meghalaya found in the Khasi, Jaintia and Garo hills, offer significant nutritional and medicinal benefits. Examples include:

- **Sohiong & Te Gism**: A deep purple fruit with high antioxidant properties, ideal for wine production.
- **Sohlang & Blood Fruit**: A wild fruit valued for its sweet taste and bioactive compounds.
- **Wild Apple & Plum**: Known for their versatility in juices, jams, and fermented beverages.
- **Khasi Mandarin & Pineapple**: Known for their sweetness and flavours, these are excellent bases for both fruit wines and spirits.

2.2 Commercial Viability

These indigenous fruits, many of which are either underutilized or entirely neglected in commercial markets, have tremendous potential for value addition. Fermentation technology offers an innovative path to create products that appeal to both local and global markets. Furthermore, the intrinsic uniqueness of these fruits provides a competitive advantage for entrepreneurs looking to enter niche markets, particularly those focused on organic, natural, and artisanal products.

3. Fermentation Technology and Value Addition

3.1 Fruit Wine Production

The production of fruit wines through fermentation is a relatively simple but highly impactful value-addition process. Wild fruits such as Sohiong and Te Gism can be transformed into premium fruit wines with high market demand. While Sohlang and Blood Fruit combined with honey can be crafted into rare meads, fruit forward and crisp wines can be made from plum and pineapple, while Khasi Mandarin and Khasi Mandarin Honey can be naturally fermented to an umber local premium mead full of flavours and complexities. This process involves minimal technological inputs, making it accessible to small and medium enterprises (SMEs). The production process requires:

- **Harvesting**: Gathering fruits at optimal ripeness.
- **Fermentation**: Using yeast to convert the sugars in fruits into alcohol.
- **Aging and Bottling**: Allowing the wine to mature for enhanced flavours and packaging it for market distribution.

3.2 Distillation for Fruit Brandies

Beyond fruit wines, Meghalaya's entrepreneurial ecosystem could benefit from the production of fruit brandies. A micro-distillery setup could utilize fermentation and subsequent distillation to create high-quality fruit spirits. Sohiong, for instance, has already shown promise as a base for both wine and brandy production. Captain Harold Douglas Hunt was an influential figure in the history of fruit wine and distillation in Meghalaya, particularly in the region of Mawphlang. His pioneering efforts in establishing one of the first fruit wineries and distilleries in the Khasi Hills and the country, in 1947, laid the groundwork for the fruit wine industry in the state. Located in Mawphlang, a scenic village known for its sacred forests and natural beauty, Captain Hunt's winery and distillery played a vital role in preserving and promoting the use of indigenous fruits for wine and spirit production.

3.3 Additional Fermented Products

Beyond alcoholic beverages, fermentation technology can be applied to create non-alcoholic beverages such as fruit vinegars, kombucha, and probiotic drinks. These products have rising demand in health-conscious markets, especially as they emphasize natural ingredients and sustainability.

4. Entrepreneurial Ecosystem Development:

Prior to September 2020, fruit wines made by enthusiasts if any, were only for home consumption and could not be distributed or sold in the open market. In fact, it was illegal to make or sell any fruit wine without obtaining a licence and licences could not be given to anyone for want of an enabling legal framework. The policy, approved by the Government of Meghalaya in September 2020 finally closed the long-pending demand for legalising local fruit winemaking. The 'Manufacture and Sale of Home-made Fruit Wines Rules, 2020 authorizes the excise department to issue licences to local fruit wine makers of the state. A step forward, but still, just a beginning with a lot more ground to cover.

4.1 Ecosystem Components

Creating an entrepreneurial ecosystem based on wild edible fruits and fermentation technology requires the integration of several components:

- **Farmers and Foragers**: The primary suppliers of wild fruits. Empowering local communities to sustainably grow and harvest wild fruits is crucial.
- **Entrepreneurs and SMEs**: Key players who will utilize fermentation technology to create value-added products.
- **Technical and Research Institutions**: Entities like universities and technical colleges that provide training in fermentation technology and product development.

- **Government and Policy Makers**: The role of the state in creating policies that support agro-based entrepreneurship, improve market access, and provide incentives for innovation is critical.

4.2 Role of Innovation Hubs and Incubators

Innovation hubs and incubators can provide the necessary support infrastructure for budding entrepreneurs in Meghalaya. These hubs can offer training in fermentation technology, business development, and marketing, enabling local entrepreneurs to bring their products to national and international markets. Setting up research and development (R&D) centres or fruit wine academies focused on fermentation, with a specialization in indigenous fruits, will create a pipeline for continual innovation.

4.3 Sustainable Harvesting, Propagation, Conservation and Apiculture

The entrepreneurial ecosystem must also emphasize sustainability. Over-harvesting of wild fruits can deplete natural resources. Therefore, sustainable harvesting practices must be adopted, and nurseries should be established for propagating indigenous fruit trees. Additionally, the integration of Apiculture with wine making can further enhance the ecosystem by providing cross-pollination benefits to orchards and a secondary product line in honey, spawning the production of exotic meads as a value add.

5. Challenges and Solutions

5.1 Lack of Infrastructure

One of the primary challenges in Meghalaya is the lack of proper infrastructure for the transport, storage, and processing of wild fruits. Cold storage facilities, better road connectivity, small-scale fermentation plants and primary processing units closer to production clusters need to be developed.

5.2 Limited Access to Markets

Currently, Meghalaya's entrepreneurs face limited market access due to logistical challenges and a lack of marketing skills. Solutions include:

- Creating cluster and cooperative marketing platforms for fruits and other agricultural commodities
- Promoting wine tourism that showcases local products through specialized and dedicated wine boutiques and at national and international events
- Utilizing e-commerce platforms for direct sales to customers outside the region.

5.3 Training and Knowledge Gaps

There is a significant gap in the knowledge of modern fermentation techniques among local entrepreneurs. This gap can be bridged by establishing partnerships with technical institutions and offering hands-on training and certifications in fermentation technology.

5.4 Lack of awareness and knowledge

- There was not enough extension or awareness about the law – so the Commission took it upon itself, with support from the Excise department and Food Safety labs, to educate potential entrepreneurs as to how to obtain licences to make, distribute or sell fruit wines.
- The complex and sophisticated art of making commercial quality fruit wines was still to be figured out by our local wine makers but with advanced wine making training courses, this should no longer be an impediment.
- There is a definite lack of clarity even at the national level with regard to the food safety standards for the fruit wines which needs to be addressed through research, case studies and rigorous testing.

