Souvenir and Book of Abstracts

NATIONAL CONFERENCE

Rebooting the hill farming for future sustainability and livelihood

8 - 9 June, 2023

Organized by

Indian Association of Hill Farming

ICAR Research Complex for NEH Region
Umiam, Meghalaya

50 Years Golden Jubilee

Souvenir and Book of Abstracts

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Indian Association of Hill Farming & ICAR Research Complex for NEH Region, Umiam, Meghalaya

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फागू चौहान
PHAGU CHAUHAN

सत्यमेव जयते

राजभवन
शिलांग-793001
RAJ BHABAN
Shillong-793001

राज्यपाल, मेघालय
GOVERNOR OF MEGHALAYA

MESSAGE

It brings me immense pleasure to learn that ICAR Research Complex for NEH Region, Umiam, Meghalaya, will organize the National Conference-2023 of the Indian Association of Hill Farming centered around the imperative theme of "Revitalizing hill farming for sustainable livelihoods", on the 08th and 09th of June, 2023.

Agriculture serves as the cornerstone for employment and income generation within the rural populace of the North Eastern Region. However, the farming community confronts a myriad of predicaments and hurdles, ranging from capricious weather patterns and insufficient credit accessibility to a lack of market opportunities and skills deficiency.

I am sanguine that the erudite assembly of scientists, researchers, educators, students, and all other participants partaking in the "National Conference-2023" will engage in profound discussions on these pressing matters and emerge enlightened with novel insights and strategies.

I extend my best wishes for event's success. I am sanguine that it will profit all those who attend.

(Phagu Chauhan)

दूरभाष : 0364-2223001 / 2223487
फैक्स : 0364-2224902
ई-मेल : rajbhavan-meg@gov.in

नरेन्द्र सिंह तोमर
NARENDRA SINGH TOMAR

D.O. No. ST 31 /AM

सत्यमेव जयते

कृषि एवं किसान कल्याण मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली
MINISTER OF AGRICULTURE & FARMERS WELFARE
GOVERNMENT OF INIDIA
KRISHI BHAWAN, NEW DELHI

आज़ादी का अमृत महोत्सव

MESSAGE

The future of agricultural sector is going to be more challenging in order to feed the burgeoning population with minimal resource utilization. Agriculture must be sustainable, cost-effective and environment friendly to secure future of humanity. Smart farming has the potential to utilize the high-tech farming techniques and technologies for enhancing production while minimizing cost and preserving resources. Keeping in tune with the present government policies I am pleased to note that ICAR Research Complex for NEH Region, Umiam, is organizing a National Conference of Indian Association of Hill Farming on the theme, **"Rebooting the hill farming for future sustainability and livelihood"** at the complex from 08th-09th June, 2023.

I extend my heartiest greetings to the organizers and good wishes for the grand success of **National Conference-2023**.

(Narendra Singh Tomar)

Office : Room No.120, Krishi Bhawan, New Delhi-110 001, Tel. : 23383370, 23782691, Fax : 23384129
Resi. : 3, Krishna Menon Marg, New Delhi-110001, Ph. : 011-23794697 / 98, Fax : 011-23794696

कैलाश चौधरी
KAILASH CHOUDHARY

सत्यमेव जयते

कृषि एवं किसान कल्यानं
राज्यमंत्री
भारत सरकार
MINISTER OF STATE FOR AGRICULTURE
& FARMERS WELFARE
GOVERNMENT OF INIDIA

MESSAGE

North-East region of the country is rich in biodiversity and agriculture sector is the major source of employment and income. Climate change has posed a serious threat to the sustainable hill agriculture and environmental security. Hence, likely changes of climatic parameters of temperature and rainfall may exhibit recurrence of frequent drought, flood and environmental health risk subsequently adverse impact on production system and income of the farming community. Climate smart farming technology for enhancing income of the farmers with sustainable agriculture is the way forward for livelihood security. The common platform that will be provided through the conference for interactions among the scientists, researchers, policy makers, farmers, entrepreneurs and academicians to explore various aspects of emerging challenges in agriculture and allied sectors. The strategies to develop smart farming for profitable and sustainable production addressing the challenges.

I appreciate the initiatives taken by Indian Association of Hill Farming for organizing this National Conference 2023 to address the most pressing issue and wish the conference a grand success.

(Kailash Choudhary)

Office : 199Q, Krishi Bhawan, New Delhi-110 001, Tel. : +91-11-23782343, 23388165 Fax : 23074190
CAMP OFFICE : Bunglow No. 22, Mother Teresa Crescent Road, New Delhi-110011, Tel. : +91-11-23015410 Tel./Fax : 23015411

शोभा करांदलाजे
SHOBHA KARANDLAJE

सत्यमेव जयते

आज़ादी का अमृत महोत्सव

राज्य मंत्री
कृषि एवं किसान कल्याण
भारत सरकार
Minister of State For
Agriculture & Farmers Welfare
Government of India
D.O. No.....MOS(A&FW)/VIP/2021-22/

संदेश

मैं एनईएच क्षेत्र के लिए आईसीएआर रिसर्च कॉम्प्लेक्स, उमियाम, मेघालय को भारतीय पर्वतीय खेती संघ (आईएएचएफ) के राष्ट्रीय सम्मेलन के आयोजन के लिए "Rebooting the hill farming for future sustainability and livelihood" (8 से 9 जून, 2023) बधाई देती हूं।

तेजी से बढ़ती हुई जनसंख्या को ध्यान में रखते हुए, खाद्य, चारे और रेशों की बढ़ती हुई मांग के कारण कृषि क्षेत्र पर स्थायी तरीके से अधिक उत्पादन करने का भारी दबाव पड़ रहा है। परिदृश्य महत्वपूर्ण हो जाता है, क्योंकि कृषि योग्य भूमि, पानी, जीवाश्म ईंधन आदि घटते प्राकृतिक संसाधनों और दूसरी जलवायु परिवर्तन के प्रभाव जैसे कम अनुमानित कारकों के खिलाफ उत्पादन लक्ष्य प्राप्त करना होता है। इसका मतलब यह है कि पर्यावरण पर बिना किसी नकारात्मक प्रभाव के, अधिक उत्पादन करने के लिए, नए और अधिक सटीक उपकरणों का उपयोग करके कृषि/खेती के तरीकों को स्मार्ट बनाने की आवश्यकता है। ये प्रौद्योगिकियां प्रति हेक्टेयर ईंधन की खपत को कम कर सकती हैं, उर्वरक या फसल सुरक्षा उपायों का उपयोग भी कम कर सकती हैं। मैं इंडियन एसोसिएशन ऑफ हिल फार्मिंग के प्रयास की सराहना करती हूं।

मैं इस आयोजन की भव्य सफलता की कामना करती हूं।

Shobha Karandlaje

(शोभा करांदलाजे)

Delhi Office : Room No. 322, 'A' Wing, Krishi Bhawan, Dr. Rajendra Prasad Road, New Delhi-110 001
Tel. : +91-11-23383975/76 **Fax** : +91-11-23383971, **E-mail** : mos.shobha.agri@gmail.com
Residence : 101, Narmada Apartments, Dr. B. D. Marg, New Delhi-110 001

सत्यमेव जयते

डॉ. हिमांशु पाठक
DR. HIMANSHU PATHAK
सचिव (डेयर) एवं महानिदेशक (आईसीएआर)
Secretary (DARE) &
Director General (ICAR)

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली–110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH AND EDUCATION (DARE)
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
Krishi Bhavan, New Delhi 110 001
Tel: 23382629 / 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

MESSAGE

Hill farming has always been a precarious pursuit, but rarely has its future looked as uncertain as it does today. The long-standing issues of low profitability and an ageing workforce are now being compounded by the multiple threats, while the impacts of climate change are only just starting to be felt. To some, this is a major cause for concern – hill farming in different forms has, after all, been a key part of our country's social, cultural and ecological tapestry for millennia. However, a major reduction in the size of the sector is not something we should try to prevent, but actively seek to encourage.

I am happy to learn that a **National Conference "Rebooting the hill farming for future sustainability and livelihood (**RHFFSL 2023)" is being organized by ICAR Research Complex for NEH Region, Umiam, Meghalaya during 08th-09th June, 2023. It is delighted to note that many important and useful scientific and technological issues and prospects will be addressed with the emerging matrix of the agricultural problems in holistic manner for sustainable development of hill and mountain ecosystem globally for income and employment generation.

I hope the National Conference will motivate a greater extend of people to adopt useful agro-technologies for ecological sustainability and socio-economic development in the region.

12th May, 2023
New Delhi

(Himanshu Pathak)

भारतीय कृषि अनुसंधान परिषद
कक्ष क्र. 101, कृषि अनुसंधान भवन-II, नई दिल्ली-110 012, भारत
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Room No. 101, Krishi Anusandhan Bhavan-II, Pusa, New Delhi-110012, India

डॉ. सुरेश कुमार चौधरी
उप महानिदेशक (प्राकृतिक संसाधन प्रबंधन)
Dr. Suresh Kumar Chaudhari
Deputy Director General (Natural Resources Management)

MESSAGE

The hill agriculture is, by and large, complex, diverse and risk prone. Agriculture in Eastern Himalayan zone is altogether different from the settled cultivation, practiced in other Himalayan zones. Of late, 10-15 years of shifting agriculture cycle was considered to be sustainable and environmentally friendly. However, shorter *jhum* fallow in recent years has caused a serious concern for food security and degradation of natural resources in Eastern Himalayan zone. Multiple livelihood options are required to sustain hill agriculture in general and agriculture in Eastern Himalayan region in particular. Integrated farming systems, crop diversification, organic agriculture and home gardens have potential to create need based employment opportunities in hilly regions. It is also a well-established fact that the recent development process and changing lifestyle of the Himalayan folk have impacted ecological sustainability both in terms of land degradation and food production, thus posing a threat to biodiversity conservation and food security.

In order to address the diverse issues of hill and mountain agriculture, Indian Association of Hill Farming is organizing the **"National Conference-2023"** at ICAR Research Complex for NEH Region, Umiam, Meghalaya from 08th-09th June 2023. I am sure that the organizers of the conference will come out with impactful and actionable recommendations, which could be employed for betterment of the hill agriculture.

I wish the National Conference 2023 a grand success.

(Suresh Kumar Chaudhari)

Ph.: +91-11-25848364 Fax: +91-11-25848366 Email: ddg.nrm@icar.gov.in Website: www.icar.org.in

केन्द्रीय कृषि विश्वविद्यालय
लम्फेलपात, इम्फाल - ७९५००४, मणिपुर (भारत)
CENTRAL AGRICULTURAL UNIVERSITY
LAMPHELPAT, IMPHAL-795004, MANIPUR (INDIA)

Dr. Anupam Mishra
Vice Chancellor

Phone : (0385)2415933(O)
Fax : 2410414
Email : vc@cau.ac.in

MESSAGE

Hill agriculture in our country is characterized by low input, low productivity, labour intensive and climate dependent. The socio-economic status of the hills peoples is mainly rural and agrarian. Agriculture in the hills and mountain ecosystems is mostly rainfed and falls under complex, diverse and risk prone category. Agriculture is the most vulnerable sector to climate change as it is inherently sensitive to climate variability. The poorest people of the disadvantage's areas like in the hills are likely to be harder hit by the impacts of climate change. The poor are also less capable to respond due to limited human, institutional and financial capacity and have very limited ability to cope with climate impacts and to adapt to a changing hazard burden. Bur with rich land and biodiversity, diverse edaphoclimatic situation, abundant water, favourable climate and rich ITKs, hills agriculture has considerable potential to grow and contributes towards improving farm income and livelihood of rural populace. Resource conservation and climate smart strategies and technologies will have an importance role to play and helping producers in the hilly areas to adapt the changing climate and adapt more sustainable farming methods that protect the fragile natural resources and improve the livelihood.

It gives me immense pleasure to know that ICAR Research Complex for NEH Region, Umiam, Meghalaya is organising a **National Conference-2023 of Indian Association of Hill Farming on the theme, ""Rebooting the hill farming for future sustainability and livelihood"** at the complex during 08th-09th June, 2023.

I wish the National Conference a grand success.

(Anupam Mishra)

Dr. Bidyut Chandan Deka
Honorable Vice Chancellor

ASSAM AGRICULTURAL UNIVERSITY
JORHAT - 785013, ASSAM (INDIA)

(Recipient of Sardar Patel Outstanding Institution Award)

MESSAGE

I am delighted to know that the ICAR Research Complex for NEH Region, Umiam, Meghalaya is organizing the National Conference 2023 of Indian Association of Hill Farming on the theme '*Rebooting the Hill Farming for Future Sustainability and Livelihood*' during June 8-9, 2023 at the complex, Umiam.

I trust that the organizers will put in their best efforts to make this important conference highly fruitful in view of the importance of hill farming to the wider rural economy for future sustainability and livelihood which will provide the ways and means of science and technology to address the identified issues in holistic manner for sustainable development of hill and mountain ecosystem globally.

The abstract booklet brought out on this occasion, I am sure, will be of great source of information to highlight cutting edge research from academician, scholars and researchers from various organizations both within and outside the country.

I congratulate the organizers and the editorial team of the abstracts *cum* souvenir which is all set to be published during the special occasion.

I wish the Conference a great success which will definitely turn the million dollar hopes of farmers and entrepreneurs of our state into reality in near future.

(Bidyut Chandan Deka)

Phone : (91) 376 2340013 (O), 2340050 (R), Fax : (91) 376 2340001 Website : www.aau.ac.in Email : vc@aau.ac.in

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जिला: पूर्वी खासी हिल्स, शिलांग- 793022
मेघालय, भारत

Professor Prabha Shankar Shukla
Vice-Chancellor
North-Eastern Hill University
District: East Khasi Hills, Shillong - 793022
Meghalaya, India

MESSAGE

It is a pleasure to learn that ICAR Research Complex for NEH Region, Umiam will be organizing a National Conference of Indian Association of Hill Farming on the theme, "**Rebooting the hill farming for future sustainability and livelihood**" at the complex from 08th-09th June 2023.

Farming in the hills is subsistence farming and the ecosystem is fragile. Farmers in the hilly region of India mostly have small and marginal land holdings which generate very less income particularly in the hilly and tribal areas. Use of fertilizers, pesticides in hill farming are still less in comparison to the plains. Due to the lack of market linkages, storage godowns and lack of processing units result in glut of produce during harvest and scarcity in the lean period are often faced by hilly farmers. This is an issue at multiple levels. Besides increasing the productivity for present generation; sustainable technology must be developed for conservation of agricultural produce along with natural resources for future generations. Activities should be conducted to increase awareness on the benefits of sustainable agriculture should be spread to help our agricultural community grow and prosper in their lives. The National Conference on the theme, **"Rebooting the hill farming for future sustainability and livelihood"** being organized by ICAR is apt and time relevant considering the present farming conditions and effect of climate change in future. I am sure that the conference will prove to be beneficial not just for the hill farming community but also for the young budding entrepreneurs of the state and the North-East region.

I compliment the organizers and wish them all the very best for the successful and productive conduct of the event.

(Prof. Prabha Shankar Shukla)

Dr. Amulya Kumar Mohanty
Director
ICAR–Agricultural Technology Application Research Institute (Zone-VII)
Umiam- 793103, Meghalaya

MESSAGE

It gives me immense pleasure to learn that the Indian Association of Hill Farming (IAHF), Meghalaya in association with ICAR Research Complex for NEH Region, Umiam, Meghalaya is organizing a National Conference entitled, **"Rebooting the hill farming for future sustainability and livelihood"** in its main campus at Barapani from 08-09 June, 2023.

Presently, in the context of emerging challenges of global climate changes, hill farming systems needs a paradigm transformation in terms of resource management, biodiversity conservation, diversified farming, demand-driven extension and trade liberalization; which may ensure sustainable farm production to meet the growing food demand of the burgeoning hill population. In this connection, the contemplation of this National Conference is a real-time and most apposite solution to bring a holistic development in the fragile mountain ecosystem through meaningful deliberations by the researchers on common platform followed by suitable policy recommendations. I firmly believe that this conference will bring forth several innovative solutions for the balanced development of hill agriculture and divulge various opportunities that can revitalize the status of hill farming in line with accomplishment of the target of zero hunger and poverty by 2030 as envisioned in the UNDP Sustainable Development Goals (SDG).

I congratulate the efforts of the office bearers of the IAHF for organizing the National Conference and wish the event a grand success.

(Amulya Kumar Mohanty)

Dr. G. Kadirvel
Director
ICAR–Agricultural Technology Application Research Institute,
Zone-VI, Guwahati

MESSAGE

The North-Eastern region of India is one of the major biodiversity hotspots in the world contributes both plant and animal genetic diversity. It occupies about 8% of total land area and 4% of total population of the country. This region has unique agro ecosystem in terms of high rainfall, water resources, hilly terrain, socio-economic and ethnic diversity. This unique geographical location leads to diversity in both plants and animals in demand driven substantial traditional production system. Soil erosion, land degradation, jhum cultivation, water scarcity during winter, low cropping intensity, greater post-harvest loss of farm produce and poor access to market pose major challenges in the region. Steeper slopes on the farmland makes mechanization difficult and further adds to the cost of maintaining agricultural production systems. Global warming added additional dimension to increase vulnerability and reduced resilience of the mountain ecosystem in traditional production system. In this context, farm mechanization particularly small and light weight farm implements, conservation and bioprospecting of traditional specialty in species, fruits and vegetables, effective post-harvest management and value addition, use of artificial intelligence, water harvesting system, smart decision support and irrigation system, cost effective feed and fodder produce, control of transboundary livestock disease and management, effective value chain management, strong extension support system and small scale entrepreneurship development are the major area need to be focused to enhance agricultural production, productivity, livelihood and inclusive economic growth of the North East hilly region. In this context, it gives me immense pleasure to learn that the Indian council of Agricultural Research, ICAR Research complex for NEH Region, Umiam, Meghalaya is organizing a "**National conference-2023** of Indian Association of Hill Farming on the theme, "**Rebooting the hill farming for future sustainability and livelihood**" at the complex from 08th-09th June 2023.

Best wishes for making this event a grand success.

(G. Kadirvel)

भाकृअनुप उत्तर पूर्वी पर्वतीय क्षेत्र अनुसंधान परिसर
ICAR Research Complex for North Eastern Hill Region
भारतीय कृषि अनुसंधान परिषद INDIAN COUNCIL OF AGRICULTURAL RESEARCH
उमियम, मेघालय -793103 Umiam, Meghalaya-793103

Dr. V. K. Mishra
Director

Phone: 0364-2999450
Email: vk.mishra@icar.gov.in
director.icar-neh@icar.gov.in

MESSAGE

Hill farming or terrace farming is an extensive farming in upland areas which is becoming increasingly unsustainable, both economically and ecologically. Infrastructure, reliable supply of inputs and market guarantee are the primary concerns of hill farmers. The North Eastern Hill (NEH) Region of India comprising of seven states viz., Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim, habitats 124 tribal communities, each tribe having distinct agricultural practices. Shifting cultivation, locally known as jhum cultivation, is predominant farming system in the region, except in the state of Sikkim.