6. Policy Recommendations

6.1 Government Support and Incentives

The government of Meghalaya should introduce policies that:

- Offer tax incentives to agro-entrepreneurs and winemakers
- Provide financial assistance for setting up fermentation facilities.
- Encourage sustainable harvesting practices, propagation and conservation of wild fruit species.
- Facilitate the establishment of Fruit Wine Boutiques

- Inclusion of Mead, Perry / Ciders, Fruit spirit, fortified wines, fruit brandy, Ales (Ginger/ Buckwheat/Millets etc) in the existing licenses
- Creation of a Meghalaya Wine and Mead Board
- Establishment of a Wine and Mead Park and a Fruit Wine Academy within the park.

6.2 Emphasis on Wine Tourism and its Impact on Existing Tourist Areas in Meghalaya

Fruit Wine tourism, centred around the state's unique wild fruit wines, can significantly enhance the tourism experience in Meghalaya. Known for its breathtaking landscapes, waterfalls, caves, and rich cultural heritage, Meghalaya already attracts a large number of tourists. Integrating wine tourism into the region's existing tourism framework can create a synergistic effect, boosting local economies and diversifying the state's tourism offerings. The following are the key ways in which wine tourism can boost existing tourist areas in Meghalaya:

6.2.1 Diversifying Tourism Offerings

Meghalaya's existing tourist hotspots such as Shillong, Cherrapunji, Mawlynnong, and Dawki can benefit from additional attractions like orchard tours, wine tastings, and wine festivals. Offering wine tourism alongside natural sightseeing would enhance the overall experience for tourists, providing them with an authentic, locally-inspired activity that goes beyond traditional sightseeing.

- **Wine Tasting Experiences**: Creating dedicated wine tasting rooms and experiences, particularly around Shillong and the Khasi Hills, would add a layer of cultural and culinary engagement for visitors. This could appeal to a different demographic of tourists, such as wine enthusiasts, culinary travellers, and eco-tourists, increasing the diversity of visitors to Meghalaya.
- **Winery and Orchard Tours**: Tourists can visit fruit wine wineries in areas like the Khasi Hills and tour orchards that grow local fruits such as Sohiong, Khasi Mandarin, and Pineapple. These experiences would not only introduce tourists to Meghalaya's biodiversity but also educate them about the traditional methods of winemaking, indigenous fruits, and fermentation processes.

6.2.2 Creating New Tourism Circuits

Fruit Wine tourism can help create new tourism circuits that integrate Meghalaya's natural beauty with its growing fruit wine industry. Combining visits to wineries with existing attractions can generate new business opportunities and increase tourist footfall across different regions.

- **Shillong Wine Circuit**: A tour starting from Shillong, covering local orchards and wineries in the Khasi Hills, can be designed. Tourists can visit Shillong's markets and cultural hubs, then explore nearby wine production centres, blending cultural tourism with the culinary experience of wine tasting.
- **Eco-Friendly Wine Trails**: Eco-tourism destinations such as Mawlynnong (Asia's cleanest village) and the Living Root Bridges of Nongriat could introduce visitors to wine trails where they not only explore nature but also enjoy local fruit wines made from the region's unique fruits. This offers tourists an immersive experience, with a balance between cultural heritage and environmental conservation.

6.2.3 Extending Tourist Stays

Integrating wine tourism with existing tourist spots has the potential to increase the length of stay for visitors. Offering wine tours, tastings, and orchard experiences provides additional activities that can encourage tourists to spend more time in Meghalaya.

- **Seasonal Wine Festivals**: Hosting wine festivals in major tourist destinations such as Shillong and Cherrapunji can be timed with harvest seasons, attracting tourists during off-peak periods. This not only increases footfall during the slow seasons but also creates an incentive for tourists to stay longer to experience the local wine culture.
- **Culinary Tourism and Food Pairing Events**: Pairing Meghalaya's traditional cuisine

with local fruit wines can open up new avenues for food tourism. Food studios and restaurants can host wine and food pairing events, introducing tourists to Meghalaya's indigenous flavours and culinary traditions, while promoting locally- produced wines. This culinary dimension adds depth to the tourist experience, encouraging longer stays.

6.2.4 Boosting Local Economies and Employment

Fruit Wine tourism would directly support Meghalaya's local economy by creating jobs and generating income through increased tourist spending. Establishing wine tours, tasting rooms, and festival events would require new infrastructure and services, leading to employment opportunities for local communities.

- **Rural Economic Development**: Villages surrounding wine production areas, such as those in the Khasi Hills, would see increased demand for agricultural produce, hospitality services, including accommodations, restaurants, and guided tours. By involving local communities in the tourism value chain, wine tourism can foster inclusive development and raise income levels in rural areas.
- **Craft and Souvenir Markets**: Wine tourism can also encourage the growth of local artisanal markets. Tourists who visit wineries often look for souvenirs, which can boost the sale of locally-made crafts, wine-related merchandise, and other indigenous products. This could help sustain traditional crafts and generate additional income for artisans in tourist-heavy areas.

7. Role of the Meghalaya Farmers' (Empowerment) Commission

The fruit wine sector needed much deeper governmental support – of a kind that is beyond the scope or competence of many of the line departments. The issue had fallen in between the departmental cracks and no department owned the idea of promoting Fruit Wine industry in the state. The Meghalaya Farmers' (Empowerment) Commission had to step in, because its singular focus is the farmer, the end beneficiary who is struggling to market his produce. Seeking to enhance the demand for agri-horti commodities, the Commission has been and is playing a pivotal role in the entrepreneurial ecosystem development by actively supporting farmers through sustainable agricultural practices and policy advocacy. Its contributions to the creation of an entrepreneurial ecosystem based on wild edible fruits and fermentation technology include:

- **Farmers' Empowerment**: The Commission works to improve the livelihood of farmers by advocating for better pricing mechanisms, capacity building, facilitating access to technology and credit, and ensuring that farmers receive fair compensation for their produce. This is crucial in the wild fruit sector, where traditionally underutilized resources like Sohiong and Sohlang can become more valuable through fermentation technology.
- **Training**: In partnership with fruit wine experts and wine educators, the Commission provides training in wine making. This enables wine makers to improve the quality and quantity of their products, which are essential from a global perspective, and which opens up access to markets.
- **Sustainable Harvesting Practices**: The Commission is a strong advocate for sustainable harvesting methods to protect the biodiversity of Meghalaya. It encourages the propagation and conservation of wild fruit species and promotes agroforestry systems, which can enhance the supply of raw materials for fermentation while preserving the environment.
- **Market Linkages**: The Commission facilitates direct market linkages between farmers and entrepreneurs in the fermentation sector, improving market access for local farmers. By connecting farmers with value-adding industries, such as fruit wine production and distillation, it helps integrate them into the broader entrepreneurial ecosystem while ensuring fair compensation for their efforts.

- **Policy Advocacy and Support**: The Farmers' Commission has been instrumental in advocating for policies that support agri-based entrepreneurship especially in the fruit wine sector. It works with the state government to create a favourable business environment by ensuring that policy frameworks are conducive to the growth of fermentation-based industries. Additionally, it promotes Wineries and Wines of Meghalaya on global platforms such as Vinexpo and SIAL which are some of the largest wine trade platforms in the world.

Through its efforts, the Meghalaya Farmers' (Empowerment) Commission is an essential contributor to the creation of a sustainable and inclusive entrepreneurial ecosystem in the state, helping farmers benefit from value addition via fermentation technology. Its work strengthens the connection between agriculture, innovation, and entrepreneurship, ensuring that local communities directly benefit from the economic opportunities arising from the region's natural resources.

Conclusion

Modern fermentation technology is an emerging and potent opportunity for the state to not only promote enhanced farming incomes but also address the wastage of perishable produce in the supply chain, which is as high as 40%. Through the creation of an entrepreneurial ecosystem around Wine, farmers will be happy, entrepreneurs will be happy, wine aficionados will be happy and of course, tourists will return happy with a bottle or two of Meghalaya's Fruit Wines. The Government gains too because of the increased tax revenue and the wealth thus generated circulates within the local economy. Combined with wine tourism, this is a powerful opportunity to enhance and diversify the state's tourism industry by integrating it with its existing natural and cultural assets. By creating new tourism circuits, extending tourist stays, and promoting local economies, wine tourism can transform Meghalaya into a major destination for experiential travellers. Furthermore, this initiative would help preserve and promote the state's biodiversity and cultural heritage, benefiting local communities while offering tourists a unique and immersive experience.

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Impact of Frontline Demonstration in Uses of Improved Cultivars of Genetic Resources in North-Eastern India

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Introduction

The Eastern Himalayas region of the country with diverse climatic conditions give rise to a vibrant spectrum of **biodiversity**, earning it a place among the world's mega **biodiversity** hotspots.The North Eastern states of India possess abundant flora and fauna with extensive availability of dense forests and abundant rainfall. Complex Diverse and Risk prone (CDR) agricultural systems in NE India having about 80% rainfed agricultural area and 77% population of the region engaged in agricultural operations.The existing agro-biodiversity in the NER having different iindigenous crop, animal and fish resources make the region as one of the twelve (12) mega-biodiversity centres of the world. The various plant/crop genetic resources found in this region have got paramount importance for future crop improvement programmes.

Krishi Vigyan Kendra (KVKs)

The Krishi Vigyan Kendras working at the grass root levels have been involved in facilitating adoption of technologies developed by the National Agricultural Research System. At present there are twenty (20) KVKs under the administrative control of ICAR Research Complex for NEH Region, Umiam, Meghalaya located across the North Eastern Region viz., (Hailakandi in Assam, Anjaw, Longding, Namsai, West Siang in Arunachal Pradesh, Chandel, Churachandpur, Imphal West, Tamenglong and Ukhrul in Manipur, Ri-Bhoi and West Garo Hills in Meghalaya, Peren, Longleng, Kiphere, Wokha and Dimapur in Nagaland, East Sikkim in Sikkim, South Tripura and West Tripura in Tripura). The KVKs in both the Zones i.e ICAR- Agricultural Technology Application Research Institute (ATARI), Zone VI, Guwahati and Zone VII, Umiam are performing multi-dimensional roles, starting from core activities such as technology backstopping, resource-conservation methods, introduction of cutting-edge technologies and upscaling at one end and envisioning entrepreneurial opportunities in rural areas, providing vocational/skill training to rural youth, women folks, school drop outs and extension functionaries of line department of the district and state agriculture and allied sectors.

ICAR- KVK Ri-Bhoi was established in 3rd August 2002 under the administrative control of ICAR Research Complex for NEH Region, Umiam, Meghalaya under ICAR- Agricultural Technology Application Research Institute (ATARI), Zone-VII, Umiam, Meghalaya for testing location specific technologies developed by research Institute/Agricultural Universities for large scale demonstration with the capacity building/skill development for farmers, farm women, rural youths, school drop outs and extension functionaries in the district. The Vision of KVK is "Science and technology-led growth leading to enhanced productivity, profitability and sustainability of agriculture" with the Mission of "Farmer-centric growth in agriculture and allied sectors through application of appropriate technologies in specific agro-ecosystem perspective". The Mandate of KVK is "Technology Assessment and Demonstration for wider Application and to enhance Capacity Development (TADA-CD)". The KVK Activities includes (i) On Farm Testing (OFT) to assess location specificity of agricultural technologies under various farming systems. (ii) Out scaling of farm innovations through Front Line Demonstration (FLD) to showcase the specific benefits/ worth of technologies in farmers' fields.(iii) Capacity development of farmers and extension personnel to update their knowledge and skills in modern agricultural technologies and enterprises. (iv) Work as Knowledge and Resource Centre for improving overall agricultural economy in the operational area.(v) Conduct front line extension programmes and provide farm advisories using Information Communication Technology (ICT) and other media on varied subjects of interest to farmers and (vi) Data documentation, characterization and strategic planning of farming practices. To demonstrate the production potential of newly released technologies on the farmers' fields at various locations,various technologies were demonstrated on cereals, pulses, oilseeds, vegetable crops, fruit crops, flower crops, plantation crops, fodder crops, livestock, fisheries, feeding management, vaccination, breed performance, etc.