Strategic farmer-centred plans giving due consideration to the nature of marginality, fragility, diversity and accessibility of the area must be formulated. Strengthening climate-smart agriculture and promotion of sloping agricultural land technology, niche-marketing, rainwater harvesting, harnessing indigenous knowledge systems and ensuring land rights to the tribal and ethnic communities are crucial to encourage people-based initiatives in different areas.

The National Conference on **"Rebooting the hill farming for future sustainability and livelihood",** organised at ICAR Research Complex, Umiam, Meghalaya during 8-9 June, 2023 will serve as an effective forum to deliberate on emerging issues and make appropriate recommendations for the benefit of hill farming community for sustaining food security and enhancing input use efficacy to meet the challenges in the era of changing climate.

On behalf of the organizing committee, I thank all the members of the organizing committee, invitees, delegates, patrons and sponsors for extending untiring efforts and full support in organizing this event.

The financial assistance received from Research and Development Fund of National Bank for Agriculture and Rural Development (NABARD) towards holding this Conference is gratefully acknowledged. Financial assistance provided by CAU, Imphal, ATARI, Guwahati and ATARI, Umiam is also gratefully acknowledged.

(V. K. Mishra)

CONTENTS

Keynote Address

Ensuring water security in India in a changing World: The external dynamics

U. C. SHARMA
Center for Natural Resources Management, 222- Adarsh Enclave, Lane 2, Jammu – 180020, Jammu & Kashmir

India is anticipated to experience "water stress" by 2025 and "water scarcity" by 2050 due to its severe water resource issues. It raises important concerns concerning the factors influencing water demand and the political dynamics of riparian relations among governments in the subcontinent, both in terms of challenges and opportunities. Rivers, a significant source of water resources, physically connect users upstream and downstream while also erecting barriers. Rivers have an impact on bilateral relations since they are closely related to domestic needs and developmental ambitions. While it is crucial to establish appropriate riparian policies and "healthy rivers" initiatives in light of the region's water concerns, it is also crucial to keep in mind the political realities. Many of the current treaties could need to be reevaluated, and new ones based on the most recent hydrological research will need to be drafted. India's high, middle, and lower riparian geographical features suggest that this country would eventually become the focus of riparian politics. India will need to use effective "hydro-diplomacy" to strike a balance between its expanding water requirements and bigger security concerns as a prominent regional player. The research starts off with a discussion of what water security means for India and looks at how important water is in the context of overall national security. The paper assesses India's water situation and offers criticism of certain of its water management practises while looking at the water management challenge. However, the focus is on the riparian dynamics outside of the river. The next step is a regional riparian assessment, which is followed by in-depth analysis of India's water-related challenges with Pakistan, China, Bangladesh, Nepal, and Bhutan.

Hill farming - the niche area for regenerative agriculture

ANUPAM MISHRA, L. M. GARNAYAK
Central Agricultural University, Imphal-795 004, Manipur

Mountains share more than one-fifth of total global surface area and play a crucial role in sustaining about 12% of the world population directly, and indirectly that living in the plains as they are the major source of water through the river systems. Half of the mountain population lives in the region of Asia-Pacific. The life and livelihood of the mountain people in India largely revolves around agriculture, horticulture and allied activities. But the mountain ecosystem is fragile in nature and the geo-tectonic feature of the mountain makes it prone to landslides and earthquakes, and the diverse river system and monsoonal climate make it prone to floods and landslides making its inhabitants vulnerable to natural calamities, which negatively affect availability and accessibility of food. The major mountain ranges in India are the Himalayas, the youngest mountains range of the world, which are active and fragile in nature that makes them more vulnerable to the natural disasters. The sparsely populated Indian Himalaya Region (IHR) comprising of 12 states i.e., Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and West Bengal covers 53.7 Mha area over 2400 km long (15.8% farm land, 69% rangelands, pastures, wastelands, the so called bush land- grazing areas and the forests, and rest 15.2% under permanent snow cover and rocky mountains) and accounts to 3.92% of the country's population with over 51 million people engaged in hill farming for subsistence. About 37% of the cropland is sloping land and the farmers are even cropping sloping lands beyond 25 and 30 degrees. Agriculture is mostly rainfed (about 60%) and is the primary sector of the economy contributing 45% to the total regional income of the inhabitants. Women are today heading farming households and the economy of these households is at best known as 'money order economy'. Majority of the farming households are small landholders (0.5 to 1.0 ha). The region is favourable for growing a wide range of fruits, vegetables and other cash crops such as apples, citrus, walnuts, plums, peaches, bananas, mangoes and pineapples; vegetables such as tomatoes, radish, potatoes, cabbage, cauliflower, other cash crops like ginger, chillies, cardamom and saffron; and flowers such as orchids, gladioli, marigolds and chrysanthemums. This region supports about 50 million domestic animals (1.6 animal/ha); cattle (47.5%), goats (15.8%), buffaloes (12.3%) and sheep (10.4%). A large proportion of livestock species is raised under mixed cropping systems because of small land holdings. As shortage of fodder and feed (70%) is rampant in the hills, farmers of the region usually complain, "livestock fodder problem is more acute than the human food problem in the hills". The agroclimatic regional planning has divided the IHR to two major regions namely, North-West Himalaya Region (NWHR) and North-Eastern Region (NER).

The North-West Himalaya region (NWHR) comprising of Jammu and Kashmir, Himachal Pradesh and Uttarakhand, covers 33.1 Mha of land housing interspersed human population with lower population density/km^2 than the national average of 382 (J&K = 56, HP = 123 and UK = 189). Its 78.6% population is rural. It is home to a large population of domesticated animals, which are used for milk, meat, fur, wool, draught and manure and is the largest storehouse of fresh water feeding to two major river systems - Indus and the Ganga. Significant portion of

this area lies in high altitudes above 3000 m above mean sea level (m asl). The crop production systems in the region are based on agriculture (field crops), olericulture, horticulture or agri-horticulture, and agroforestry/agri-horti-silvi-pastoral system. Wheat, rice, maize, barley, buckwheat, finger millet and barnyard millet are the major cereals and millets of the region and black gram, horse gram, rajmash and *bhat* (a variant of soybean with high level of protein and healthy fats) are the major pulse crops. Mustard and soybean constitute the major oilseed crops. Among vegetables, cole crops, cucurbits, capsicum, tomato, radish, pea, french bean, potato and onions are the major crops. Mushroom production and its value addition and promoting apiculture have a greater scope in the region. The area has an advantage and competitive edge over other states in the plain for off-season vegetables, European vegetables, temperate fruits, organic fruits and vegetables, aromatic rice, medicinal and aromatic plants, flowers and development of specialty crop varieties like QPM, sweet corn and popcorn in maize, product-specific wheat, finger millet, rajmash, horse gram and *bhat*. The average cropping intensity is 162%.

The north-eastern region (NER) of India comprising of 8 states namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim, geographically lies in between 22°05 and 29°30N Latitudes, 87°55and 97°24E longitudes, and 500 to 1500 m asl. Total geographical area of the region is 26.2 Mha, which occupies about 8% of the total area and 3.4% of the total cultivable area of India and inhabited by 4.5 crore people in 119 districts. Most of the landscapes have mountainous topography endowed with diverse edaphoclimatic situation inhabited by equally diverse ethnic communities. Around 56% of the area is under low altitude, 33% mid altitude and the rest 11% under high altitude. Sikkim, Mizoram and Nagaland have > 99% landform under mountainous topography against the minimal share for Meghalaya, followed by Tripura (39.9%). Meghalaya has the largest share of the plateau region (96.3%). About 54.1% area is under forests, 16.6% is under crops, and the remaining land is either under non-agricultural uses or uncultivated land. In the absence of major industries, the socio-economy status of the people is mainly rural (82%) and agrarian, as more than 70% of population is engaged either directly or indirectly in agriculture and allied sectors. The region has six agro-climatic zones (Alpine zone: > 3500 m asl, Temperate and sub-alpine zone: 1500-3500 m asl, Sub-tropical hill zone: 1000-1500 m asl, Sub-tropical plain zone: 400-1000 m asl, Mild-tropical hill zone: 200-800 m asl and Mild-tropical plain zone: 0-200 m asl) with 34 farming situations. Rice is the staple food crop occupying about 81% of the cropland area under food crops. A diverse mixture of 8 to 10 crops is grown in a mixed farming system. The net sown area in this region is 4.13 Mha (Cropping intensity 131%) out of which, approx. 1.3 Mha suffers from serious soil-erosion problem @ average 46 t/ha. Among the top seven states in India with the highest increase in land degradation in last 10 years, six are from NER. Approximately, 84% of the soil in the region is acidic and low in available P and Zn but rich in organic matter, high to medium in available N and K. The region receives plentiful of rainfall (2400 mm/year), mainly concentrated in the monsoon season, accounting for around 10% (42.50 Mhm, out of which only 0.88 Mhm is used) of the country's total precipitation of 420 Mhm. The NER has 4 out of 75 Ramsar wetland sites in India namely, Loktak Lake (266 sq km) in Manipur Deepor Beel (40 sq km) in Assam, Pala Wetland (18.5 sq km) in Mizoram and Rudrasagar Lake (2.4 sq km) in Tripura. The region is hot spot of bio-diversity with many

endemic species including more than 50 bamboo species (50% of the country), 6000 indigenous crop germplasm, 14 species of banana, 17 species of citrus, and around 600 kinds of orchids (out of which 175 are rare) besides many medicinal and aromatic plants (5000). Wild relatives of 132 economically important species like rice, banana, citrus, mango and pulses are either primary or secondary centres of origin in the region. The region has 303 different indigenous fish species and 95% of the people relish fish in their diets. There is vast scope for entrepreneurship development and agri-marketing system which are highly unorganized.

Nearly 59% of the total workforce in the IHR is involved in subsistence agriculture, which is hardly adequate to sustain the expanding population for 5-6 months in a year. Prevalent agricultural system in the region is as follows:

Eastern Himalayas (NER): Several tribes of north-east Indian states practiced location-specific indigenous farming practices, viz. *Apatani* method of rice cultivation in Arunachal Pradesh, rice cultivation on wet terrace (*Panikheti*) in Sikkim and Nagaland, ginger cultivation on *buns* (raised beds), shifting or *jhum* cultivation, *Zaboo* farming etc. Mixed farming system is more prevalent as most of the farmers want to produce their household food and nutritional needs from their own farm. They mostly rely on medium to subsistent level crop cultivation. The agricultural production system is broadly divided into two categories: shifting and settled agriculture.

(a) Shifting agriculture: In shifting cultivation parcel of land are cultivated temporarily, then abandoned and allowed to revert to their natural vegetation, while the cultivator moves on to another plot. It is also known as '*slash and burn*', '*bush fallow*' and *Jhum* agriculture. Tribes inhabiting in parts of Nagaland, Mizoram, Manipur, Meghalaya, and Arunachal Pradesh practiced this traditional agriculture (0.88 M ha). This system is economically and ecologically viable until the population density is very low and the fallow period is long enough to recuperate the soil fertility. Cereal (maize and rice)-dominated mixed farming is practiced mostly with traditional landraces of different domesticated crop species. Optimum 10 years of secondary fallow was optimum to maintain soil health (enzyme activities and soil-microbial biomass carbon) under *jhum* agro-ecosystems in subtropical humid regions, which has now been reduced to 3-6 years instead of extended 20-30 years in older days jeopardizing the overall sustainability of the system. Establishment of agroforestry or plantation crop culture in *jhum* fallows is the popular means of *jhum* improvement in the region. Agroforestry systems involving fast-growing MPTS and economically important timber species with location-specific intercropping of pulses (soybean, groundnut, rice bean) and cash crops (ginger, turmeric, black pepper) has been proven to be economically viable, ecologically sustainable and socially acceptable alternatives to *jhum* system. Intercropping of groundnut, soybean, French bean, blackgram, etc with rice or maize across slopes in *jhum* areas is also recommended. Integrated farming system involving situation specific combination of poultry, piggery, fishery, bee keeping, fruits, vegetables, floriculture, tea, rubber and terrace cultivation is an alternative to shifting cultivation in the region.

(b) Settled agriculture: The agro-ecosystem of settled agriculture is broadly categorized into (i) rainfed terraced land, and (ii) lowland valley ecosystem. In Sikkim and Meghalaya, terrace

farming is much popular with diverse cultivation of improved varieties. The '*Zaboo'* farming (indigenous farming system practiced in sloping lands with water harvesting tanks in upper slope and farming practices in mid and lower slopes) is practiced in Nagaland. Tripura accounts lion share of lowland rice farming in the region. Scattered low-lying areas in other hill states also experienced settled rice-based cropping systems.

Western Himalayas (NWHR): Considerable proportion of NWHR is under terrace farming. Rainfed cultivation of coarse cereals and pulses along with horticultural crops are much popular. The *Sari* system is a unique agricultural practice established by the people of Uttarakhand Himalaya. Crops are rotated every two years under this system. Winter (*rabi*) cultivation of wheat, barley and lentil is more common. Rice and barnyard millet are grown as a mixed crop during *kharif* season to reduce the risk of complete crop failure under extreme weather aberrations. Rainfed maize-wheat is the most prevalent cropping system. The most common farming systems today are rainfed crop + livestock mixed farming and apple cultivation in Kashmir valley, commercial fruits and vegetables growing in Himachal Pradesh, rainfed mixed farming in hills of Uttarakhand and pastoral and agro-pastoral systems in the highlands of Ladakh. Growing nine crops *(Nau anaj*) including fox tail millet, maize, ragi, buckwheat, amaranth, rajmash, *urad*, mung and beans each in *kharif* and *rabi* season totalling to 18 crops in a year is also made possible by Padma Shree Nekram Sharma in Himachal Pradesh.

Agriculture in India, in general remains an important sector for livelihood and economic growth despite its declining share in the economy (51% to 20%). Investment in agriculture in India is 3 times more effective than in other sectors in alleviating hunger, malnutrition and poverty. With rich land and biodiversity, diverse edaphoclimatic situations, abundant water, favourable climate, organic farming in default and treasure of ITKs, hill agriculture has considerable potential to grow and contribute towards improving farm income and livelihood of rural populace and has started receiving renewed attention from all sectors for ensuring food, nutrition, environment and energy security. But it has some inherent constraints of remoteness and inaccessibility, marginality and fragility in terms of moisture stress and the poor soil conditions and a short growing season. As such its potential remained under-exploited due to various mountain specifities like increasing crop land scarcity (too little to sustain livelihoods) and water scarcity, lack of system specific production technologies, poor infrastructure (transport, marketing and processing), and under developed supporting institutions (credit, extension, information, insurance), notwithstanding the socio-economic constraints such as small, scattered and fragmented land holdings (more than 3/4th land holdings are < 2 ha), poor productivity, production management, post-production management, marketing and networks as well as lack of entrepreneurship and acute labour shortages. The key issues are the shrinking size of land holdings, erosion from sloping farmlands, a decline in soil fertility and above all a widening cycle of inadequate food production-food insecurity-poverty-resource degradation and increasing unemployment and frustration. "Unless urgent solutions are found for cropland scarcity and water scarcity so as to make farming-based livelihoods sustainable; agriculture as a source of sustenance for the hill farmers will continue to lose its significance". The second generation issues of agricultural diversification in hills are of unsustainability and are also of

ecological and social nature such as equity, gender and ethnicity. In addition to climate change impact on hill agriculture and biological degradation of support lands, the new generation of farmers no longer finds hill agriculture remunerative necessitating more knowledge and skill in farming, entrepreneurship and agribusiness.

Much of the farming development efforts made in the hills in the past were based on the poor understanding of the hill/mountain conditions, resources, environment and the socio-cultural setting of the people. To unlock the growth potential of hill agriculture, it is essential to conjugate the traditional practices with the improved one carefully without disturbing the natural ecosystem and in harmony with socio-economic and cultural factors. Considerable emphasis is needed on terrain-specific technology changes, area expansion, cropping intensity and farming systems (need land and water management on watershed basis, *Jalkund* in hill top, appropriate land use planning), diversification from lower- to higher-value crops, value addition by attracting private investment in agro processing for improving hill agriculture. Most of the hill areas have favourable climate to promote production of export oriented high value crops like apple, pine apple, banana, citrus, passion fruits, orchids, ginger, turmeric (curcumin content >7 %), chillies (i.e., king chilli, bird's eye chilli), large cardamom and black pepper. High value crops also generate 3 to 7 times more returns to land and have a larger concentration among small landholders because these are labour intensive crops and the latter have sufficient family labour. Besides lower yield (25-50% lower than national average for rice and 25-75% for fruits and vegetables), thin local market reduces income to the community. But transportation cost mainly of the perishable fruits and vegetables to urban centres accounts for 18-28% of total cost of production, which necessitates linking producers to markets. Demand for attribute based products that can be produced only in hill ecosystem such as the apples in Himachal and saffron in the Soppore valley of Kashmir, pashmina goats and yak in the highlands of Ladakh, mithun in Arunachal Pradesh and Nagaland, pineapple in Tripura, high altitude honey and job's tear of Arunachal Pradesh, organic fruits and vegetables, off season vegetables, greens and orchids is rising. Value addition will add to farm income, self employment, entrepreneurship development and overall improvement in the livelihood of the hill inhabitants.

Livestock and fisheries are recognized as major components of hill agro ecosystems. The NER has diverse aquatic resources in the forms of rivers, wet lands, paddy fields, lakes, reservoirs, pond, etc and has vast number of wetlands (Arunachal Pradesh-806, Assam-11,178, Manipur-167, Meghalaya-135, Mizoram-88, Nagaland-267, Sikkim-160, and Tripura-432), most of which are underutilized for fishery purpose. Sustainable utilization of these natural resources has great potential to contribute not only to food and nutritional security but also livelihood security of the region. The fishery resources of the region fall in all the three types of climate i.e., tropical, sub-tropical and temperate and the region is considered as hot spot of fish biodiversity (303 species). About 15.2% of fish diversity in the region comes under the threatened category and about 30% of fishes come under the Data deficient (DD) and Not evaluated (NE) category. The local populace have special liking for some local fishes due to their exquisite taste and hence, these fishes have local niche market. But culture technology including seed production, feed development and stocking density, etc. for them have not been

standardized. In addition to difficult terrain, non-availability of quality fish seeds in time is the major constraints in expanding aquaculture in the hilly region. Most of the capture fishery resources are under severe pressure from habitat alterations and over exploitation. Approaches in development of fishery sector are mapping of the fishery resources in mountain/ hill region, prioritization of traditional species (*Pabda* in Tripura and Assam, *Pengba* and *Khabak* in Manipur, Assamese Kingfish in Arunachal Pradesh, Assam and Sikkim, trout in Sikkim and Arunachal Pradesh) with efficient breeding and culture practices, recirculation aquaculture system (RAS), biofloc, cage culture, poly culture, feeds and feeding for different life stages of cultured fish utilizing local resources, transboundary aquatic animal disease management, breeding and seed production of ornamental fishes, sport fisheries and eco-tourism, cold water fishery, etc.