Impact of Technology Demonstrations by KVKs

The most successful interventions on various genetic resources has been found including jalkund, vermicomposting, cultivation of ginger & turmeric on raised bunds with mulching and in-situ moisture conservation through mulching in broccoli etc. The farmers were able to get a net income of Rs. 1, 11,200 per hectare from selling of vegetables using the jalkund water in rabi season. The demonstration on recycling of weed biomass and agricultural waste through vermicompost (2 × 1 × 1 m) and harvested 1500kg/year. A demonstration on in-situ moisture conservation to get a net income of Rs. 1, 32,00 /ha from ginger, Rs. 1,50,000/ha from turmeric and Rs. 1,92,600/ha from broccoli. The most successful were pea cultivation under raised beds, system of rice intensification, nursery raising and off season vegetable production under low cost poly house, cultivation of high yielding variety of vegetables, cultivation of oyster mushroom and nutrition gardening. The rice-fallow was utilised through crop diversification with pea in raised and sunken beds in rice fallows and the farmer gained a net return of Rs. 58,925/ha. Resource conservation technology (SRI) on Paddy was demonstrated with a net income of Rs. 34,778/ha. Protected cultivation to cope with various climate abnormalities like high intensity rainfall, hail storm, frost and cold wave which caused damage to crops with net income received from low cost polyhouse was Rs. 30,952/unit. Nutrition Gardening to get nutritious vegetables for their own consumption and they can sell the surplus vegetables to get additional income. Oyster Mushroom demonstrated to help the farmers in getting an additional income and to cope in time of crop loss and to reduce the burning of straw. The average yield of mushroom from each unit was 168 Kg and it was sold at the rate of Rs. 200/Kg in the local market. Deep litter housing system of pig helped the pigs increase the body weight of pis by 60-80 %. Duck cum fish integrated farming system demonstrated to obtained net income from each unit Rs. 14,500/-. Backyard Vanaraja poultry farming gave net income of Rs. 4960/unit (Islam *et al.,* 2024).The farmers were happy with the production of onion and it has helped to increase their livelihood. The farmers expressed their desire to go for increasing the onion var. Arka Bheem production by bringing more areas under the crop (Utpal *et al.,* 2022). The technology has helped to increase the cropping intensity. Paddy fields, which were fallow after harvest has been utilized to grow onion and same fields, were utilized to grow paddy during June – November. The farmers were happy with the production of Arka Priya and it has helped to increase their livelihood. The farmers expressed their desire to go for increasing the Arka Priya production by bringing more areas under the crop (Utpal *et al.*, 2022). Sensing the good traits like yield, productivity, disease tolerance, etc. few farmers even saved the seeds of this garden pea variety. This technology enabled them to have increased the cropping intensity as well as imporved soil fertility status. The farmers were happy with the production of yard long bean *cv*. Arka Mangala and which helped them to increase their livelihood. The farmers expressed their desire to go for increasing the Arka Mangala production by bringing more areas under the crop (Utpal *et al.,* 2022). The technology not only helped to increase the cropping intensity but also soil fertility status. Thus, there is scope for engaging youth in agriculture for achieving a sustainable agriculture.

Success stories/Case studies of KVK Interventions

A. Jalkund: A sucessful venture for tribal farmers of Meghalaya

Water is considered to be the key input for augmenting agriculture production all over the world. The changing weather, unpredictable rainfall pattern and drought are the main reasons contributing to water stress. This water scarcity during post monsoon is one of the main reasons for poor crop and animal production even after high fertility and human efficiency. Though this region receives high rainfall, lack of appropriate rainwater management condition coupled with lack of suitable soil and water conservation measures lead to severity of the situations. Rainwater harvesting structures has tremendous potential of being an irrigation water resource for domestic use as well as for agricultural purposes for the resource poor farmers in their environment. In this hilly region the major constraints for this structure is high seepage loss from storage tanks. Low cost rainwater harvesting structure called JALKUND for the hill tops has been developed with an objective to diversify homestead farming by growing high valued crops and rearing of livestock (pig, poultry, goatery *etc.*) against their conventional practice of remaining workless for water stress during post rainy season.

Technology: Benchmark survey was conducted in Khweng– the adopted village under TSP during the year 2021-2022 and accordingly profile of village was studied. Various programmes like, trainings and demonstrations were chalked out seeing the felt need of the farmers. Ten (10) farmers were selected for Jalkund construction after site selection through field visits and discussions with the farmers in order to disseminate technology on water conservation during lean season. Site for Jalkund was selected at higher slopes of crop catchment areas so that water can be irrigated through gravitational force. Selected farmers were given a demonstration on the technology in the field itself and digging work was carried out in all the spots with proper monitoring by KVK experts and finally silpauline sheets of size (5m x 4m x 2m) were distributed where 40,000 litres of water can be stored.

Impact: After irrigating the winter vegetables from the harvested water had tremendously helped the farmers to raise their income and livelihood pattern. Mr. Pester Muktieh from Khweng village has got a very good net profit with high BC ratio by cultivating winter vegetables like Capsicum, cabbage broccoli, leafy vegetables etc. Also in other enterprises like piggery, poultry, goatery he could support 5 pigs and 50 poultry birds, 5 goats during dry spell periods (Nov-March) of the year. The vegetables like broccoli was never been tried by the farmers which has a high market demand due to its health benefits. Similarly, other farmers also earned handsome money in 5 months period after selling of their vegetables in the local markets during the lean season. The BC ratio will eventually increase in the next year as there will be no other construction charges. Consequently more farmers from neighbouring villages are showing interest and asking for adoption of this technology.

Table1. Production and income generation from vegetable cultivation with Jalkund Size-(5m × 4m × 2m), quantity of water stored: 40,000 litres

Crop	WR (L)/week /0.1 ha	Yield (q/0.1 ha)	Expenditure (Rs./0.1 ha)	GR (Rs/0.1ha)	NR (Rs./0.1ha)	BCR
Capsicum	4500	5	12460	25000	12540	2.00
Cabbage	4500	25	10250	37500	27250	2.65
Broccoli	4500	18	14250	54000	39750	2.78
Coriander	3500	0.5	2900	7500	4600	2.58

B. Innovative integrated rresource use for higher income of tribal farmers

Integrated resource use is an interdependent, interrelated often interlocking production systems based on few crops, animals and related subsidiary enterprises in such a way that maximize the utilization of resources of each system and minimize the negative effect of enterprises on environment. But the land terrain of Meghalaya hilly regions does not give advantage to the farmers to conquer the idea in large scale. Mr. Colbert Shadap from Kyrdem village along with KVK Ri-Bhoi has developed an Integrated Resource Use model by utilizing his Jalkund, poultry unit, piggery unit, Vermicompost unit and low cost polyhouse to an economically viable innovative model for round the year production to enhance his income.

Details of Innovation:

i) A Jalkund unit of size 5 × 4 × 2 cu. ft. with a capacity of 40,000 litres of water was demonstrated by lining the Jalkund with HDPE 1000 ų for effective storage of rainwater during kharif season and for rearing of fish and ducks.

ii) A vermicompost unit for recycling of wastes into organic manure for farm use.

iii) A poultry shed constructed with 200 numbers of Kuroiler breed of poultry giving additional income from meat and eggs along with deep litter piggery system with Hempshire cross breed of pig for better body weight gain and less mortality.

iv) A low cost polyhouse for round the year production of high value crops like Broccoli, Cabbage, Cauliflower, Capsicum, Cucumber etc. especially during extreme weather events like hailstorm, erratic rainfall and drought in the Kyrdem village.

Table2. Economics of Innovations

Sl. No.	Interventions	Output	Gross Income (Rs.)	Net Income (Rs.)	B:C ratio
1.	Poultry meat	Avg. Weight-4.5 kg	1,35,000	1,00,000	3.9:1
2.	Poultry eggs	120 nos/yr/bird	1,12,000	95,000	6.5:1
3.	Pig	60 kg/pig	98,000	72,500	3.8:1
4.	Piglets (10 nos.)	4000/piglet	40,000	30,000	4:1
4.	Vermicompost	3.1 q/year	57,300	40,390	3.4:1
5	Polyhouse	445 q /year of vegetable	1,15,600	95,760	5.8:1
6.	Maize seed	1560 kg/year	73,600	58,600	4.9:1
7.	Duck	Avg. weight-2.1 kg	11,500	7,800	3.1:1
8.	Fish from jalkund	30 kg/Jalkund	6,000	4870	5.3:1
Total			**6,49,600**	**5,04,920**	**4.5:1**

Horizontal spreading:

i) Numbers of farmers exposed to the technology: 78

ii) Number of SHGs/ FPOs formed through the initiative of the farmer FIGs: 1 & SHGs: 5

iii) Entrepreneurs developed from the initiative: 15

Outcome:

1. The result of the activities that he could earn a net income of Rs. 5,04,920 from the mutually

complimenting components of integrated resource use system.

2. With effective utilization of resources Mr. Shadap has climbed a step towards sustainability to enhance resource use efficiency in existing production system and enhancing his income into four fold.

C. Role of improved germplasm of poultry in improving farmer's income- A case study

Background about the district:

The Ri-Bhoi district of Meghalaya lies between 25° 40' N to 25° 21' N longitude and 90° 55' E to 91°16' E latitude with and elevation of 100m to 1350 m above sea level. Poultry keeping is an age old practice among rural and tribal community in Meghalaya and so with the case of Ri Bhoi district. Mostly women and children are involved in village poultry rearing. Most of them rear local poultry at their backyard as secondary source of their livelihood and also to supply family nutrition through production of egg and meat. Most of the farmer in Ri Bhoi district practice multi-disciplinary activities or multi enterprise for their livelihood and some of the activities is just supplementary in nature right from the time of their fore fathers. With recent advancement in agriculture though the various revolution many farmers are now focused on a single enterprise due to various factor like market demand, price of the produce and also due to soil fertility, shortage of labour during peak agricultural time and also other source of livelihood. All these have a direct impact on the food and nutritional security of many farmers. Many are reluctant to continue with agriculture and many have express dissatisfaction over how farmer are being treated badly in the country as a whole. We have seen many farmers are resorting to suicide due to rising debt and low price being offered for their produce without any sort of help from the government and even to the extent that farmers resorting to various kind of agitation. Agriculture contributes roughly 3-4% of GDP but farmers are not being provided enough attention as they required. Various expert and leader of various organizations have provided suggestion for various ways and measure whereby the income of farmer can be strengthen, but even the government is reluctant to implement all the measures due to socio economic and political factors. With the new government at helm of affair a lot of initiative and attention are being provided and laid down for the upliftment of the farming community. The Government of India has made an announcement about Doubling Farmers' Income by 2022. One of the suggestions for doubling farmer's income within a short period of time is the introduction of improved germplasm or breed of poultry. This paper focus on the role of improved germplasm of poultry in enhancing farmer's income

The climate of the district is very congenial for cultivation of various species of poultry breed round the year. The district has loamy to fine loamy soil and receives an average annual rainfall of 1636.46 mm. The maximum rainfall is in the month of June and July. Temperature ranges approximately between 2°C and 36° C. Since most of the farmers are small, marginal or landless agricultural labourers (18.8%) and cultivators (52.4%) among total workers in the district (Census 2011), their income level is quite low for a sustained livelihood. In order to raise their family income, mushroom cultivation was considered to be an alternative and additional source of income through individual as well as women SHG members for improvement of their livelihood.

Background about Madan Nonglakhiat

Madan Nonglakhiat is a medium size village located in Umsning Block of Ri Bhoi district, Meghalaya with total 138 families residing. The Madan Nonglakhiat village has population of 663 of which 344 are males while 319 are females as per Population Census 2011. In Madan Nonglakhiat village out of total population, 275 were engaged in work activities. 100.00 % of workers describe their work as Main Work (Employment or Earning more than 6 Months) while 0.00 % were involved in Marginal activity providing livelihood for less than 6 months. Of 275 workers engaged in Main

Work, 259 were cultivators (owner or co-owner) while 1 were agricultural labourers.

KVK Intervention

Initially a training programme was organized by KVK on backyard poultry with improved germplasm in comparison with local indigenous breed to make the farmers better understand the technology and its advantage. The technology is very simple and easy for farmer to replicate in their home and the farmers need not spend a lot of money like broiler farming. They just need to rear the improve germplasm breed, kuroiler provided by KVK. They can rear them like their local breed with no specific requirement for their housing. During the year 2018-19 10 farmer were provide with 10 nos of Kuroiler poultry chick each which is 4 weeks old under KSHAMTA funded by ICAR-ATARI Umiam. These farmers were selected randomly base on their experience in keeping or rearing indigenous poultry breed. The selected farmers were also having local breed in their household. These birds were reared under backyard system. These were already vaccinated against diseases like Ranikhet etc. The kuroiler chicks were purchased Regional Poultry Breeding Farm Govt of Meghalaya, Umsning. One of the advantages of Kuroiler bird is that is it's laying capacity, it is a good layers and it lays about 140-150 eggs per year. The meat yield per bird of Kuroiler is also greater; males weigh approximately 3.5 kg and females about 2.5 kg whereas the native male bird weighs 2.5 kg and females 1.2 kg. Due to its unique genetic features, the Kuroiler is resistant to diseases. The kuroiler chick is a potential bio-converter of no cost agricultural, household and natural waste abundant in villages — into human protein food and substantial incomes for rural households.