Livestock and livelihoods in rural India are intimately related and the ownership of livestock is more egalitarian than that of land. The livestock component is an indispensible and integral part of every farm and farming systems in the hills as it fulfills the animal protein requirement of the population and acts as a stabilizing factor in the system due to its symbiotic relationship with other components such as fishery, horticulture and field crops, maintaining its most vulnerable soil fertility, main source of draught power in terrain, besides the various animal products. The NER is the house for 24.35 million livestock (4.54% of India), most of which are from rural areas (96.55%) including most of the pig population of the country. Yak and Mithun ("Cattle of Mountains", "Ceremonial Cattle") are the two most important animals available in NER region of India only. The growth of livestock and poultry sectors in NER remains slow compared to other parts of India, the major obstacles may be due to non availability of good quality germ plasm through supply of quality frozen semen, piglets, chicks, etc., ad-libitum feeds and fodder, grazing land, incursion of various transboundary diseases including recent outbreaks of CSF, PRRS, ASE, Avian influenza, LSD through the porous international boarder, difficult topography, lack of organized farm and milk unions and transportation. But the region has a tremendous potential to grow faster than the current rate and can generate employment to the unemployed youth. But development strategy for livestock needs to be focused on the small farm sector as 57% of households in NER possess livestock and 82% of the smallholders rear them to supplement their livelihood. A pork revolution is necessary in the region, as pig is the most preferred livestock among the tribal population.

Sustainable crop production with no degradation of natural resources in hills can be achieved through a set of crop-nutrient-water-landscape-system management that involves minimal soil disturbance, permanent soil cover, and ecologically viable crop rotations/ diversification. The tribes in hills all over the world are known for the primitive or subsistence types of farming which is farmer and nature friendly, zero fossil fuel system, sustainable and climate resilient that ensures their livelihoods and nutritional security while preserving the rich biodiversity. Regenerative agriculture, a holistic farming system that focuses on soil health, food quality, biodiversity improvement, water quality and air quality have a greater scope in hill farming. It is a conservation and rehabilitation approach (to reverse negative impacts rather than eliminate them) to food and farming systems that focuses on top soil regeneration, increasing biodiversity, improving the water cycle, enhancing ecosystem services, supporting bio-

sequestration, increasing resilience to climate and strengthening the health and vitality of farm soil. It improves soil health through practices that increase soil organic matter, biota and biodiversity, where food and agricultural products are grown in a way that mimics nature. The principles of regenerative agriculture are minimization of mechanical, chemical and physical disturbance of the soil and soil surface, protecting the soil surface by vegetation or mulch, etc, year round cover crops, maximize living roots in the soil (crop rotation, agroforestry, perennial crops), creation of a high diversity (crop rotation, mixed crops, etc.) through enhancement of biodiversity and integrating animals (holistic management, grazing, silvipasture). In hilly terrain, location-specific conservation agriculture (CA) based strategies, viz. contour cultivation, retention of crop residues or standing stubbles, hedgerow crops on farm boundaries or contours or terrace risers, vegetative barriers, minimum tillage and no-till farming that conserved natural resources (soil, water, nutrient, etc.), facilitated second crop in succession after the rainy-season crop and boost crop productivity. All these, reduced runoff and soil loss and improved crop productivity by 10-50%. No-till cultivation of crops like field pea, lentil or mustard in rice fallow; French bean and rapeseed in maize fallow conserved soil moisture, improved soil aggregation, carbon stocks and available nutrients in soil, enhanced farmers' income and promoted cleaner environment. Micro-watershed based integrated farming and agro-forestry models like agri-horti-silvi-pastoral system along with minimal soil disturbances and residue retention enhanced soil organic C by ~45%, conserved 21% more soil moisture and decreased clay dispersion by 53% over traditional land-use system. The resource use efficient, productive and profitable cropping systems identified for different hills of India are rice-maize (green cob)-vegetable pea (Sikkim), cowpea/okra-rice-pea/vegetable mustard (Mizoram), cowpea/okra-rice-vegetable (south Odisha), maize-pea-wheat (Uttarakhand), maize + soybean/groundnut-potato/tomato/ French bean (Meghalaya) (Table 1). But lack of topography-specific light-weight farm machineries for small sized farms and irrigation facilities during dry season and prevalence of jhum farming are important constraints for popularization of CA in hill region.

Table 1. Efficient cropping systems for sustainable ecosystem productivity in hilly regions of India

State	**Existing cropping systems**	**Potential cropping systems**
Sikkim	Maize–fallow	Maize–*pahenlo* dal–buckwheat
	Maize–rice	Maize–vegetables pea
	Maize –rapeseed	Rice–baby corn–fenugreek
	Maize – buckwheat	Rice–maize (green cob)–vegetable pea
Manipur	Rice–fallow	Rice–pulses (pea/ lentil/ broad bean)
	Vegetable–fallow	Rice–rapeseed mustard
	Rice–rice	Rice–vegetables
Meghalaya	Rice–fallow	Rice–pea/lentil/rapeseed
	Ginger/ turmeric–fallow	Maize–french bean/ black gram/ rapeseed
		French bean/ carrot/ potato–okra–french bean/ rajmash
		Maize + soybean/ groundnut–potato/ tomato/ french bean

Tripura	Rice–rice	Rice–pea/ lentil/ rapeseed
	Rice–fallow	Rice–rice–pea/ lentil
	Vegetable–fallow	Maize–rice–pea/ lentil
Uttarakhand	Maize–wheat	Maize–vegetables
	Maize–pea	Vegetables–wheat
	Maize–rapeseed	Maize + vegetables–wheat
	Rice–wheat	Maize–pea–wheat
Mizoram	*Jhum* maize–fallow	Sweet corn – soybean/ vegetable mustard/ french bean (Zorin bean)
	Jhum rice– fallow	Rice + maize (sweet corn/ popcorn)–brocolli/ chilli/ brinjal/ cabbage/ french bean (Zorin bean)
	Lowland rice –fallow	Cowpea/ okra–rice–pea/ vegetable/ mustard
Southern Odisha	Rice–rice	Cowpea/okra–rice–vegetable (tomato/ cabbage/brinjal/ french bean/ sweet corn)
	Pigeon pea–wheat	Upland rice + ragi–niger
	Sole maize–fallow	Pigeon pea + ragi–wheat
	Potato/ginger–fallow	Okra + sunflower + maize
Nilgiri hills	Potato-fallow	Potato–carrot
	Groundnut–fallow	Groundnut + pigeon pea
	Groundnut– tobacco	Groundnut + marigold–tobacco

Source: Saha *et al*. (2021), *Indian Journal of Agronomy* **66** (5th IAC Special issue): S128-S141.

The traditional knowledge and practices of organic farming still sustained in the Himalayan regions. With rich biodiversity, plentiful availability of biomass and animal manure and low use of synthetic fertilizers (< 12.0 kg/ha in NER) and chemicals, the hill agriculture has tremendous potential for promotion of organic farming. Sikkim was declared the first organic state of the country during 2016. Potential cropping systems for rice- and maize-fallow, which are responsive to organic farming i.e., rice-tomato, rice-carrot, rice-pea, maize + soybean - french bean with an average yield advantage of 13-29% have been identified. Paddy varieties CAUS 105 and CAUS 107 are proposed suitable for low fertilizer and organic farming in NER. Traditional use of bulky organic manure (FYM) has been substituted through integrated organic nutrient management (IONM) approach by combining application of mixed compost, vermicompost, poultry manure, pig manure, in addition to *in-situ* and *ex-situ* bio-mulches and alley-cropping approach. The Central Agricultural University (CAU), Imphal has formulated acid soil compatible NPKZn biofertilizer consortium for rice-oilseed rotation and *jhum* mixed cropping, and biofertilizer consortium for citrus as well as standardized the seedling root-dip method of co-application of compatible liquid formulations of biofertilizer (CAU-Bioenhancer) and biopesticide (Um-Comb) for cultivation of organic scented rice and sticky rice. Biological control agents *viz. Pseudomonas* spp, *Trichoderma* spp., *Metarhizium anisopliae, Beauveria bassiana* and *Bacillus* spp., were effective in the region. Adoption of Integrated Organic Farming System (IOFS) model, comprising viable enterprizes like crops, livestock, fishery, duckery etc. not only ensured the generation of quality manures within the system but also enhanced the total system productivity and income of farmers. The NER can be the potential hub for organic spices and condiments, viz. ginger, turmeric, large cardamom, bay leaf, black pepper, etc, cashew, pine apple, oranges, tea and many more local landraces of foodgrain crops, viz. black rice, aromatic rice, beans, black gram, green gram, rajmash, buckwheat, etc. and

vegetables rich in nutraceuticals. However, much more research and development activities are required in seed production, pest management, processing and marketing for achieving actual benefit of organic farming in the region.

As the hill farmers practice agriculture system in harmony with nature to meet their food and nutrition needs, regenerative agriculture has a greater scope in the hills having rich biodiversity, treasure of indigenous nature friendly cultivation practices, organic by 'de fault', natural ways of resource conservation, existing traditional integrated farming and agroforestry systems, diversified cropping, etc. But it necessitates a separate hill agriculture policy, shift in small scale household production systems to semi-commercial/commercial system of farming, market driven production and processing, market led extension, capacity building and effective trading policy. Any alternative agri-production system should support the strength and self-reliance of the locals on traditional food systems instead of harming them.

Challenges, Opportunities, and Future Prospects of Hill Agriculture

A. PATTANAYAK[1], LAXMIKANT[2], J.K. BISHT[2], ARIJIT PATTANAYAK[3]
[1] Formerly at ICAR- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora 263 601, India, [2]ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora 263 601, India, [3]Ex-student, Department of Environmental Studies, Delhi University, North Campus, New Delhi

Hills and mountains are fragile ecosystems yet globally important in terms of being water towers of the earth, an enormous source of renewable energy and repository of rich bio-diversity. Hills represent 20% of the world's land and provide life-support to 10% of humankind and about 40% people occupying adjacent medium and lower areas. However, a whopping 39% of mountain dwellers reside in underdeveloped nations, mostly subsistence farmers. As a result, they are highly susceptible to food insecurity.

The hilly and mountainous areas in India distributed all over the country with a larger area located in the Himalayas, extending up to 2500 km in length and 250 to 400 km in breadth, longitudinally; Himalayas are also classified as Shivalik's flat summits (600-1200m msl altitude), Middle Himalayas (65-75km width, average height 3000 m), Greater Himalayas (average altitude 5,200m), and Trans Himalayas (average width 60km, average altitude 4500 m).

Along with the Himalayas, the regions classified as Hill and Mountain Zones are spread across 23 states, including Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, and West Bengal. Thirty-five percent of the country's entire geographical area comprises these areas, the majority of which have slopes of at least 15 percent. The hilly region is further classified into three major categories comprising, (i) North Western Himalayas (NWH): Jammu, Kashmir, Ladakh, Uttarakhand, and Himachal Pradesh; (ii) North Eastern Himalayas (NEH): Sikkim, Manipur, Meghalaya, Nagaland, Tripura, Arunachal Pradesh, Mizoram, hilly areas of Assam and Darjeeling district of West Bengal; (iii) Trans-Himalayas (TH): Tibet and Central Himalayas as well as Nepal, which is outside the territory of India. The present discussion is on the seven hilly states of northeast and three hilly states of northwest India.

Agriculture remains the primary source of livelihood in mountainous areas despite the challenges of a harsh environment, potential effects of climate change, limited infrastructure, and remoteness that limit farmers' productivity and access to markets. As opposed to pastoral production systems, which rely on natural pastures, mountain farming is done on highlands with relatively flat plateaus (valleys in Kashmir, Manipur, and Meghalaya), or on terraces. The hill region has four main agricultural production zones: zone I (low hills) and zone II (mid-hills) are strategically essential for agriculture. The Himalayan agriculture can be divided into four major sub-farming systems:

Livestock-based pasture farming system

The Western Himalayas, Arunachal Pradesh, and Sikkim in the NEH are the main regions where this system is practiced at altitudes ranging from 2500 to above 5000 m. Sheep, goats,

yaks, mules, and other animals are raised on natural pastures primarily by indigenous populations. The farmers also plant a range of pulses, vegetables, and root crops on the marginal lands to maintain food and nutrition security, especially during summer at higher altitudes. The cultivation of medicinal and aromatic plants as well as the gathering of wild mushrooms like cordyceps, are done in Uttarakhand in the region that borders Tibet.

Crop and livestock-based mixed farming system

This is the most prevalent agricultural system in the hills between elevations of 500 and 2500 m, constituting the most heavily populated regions. The traditional integrated agricultural systems in the hills, which consist of five categories of crops: cereals, millets, pulses, vegetables, and oil seeds, have a mixed cropping pattern that is one of its most distinctive features. Additionally, this strategy helps maintain high crop genetic heterogeneity in a low-carrying capacity situations and guarantees optimal output for food and nutrition security. By consuming agricultural waste and grasses, livestock in the system serves as a means of cyclical agriculture, a source of animal protein, and a monetary reserve.

The upland farming system

The upland and hills of moderate elevation are characterized by complex terrain and varied climatic conditions ranging from humid, sub-humid, tropical, and sub-tropical to temperate. Key features of this system are cultivation (depending on geographic area, agro-climatic conditions, slopes, and availability of water resources) of a wide range of mostly permanent crops, including paddy, wheat, millets, pulses, maize, sugarcane, oilseeds, fruits, vegetables, and livestock. Livestock production is an essential component of the system across the region that contributes draught power, meat, milk, and a ready source of cash income. More marginal lands are being intensively farmed without proper soil and water management practices due to growing population pressure.

The highland farming system

This type of farming is very prevalent in mountainous regions with moist, humid, and sub-humid agroecological conditions. The permanent and shifting cultivation sub-types of the highland farming system produce crops (including perennial crops like fruit trees), livestock, and forest products and provide a means of subsistence for a significant number of tribal populations. The main crops grown under the highland farming system include wheat, barley, millets, pulses, maize, oilseeds, fruits, forest products, and livestock.

Agricultural scenario in the hill region

The diverse agro-climatic conditions impart a unique advantage and competitive edge over other states (of the plain region) for cultivating off-season vegetables, temperate fruits, production of organic fruits and vegetables, aromatic rice, and medicinal and medicinal and aromatic plants, fisheries, quality milk, and milk products. High-value perishable cash crops, however, have poor marketing and transportation infrastructure, which lowers net return and decreases farmers' interest in these commodities.

The land utilization pattern and irrigated area-vis-à-vis net sown area do not show an appreciable increase over the last decade. Forests cover the largest land area, more than double that of the national percentage. A low level of developmental activities is pointed by a relatively less area put to non-agricultural use. NWH has a considerable area under permanent pastures and other grazing fields, significantly supporting livestock. Culturable waste, almost equal in both regions, is probably due to migration from rural areas and calls for creating more opportunities for employment in rural areas. The total fallow in both the regions is less than the all India level. The net area sown is far below the national average due to high forest cover. The cropping intensity in NWH and NEH states also showed slow progress in the last decade.

The economic value addition to agricultural products in the last decade showed an impressive 88.48% increase in the NWH region and a whopping 196% increase in the NEH region (the base year 2011-12). Uttarakhand, Jammu and Kashmir, and Tripura are leaders in this. However, industries' contribution to the region's overall economic growth was phenomenal in the NWH, while it is very low in the NEH. The total food production increase in NEH was 37.32% compared to a little more than 7% in the NWH during the same period. Vegetable production increase also showed a similar trend (52.6% increase in NEH compared to 5.3% in the NWH). Fruit production showed 13.14% growth in the NWH during the 2011-22 period, while during the same period, fruit production decreased in the NEH by 4.43%. During 2011-2021 the NEH region showed production growth of 34.82% in egg, 66.66% in fish, -8.0% in meat, and 31.70% in milk. During the same period, the NWH region grew by -20.61% in egg, 29.03% in fish, 113.46% in meat, and 43.77% in milk. Grain storage capacity in the NEH decreased by 2.78%, while it increased by 29.2% in the NWH during 2011-21. Accessibility, as measured by increased road length, was very high in both regions. Although growths in some areas are impressive, there is very poor cointegration among data of various sectors, and they are not stationary (except fish production) with respect to time.

There are several issues in the area. These might be grouped as local and agricultural issues from the agriculture perspective. Hill physiography makes some areas hard to access and sparsely populated, seismic sensitivity, low water retention capacity, large magnitude of soil loss, sloping terrain, and thin soil cover leading to a slow recovery of the ecosystem from natural and human disturbances, high temporal variations in climate and uncertain weather, the relatively low temperature throughout, and high humidity are among the significant local problems in the hill areas.

Small and fragmented land holdings, low risk-bearing capacity due to poor economic conditions, largely rainfed agriculture, low input use, and negligible farm mechanization (together causing low returns) lead to reluctance to choose agriculture as the preferred occupation. In addition, the limited spread of improved technologies, a significant yield gap between research farms and farmer's fields, women dominating agriculture due to the outmigration of male workers, and inefficient and inadequate farming methods are some other issues related to agriculture.

One of the key elements of hill farming is livestock. But there is a severe lack of green and dry fodder; most livestock is of local breeds, and livestock improvement facilities and poultry hatcheries are very few in number. Similarly, limited primary/secondary processing facility in the hills forces farmers to sell their products raw, which is often affected by inadequate transport facility. The lack of sufficient raw materials and processing facilities are two opposites that hamper the processing of high-value perishables in the hills.

Challenges

The challenges to hill agriculture in the future will be enormous with fast depleting resources, unpredictable weather and changing climate, migration of youths due to unprofitable agriculture, and feeding the ever-increasing population. Some of the most critical challenges are given as under:

- In order to meet the productivity requirements for 2050, the present productivity of crops will have to be enhanced to a great extent, ranging from around 20% in vegetables to 83% in pulses.