The demonstration units were monitored on a regular basis and suggestions were provided to the farmers as per requirement. Data of day to day expenses and return were recorded for each bird till the age of 18 months. The income is calculated based on egg produced. Egg and birds were sold directly to the consumers in nearby market or in the village itself at prevailing market rates. The survival percentage ranges from 90-95%. Most of the farmers reared these poultry mainly for both meat and eggs and some of the male sold at the end of culture period where the average growth is 2.198kg within 5 months of rearing. Starter feed is also provided to each of the beneficiary @20kg/farmers. After the feed is over what the farmers did was that they purchase formulated feed from the market and replace and feed the poultry with local rice bran, rice and maize and provided 10% formulated feed. The farmers would sell the entire male stock and kept only 1-2 male.

The different costs for rearing a small unit of backyard poultry of 20 numbers of birds (10 numbers of Kuroiler and 10 numbers of local) is given below in Table No 3. From the data it was observed that maximum expenditure was incurred toward labour and feed in case of Kuroiler and for purchase of birds in case of local. When it comes to expenditure toward medicine and feed we found out that the cost is more in Kuroiler than in local and this can be accounted for the reason that it might be due to the lesser incidence of disease outbreak in local chicken because of their higher adaptability in backyard system than Kuroiler birds. The egg production period under study is up to 72 weeks. The high production cost of Kuroiler bird in comparison to local is because of high quality feed and cost of chicks.

Table3. Estimates cost of rearing small unit of local and Kuroiler

Particulars	Local	Amount	Kuroiler	Amount
A. **Fixed cost**				
a. Land	Existing		Existing	
b. Locally made poultry house/shed	L/S	500	L/S	500
c. Equipment	Not required		Not required	
Total Fixed cost				
B. **Variable cost**				
a. Cost of day old chick	@ Rs 20/birds	200	@ Rs 40/ birds	400
b. Cost of feed up to 28 days				
i. 5kg of broken rice/maize for 10 of chicks ii. For Kuroiler chick 1kg of Broiler Starter feed per bird.	@Rs 25/kg of broken rice/ maize	100	@ Rs 40/kg of feed	400
c. Cost of vaccine	@Rs 2/birds	20	@Rs 2/birds	20
d. Cost of medicine, feed supplements etc.	@ Rs 2.5/ birds	25	@ Rs 3.5/ birds	35
e. Cost of labour @ 8 hrs. per month=1 Man-days, Total Man-days: 20 for the both (Kuroiler and Local)	@ 174/man day	1740	@ 174/man day	1740
f. Miscellaneous	L/S	50	L/S	50
Total variable cos		2735.0		3145.0
Total cost of production		2735.0		3145.0
Cost of production/bird		273.50		314.5

Table 4. Estimated returns from various components.

Particulars	Local	Amount	Kuroiler	Amount
a. Income from sale of eggs (5 nos. of local and 4 nos. of Kuroiler hens)	Av. annual egg production: 50 eggs/hen, Total egg production: 250 nos. @ Rs. 10/egg	2500	Av. annual egg production: 150 eggs/hen, Total egg production: 600 nos. @ Rs. 10/egg	6000
b. Sale of cocks (4 nos. of local and 4 nos. of Kuroiler cock)	Av. weight: 1.562 Kg, Total weight: 6.248 Kg @ Rs.300/Kg	1874.4	Av. weight: 3.128 Kg, Total weight: 12.512 Kg @ Rs. 250/Kg	3128
c. Sale of spent hens (5 nos. of local and 4 nos. of Kuroiler hens)	@ Rs 350/hen	1750	@Rs 300/hen	1200
Total Gross income		6124		10328
Total Net income		3389		7183
Net income per bird		318.9		718.3
Benefit :Cost Ratio		2.2		3.2

It is revealed that the benefit cost ratio of Kuroiler chicken is better than our local chicken under backyard system of rearing, which indicates that small scale Kuroiler rearing is a profitable venture for farm women (Table 4). We can also encourage other to follow backyard poultry farming with improved germplasm with Kuroiler, Gramapriya, Vanaraja, Srinidhi etc. especially among the women folks. It can also become a source employment generation but also at the same time it will be one of the ways to double the income of the farmers and ultimate it will help in improvement of livelihood

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Role of Educational Curricula in Conservation and Sustainable Use of Biodiversity

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Abstract

Sixth Deans Committee has prepared a revised course curriculum and credit framework of 13 undergraduate disciplines in agriculture and allied sciences. Necessary provisions have been made in the curriculum to enable an individual to study major and minor courses along with choice of electives. The main features of the report included revision of course curricula, modifying academic structure of degrees/diplomas/certificate system, introduction of academic banking system (ABC), provision of multiple entry and exit system, flexibility in choosing the courses, introduction of skill enhancement courses, making internship as part of UG-certificate, UG-diploma and degree requirements and also to make internship as industry oriented while continuing focus on teaching, research and extension systems.

Keywords: New Education Policy, Academic Banking System, Sixth Dean Committee

Introduction

New Education Policy (NEP) announced by the Union Cabinet on July 29, 2020, has reoriented both school and higher education across the country. It emphasizes a multi-disciplinary approach, aimed at fostering creativity, innovation, and adaptability in students, preparing them to absorb new information in dynamic and emerging fields.. According to the NEP 2020, stand-alone agricultural universities (AUs), legal universities, health science universities, technical universities, and other stand-alone institutions are encouraged to become multidisciplinary institutions offering holistic education. The policy seeks to provide quality education, promote innovation and research, and position India as a knowledge superpower by equipping students with the necessary skills and knowledge to address the human resources shortage in science, technology, academia and industry.

Professional councils, such as the Indian Council for Agricultural Research (ICAR), Veterinary Council of India (VCI), National Council for Teacher Education (NCTE), Council of Architecture (CoA), National Council for Vocational Education and Training (NCVET), will serve as Professional Standard Setting Bodies (PSSBs). The councils will be member of the General Education Council (GEC), which will be established to define the expected learning outcomes for higher education programs, also referred to as "graduate attributes". These PSSBs will outline the curriculum framework against which educational institutions will develop their own curricula. Additionally, Agricultural Technology Parks may be established to promote technology incubation and dissemination, fostering sustainable methodologies that directly benefit local communities.