Productivity requirement for 2050 vis-à-vis 20011-12 productivity of major hill crops

Crops	Region	Requirement ('000 t)	Present area (000ha)	Required productivity (kg/ha) *	Present productivity (kg/ha)	Productivity surplus/ deficit (%)
Cereal & millets	NEH	3426.9	2903.8	2817	2165.43	-30.09
	NWH	6178.9	2264.8	2406	2216.33	-8.55
Pulses	NEH	395.8	134	1660	909.12	-82.59
	NWH	713.7	113.3	1709	948.8	-82.59
Oilseeds	NEH	791.6	158.8	1307	881.57	-48.25
	NWH	1427.4	89.2	1336	777.33	-71.87
Vegetables	NEH	2364.1	196.2	15798	12646.9	-24.92
	NWH	4262.6	251.9	17903	15327.79	-16.80

Projected population in 2050('000)- North Eastern Hill (NEH)-21689; North Western Hill (NWH)-39106.695

- Requirement (Cereal & millets @ 158 kg/capita/annum; Pulses @ 18.25 kg/capita/annum; Oilseeds @ 36.5 kg/capita/annum; Vegetables @ 109 kg/capita/annum)

* - On the basis of 2020-21 area Source - (*Fertilizer Statistics 2020-21*)

- Increasing crop productivity, storage, distribution, and value addition are major

challenges. For example, coarse cereals have high potential, but their production and area growth, value addition are low. Also, the off-season vegetable market is in the hands of middlemen in the nearby plains.

- Climate change is increasing the frequency of extreme events.
- The migration of youths is increasing because of increasing unemployment and low return from agriculture in the hills.
- Wildlife, such as wild boars, monkeys, deer species, bears, porcupines, and wolves are now cataclysmic agricultural pests.
- A high number of low-productive animals (more than 90%) and male calves without humps that are unsuitable for plowing are also affecting economic returns from animal husbandry.
- The untapped potential of horticulture and post-harvest technology
- Insufficient fodder production and availability

Opportunities

- Water harvesting and using the micro-irrigation system (MIS) can enhance water use efficiency and production, especially of high-value crops and off-season vegetables in protected cultivation. Moreover, utilizing renewable energy resources, water harvesting can be put to high-income generating ventures.
- Himalayan hills harbour rich genetic diversity; this offers opportunities for discovering novel genes, and expanding the gene pools for further improvement in crops, fruits, trees, livestock, etc. Much scope exists to improve food production and productivity. Mushroom production and its value addition are profitable ventures for farmers having small land holdings.
- Hills have great scope to promote organic farming. Promoting apiculture for procuring honey along with an increased level of pollination in crops is also a viable proposition.
- There is enormous scope in designing and developing small and lightweight implements for farm mechanization and, consequently, drudgery reduction.
- Exploring and tapping the potential of locally available bio-agents and botanicals to combat pests will also be an essential area to reduce the pesticide load and be a boon to organic farming.
- Application of information and communication technology (ICT) for extension of agricultural technology and farmer's help.

Future requirements for the development of hill agriculture

There is a wide gap between the projected productivity of crops in 2050 and current yield levels in both the NE and NW Himalayas. Among all major hill crops, the disparities for

oilseeds and pulses are far broader, requiring a quantum jump in productivity to realize the projected requirement. Focus on future smart foods like millet, cowpea, mungbean, buckwheat, colocasia, quinoa, moringa, and traditional products like turmeric, king chili, mushrooms, and some wild fruits may boost the agricultural economy. The strategies suggested below will, hopefully, help in achieving this goal.

Possible strategies

- Application of watershed approach for holistic development. Expansion of water storage capacity, popularization of water conservation and management technologies, and use of renewable energy, especially solar pumps.
- Developing technology for rainfed farming, conservation and efficient utilization of water, and determining alternative crops and crop sequences to minimize the land being kept fallow. A modern farm design approach for effective utilization of farm.
- Developing varieties having wider adaptability and dual purpose (grain and fodder) as far as possible, otherwise developing altitude-specific varieties and the associated packages of practices. Diversion of areas with assured inputs to high-value crops. Production of quality seed and planting materials of various crops. Extending the cultivation of cut flowers and mushrooms.
- Biodiversity conservation, popularization of integrated pest management, and plant nutrient modules. The exploitation of potent local bio-agents and botanicals against major fungi and insect pests, besides conservation and augmentation of exotic as well as native natural enemies. Encouraging beekeeping for the dual benefit of getting honey and enhanced quality seed production in cross-pollinated crops.
- Post-harvest management and value addition. Development of small processing and packaging units to minimize post-harvest losses, value addition, and enhanced presentability of goods. Increased use of renewable energy sources in processing.
- Organic farming in niche areas. Market segment-oriented crop/livestock production programmes.
- Encouraging off-season vegetable cultivation and seed production of European and temperate vegetables and aromatic and medicinal plants utilizing nitch potential.
- Introduction of the maximum possible mechanization to reduce cost of production and drudgery.
- Development of mechanical and electronic devices to repel menacing wild animals.
- Devising crop insurance policy appropriate for hills.
- Practical land consolidation policy formulation and effective implementation.
- Simplification of micro-credit policy.

- Setting up effective cooperative chains for the sale of off-season vegetables, organic produce, cut flowers, etc.
- Collaboration with the remote sensing department to locate natural resources.
- KVK's and farmers' participation in seed production to improve seed availability, information exchange, and capacity building.

Conclusion

The Himalayan region has enormous potential for growth in agriculture. However, the agricultural productivity in hills has remained low for various reasons, including rainfed farming and low input usage. With the development and extension of new technology, agricultural productivity is sure to attain a quantum jump soon. Providing suitable, efficient technologies will also be helpful to create a renewed interest in this most important subject, which otherwise is highly challenging as it faces several constraints, including rainfed farming. This will also help enhance the farmers' economic status, which will put a brake to the migration of the young.

Lead / Invited Lectures

Status and prospects of commercial mithun farming in India

M. H. KHAN[1], NAZRUL HAQUE[2], GIRISH PATIL S[3], ABHIJIT MITRA[4]

[1] Head, Animal Reproduction Division, ICAR-Indian Veterinary Research Institute, Izatnagar, Bareilly-243122, UP, [2]ICAR-National Research Centre on Mithun, Medziphema, Nagaland-797106, [3]Director ICAR-Natonal Research Centre on Mithun, Medziphema, Nagaland-797106, [4]Animal Husbandry Commissioner, DAHD, Govt. of India

1 Status of mithun farming in India

Often misunderstood as a domesticated type of Indian Gaur because of the similar appearance, Mithun/Gayal is a unique bovine species endemic to Northeast India, Bangladesh, China, and Myanmar. It is an important cultural resource of the ethnic tribes of Northeast India, especially Arunachal Pradesh and Nagaland. It is the only domesticated bovine species often reared under free-range conditions. The Mithun population of India are distributed unevenly across Arunachal Pradesh, Nagaland, Mizoram and Manipur, with the largest population in Arunachal Pradesh followed by Nagaland. This massive and magnificent bovine species produces average two calves per three years. They are often associated with playing multidimensional roles in tribal lives. It is a symbol of prestige for the ethnic communities as well as a traditional medium of exchange in the barter system.

Mithun is a rare bovine species mainly found in forests of northeastern hilly states at an altitude of 300-3000 m. Mithun is very hardy and well adoptive animal which has a potential to survive in the tropical and sub-tropical plains to sub-temperate and temperate region. It is exclusively reared by indigenous tribes of Arunachal Pradesh, Nagaland, Mizoram and Manipur. Mithun rearing is an important activity intrinsically linked to sustainable livelihood in northeast India. In India, mithun is considered not just an animal but a symbol of prestige and prosperity. It plays a central role in the socio-economic and cultural life of tribal people. The origin of mithun is quite complex and ambiguous and it is phylogenetically distinct from other *Bos* species. Studies conducted at ICAR-National Research Centre on mithun, Nagaland has revealed a common origin of mithun and gaur from an ancient and extinct bovine species. In Arunachal Pradesh, mithun is called *'Eso'* or *'Hoho'* or *'Sebe'*, the Mizos call it *'Sial'*, *'Sandong'* in Manipur and *'Wei'* and *'Seizang'* in Naga tribes. In general, mithun is a medium to a large-sized ruminant, characterized by a jet-black body with ash-colored forehead and white stockings in the legs. However, the variation in coat color, shape and placement of horn, frontal bone size and shape varies from population to population. Coat color may vary from complete black to complete white and a mixture of black and white. Currently, total mithun population in the country is 3.8 lakhs (livestock census 2019). The highest population of mithun is found in Arunachal Pradesh which constitutes about 90 % of its total population, followed by Nagaland (5.98 %), Manipur (2.36 %) and Mizoram (1.02 %). According to 20th Livestock Census (2019), mithun population has shown an overall increase of 30.6%.

1.1 ***Socio-economic importance of mithun:*** From ancient times, it is believed that mithun is related to indigenous tribal culture and in some folklores, mithun is regarded as a descendant of sun. Mithun plays an important role in social, economic and cultural life of tribal population.

Mithun ownership is still considered a symbol of prestige and prosperity in northeast India. Mithun is mainly reared for meat purpose. It is often slaughtered for high-quality organic meat during marriage ceremonies, religious festivals, elections and community feasts. Mithun is regarded as a last resort of money and sold by poor farmers at the time of adversity to fulfill money requirements for children's education and health emergencies. It is also used for barter trade purposes apart from paying fine, ransom and price of bride by groom's family (bridal gift).

1.2 ***Agro-ecological conditions with reference to mithun rearing:*** Mithun (*Bos frontalis*), being a socio-cultural emblem of mithun rearing, has got a clear link with agricultural practices, environment, ecology and overall economy of the mithun inhabited States. Since time immemorial, it has been regarded as an inseparable component during celebration of socio-cultural and religious ceremonies. Presently, the existence of this animal is at stake both from social and environmental point of view. The forest area in which these valuable animals inhabit is decreasing day by day due to some faulty agricultural practices like Jhum with shorter cyclic period, indiscriminate felling of trees and other factors. The young generations are lured to other easy ways of income generation and are less interested in continuing the comparatively more labour intensive mithun rearing practices. In some areas, mithun females are being bred with local cattle bull (crossbreeding) for increasing milk production with higher butter fat content. It poses a great threat to the existence of this unique animal before evaluation and full exploitation of its inherent genetic potentials. Mithuns are having sufficient genetic variations in terms of their physical and productive characters. It seems to be a unique animal in terms of vulnerability/resistance against different diseases compared to that of cattle. This animal is also very special in their feeding behaviour and maintaining themselves in free range system without material inputs from mithun rearers except salt. Considering the existing socio-ecological conditions and above-mentioned characteristics of this species, there are ample scopes for improvement in growth, production and reproduction characters. Further, searching for specialties in disease resistance, rumen microbes, and meat, milk and hide products needs a long-term planning.

The normal annual rainfall in NER ranges from 200-300 cm and by virtue of receipt of heavy rainfall, it falls in low-rainfall-variability (8-15%) category. In high rainfall areas, distribution of rainfall is of more concern as compared to its amount received. Erratic nature of rainfall, its intensity and frequency often make crop planting a difficult task in rain fed areas. Analysis of long-term temperature data of the region suggests a distinctly rising trend in surface temperature. The annual mean maximum temperature in the region is rising at a rate of +0.11°C per decade. The annual mean temperature is also increasing at a rate of 0.04°C per decade in the region.

Extreme precipitation events (e.g., heavy rain, storm, cloud burst) may have their own impacts on the fragile geomorphology of the Himalayan part of the Brahmaputra basin causing more widespread landslides and soil erosion. Jhum (shifting) cultivation with shorter duration may further worsen the situation. In the wake of such a shift in climate change in the region, there is an urgent need for reassessment of the diversity of plants consumed by this animal.

However, in mithun rearing states like Nagaland, mithun rearing as an alternative to jhum cultivation or mithun as an integral part of integrated farming system are being encouraged. And farmers are spontaneously joining in this venture as mithun rearing is observed to be more remunerative than jhum cultivation in long run. In this regard, NRC on Mithun is giving more emphasis to combat challenges on ecology and environmental aspects, particularly on determination of carrying capacity of forests in terms of mithun rearing, nutritional evaluation and propagation of locally available feeds and fodders, evaluation of mithun rearing as an alternative livelihood proposition to traditional jhumias (shifting cultivators), development of sustainable mithun based farming system in fields, assessment of performance of mithun under different climatic condition, development of suitable economic housing system for mithun and also studies on disease pattern of this animal in changing climatic scenario in different altitude and seasonal variations.

2 Challenges of Mithun farming

Shifting cultivation (locally known as "jhum") is thought to be one of the major contributing factors for reduced available forest area in this region. With the increased population the villagers are reducing the fallow period in order to allot jhum land. Reduced fallow period of 1-3 years is not enough for regeneration of the land for further use, resulting in degradation and encroachment of steep slopes with forests. The clearing of forest areas at regular and frequent intervals for jhum results in loss of primary forests and formation of secondary forests. This causes substantial loss of tree diversity and associate vegetation those are adapted to primary forests. Due to shortening of jhum cycle, quite often the secondary forests also do not get adequate time to regenerate. The repeated use of land with short jhum cycle finally converts the jhum follows into degraded waste lands.

Mithun is reared in the forest under free range system with almost zero input. Data on average birth weight, average growth rate, age at puberty, age at first calving, inter-calving period of mithuns reared in free range system are not available. However, the same under semi-intensive system was observed to be 20.09 kg, 400 g/day, 35 months, 44 months and 19.3 months, respectively. Presently, on an average two calves are available in every three years from an adult female mithun reared under semi-intensive condition and the target is to have one calf in each year. There is a need to increase the birth weight to about 25-30 kg, average growth rate up to maturity about 700-900 g/day and reduction of age at puberty to about 25 months and age at first calving about 34 months. The challenges to achieve these targets are to develop animals with high genetic worth for economically important traits, to assure availability of feed and fodder in its natural habitat through propagation of fodder trees and to provide supplement feeds during scarcity period particularly winter season and to develop an integrated fertility enhancement protocol.

Emphasis has to be given on manipulation of rumen microbial ecosystem through genetic/non-genetic techniques for cent percent utilization of lignocellulosic biomass. Model animals will have to be developed for improving fibre degradation. Exploiting rich biodiversity in terms of flora and fauna of this region, identification and characterization of neutraceuticals will be done for better nutrient utilization. Though mithun meat is highly preferred in the region, but

no organized market for mithun meat exists at present. Mithun production system linked with market should be developed to increase its visibility in the Animal Husbandry Sector of the NER. Development of commercially viable mithun rearing unit is yet to come. Scientific propagation of mithun population in farmers' field using modern biotechnological tools could not be implemented yet. Presently about 10% of the population is sacrificed. To make the mithun rearing system more remunerative, value-added designer milk and meat products with high functional attributes and leather products are to be developed. It will be helpful in enhancing the availability of organic meat and reduce the pressure of environmental pollution. This will be possible only with the increase in number of animals which is a challenging task. Mithun is reared in an organic mode by default in free range system. Now, it is our responsibility to maintain this system with scientific inputs and passing it through certification process for better remuneration to mithun farmers. Exposure of mithun to external elements during scientific interventions might make these animals more prone to external diseases which need attention. Trans-border transmission of diseases is a bottleneck for overall development of mithun as all the four mithun rearing States having international border. Special attention is to be given on trans-boundary diseases. Calf mortality under free-range condition is observed to be as high as 20%. It has to be reduced to about 5% level. Identifying genetic features in the mithun genome that are related to economically important traits like growth, meat quality as well as genetic basis for disease resistance might be helpful.

Future increase in environmental temperature and erratic precipitation pattern in this region might affect mithun physically as well as with emergence of new diseases and parasites and change in the vegetation pattern in the forest. Strategies for better management for improved productivity of mithun under climate-change scenario will have to be developed. Water economy for production of per kg boneless mithun meat has to be estimated both for free range as well as intensive system. Development of elite animals through selection having capacity to tolerate higher abiotic stress is another challenging task. Suitable measures have to be taken after epidemiological studies on prevalent diseases like FMD, Haemorrhagic septicemia and other emerging diseases under climate-change scenario. Development of rapid and cheap diagnostic kits is the key issues to be considered in these aspects.

In the present scenario, mithuns are being reared in pockets confined with natural barriers. Otherwise, when reared in comparatively accessible jungle, mithun comes out to cultivated crop area igniting social conflict. Rearing mithun in small groups in isolated places makes them more prone to inbreeding. Farmers do not have the knowledge about the deleterious effect of uncontrolled breeding under free-range condition, which might lead to a mithun population with lethal genes and inbreeding depression. Open nucleus breeding herd will be developed for production of elite animal with farmers' participatory approach. Male animals from it will be used for breeding for overall genetic improvement of mithun herds.

Presently mithuns are reared in 34 out of 44 districts of Arunachal Pradesh, Manipur, Mizoram and Nagaland in a very scattered way, in an altitude between 300 to 3000 MSL by resource poor famers with inadequate exposure towards modern scientific knowledge technologies makes proper implementation of scientific mithun rearing is a challenging job. We need to

reintroduce mithun in non mithun rearing districts as well as introduction of mithun in the neigbouring states having similar agroclimatic conditions by 2050.

In nutshell the major challenges are :

1. To standardize sustainable mithun production system without affecting the ecology in some designated forest area of mithun rearing states.

2. To enhance the reproductive efficiencies of mithun to get a calf each year from a mithun cow.

3. To increase birth weight to about 25-35 kg, average growth rate to maturity about 700-900 g/day, reduction of age at puberty to about 25 months and age at first calving about 34 months.

4. To replace about 15-20% of mithun population by 2030 and about 30-40% by 2050 by genetically upgraded elite animals and increasing the population to about 0.40 million by 2030 and about 0.50 million by 2050 and feeding them with cent percent utilization of lignocellulosic biomass through manipulation of rumen microbs using genetic and non-genetic techniques.

3 SWOT Analysis of Mithun production

3.1 Strength

3.1.1 Adequate Forest Cover: The India State of Forests Report (ISFR) 2021, released by the Ministry of Environment, revealed that the north-eastern states have a total forest cover of 1,69,521 square km, out of their total geographical area of 2,62,179 sq km, which is 7.98 per cent of the country's geographical area. The forest cover in the eight north eastern states accounts for 23.75 per cent of the total forest cover of the country. According to the report, this region of the country is characterised by shifting/jhum cultivation, where forest land is converted into agricultural land and the fields are cultivated for a relatively short time. Thereafter, the area is allowed to recover or is left fallow for a long time, and this activity is repeated after certain years. This left over jhoom land is ideal for commercial mithun farming with the integration of other agricultural components which not only improve the soil fertility, soil and water conservation but also improve the income generation of mithun farmers.

3.1.2 Strong Network of Mithun Reares Societies: Mithun is generally reared under free range forest ecosystem where animals are let loose in the jungle without any shelter. They fulfil their nutritional requirement from tree leaves, bushes and grasses available in the forest. Mithun are reared on community basis. all the mithun of a particular are reared in a particular forest area designated by the Village Council. Most of the mithun rearing villages have regsitered Mithun society which is a major boon for commercial mithun activities.

3.1.3 Subsistence Agriculture: Agriculture in northeast region is characterised by low crop intensity (117 per cent). Physical constraints like weak and underdeveloped irrigation network, extremely cold weather in the higher elevations limit the crop season to summer months only.