Key Features of the Sixth Deans Committee Report

Multiple Entry and Exit Options: The program provides multiple entry and exit points at various levels. Students have the option to exit after the first year with an undergraduate certificate, or after the second year with an undergraduate diploma. After completing four years of study, students will receive an undergraduate degree (with honors) in their chosen discipline. However, an exit option after three years (six semesters) is not recommended due to the professional nature of the courses.

Academic Bank of Credits (ABC): The provision of an ABC system enables credit transfer, allowing students to move between institutions while retaining the credits they have earned.

Increasing Gross Enrolment Ratio (GER): To improve the GER as emphasized in the NEP-2020, stand-alone undergraduate certificate and diploma courses will be launched in select subjects at all Higher Agricultural Education Institutions (HAEIs). Additionally, initiatives will be implemented to increase student intake capacity in undergraduate programs.

Enhancing Employability: All programs have been restructured to focus more on skill development, ensuring students are job-ready for various roles in agriculture and allied fields. Skill enhancement courses are mandatory for undergraduate programs (certificate, diploma, or degree) and will be offered as electives, allowing students to select from a variety of modules offered by the institution. Institutions are encouraged to collaborate with organizations, companies, NGOs, and progressive entrepreneurs to deliver these skill enhancement programs.

New Age Courses: The curriculum now includes courses in emerging fields such as artificial intelligence, robotics, and machine learning, aimed at fostering imagination, innovation, and creativity among the next generation.

Induction-Cum-Foundation Course: A non-graded course titled "Deeksharambh" (0+2) will be offered at the beginning of the first semester for two weeks. This course will provide a platform for students to learn from one another's experiences, promote cultural integration among diverse backgrounds, familiarize students with the academic process, and instill essential life skills, social awareness, ethics, values, teamwork, leadership, and creativity.

Promoting Entrepreneurship: Emphasis is placed on experiential learning and problem-solving through practical activities like the Rural Agriculture Work Experience (RAWE) under the Student READY program, addressing the needs of sustainable agriculture and rural development. The restructured undergraduate curricula are designed to prepare students for entrepreneurship as a viable career path. In alignment with NEP-2020, the curricula across all agricultural education disciplines have been refined to emphasize choice-based skill enhancement programs.

Modes of Skill Enhancement:

- Skill enhancement courses in the first and second years as part of the program.
- Internships available for exit programs after the first or second year.
- Advanced skill enhancement through the Student READY program, including in-plant training, internships, and projects in the fourth year.

Enhancing Communication Skills and Broader Perspectives: Mandatory common courses across all disciplines will help students develop better communication skills and foster personal growth, while also providing a broader understanding of agriculture and allied sectors to prepare for future collaborations that address emerging challenges holistically.

Common Courses: To develop comprehensive capabilities, the following common courses will be included in all undergraduate programs:

- Farming-Based Livelihood Systems
- Entrepreneurship Development and Business Management
- Agriculture Marketing and Trade
- Communication Skills
- Personality Development
- Environmental Studies and Disaster Management
- Agricultural Informatics and Artificial Intelligence

Innovation and Technology: To expose students to the latest technologies and innovations, student projects will be an integral part of the course program.

New Degree Programs:

Natural Farming: A new undergraduate course on Natural Farming has been introduced, based on the Bhartiya Prakartik Krishi Paddhati (BPKP) to enhance production, sustainability, water conservation, soil health, and reduce reliance on market inputs.

Agribusiness Management: A new degree program in Agribusiness Management will empower students to start their own enterprises and provide them with the skills needed for employment.

Imparting Traditional Knowledge, Values, and Ethics: The curriculum emphasizes traditional knowledge, values, and ethics through courses like Deeksharambh. Proposed study tours will expose students to the socio-cultural and economic conditions of various communities, fostering respect for their values. Additionally, programs in NCC/NSS, Physical Education, First Aid, Yoga, and Meditation will promote social awareness and health for future generations.

Online Courses: Students are required to complete a minimum of 10 credits in online courses, which may include subjects from various fields such as Basic Sciences, Humanities, Psychology, Anthropology, Economics, Engineering, Business Management, and Languages (including foreign languages). This flexibility allows students to pursue their passions or strengthen their knowledge in areas beyond the prescribed curriculum.

Elective Courses: Institutions will offer a range of elective courses, allowing students the freedom to choose subjects that align with their interests. Institutions are encouraged to develop capabilities to provide the maximum number of electives proposed in this report and to create new courses based on local needs and expertise.

Projects: For certain disciplines, projects will be integral to the course program, helping students develop competencies and skills in research, entrepreneurship, or employment pathways. This approach will enable students to discover their interests, aptitudes, and potential while enhancing their self-confidence, creativity, and critical thinking.

Interdisciplinary Approach: The curriculum emphasizes an interdisciplinary approach to education.

Progressive Evaluation: The program allocates 20% of the assessment to progressive evaluations within the semester, incorporating quizzes and group assignments that encourage critical thinking and creativity rather than rote memorization. These assessments will foster collaboration and problem-solving skills among students.

HRD in Plant Genetic Resources Management:

Over the past four decades, both national and international communities have consistently highlighted the importance of Plant Genetic Resources for Food and Agriculture (PGRFA). Effective PGR management involves the collection and conservation of these resources, enhancing their value through characterization and evaluation, ensuring quarantine and pest-free samples, and addressing biosecurity measures. A recent study by CGIAR genebanks indicates a shifting landscape influenced by the “highly politicized nature of access and benefit-sharing issues” at various levels—international, national, and local. At the ICAR, there has been a concerted effort to enhance the utilization of crop wild relatives, improve characterization and documentation, conserve resources in genebanks, streamline germplasm exchange while safeguarding national interests, resolve contentious issues, and implement a multilateral system to foster a robust vision for agrobiodiversity management.

Given this evolving context, there is a pressing need for specialized human resources capable of teaching cutting-edge technologies and applying both basic and advanced concepts—such as germplasm assemblage, handling, equitable access, long-term genebanking to international standards, biotechnology, and pre-breeding using wild species for future crop improvement. This necessitates that students acquire strong practical and management skills to thrive in both public and private sectors. Consequently, a restructuring of the course curricula and delivery methods has been deemed essential to align with current needs.