Low density of population in the hills and sociological constraints like values and attitudes, which are not wholly conducive to market oriented agriculture, have resulted in near stagnation in agricultural production in the region. These factors lead to more dependency of tribal population on livestock. Mithun is the most suitable livestock as it survives in varied agro-ecological conditions (from 100- 3000 MSL).

3.1.4 Socio-economic value associated with mithun: Mithun is considered as the pride of North Eastern Hilly region of India. This animal plays an important role in the social, cultural and economic life of the local tribal population. The ownership of the Mithun is considered to be the sign of prosperity and superiority of an individual in the society. Farmers mainly rear the animal for meat purpose. Besides, this animal is also used as marriage gift and sacrificial animal for different social and cultural ceremonies. Though at present farmers do not consume its milk, this animal produces highly nutritious milk.

3.1.5 Non-vegetarian Food Habit: The consumption of meat is increasing in India and agriculture is considered as the backbone of a majority of people. Livestock plays a significant role, and poultry and dairy are the major sectors contributing to economic development. The majority of meats consumed in India are fish, bovine, mutton, goat, pig, and poultry. In Indian context, culture, traditions, customs, and taboos influence meat consumption to a great extent. However, in tribal population of northeast India there is no taboo in consuming meat. Though pork is the preferred meat across northeastern states, mithun meat is also being consumed as a delicacy. Currently FSSAI also notified mithun as a food animal which would definitely attract more farmers to join mithun farming.

3.2 Opportunities: As a recent development, mithun rearing is observed to be more remunerative on long-term basis compared and some farmers forming SHGS are voluntarily opting for the sauce Besides mithun rearing, it may be beneficial for increasing the forest cover, maintaining the biodiversity and sequestration of more carbon. The SHGs can have additional monetary benefit in the form of carbon credit under Clean Development Mechanism (CDM). It is a common belief that mithun is comparatively less affected by some diseases compared to cattle. It may or may not be correct. As mithun is reared in jungles and does not come in contact with different types of diseases, might be the reason of showing less disease incidences. Otherwise, if it is true, comparative genetic studies on disease incidence between mithun and cattle be helpful for having some insight and eradicate many diseases. Genetic studies in mithun will also help us to identify the desirable genetic quality in terms of production parameters, which in turn will be helpful for the genetic improvement of other species under genus *Bos*. As this animal is reared exclusively in jungle, their products are organic by default. Little efforts in terms of management and certification may bring good remuneration to the mithun rearers by selling their products in international market. Mithun is a large ruminant depends mostly on forest based forages and therefore is not a competitor to human and other livestock species for consumption of cereals, oil seeds and other related ingredients. This animal can be incorporated as a viable component in integrated hill farming system and propagated under forest based framing system with almost zero investment. Milk yield of this animal can be increased through better nutrient management and selective breeding. In situ conservation of individual strain will help us to understand the capability of

individual strain in respect of production and other traits which in turn can be amplified with proper breeding policy. The identification and evaluation of locally available feed resources preferred by mithun will be helpful to identify promising feed and fodder resources. Farmers can be motivated for conserving both the animal as well as their feed and fodder resources. It will open an avenue for propagation and cultivation of suitable grasses and tree fodders at different altitude. Traditional testified knowledge of the farmers will be very handy for incorporation in the semi-intensive scientific mithun management. As mithun *(Bos frontalis)* and gaur *(Bos gaurus*) are genetically identical, any research information generated in mithun will also be helpful for implementing any effective conservation programme for gaur, which is currently identified as an vulnerable species since 1986 (Duckworth et al., 2008).

Above all, the National Research Centre on mithun (NRCM) functioning from its main centre at Jharnapani, Medziphema with state-of-art infrastructural facilities for various disciplines with skilled manpower. So, we will definitely be able to capitalize opportunities for generating appropriate technologies for making the mithun production system a remunerative one.

3.3 Weakness:

3.3.1 Lack of financial support: Lack of financial support from banking institutions and NABARD is the major hurdle in popularizing mithun husbandry. ICAR-NRC on Mithun has taken initiatives to develop bankable scheme for mithun in consultation with banks and NABARD and it is supposed to be finalized soon.

3.3.2 Poor marketing channel: Agricultural marketing has a pivotal role to play in the socio-economic transformation of the predominantly agrarian economy like India. This is now a well recognized fact that our nation cannot march ahead on the road of economic growth without ensuring a remunerative price to the farmers for their produce. Development experiences have demonstrated that efforts to increase agricultural production have generally been frustrating unless there were parallel developments in marketing. A good agricultural marketing system, especially food marketing, is crucial for effective agricultural and rural development, particularly with regards to sustained increase in agricultural production and farmer's income and improvement of the food security capabilities of concerned countries.

3.3.3 Lack of infrastructure facilities: In the northeast region of India, the infrastructural development is still progressing at a very lazy pace despite the fact that NER has the potential to become a powerhouse "globally". Surrounded by international borders, infrastructure development-both internal and international could be the best choice for inclusive development in India's northeast. International infrastructure, which is also termed connectivity, may help the NER to become more economically engaged with the neighbouring countries. The miserable condition of infrastructure in the region demands serious attention.

3.3.4 Lack of Scientific knowledge: Enhancing farm production efficiently ultimately depends on management efficiency. Improvement in managerial efficiency can only be brought through empowering farmers by upgrading their knowledge and skill. Empowerment on various facets of Farm management right from housing, feeding, breeding and health care is essential to

farmers to enable them to reap the benefit for their toil. While some of the farm activities need individual empowerment, like technology adoption, carrying out timely farm operations, etc., the other activities like information on markets, transportation of farm produce need group approach to strengthen especially small and marginal farmers with bargaining power to realize remunerative prices to their produce

3.3.5 Poor Delivery of Veterinary Services: Over time, there has been a significant improvement in animal health infrastructure and manpower. In 2018-19, the country had 65,815 veterinary institutions comprising 12,076 polyclinics and hospitals, 25,571 dispensaries and 28,168 veterinary aid centres like stockmen centres and mobile dispensaries (Government of India, 2020a). They engaged more than 49,030 veterinary professionals and over 62,316 para-veterinary professionals (World Organisation for Animal Health, 2019). As per the recommendations of the National Commission on Agriculture (1976), one veterinarian is sufficient to serve 5,000 livestock units. Over time, the number of livestock units per veterinarian has reduced considerably (Birthal and Jumrani 2019), and it is now closer to the recommended level. Despite that, there are frequent outbreaks of the diseases like foot-and-mouth disease (FMD), black quarter (BQ), paste des petits ruminant (PPR) and influenza. What this implies is the need to improve the efficiency of the service delivery system and their re-orientation towards prophylactic management.

3.4 Threats

3.4.1 Animal-Human conflicts: Mithun generally do not go outside the forest area in sufficient green grasses and trees are available within the forest. But due to excessive deforestation, there is shortage of tree leaves. Further, during winter months, grasses get dry and animal experience shortage of fodder. Under such conditions, mithun move out of the forest area and enter in the agriculture field which causes damage of crops resulting in conflicts between mithun owners and agriculture farmers. Sometimes, mithun owners are fines heavily or even loss of mithun. Some of the village stopped mithun farming due to heavy fine imposed on mithun owners.

3.4.2 FMD outbreaks: Mithun is highly susceptible to foot and Mouth disease (FMD). Foot and Mouth Disease (FMD) causes heavy morbidity and mortality in mithun. During FMD outbreaks, mithun owners suffers huge economic loss due to heavy mortality. Efforts are being made by ICAR-NRC on Mithun as well as State Veterinary department to vaccinate entire mithun population against FMD. due to inaccessible terrain and difficulty in handling of mithun in the free-range system, it is not possible to cover 100% population.

3.4.3 Heavy calf mortality due to predator's attack: Mithun is reared under free-range conditions in the community forests and thus, farmers do not provide adequate care to mithun and their newborn calves in the form of housing, nutrition, veterinary care, etc. Consequently, it is reported that about 60% mithun calves die every year due to the attack of wild predators such as wild dog, wolf, etc.

3.4.4 Inbreeding: Inbreeding is also a problem in some herds due to declining in the population of superior fertile adult bulls in a herd. Since, mithun in a particular herd do not go outside the herd, there are minimum chances a migration of bulls from one herd to other. Usually in a herd, most dominant bull mate all the breedable mithun cows. If bulls of a herd are not exchanged or replaced, it may result in inbreeding. Inbreeding further results in reduced growth rate, reduced fertility and infertility of the herd.

3.4.5 Excessive slaughtering of Mithun: Mithun are generally reared for meat purpose. mithun being an auspicious animal are sacrificed during ceremonies such as marriage, christmas, social gatherings etc. and large number of mithun are being slaughtered. generally adult, full grown mithun are slaughted which resulted in decline in superior bulls in a herd. In the absence of superior quality bulls, mithun cows in a herd are mated by inferior and small size bulls leading to degradation of offsprings.

4 Potential of Mithun for diversified use

Over the last few decades, increased deforestation is constantly leading to a decline in mithun population in northeastern states of India. Moreover, the declining population has increased the risk of inbreeding in mithun. Today, considering the socio-economic importance of mithun in tribal culture, special attention is being given to mithun conservation. The need of time is to bring free-ranging mithun under a semi-intensive system and promote the scientific method of mithun rearing among indigenous tribes. To date, the potential of mithun to produce meat, milk and leather is not fully explored and it remains as an underutilized animal in northeast India. There exists a great scope to promote mithun farming as a valuable source of organic meat and milk. Also, mithun possesses immense potential for use as a draught-purpose animal in hilly tracts.

4.1 Mithun Meat: Being low in fat, mithun meat is good for human health. There is a very high demand and preference of mithun meat among indigenous tribes. It is always advisable to slaughter mithun at the age of 4-5 years in order to get the highest amount of meat. Generally, the dressing percentage in mithun is 58-62%. Many value-added mithun meat products like smoked meat, meat sausages, meat pickle, meat chatni, petties, meat slices and nuggets have been prepared and standardized.

Table 1. Carcass characteristics of Mithun meat

Parameters	Mithun	Beef	Cara beef
Moisture %	71.18	72.4	73.42
Fat (%)	1.04	6.7	3.5
Calorific value (Kcal/100 g)	108.24	133.32	125.15
Cholesterol (mg/100 g)	38.32	52.3	57.42
Calcium (mg/100g)	5.61	4.64	6.18
Thiamine(mg/100g)	0.56	0.02	0.05
Riboflavin(mg/100g)	1.55	0.06	0.13

4.2 Mithun Milk: Mithun is mostly reared for meat purpose however it has immense potential for milk production. Mithun milk is rich in fat (6-8%), solids-not-fat (18-24%) and protein (5-7%). Milk yield ranges from 0.87 to 1.46 kg/day. Saturated fatty acids in mithun milk are higher as compared to cattle milk but lower than buffalo milk. Unsaturated fatty acids are higher in mithun milk as compared to cattle milk. Among the unsaturated fatty acids, oleic acid is found in very high amount as compared to milk of cattle, goat, camel and yak. Amino acids in mithun milk are higher as compared to other species. Among the amino acids, lysine, a critical amino acid, is found in very high amounts as compared to other species (cattle, buffalo, sheep, goat, yak, camel). Among vitamins, fat-soluble vitamins *viz.*, Vitamin A, D & E are found in very high amounts as compared to other species. Among minerals, calcium and magnesium are found in higher concentrations as compared to other species. High lactoferrin in mithun milk, an antimicrobial compound, is associated with its medicinal property. Mithun milk can be exploited to produce superior quality dairy products like cheese, curd, ghee, rasgulla, etc.

Table 2. Characteristics of Mithun milk

Parameters (n=8)	**Mean**	**Range**
Milk fat %	6.15±0.12	3.07-9.81
SNF %	10.65±0.07	8.37–12.1
Protein %	4.14±0.03	3.23–4.72
Lactose %	5.99±0.04	4.73-6.83
Conjugated linoleic acid (CLA) (n=18)	87.67±10.92	19.92 to 274.03

4.3 Draught and Pack Power of Mithun: Being a hardy and sure-footed animal, mithun is well suited for draught and pack purpose on steep slopes of hilly areas. Due to its outstanding work power, mithun could be used for various agricultural operations, land management and pulling carts in hilly landscapes. Animal power is a renewable energy source that can be sustained in rural areas with little external input. So, in order to assess the draught ability of mithun bulls in terms of ploughing and carting, a project has been initiated by the Institute.

4.4 Mithun Leather/Hide/Skin: The leather processed from the skin of mithun is of superior quality due to its toughness and long life. This unique mithun leather has ample scope in the

tanning industry for the production of expensive goods like bags, purses, jackets, shoes, etc. which can fetch a very high commercial value in the national and international market. Physical characteristics like tensile strength, grain crack strength and ball bursting strength of bag leather are higher in mithun leather compared to cattle leather.

4.5 Farmyard manure (FYM): Farmyard manure (FYM) produced in Mithun Farm is used as an organic fertilizer in the fodder field. The decomposed mixture of dung and urine of farmed mithun along with litter and leftover fodder materials is collected and put in a manure pit and spread to the fodder field when it is dried. FYM increases the soil capacity to hold more water and nutrients. It also increases the microbial activity of the soil to improve its mineral supply and thus, increases the fodder yield. Besides, the Institute has taken the initiative to utilize FYM for vermin-compost production.

5 Existing mithun rearing practices

The farmers rear mithun in forests under a free-grazing system where they consume a variety of grasses, tree leaves and young plants. Under a free-range system, farmers do not offer additional feed or fodder supplements to mithun. However, occasionally common salt is offered to mithun especially when they need to be restrained. Mithun has a great liking for salt feeding. In general, mithun are reared in forests in community herds where mithun of different owner's graze together. The forest areas are not usually fenced and few herdsmen are appointed by the village council for supervision of mithun in the forests during the daytime and bringing them back to the village at night.

The existing free-range system of mithun rearing suffers from several constraints as follows:

i) Difficulty in implementation of scientific interventions like vaccinations, health care, and supplementations for further improvements. Poor or no veterinary care often leads to high mortality.

ii) Lack of a proper identification system for mithun under the existing free-range system leads to ownership conflicts between the mithun farmers.

iii) Grazing of a limited number of mithuns in a particular hill pocket without any migration to other locations and vice versa may result in inbreeding.

iv) Grazing of local cattle together with mithun in the same forest area is also increasing the chance of crossbreeding with the local cattle.

v) Lack of feed supplementation and non-availability of sufficient feed/ fodder viz., tree leaves and grasses, particularly during the lean season, may adversely affect the growth and reproductive performance

vi) Indiscriminate breeding under a free-range system may result in inbreeding, fertility problems, and a long inter-calving period.

vii) High calf mortality due to attack by wild carnivores.

viii) Lack of interests among the young generations in continuing the comparatively more labor-intensive traditional mithun rearing practices as they are lured to other easy ways of income.

ix) Due to the trespassing of mithun into agricultural fields, there are disputes between mithun owners and farmers. These conflicts sometimes lead to the killing of mithuns and imposing huge fines to the mithun owners. As a fallout, many tribal villages are even forced to stop rearing mithun.

(x) Decreasing forest cover adversely affecting the population of mithun.

(xi) The poor growth rate of mithun due to insufficient tree leaves and grasses may result in delayed age of maturity and first calving.

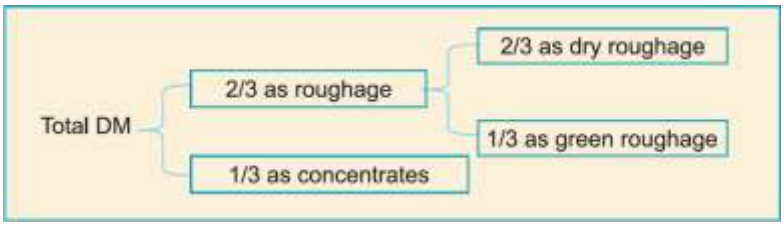
Besides, the inherent problems of the existing system of rearing mentioned above, there is no institutional supports like bankable schemes and insurance policies. As a result, the tribal farmers are deprived of the benefits of the government-sponsored schemes including the National Livestock Mission. For ages, mithun is primarily reared by the tribal communities as a meat animal. However, as per the FSSAI, mithun is neither recognized as a food animal nor there is any standard available for mithun meat. This has impeded entrepreneurship development and promoting mithun meat for ensuring better income to the tribal mithun rearers. The existence of this unique animal is at stake both from a social and environmental point of view. To address the above-mentioned constraints and shortcomings, it was envisaged to encourage the scientific mithun rearing practices by implementing and popularizing an alternative package of practices of a "semi-intensive rearing system/models" of mithun rearing in the farmers' field and to liaison with the stakeholders and government bodies to give a policy push for repurposing the mithun rearing as an enterprise under a sustainable production system.

6 Semi-intensive Mithun rearing: A tool for commercial mithun production

At present, efforts are made to popularize a semi-intensive system of mithun rearing with and controlled breeding. Semi-intensive mithun farming is promoted as a profitable venture to sustain the livelihood of poor farmers. Under this system, adequate care, appropriate treatment and ample protection can be given to mithun calves, pregnant females and sick mithun and hence, the mortality rate can be minimized. For this, mithun sheds (Fig. 1) need to be built where mithun can be housed at night time once they return from jungles after grazing during daytime. Furthermore, these sheds require the availability of fodder and drinking water. Moreover, this semi-intensive farming enables the detection of mithun females in heat and breeding with superior bulls. The biggest advantage of this system is that the animals can be monitored by the owner regularly for growth, reproduction, health care, and breeding. Since 2016-17 to 2020-21, the Institute has established 26 semi-intensive mithun rearing model under field conditions across all mithun rearing states.

Feeding practices in mithun

Proper feeding is the key for profitable and sustainable farming. It has a direct impact on the growth rate, production capacity and health status as well as on the animal's product quality. The feed requirement (Dry matter) of an animal depends on its body weight and status of productivity. In ruminant bulk is essential and the dry (DM) matter allowance is divided as follows:



Apart from 6 hours/day free grazing on mixed pasture, the dietary components provided in the semi-intensive unit were standard concentrate mixture (88% dry matter, 15% crude protein and 55% total digestible nutrient) fortified with a mineral mixture and salt (3 kg/cow/day) and ad libitum paddy straw and green fodder (Napier grass, Congo signal grass).

Scientific Feeding of Mithun in a commercial Farm

Colostrums Feeding: The calf must receive the first milk which the cow gives after calving and is called colostrums. Be sure to feed the calf enough of colostrums between 2 to 2.5 liters daily or whatever the quantity available from the mithun dam, for the first 3 days following its birth. Any excess colostrum may be fed to other calves in the herd in amounts equal to the amount of whole milk normally fed. None of it should be wasted. The digestibility of colostrums increases when it is given at a temperature between 99°F and 102°F. The importance of colostrums can be felt more from the following virtues. The protein of colostrums consists of a much higher proportion of globulin than normal milk. The globulins are presumed to be the source of antibodies which aid in protecting the animal from many infections liable to affect it after birth. The protein content of colostrums is 3 to 5 times as that of normal milk. It is also rich in some of the materials, of which copper, iron, magnesium and manganese are important.

- Colostrums contain 5 to 15 times the amount of vitamin A, found in normal milk, depending upon the character of the ration given to the mother during the rest period.
- Colostrums is also superior to milk in having a considerably greater amount of several other vitamins which have been found essential in the growth of dairy calves, including riboflavin, choline, thiamine and pantothenic acid.
- Colostrums act as a laxative to free the digestive tract of faecal material.

Feeding whole milk: In feeding whole milk, calves may be fed as per feeding schedule. While feeding whole milk the following points should be remembered. As far as possible provide milk from the calf's mother. Feed milk immediately after it is drawn. The total amount of milk may be fed at 3 or 4 equal intervals up to the age of 7 days and then twice daily.

Feeding calf starters: Calf starter is a mixture consisting of ground farm grains, protein feeds and minerals and vitamins. After a calf attains the age of 2 weeks the amount of whole milk given to it may be cut down. One should then rub a small amount of starter on the calf's mouth, after each milk feeding for a few days when the calf will be accustomed to it. When they reach four months of age, one should then transfer the calves to a "growing" grain ration.

Feeding grain mixture: Better growth and greater resistance to calf ailments result from consumption of grain and milk by the calf then when the calf is fed only on milk. At the age of 7-15 days the feeding of grain mixtures may be started. In order to get calves accustomed to grain mixtures, place a small handful of grain mixture in the pail. As the calf is finishing its milk it may consume a portion, or one may offer a little in the hand immediately after feeding milk. Excessive protein rich grain mixture is not desirable as milk is already rich in proteins. A medium protein grain mixture is most suitable when milk is fed freely.

Feeding of heifer: Heifer is growing animal, so the requirements for growth are of higher order than others for more maintenance. During early stage relatively more protein is required than energy. Most young heifers grow well if excellent is given as much as they eat. The amount of growth depends upon the quality of forage in unlimited amounts. Feed ad libitum of green fodder so that the animal gets enough carotene. If leguminous fodders are fed it gives enough calcium, and other minerals. When the heifer is fed with ad libitum of roughages and concentrates, now and then check for its growth. Fat animal should be discouraged. The heifer with pregnancy should be fed very carefully, because the animal is still growing and for compensation for the growth of the foetus. An extra amount of 1.20 kg to 1.75 kg concentrate may be provided to allow the growth of the foetus normally. 6 weeks before calving 2-3 kgs of concentrates should be given. Laxative-feeding should be practised from two weeks before calving which prevents constipation and difficulty in parturition. Unless the heifer is well-nourished, the calf will not be healthy, and also causes dystocia, retained placenta etc. The production of the animal during first lactation and also subsequently, solely depends upon the conditions of the animal at the time of first calving.

Feeding milch and pregnant animal: A mithun cow needs feed for maintenance, for development of foetus and for milk production. Besides in the first lactation a mithun cow may be growing and producing simultaneously, so allowances for growth and production have to be incorporated over and above the maintenance requirement. Therefore, the first step in feeding a mithun cow is to calculate the total requirements as per the standards. A mithun cow may be fed with 1 kg concentrate mixture for every 2 kg milk produced besides fulfilling the other requirements. Actual feeding may be done on the basis of requirements calculated as per feeding standards. Individual computation for daily feeding of cows is impracticable. Therefore, certain thumb rules are widely employed. It is common practice to feed grains at the time of milking, and roughages after milking. This causes changes in digestion. The remedy for it, is mixing concentrates with roughages and feeding during milking.

Feeding of bulls: Male calves to be reared as future breeding bulls, should be fed on a higher plane of nutrition than female calves. A bull in service should be given good quality roughage with sufficient concentrates. Too much roughage should be avoided as it makes the bull

paunchy and slow in service. A large concentrate allowance may make the bull too much fatty and less virile.

Tips for feeding

- Concentrate must be fed individually according to production requirements.
- Good quality roughage saves concentrates. Approximately 20 kg of grasses (guinea, napier, etc.) or 6-8 kg legume fodder (cowpea, lucerne) can replace 1 kg of concentrate mixture (0.14-0.16 kg of DCP) in terms of protein content.
- 1kg straw can replace 4-5 kg of grass on dry matter basis. In this case the deficiency of protein and other nutrients should be compensated by a suitable concentrate mixture.
- Regularity in feeding should be allowed.
- Over-feeding of concentrates may result in off- feed and indigestion.
- Abrupt changes in the feed should be avoided.
- Grains should be grounded to medium degree of fineness before being fed to cattle.
- Long and thick-stemmed fodders such as Napier may be chopped and fed.
- Highly moist and tender grasses may be wilted or mixed with straw before feeding. Legume fodders may be mixed with straw or other grasses to prevent the occurrence of bloat and indigestion.
- Silage and other feeds, which may impart flavour to milk, may be fed after milking. Concentrate mixture in the form of mash may be moistened with water and fed immediately. Pellets can be fed as such.
- All feeds must be stored properly in well-ventilated and dry places. Mouldy or otherwise damaged feed should not be fed.

Health care and management: Mithun is quite sturdy with an extraordinary ability to withstand various pathogens and diseases. Foot and mouth disease (FMD) is a common disease of mithun. It is a highly contagious and fatal viral disease. The infected mithun develops signs of fever followed by swelling of limbs, wounds in feet, excessive salivation, ulcers in the tongue, gums and lips, limping, abortion and a high mortality rate. To date, no treatment is available for FMD, thus, it is advisable to vaccinate newborn calves at 4 months of age and repeat it every 6 months before monsoon season. Other major diseases of mithun include hemorrhagic septicemia (HS), a black quarter (BQ), tick & leech infestation, nematodiasis, Johne's disease (JD), pneumonia, anthrax, coccidiosis, etc.

7 Economics of mithun farming under low-cost semi-intensive system

7.1 *For Meat Purpose*

Duration: 4 years

No. of mithun: 5 calves

(A) Period 1 to 4 years no sale

SL. No.	Particulars	Mithun unit (Rs in lakhs)
1	**Fixed capital or non-recurring expenditures**	
	(a) Animals	
	• Cost of 5 mithun calves male @ Rs. 15000/- per mithun	0.75
	(b) Buildings	
	• Animal house for 5 mithuns, space required 60 sq feet per mithun 5x60= 300 sq feet @ Rs. 200 per sq ft	0.60
	• Office cum equipment room cum herdsman shed 200 sq feet @ Rs. 200 per sq ft	0.40
	• Storage for feed and fodder 250 sq ft @Rs. 200 per sq ft	0.50
	• Cost of constructing salt lick platform 10x2 feet	0.50
	• Barbed wire fencing for 3 ha area with 4 rows and locally available bio-plant post (*average weight per roll 35 kg @Rs. 40/-kg*) 40 rolls ≈1600kg	0.64
	(c) Equipments	
	• Cost of ropes, chaff cutter etc.	0.50
	Total fixed capital investment (a+b+c)	6.89
II	**Fixed cost or overhead cost per year**	
	(a) Depreciation on cost of animals @10%	0.075
	(b) Depreciation on cost of building @10%	0.264
	(c) Depreciation on cost of equipment's @10%	0.05
	Total operational fixed cost per year	0.389
III	**Working capital or recurring expenditures**	
	• Cost of feeding (concentrates, mineral mixture, salt etc.) @ Rs. 1000 per mithun per year	0.05
	• Hiring of 1 herdsman @Rs. 1000 per month	0.12
	• Cost of medicines, veterinary aids etc.	0.050
	Total recurring expenditure	
IV	**Operational cost per year**	
	• Total operational fixed cost per year	0.389
	• Total recurring expenditure	0.40
	Total operational cost per year	0.789

(B) 5th Year sale of mithun meat

I	**Total operational cost for four years** (Rs. 0.789*4 years)	3.16
II	**Income**	
	Sale of mithun meat @Rs. 500 per kilo (Each adult mithun avg. weight 480 kgs, after 70% dressing percentage avg. carcass weight for sale 336 kg) for 5 mithuns 336*5= 1680 kgs	8.40
	Gross returns	8.40
III	**Profit (**Operational cost per year including depreciation on animals, buildings & equipment's)	
	Gross returns	8.40
	Total operational cost	3.16

	Total profit earned (Gross returns-Total operational cost)	5.24
	BC ratio (Gross returns/ Total operational cost)	1: 2.66

** The BC ratio is greater than 1.0, the project is viable and expected to deliver a positive net present value in terms of profit.

Additionally, the Collection of dung and converting it into FYM and vermicompost will fetch additional income under semi-intensive rearing of mithun.

7.2 For Milch Animal

Duration: 10 years

No. of mithun: 10 female mithuns (1st calving) & one breeding bull preferably 3 years old

SL. No.	Particulars	Mithun unit (Rs in lakhs)
1	**Fixed capital or non-recurring expenditures**	
	(a) Animals	
	• Cost of 10 female mithun 1st calving @ Rs. 45000/- per mithun	4.50
	• Cost of one breeding bull preferably 3 years old	0.50
	(b) Buildings	
	• Animal house for 11 mithuns, space required 60 sq feet per mithun 11x60= 660 sq feet @ Rs. 200 per sq ft	1.32
	• Calf and growing heifers shed for 10 calves space required 30 sq. ft 30x10 = 300 sq feet @ Rs. 200 per sq ft	0.60
	• Office cum equipment room cum herdsman shed 200 sq feet @ Rs. 200 per sq ft	0.40
	• Storage for feed and fodder 250 sq ft @Rs. 200 per sq ft	0.50
	• Cost of constructing salt lick platform 20x2 feet	0.50
	• Barbed wire fencing for 3 ha area with 4 rows and locally available bio-plant post (*average weight per roll 35 kg @Rs. 40/-kg*) 40 rolls ≈1600kg	0.64
	(c) Equipment's	
	• Cost of ropes, milking pans, buckets etc.	0.50
	• Chaff cutter	0.15
	Total fixed capital investment (a+b+c)	9.61
II	**Fixed cost or overhead cost per year**	
	(a) Depreciation on cost of animals @10%	0.50
	(b) Depreciation on cost of building @10%	0.396
	(c) Depreciation on cost of equipment's @10%	0.065
	Total operational fixed cost per year	0.961
III	**Working capital or recurring expenditures**	
	• Cost of feeding (concentrates, mineral mixture, salt etc.) @ Rs. 1000 per mithun per year	0.11
	• Hiring of 2 herdsman @Rs. 1000 per month	0.24
	• Cost of medicines, veterinary aids etc.	0.050
	Total recurring expenditure	0.40

IV	**Operational cost per year**	
	• Total operational fixed cost per year	0.961
	• Total recurring expenditure	0.40
	Total operational cost per year	1.36
V	**Income**	
	• Sale of milk @Rs. 100 per liter (provided per mithun yields 2 liter milk per day throughout the lactation period 2x290 days = 580 liters for 10 cows 580x10= 5800 liters per year)	5.80
	Gross returns	5.80
VI	**Profit (**Operational cost per year including depreciation on animals, buildings & equipments)	
	• Gross returns	5.80
	• Total operational cost	1.36
	• Profit per year (Gross returns- total operational cost)	4.44
	• Profit per animal per year (Profit per year/no. of milch animals)	0.44
	• Profit per animal per month (Profit per animal per year/no. of months)	0.04
	• Cost of production per litre of milk (Total recurring expenditure per animal {cost of feeding @Rs 1000, hiring of herdsman @Rs 1000 & Medicines per animal @ Rs. 500 /total milk produced per animal per year)	4.31
	• BC ratio (Gross returns/ Total operational cost)	1: 4.26

** The BC ratio is greater than 1.0, the project is viable and expected to deliver a positive net present value in terms of profit.

Suggestive measures for genetic improvement and enhancing productivity

1. Genetic improvement of mithun population through selective breeding
2. Establishment of nucleus herd of superior germplasm at farmers' field
3. Genetic improvement of a field population of mithun by superior bulls from nucleus herd.
4. Expansion and strengthening of breeding infrastructure and support mechanism to propagate elite germplasm through Artificial Insemination (AI).
5. Holistic development of mithun husbandry *w.r.t.* breeding, feeding, management, housing, value addition and marketing. The target is to improve the integration and position of local farmers and entrepreneurs into a mithun production and marketing value chain.

1. Recognition and Conservation of Superior Germplasm: Breed registration: All the states will take the necessary steps for breed registration in collaboration with ICAR-NRC on Mithun and ICAR-NBAGR, Karnal. Nucleus breeding farm individual breeds need to be established in its breeding tract separately. The breeding pyramid should be followed breed-wise. Superior animals may be collected from farmers' fields/state/central Govt. Farm to the nucleus hard. The establishment of ONBS units at the field level with the inclusion of mithun rearing farmers. The farmers with the superior animals in the ONBS can be identified and provided with separate rates and incentives from the state departments. No crossbreeding should be

allowed in farmers' fields for these superior animals. The establishment of ONBS with MOET at the field aid in the maximum genetic improvement and the superior bulls from the ONBS can be sent to the base population.

2. Establishment of Nucleus Mithun Farm: Establishment of nucleus farm at Central or state govt. level or at farmers' fields by adopting an intensive or semi-intensive model. Nucleus farm may be of superior germplasm of different breeds. In case of the nucleus hard of superior animals, mixing/crossing of germplasm must be restricted. The inferior males in the field must be castrated. Minimum 150 breedable mithun cows unit should be maintained with a sex ratio of 1:25 and thus 6 sires need to be maintained by each of the unit. The selection of male animals should be based on weaning weight (best 25%), subsequent body weight, and phenotypic characters, based on two-stage sequential selection. The selection of female animals should be based on the dam's phenotype and weaning weight (best 25%) and the number of functional teats (at least 6 pairs of functional teats). However, these can be changed as per the performance of different breeds. A centralized data recording system may be initiated. Generation wise genetic evaluation may be carried out to estimate the response to selection. The overall genetic gain due to selection, selection differential and heritability may also be calculated. Inbreeding should be avoided. Replacements of bulls need to be done at regular intervals of 5 years of productive herd life. A bull exchange program among the farms or Mithun rearing communities will also be helpful to reduce the inbreeding effect. Culled male animals should be castrated before selling to avoid indiscriminate breeding. Three number calvings per cow need to be recorded. Weightage of selection needs to be given on birth weight and weaning weight. Besides routine productive, reproductive, adaptive and carcass traits lifetime production traits may also be recorded.

3. Multiplier and Farmers' Farm: Multiplier farms should maintain grandparent (GP) and parent (P) stock of different breeds. The replacement (GP and P) stock of the multiplier farm should be made available from the nucleus farm. Multiplier farms should produce desired superior animals for propagation to farmers' fields. Bull mother farms may be established to produce superior bulls. The breeding plan for farmers' fields should be separate from that of the nucleus and multiplier farm. They are only to make *inter-se-mating* among the breeds. No indiscriminate crossbreeding is allowed in farmers' fields.

4. Mating system: All the breeding propagation activities should preferably follow Artificial Insemination (AI) practice. To achieve the target the State level Multiplier farm must have a training center for the local farmers and veterinarians including a modest facility/laboratory for semen collection, evaluation and preservation. However, natural mating in some cases may also be adapted based on the infrastructure of different states. The selection of bulls in the breeding program should be based on the following points:

1. The breeding bulls require a recorded pedigree, a quality certificate for the breed issued by the authority for bulls used for AI/natural mating. If pedigree is not available, the best bulls in terms of weight, larger testes and higher conception rate should be selected.
2. The bulls used for AI must be quarterly performance tested for semen quality.

3. The maximum frequency of use of bulls for semen collection and AI is 2 times a week for AI. In natural mating, bulls may be allowed with the females in open paddock.
4. The earliest age of use for AI or natural mating is 2 or 2.5 years
5. AI or natural mating bulls should not be used for more than 3.5 to 4 years.
6. The reports on the quality of these bulls shall be annually sent to DADF for evaluation.
7. Bulls need to be vaccinated against foot and mouth disease, hemorrhagic septicemia, black quarter and other diseases as listed in OIE.
8. A certification system should be implemented step by step for better quality breeding bulls and cows for organized farms which can be recognized as certified breeding animals

5. Culling: Inferior/ unproductive animals should be eliminated from each generation. Animals along with its family with specific genetic disorders should be eliminated from the breeding program.

6. Traceability and disease control: A systematic process of identification, registration and recording of animals should be followed to keep track of the individual animals. Artificial intelligence-based drone systems can be employed for identification and disease monitoring. A specific system should be developed for mithun disease surveillance and monitoring.

7. Capacity building: Training of progressive farmers/farm managers/large scale entrepreneurs on breeding management Regular/refresher training for veterinarians, technical personnel, para-vets and livestock service providers.Training on semen collection and AI to veterinarians/para-vets/service providers.

8. Infrastructure building: Provision may be kept for import/purchase of advanced machinery for better management including feeding and watering. Development/provision of infrastructure at farmers' field for climate-resilient housing for mithuns. Establishment of community slaughterhouses at a specific location to reduce the transportation cost and boost Mithun husbandry in the State. Value addition of mithun and mithun-products should be promoted for a better profitability of the farmers. A Cooperative based market chain should be developed. All the states should develop specific quarantine facilities for the import of animals.

9. Subsidies and other financial support: Easy bank credit facility or bankable projects for mithun. One time subsidy for smallholders purchasing breeding mithuns. Annual subsidies for using AI services. One time subsidy for AI service providers. One time subsidy for waste management system. Subsidies for the import of GP and PS stocks. Price subsidies for the production of value-added products. Subsidies for infrastructure development

10. Development of state-specific policy and Implementation: The states having a significant effect of Mithun in the livelihood of the population should work upon as per their requirement within the framework of this policy considering the following facts:

i) Involvement of cultural and social system of the state.

ii) Sectoral analysis of mithun rearers of the states needs to be done for the formulation of specific policy with zero input, low input and semi-intensive mithun farming system.
iii) Formulation of a state-specific breeding plan should target the defined single or multiple objectives mentioned in para 1.
iv) The tentative period for achieving the breeding objective needs to be fixed based on the socio-cultural status of the states.
v) The state may target to encourage entrepreneurs and commercial mithun farmers.
vi) Policies for the development of state-specific organic Mithun production may be taken up.
vii) The Policy should target to improve the integration and position of local farmers and entrepreneurs into a Mithun production and marketing value chain.

Conclusion: Mithun can be fully exploited to its marketable potential only if the farmers shift from the traditional method of rearing. The constraints of the high cost of inputs involved in fencing and predator attack may be mitigated by adopting a scientific and alternative semi-intensive method of rearing wherein the diversified use of mithun for meat, milk, hide, and draught potential can be encouraged. The state government should also work for inclusion of mithun under the National Livestock Mission and take initiatives to frame policies, strategies and legislative laws so that mithun can be a constant source of their livelihood security for the farmers without having any impact on the population conservation and propagation.