In response, the BSMA sub-group has organized a series of meetings and electronic consultations to develop an updated curriculum suitable for M.Sc. and Ph.D. students in the field of Plant Genetic Resources. Key areas of focus include foundational concepts in Germplasm Exploration and Plant Systematics, Plant Diversity and Conservation, Genetic Enhancement for PGR Utilization, and Genomics in PGR management. Advanced topics such as Phenomics and Genomics for PGR Utilization, Plant Taxonomy, Eco-geography, and Ecology are also incorporated for Ph.D. students. The latest state-of-the-art technologies in biotechnology and molecular biology will be integrated to ensure comprehensive coverage of these subjects.

Compulsory courses will be established for all students, regardless of their area of specialization, ensuring a foundational understanding of genetics that fosters analytical, quantitative, and problem-solving skills in both classical and molecular genetics for PGR management. One course will focus specifically on genomic tools and their application in the exploration, collection, conservation, and utilization of plant genetic resources, emphasizing high-throughput, genome-wide technologies to elucidate genetic traits and diversity.

HRD in IPR

In an era characterized by Intellectual Property Rights (IPRs), it is crucial to educate students on concepts such as plant breeders' rights, farmers' rights, access and benefit-sharing, as well as international treaties and national legislation related to plant genetic resources. One course will specifically address these topics. In addition to conventional hybridization techniques, there is a growing demand for precise molecular tools to decipher the genetic diversity through mapping and sequencing. Another course will cover the fundamentals of genome structure and organization, molecular marker generation, and data handling and analysis.

Furthermore, a course on biosecurity will focus on protecting the economy, environment, and plant health from pests and diseases, including strategies for preventing the introduction of new threats and managing outbreaks when they occur.

After extensive discussions with core faculty and PGR experts, as well as feedback from the ICAR-National Bureau of Plant Genetic Resources, the entire syllabus has been restructured to enhance existing courses and introduce new ones. This revised curriculum is designed to equip students with the knowledge and skills necessary to foster entrepreneurship and prepare for global competitiveness. The BSMA Committee engaged in multiple sessions to address topical issues concerning Plant Genetic Resources. The updated curricula and syllabi have been thoroughly deliberated upon in workshops and meetings.

The new and restructured PG programs in PGR reflect the latest international commitments, the growing role of the private sector, modern research tools and their applications, and the supplementary skills required to enhance the global competitiveness and employability of our students. Considerable efforts have gone into the preparation of this document, resulting in an upgraded course offering that meets current needs. Newly incorporated courses include Genetic Enhancement for PGR Utilization, Genomics in PGR Management, Phenomics and Genomics for PGR Utilization, Concepts in Conservation Genetics, and Genomic Tools and Current Applications.

DETAILED DOCUMENT OF A. H. & VETERINARY DEPARTMENT

The Animal Husbandry and Veterinary Department is entrusted with the responsibility of promoting livestock sector, augmenting production of meat, milk egg and providing veterinary care to livestock and preventing spread of animal diseases. The Department is also providing the required training in scientific rearing of livestock and Poultry to the farmers and generates employment avenues in the rural areas.

- Department has launched a scheme 'PROGRESS' (Prosperity of Grassroot Families Through Livestock Interventions) under which high yielding piglets, poultry birds and goats will be distributed freely to poorest households to take up livestock rearing activities.
- About, 74,000 high yielding pigs, 1.5 lakhs Kuroiler poultry birds and 4642 Nos of Automatic Incubator 48 Nos egg capacity have been distributed to poorest households in the last year to take up livestock rearing.
- The Department has established 15 Pig Farms, 12 Poultry Farms and 5 Cattle Breeding Farms for to supply the improved breeds and increasing the meat and milk production.
- A pilot project of crossing Ongole Bull with local cattle has been successfully completed to increase productivity and growth rate of local cattle.
- 7 Vocational Training Centers (VTC) are involved in providing training to farmers in scientific rearing of livestock and to promote livestock entrepreneurship in State.
- At present the Department has 4 (four) Nos. of Veterinary Hospitals at Shillong, Jowai, Nongstoin and Tura. The Department has established 126 Veterinary dispensaries and 45 Veterinary Aid Centers to provide veterinary care to livestock. These institutions are **manned by a total of 134 nos. A.H & Veterinary Officers, and assisted by 358 Para-Veterinarians**.
- Recently, 17 Mobile Veterinary Clinics have been launched to provide veterinary care at the doorstep of the farmers. Helpline Number 1962 has been launched to avail veterinary service. Farmers can just dial helpline number and Mobile Veterinary Clinic will reach to farmer to provide veterinary service. Each mobile Veterinary clinic is equipped for treatment of animal, vaccination and Artificial insemination and will have doctor and a paramedic.
- The Department conducts vaccination against FMD disease and Brucellosis in cattle, Classical swine fever in pigs. IBD disease in poultry, PPR disease in goat etc. To prevent Foot & Mouth Disease (FMD), about 3.39 lakhs of cattle have been vaccinated against FMD. Total about 7.76 lakhs livestock population was vaccinated in 2023-24.
- The Department had conducted 250 nos of awareness programme in all the 11 Districts of the state, on advantages of Artificial Insemination in Indigenous cattle, ear-tagging of the livestock, mandatory vaccination programme against various infectious.
- Several initiatives have been taken up to promote dairy sector. A separate Directorate of Dairy Development has been created to focus on dairy sector. Milk Mission is being implemented to achieve self-sufficiency in milk production.
- To boost milk production and improve productivity of local cattle breeds, Artificial Insemination in local cattle population with improved exotic breeds and improved indigenous breeds is being carried out under the scheme Rashtriya Gokul Mission. Artificial Insemination of about 1 lakhs local cows done in last one year which will help in improving the productivity of local breeds.
- CENTRAL SEMEN BANK has been established at Upper Shillong to extract and supply semen straws of high yielding improved breeds of cows such as HF, Jersey, Tharparkar, Sahiwal, Red Sindhi for upgrading the local non-descript cattle through Artificial insemination.
- The Department also leveraging latest technology, Sex Sorted Semen Technology to produce only female dairy cows to increase the supply of Dairy cows. The Department has procured about 13,000 Doses of Sex Sorted Frozen Semen Straw of elite indigenous breeds and exotic breed. These sex sorted semen will be used for Artificial insemination of cows of dairy farmers to produce only female calf.

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