Scope and potential of agribusiness in Northeast India

G. KADIRVEL[1*], THAMERIDUS B. MARAK[2], ANIRUDDHA ROY[2]

[1] Director, ICAR-ATARI, Zone-VI, Kahikuchi, Guwahati, Assam, [2]Agribusiness Incubation Centre, ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Corresponding email: velvet.2007@rediffmail.com*

The Northeast region (NER) of India has an agrarian economy composing of rich agricultural diversity. However, the revenue earned from the agricultural sector in the region is low as compared to the national average due to underutilization and exploration. Despite of rich agrian resources, this region encounters huge loss due to lack of knowledge and low initiative in processing and value addition. The inefficient marketing functions, improper storage facilities and price instability in the region also lead to huge wastage of resources. Such constraints can be overcome through the realization of the immense scope and potential for agribusiness in the region. In recent times there is a push in policy makers to shift the paradigm from production to profit through value addition via entrepreneurial development. This can be achieved through various agri-business models, where farmers are transformed into entrepreneurs through provision of resources and capacity building. This region has huge potential to be promoted through intensified entrepreneurial initiatives by adequately exploiting the resource potential, particularly in agriculture, horticulture, animal husbandry and fishery sector. This creation of market driven products to suffice the demands of growing middle-class consumers will lead to improve rural employment generation, augment farm income and raise revenue through intensified participation in export trade. However several infrastructural, technical and policy improvement have to be made in order to unlock the potential of these ventures. Only planned structural and strategic changes which include increased exports, impactful research and development, institutional support, etc., can be catalytic for entrepreneurial development in the region.

Innovation in diagnostic point-of-care tests for infectious and zoonotic animal diseases

I. SHAKUNTALA
Dean, College of Veterinary Sciences & Animal Husbandry, Jalukie, Peren, Nagaland
Corresponding email: ishakuntala92@gmail.com

Point-of-care tests (POCT) are those veterinary/medical tests which can be performed directly in the field near to the patient care site/ outbreak investigation site without the initial need of sophisticated laboratory. POCTs allow for rapid diagnosis of infectious diseases in non-laboratory settings, and give the first impression of the disease with profound accuracy so that the curative measures can be adopted there itself in the field without wasting much of the time and they have the potential to significantly disrupt traditional animal health surveillance paradigms including outbreak investigations. In recent years, there have been significant advances in the development of diagnostic point of care tests for infectious and zoonotic diseases. These tests are designed to be portable, easy to use, and provide rapid results, making them particularly useful in settings where access to laboratory facilities is limited. One of the widely used classical POCT in veterinary is the brucella test based on serum and milk i.e, Rose Bengal plate test (RBPT) and Milk ring test (MRT) which require almost minimum facility as the requirement of RBPT is serum which can be collected from blood without the use of any instrument and test can be performed within a minute by just mixing a drop of serum with the RBPT reagent and similar is also for MRT which need milk and the antigen with result can be seen through naked eye within an hour. Direct microscopy for eggs and blood smears are also some of the conventional POCTs. Such POCTs are required in both medical and veterinary field for prompt diagnoses and action thereafter. Lateral flow assays are commonly used in POCT as an easy-to use method to read results by the end users, especially for those who are not technology-savvy. In the field of POCTs many innovative technologies are coming forward one example of innovative diagnostic technology is the use of paper-based tests. These tests are based on the principles of microfluidics, and use paper as a substrate to wick fluids through a pre-defined channel system. By incorporating specific reagents into the paper, paper-based tests can detect the presence of infectious agents in a sample, and provide a visual readout of the results. Such card/paper strip based tests are available in pet/companion diagnostic also like for rabies, toxoplasmosis, and SARS-COV-2 in human etc. Another example is the use of nucleic acid amplification tests (NAATs)/ isothermal amplification based test like polymerase spiral reaction, Loop-mediated isothermal amplification (LAMP), Helicase-dependent amplification (HDA), Recombinase Polymerase Amplification (RPA) and Rolling Circle Amplification (RCA) for point of care diagnosis. These tests use polymerase chain reaction (PCR) technology to amplify and detect the presence of pathogen-specific nucleic acid sequences in a sample. While PCR technology has traditionally been used in laboratory settings, recent advances in miniaturization and automation have made it possible to develop NAATs that can be used at the point of care. In addition, there has been increasing interest in the use of biosensors for point of care diagnostics. Biosensors are devices that can detect and quantify specific biological molecules, such as proteins or nucleic acids, in a sample. By incorporating biosensors into diagnostic devices, it is possible to rapidly and

accurately detect the presence of infectious agents in a sample. Some innovative veterinary POCTs have been used for field-based animal disease diagnosis with good results but majority of POCT evaluation is rarely taken beyond the laboratory and into the field where they are predicted to have the greatest impact, and where conditions can greatly affect test performance. If POCTs are not well validated for field use, or substandard than it can indeed confuse the results which will lead to negative impact. Hence, a proper guidelines and regulatory mechanism must be there before implementing the POCTs in the field.

Overall, these innovations in diagnostic point of care tests for infectious and zoonotic diseases have the potential to improve patient outcomes by enabling earlier and more accurate diagnosis, and facilitating faster and more targeted treatment if properly validated and implemented.

Impact of crop residue retention and economized doses of nutrient application on productivity of soybean and soil health under conservation agriculture

A.K. VISHWAKARMA*, BHARTI PARMAR, PRAMOD JHA, A.K. BISWAS, K.M. HATI, B.P. MEENA, VARSHA GUPTA, GANESH MALGAYA, S.P. DATTA

ICAR-Indian Institute of Soil Science, Bhopal

**Corresponding email: akvish16@gmail.com, Anand.Vishwakarma@icar.gov.in*

Field experiments were conducted during *Kharif* season of 2021-22 & 2022-23 to evaluate the effect of different levels of crop residue retention and nutrient application doses on performance of soybean crop under conservation agriculture (CA).The experiment was laid out in Factorial Randomized Block Design (FRBD) comprised of 16 combinations of 4 residue level (0%, 30%, 60% and 90%) and 4 nutrient doses (N_1-RDF (25:60:20 kg N,P_2O_5 and K_2O ha^{-1}), N_2-75% N+100% P_2O_5 and K_2O ha^{-1}, N_3-75% P_2O_5+100% N and K_2O ha^{-1}, N_4-75% K_2O+100% N and P_2O_5 ha^{-1}) with 3 replication under ongoing CRP-CA (Consortium Research Platform on Conservation Agriculture) at ICAR-Indian Institute of Soil Science, Bhopal (M.P.). The data on crop growth and yield parameters indicated significant influence of crop residue retention on crop growth and yield parameters *viz.*, plant height (59.14 cm), leaf area (895.63 cm^2), dry matter accumulation $plant^{-1}$ (23.11 g) and number of branches $plant^{-1}$ (6.10) with higher level of residue retention (90%) at maturity. Among yield attributes *viz.*, number of pods $plant^{-1}$ (43.49), seeds pod^{-1} (2.93), weight of pods $plant^{-1}$ (14.23 g) and seed index (11.67 g) were recorded under higher level of crop residue retention (90%). Significantly higher seed yield (1306 kg ha^{-1}) and straw yield (2452 kg ha^{-1}) was also recorded under higher residue level retention treatment. The effect of nutrient levels was found significant on seed yield, straw and biological yield. The interaction of residue and nutrient levels were also found to be significant for most of the growth and yield attributes except plant height, DMA $plant^{-1}$, seeds pod^{-1} and seed index. Significant improvement in soil physical and chemical properties were recorded in all the levels of residue retention treatments in comparison to without/ no residue retention treatment. The present investigation proved that retention of higher levels (90%) of crop residue results in significant improvement in crop yield with saving of nutrients to the tune of 25%.

Protection challenges of potato late blight in organic production system and way forward

TUSAR KANTI BAG
Division of Plant Pathology, Indian Agricultural Research Institute, New Delhi 110012
Corresponding email: tusar.bag@gmail.com

Potato is an important tuber crop. It is used as vegetables and also used in chips and French fry making in addition to alcohol production. Potato ranked 3rd among all food crops and ranked 4th among all non-grain food crops. Global potato production is approximately 370 Mt and India ranked 2nd producing 48-50 Mt of potato alone. Several diseases damage potatoes. Among them, Late blight (LB) is the most destructive disease of potatoes. It causes 15-20 % loss in total annual production affecting food security in India. Late blight is caused by a highly proliferating pathogen Phytophthora infestans (at present not a fungus, an achlorophyllous Algae belonging to Chromista). The organism multiplies both asexually and sexually. Late blight disease is a polycyclic disease and it spread fast and far destroying hectares of land within a few days. The disease is cosmopolitan, occurring in plains as well as hills, the disease is more severe in hills where the potato is grown as a rainfed crop. The pathogen can survive in soil as well as stored potato seed tubers. The pathogen has several hosts in addition to the most common host potato and tomato. Effective control of LB is possible through resistant varieties and the application of chemical fungicides. Management of LB with chemical fungicides made it several-fold challenging in an organic production system, where the use of fungicides is prohibited or minimal.

In an organic production system, an approach involving integrated use of resistant varieties, crop diversification and existing agronomic strategies along with the use of existing blight forecasting systems and alternative treatments that can replace synthetic and copper-based fungicides was suggested to optimize control treatments and maximize synergistic interactions to harvest healthy potatoes.

The best management practices (BMPs) for sustainability, Eco balance and livelihood security in NEH India

S.S. RATHORE, SUBHASH BABU, KAPILA SHEKHAWAT
Division of Agronomy, ICAR-IARI Pusa, New Delhi

The north eastern region comprising eight states viz., Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Tripura and Sikkim has a total geographical area of 262180 Km2 which is nearly 8% of the total area of the country with more than thirty nine million populations. About 35% area in the region is plain excepting Assam where plains account for 84.44% of its total geographical area. Net sown area is highest in Assam (34.12%) followed by Tripura (23.48%). Arunachal Pradesh has lowest net sown area in the region. Cropping intensity is highest in Tripura (156.5%) followed by Manipur (152.1%), Mizoram (136.36%) and Assam (123.59%). About 1.6 million hectare area is under shifting cultivation in NE region. Out of 4.0 million hectare net sown area of the region, roughly 1.3 million hectare suffers from serious soil erosion problem. The region receives an annual average rainfall of 2000mm accounting for around 10% (42.50 mhm) of the country's total precipitation of 420.00 mhm. The soil of the region is acidic to strongly acidic in reaction. The low pH of the soil is basically due to the leaching of the bases under the influence of high rainfall. The soils are, however, rich in organic matter. The depth of the soil varies from shallow in inceptisols and antisols to very deep in alluvial soils. The NEH regions is encountering many challenges as inaccessibility, marginality and fragility, overexploitation of forest for fuel, timber and fodder, improper land use practices, shifting cultivation on hill slopes, poor infrastructural development, inadequate Agricultural Mechanization, absence of storage and agro processing activities, lack of commercialization and value addition, also the danger of extinction of valuable Bio-resources, larger areas being barren/degraded due to shifting cultivation, degradation of ecosystem services, biodiversity loss and declining people interest in agriculture sector due to poor productivity and resultant poverty. Therefore, the best management practices which can enhance productivity, profitability and also resource use efficiency are need of the hour. Hence agronomic options for sustainable intensification of rice fellow areas are of great use. Crop diversification with short duration, biotic and abiotic stress tolerance oilseeds and pulses, efficient cropping systems designing, improved Utera System (Relay Cropping) , foliar application of nutrients , timely plant protection, scheduling lifesaving irrigation through micro irrigation systems, protected cultivation of high value crops, better crop establishment practices (CA, SRI, DSR, ZT etc), integrated water management, integrated pest and disease management, integrated weed management, integrated farming system. Integrated farming systems models for jhum (slash and burn agriculture) field are some of best management practices. These BMPs help the jhumia (farmers) in Jhum area of Nagaland, Manipur, Meghalaya for enhancing their farm productivity and profitability. The rice–vegetable pea–beans cropping system was most suitable under jhum land of Nagaland. Integration of fish, pig, dairy cattle, duck, and the crops such as rice, vegetable pea and beans showed maximum system productivity, i.e., 126.5 t/ha (rice-equivalent yield). This was followed by cultivation of rice, vegetable pea and beans along with dairy cattle (free grazing), having system productivity of 105.0 t/ha of rice-equivalent

yield. The farming-system approach of land use, therefore, could be adopted for sustainable production of jhum fields, and combination of rice, vegetable pea, bean, fish, pig, duck and dairy cattle was found to be most sustainable and profitable. The ecological base of fragile agri-ecosystem was also protected adequately and this proved as an option for regenerative agriculture in North east India. The ecosystem services are better restored and hence long term sustainability from farming can be ensured. Hence, IFS approach could be adopted for sustainable crop production and also to conserve the natural resources.

Modern poultry production technologies and strategies for development of poultry sector in NEH Region

S. DOLEY, LALRHUAIPUII AND TAMILARASAN K.
ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram

The Indian poultry industry has achieved significant growth by bringing paradigm shift in its structure and operation supported by a broad and strong genetic base. Apart from those various modern technological interventions have been used to improve overall productivity and profitability in the sector. The total poultry population in the country is 851.81 million, out of which NER share is 69.22 million, accounting for 8.13% of country's total poultry. Among the NER states Assam has the largest population followed by Manipur, Meghalaya, Tripura, Nagaland, Mizoram, Arunachal Pradesh, and Sikkim. The egg production in NER during 2021-22 was 12348.64 lakh numbers which is only 0.95 percent of total country's egg production of 1296001.26 lakh numbers. The growth rate of egg production in the NER during 2021-22 increased by 2.02%, which was less than the national level growth rate of 6.19%. The poultry meat production of NER during 2021-2022 has increased by 2.01 percent over previous year which is less than the national level (6.86%). The total meat production in north-eastern states is 65.86 thousand tonnes during the year 2021-2022 and the contribution of north-eastern states is 1.38% only in the total poultry meat production. The poultry production in the North East region of India has largely been remained under unorganized subsector located in rural areas as backyard poultry. There is a huge scope for further development of the sector with proper planning and adopting right strategies which have been discussed and proposed.

Keywords: Poultry, Production, Technologies, Strategies, Development, NER.

POULTRY SECTOR IN INDIA

Poultry is one of the fastest-growing segments of the agricultural sector in India with the annual growth rate of 6.19% and 6.86% in terms of eggs and meat production respectively. The total Poultry in the country is 851.81 million in 2019, increased by 16.8% over previous Census. The total Backyard Poultry in the country is 317.07 million in 2019, increased by 45.8% over previous Census and the total Commercial Poultry in the country is 534.74 million in 2019, increased by 4.5% over previous Census. The total egg production in the country is 129.60 billion numbers during 2021-22, with this India continues to be the third in the world in terms of total egg production (FAO). The total egg production from commercial poultry is 109.93 billion numbers and backyard poultry is 19.67 billion numbers contributing 84.82% and 15.18% of total production of egg respectively. The per-capita availability of egg in the country is increased to 95 eggs per annum during 2021-2022 compared to the 90 eggs per annum in the previous 2020-21 year. The total meat production in the country is 9.29 million tonnes in the year 2021-22 and nearly 4.78 million tonnes (51.44%) of meat production is contributed by Poultry. The country has exported 320,240.46 MT of Poultry products to the

world for the worth of Rs. 529.81 Crores during the year 2021-22. Major export destinations are Oman, Maldives, Indonesia, Vietnam, Bhutan, Japan and Russia.

With all these developments, yet there is organized and unorganized poultry sectors in India. Organised sub-sector needs conducive environment to grow for which policy support & intervention is required mainly for disease surveillance, drug residue and drug and vaccine quality control, standardization and quality control of poultry feed, eggs and meat, application of HACCP (Hazard Analysis and Critical Control Point) and Good Manufacturing Practices (GMP) for compliance to WTO and CODEX norms and gradation, value addition, brand promotion and export boosting etc. The unorganized subsector is mainly located in rural areas in small scale production systems.

APPLICATION OF MODERN TECHNOLOGIES IN POULTRY PRODUCTION

The advancement in science in every field is fast approaching and specifically its application in poultry production has caught the attention of many learned poultry farmers. The new farming systems are called "Smart farms, Automated farms, Mechanized farms and Digital farms. The automation has given boost to increase the operational capacity to many folds. A simple example is change over from deep litter to cage system, to present environmentally controlled units and introduction of automated feeding and watering systems. Currently application of computer based technologies in feed formulations, egg and meat production has generated a big data on all operations. Automation can be used to replace manual labour on poultry farms when it comes to repetitive tasks like checking bird welfare, vaccinations and managing litter. The latest technologies will change the future farming systems if they are used properly looking in to the economic implications in adopting newer technologies. Some most important innovative technologies developed for poultry production have been listed below.

1. Technology in egg sexing and sex altering domain: Incubation and hatching of eggs are two important practices in commercial egg production industry and sexing is usually done after completion of hatching. As a result of which the male eggs are incubated and allowed to hatch which cannot lay eggs and thereby it is not economical to fatten them. Certain technologies have been developed to combat this.

a. **SELEGGT GmbH:** It is an automated scientific approach of endocrinological gender identification in hatching egg by which the eight to ten day incubated egg is checked, if fertilized or unfertilized using sensor.

b**. eggXYT CRISPR Gene Editing Technology:** This technology involves the insertion of a biomarker in the DNA of male chicks at the parent stock level, creating an optical signature in embryos which enable to detect the male chicks during breeding and hatching operation and the eggs with male embryos can be diverted to food production.

c. RNAi technology: Altering the sex ratios in poultry is now possible using this technology. It is capable of generating single sex population i.e. generation of only female chickens in the layer poultry industry and only males in broiler industry which can increase the productivity and profitability many folds.

2. Technology in Nutrition Domain

a. MAKEFEED POULTRY software: It is a window-based computer software through which low cost, efficient balanced feed for layer and broiler can be formulated using database of diversified agroclimatic conditions of India.

b. **Augmentation of nutrient bioavailability in non-conventional feedstuffs:** Various technologies utilizing the physical, chemical and biological treatments are now available for augmenting nutrient bioavailability in non-conventional feed stuffs.

c. Technique of in ovo injection of nutrients: Standardization of in ovo feeding and in ovo vaccination in poultry has resulted in better post hatch growth and immunity in the birds

d. Nutrigenomics: It is one of the most interesting area providing techniques that can revolutionize the poultry industry by addressing both resource issues and changing expectations.

3. Technology in Poultry Products Domain

a. Technology for bringing compositional changes: Technology advancement has led to an increasing attempt to change the composition of egg either by nutritional or genetic manipulation to meet the changing requirements of human beings like altering the fatty acids and cholesterol level and adding therapeutic pharmaceutical compounds etc. Designer eggs and designer meat are the newer concept coming up and becoming popular among the masses.

4. Other Technologies

a. Augmented reality: It is a technology that enriches the view of user by either overlaying information or showing things that human cannot detect by bare eyes. This technology can be used in the processing plant where a head mounted unit can show the trimmers where and how to operate a bird through an overlay on the screen or laser scanner can give trimming instructions directly on to the product.

b. Virtual reality: This is the budding technology in which one can experience a completely new and controlled environment. It can help in keeping eye on the birds and walking through the entire farm without disturbing them.

c. Block chain: Block chain's opportunity in the poultry industry is its ability to resolve food safety and transparency issues. Block chain can be used to monitor all aspects of the food supply chain, from farmers and producers to processors and distributors

d. The Internet of Things (IOT): IOT technology is the result of the growing web connectivity in everyday used devices and objects. It has a very rich potential for collecting data using some attached sensors. IOT can simplify the sharing and analysis of data. It allows one to have as much information as possible with easy accessibility.

POULTRY SECTOR IN NER

The North-eastern region of India comprises of the eight states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The total poultry population in the NER is 69.22 million accounting for 8.13% of country's total poultry, out of which more than 94 % are indigenous and located in rural areas. Among the NER states Assam has the largest population followed by Manipur, Meghalaya, Tripura, Nagaland, Mizoram, Arunachal Pradesh, and Sikkim (20th Livestock census, GoI). Chicken is reared in all the states, while ducks, swan, and goose are predominantly found in Assam, Manipur and Tripura. Most of the chickens are local varieties, however, some improved varieties of chicken like Vanaraja, Giriraja, Gramapriya, Srinidhi, Kalinga brown, Rainbow Rooster, Kuroiler etc. have been introduced and reared in the region. The poultry sector in the North East region of India is still dominated by unorganized sector, mostly located in the rural areas as small-scale rural poultry production which provides livelihood options for small and marginal farmers. The demand for poultry meat and eggs is increasing in the region due to population growth, changing dietary preferences, and urbanization. At present, the demand is largely met through local production, supplemented by imports from other states. The poultry sector in the region is steadily growing and has significant potential for generating employment opportunities and further development. Therefore, the government has undertaken various initiatives to promote the poultry sector in the North East region. These include providing subsidies, training programs, and financial assistance to farmers. The National Livestock Mission (NLM) and National Poultry Development Scheme (NPDS) are some of the government schemes supporting the development of poultry farming.

The details of egg and meat production, their availability and growth rates in NER and India during 2020 to 2022 have been presented in the table 1.

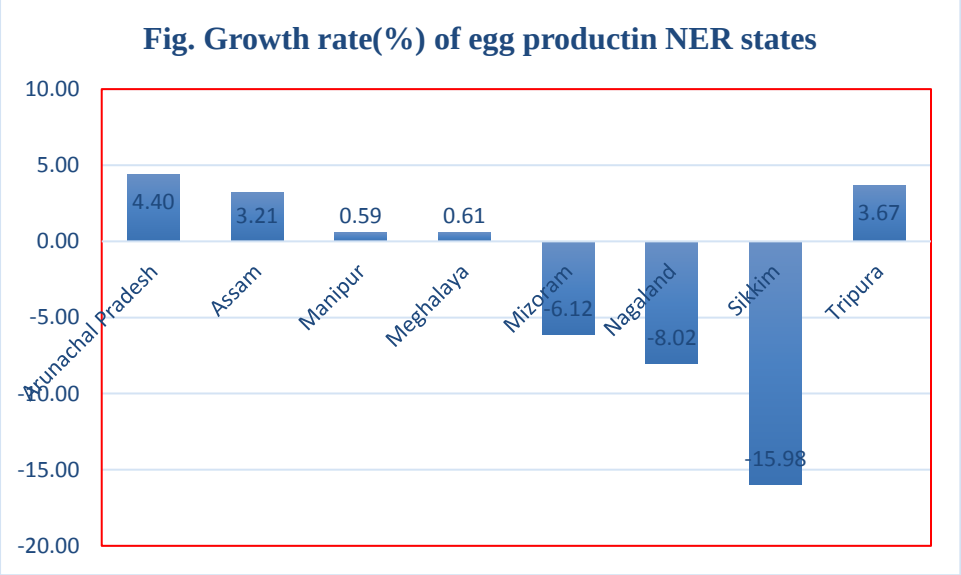
Table 1. Egg and meat production during 2020-21 to 2021-22 in NER and India.

State	Egg Production (Nos. in lakhs)		Growth rates (%)	Per capita availability of eggs (Nos.)		Meat production (In 000 tons)		Growth rates (%)
	2020-21	2021-22		2020-21	2021-22	2020-21	2021-22	
Arunachal Pradesh	638.51 (5.28)	666.62 (5.40)	4.4	42	43	0.88 (1.36)	1.32 (2.00)	50
Assam	5253.04 (43.41)	5421.70 (43.91)	3.21	15	15	11.53 (17.86)	12.01 (18.24)	4.16
Manipur	1141.63 (9.44)	1148.39 (9.30)	0.59	36	36	7.74 (11.99)	7.76 (11.78)	0.26
Meghalaya	1107.85 (9.16)	1114.62 (9.03)	0.61	34	34	4.08 (6.32)	2.86 (4.34)	-29.90
Mizoram	434.06 (3.59)	407.50 (3.30)	-6.12	36	34	4.16 (6.44)	4.63 (7.03)	11.30
Nagaland	384.87 (3.18)	353.99 (2.87)	-8.02	18	16	0.59 (0.91)	0.51 (0.77)	-13.56
Sikkim	98.13 (0.81)	82.45 (0.67)	-15.98	15	12	0.99 (1.53)	0.88 (1.34)	-11.11

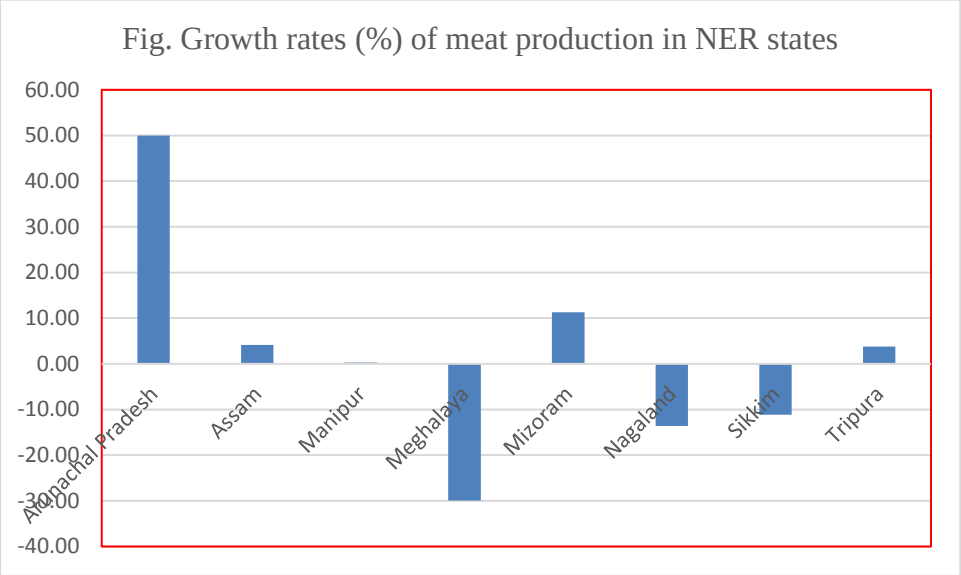
Tripura	3041.68 (25.14)	3153.37 (25.54)	3.67	75	77	34.59 (53.58)	35.89 (54.59)	3.76
NER	**12099.77 (0.99)**	**12348.64 (0.95)**	**2.06**	**33.88**	**33.38**	**64.56 (1.44)**	**65.86 (1.38)**	**2.01**
India	**1220496.44**	**1296001.26**	**6.19**	**90**	**95**	**4472.69**	**4779.60**	**6.86**

Figures in parenthesis indicate the per cent share of states in NER and NER in India. (Source: Basic Animal Husbandry Statistics,2022)

The egg production in NER during 2021-22 was 12348.64 lakh numbers. Assam (43.91%) is the leading state in NER in terms of egg production during the year 2021-22 followed by Tripura (25.54%), Manipur (9.3%) and Meghalaya (9.03%). Mizoram, Nagaland and Sikkim recorded negative growth rates of egg production during 2021-22.



The growth curve of egg production in other NER states ranges from +0.56% in Meghalaya to 4.4% in Arunachal Pradesh. The growth rate of egg production in the NER during 2021-22 increased by 2.02%, which was less than the national level growth rate of 6.19%. It was observed that the growth rate of egg production in the NER was not satisfactory despite a large number increase in the poultry population. This might be due to maximum poultry population in the region are of indigenous variety with low egg production potential. The per capita availability of eggs during 2021-2022 in the NER and the country was 33.38 and 95 numbers per annum respectively. It can also be observed that Tripura ha the maximum (77 nos.) and Sikkim is the lowest (12 nos.) in terms of per capita availability of eggs per annum during 2021-2022 among the north-eastern states. Moreover, the states of Mizoram, Nagaland, and Sikkim experienced a decreased in per capita availability of egg during 2021-2022 due to negative growth rate of egg production.



Among the NER states, Tripura (54.59) has the largest contribution towards poultry meat production followed by Assam (18.24%), Manipur (11.78%), Mizoram (7.03%), Meghalaya (4.34%), Arunachal Pradesh (2%), Sikkim (1.34%) and Nagaland (0.77%). The poultry meat production of NER during 2021-2022 has increased by 2.01 percent over previous year which is less than the national level (6.86%). The Arunachal Pradesh state has the highest growth rate (50%) of poultry meat production amongst the North-eastern states. This could be possible due to adoption of improved strategies and improvement of the traditional backyard poultry farming, conversion of demonstration farms into breeding and production units, setting up of private commercial and rural breeding farms on private public partnership mode. However, the states of Meghalaya, Nagaland, and Sikkim experienced the negative growth rate of -29.9%, -13.56% and -11.11% respectively in terms of meat production during 2021-2022.

STRATEGIES FOR DEVELOPMENT OF POULTRY SECTOR IN NEH REGION

Despite the growth and potential, the poultry sector in the North East region faces some challenges. These include limited access to quality feed and vaccines, inadequate infrastructure, lack of technical knowledge, and transportation difficulties due to the region's hilly terrain. Therefore, to promote the development of the poultry sector in the hilly regions of North East India, several strategies can be implemented. These strategies aim to address the unique challenges posed by the hilly terrain and leverage the region's potential for poultry farming. Here are some key strategies:

1. Feeding: Balanced quality feed availability at optimum price is required for getting maximum income from poultry rearing. Therefore, production of major feed ingredients like maize and soybean should be promoted through availability of quality seeds and bringing more area under cultivation in the region. There is also a need to develop cost effective balanced ration using locally available ingredients like Azolla, Chinese palak, buck wheat, rice bean etc for feeding.

2. Breeding: Availability of quality breeding birds to the farmers is to be confirmed by establishing the breeding farm in each district. Location specific dual-purpose breeds needs to be developed. Improved varieties of chicken breeds are to be utilised to get more production.

3. Research and Development: Invest in research and development activities specific to poultry farming in hilly areas. This can include studying the impact of altitude, temperature, and weather conditions on poultry health and productivity. Develop and disseminate region-specific best practices, techniques, and technologies for hilly terrain poultry farming.

4. Infrastructure Development: Improve the infrastructure required for poultry farming in hilly areas. This includes developing and maintaining proper road networks, establishing poultry processing and storage facilities, and ensuring reliable electricity supply. Infrastructure development will facilitate the transportation of poultry products and reduce post-harvest losses.

5. Training and Capacity Building: Organize training programs and workshops to enhance the technical knowledge and skills of poultry farmers in hilly regions. These programs can cover various aspects such as breed selection, disease management, feed formulation, and farm management practices. Building the capacity of farmers will contribute to improved productivity and profitability.

6. Access to Inputs: Ensure easy availability and accessibility of quality inputs such as poultry feed, vaccines, medicines, and equipment in hilly areas. Establish distribution networks and supply chains that cater to the specific needs of poultry farmers in remote and hilly regions. Provide subsidies or financial support to reduce input costs and make them affordable for farmers.

7. Promote Cooperative Farming: Encourage cooperative farming models where small-scale poultry farmers can collaborate and pool resources. Cooperative farming enables sharing of infrastructure, knowledge, and marketing channels, leading to economies of scale and increased bargaining power. This approach can help overcome the challenges faced by individual farmers in hilly areas.

8. Market Linkages and Value Addition: Facilitate market linkages for poultry farmers in hilly regions. Establish partnerships with processors, retailers, and institutional buyers to ensure a stable market for poultry products. Promote value addition by supporting the establishment of processing units, cold storage facilities, and branding initiatives to increase the value and marketability of poultry products.

9. Financial Support and Incentives: Provide financial assistance, subsidies, and incentives to poultry farmers in hilly areas. This can include low-interest loans, grants for infrastructure development, and subsidies for inputs and equipment. Such support will encourage investment in the sector and help farmers overcome financial constraints.

10. Awareness and Extension Services: Conduct awareness campaigns and extension services to educate farmers about the benefits and opportunities in the poultry sector. Promote

good agricultural practices, biosecurity measures, and sustainable farming techniques through farmer field schools, demonstrations, and information dissemination programs.

CONCLUSION

The Indian poultry industry has achieved significant growth by bringing paradigm shift in its structure and operation supported by a broad and strong genetic base. Various modern technologies have been developed to further improve overall productivity and profitability in the organized sector of the industry. However, the performance of poultry sector in NER is still not satisfactory even though there was an increased in the growth rate of poultry population in the region. This was mainly due to low production potential of local and indigenous germplasm of poultry. By proper planning and implementing these strategies, the poultry sector in the hilly regions of North East India can be further developed.

Hort Technologies for Tripura

BISWAJIT DAS, H. LEMBISANA DEVI AND BAPI DAS

E-mail of Corresponding author: biswajitsom_dr@yahoo.co.in, Ph. No. 9612813456
ICAR Research Complex for NEH Region, Tripura Centre, Lembucherra- 799210, Tripura

The north eastern state Tripura has diverged range of topography, communities, endemic flora and fauna. Topography comprises plain low land and hilly terrains with altitudinal range of 15-940 m amsl. The climate of Tripura is Tropical to sub-tropical in nature. Summer is hot (17.0-39.0^{0}C) and very much humid (75-80% RH), rainy season (June-September) experience maximum precipitation as monsoon rainfall, pre and post monsoon rain fall occurs during April-May and September-October with average annual rainfall around 2500 mm, respectively, autumn season is also hot as well as humid (October-November) and winter is mild (5.0-26.0 ^{0}C) with scattered rainfall (December- February). Tripura falls in agro-climatic zone 1 Eastern Himalayan region. The soil types of Tripura can be classified under five major groups, red loam and sandy loam soil occupies 43.07% the total area, reddish yellow brown sandy soils 33.06%, other three types are older alluvial soil (9.7%), younger alluvial soil 99.3%) & lateritic soil (5%). Distribution of 5 types of soil orders are inceptisols (80.6%), entisols (8.1%), ultisols (6.6%), alfisols (4.5%) and histosols (0.25). Soil is acidic (4.0-5.5 pH). Cropping Intensity is 191 % (All India – 142%), average size of holding is 0.49 ha (All India – 1.15 ha) and small & marginal farmers are 96% (All India – 85%). Net sown area is about 2.56 lakh ha (24% of the total area) out of which 66.6 thousand ha is under fruit and 39.1 thousand ha is under vegetable farming. The agro-climatic condition of the state is very much suitable for cultivation of majority of the tropical and sub-tropical fruit crops, winter and summer vegetables as well as some specialized cut flowers.

Salient horti-technologies are:

1. Introduction and performance evaluation of Mango Variety Amrapali and Mosambi and standardization of quality planting materials production of these varieties under Tripura condition: Mango var. Amrapali was introduced in the year 1989 at Tripura Centre and evaluated for 10 years at the experimental orchard, ICAR- Tripura Centre, Lembucherra, Tripura. Other varieties namely Mallika, Arunika and Ambika were also found to be promising. Over the years, epicotyl grafting and soft wood grafting time was standardized with 85-90% success rate for this variety under Tripura agro-climatic conditions. Fruit yield ranged from 7-10 t/ha and fruit weight 220-230 g, fruit length 10.0-12.0 cm, fruit width 6.0-7.2 cm, TSS 15.5-17.0 ^{0}B and total sugars 12.6%. Sweet orange variety Mosambi was introduced during 2002-03 at Tripura Centre of ICAR Research Complex for NEH Region and became most popular commercial variety in Tripura. Quality planting materials were distributed to the farmers and local nurseries. These varieties have become most popular commercial variety in Tripura apart from Himsagar and Fazli of Mango and Mandarin orange. ICAR has already distributed more than 1.5 lacs grafted plants to the farmers of the state. Directorate of Horticulture, Govt of Tripura has also adopted this technology for establishment of many model orchards and distributed planting materials under various developmental schemes.

Grafted plants were also supplied to different organizations and farmers in Assam, Nagaland, Manipur and Mizoram.

2. Weed mat technology for pineapple cultivation and off season fruiting by staggering and flower regulation: The agro-climatic condition is very much suitable for premium quality pineapple cultivation. Variety 'Queen' produced in Tripura has been given Geographical Indication (GI) in 2015 and was also declared as State Fruit in 2018. Export of pineapple from Tripura has started since 2018. However, production of fruit with uniform size and weight in bulk as per export standards was a problem under traditional cultivation system. ICAR Research Complex Tripura Centre, has developed a high-density planting system under mulching and foliar feeding in 2018. Healthy pineapple suckers (500-600 g) are planted in the month of September. Raised Bed double row high density planting with spacing 40 cm (plant to plant) x 60 cm (Row to Row) + 90 cm/1.0 m (Bed to Bed). Raised beds are covered with weed mat or black polyethylene sheet before sucker planting. Irrigation is required during November to mid-March in the 1st year (Planting Year) at fort night interval and in the 2nd year and in the successive years (fruiting years) during dry spells i.e. Dec-Jan. and Feb.-March (2-3 times). NPK (19:19:19) foliar sprays at 7th or 8th months after planting, and again at 30 and 60 days after fruit set. Trace element feeding: Zn (0.4%) + B (0.1%) sprays at 40 and 50 days after fruit set. Under this technology, weeds growth is completely prevented, labour cost is minimized, and fruit size and quality in improved. Fruit weight is ranges from 1.5-2.5 kg, TSS 13.0-17.00 B and yield 60-70 t/ha, in comparison to traditional cultivation practices with only fruit weight 400-800 g and yield 20-25 t/ha. Staggered planting following planting of suckers at various time interval and by planting crown, suckers and slips have been refined at Tripura centre. However, most popular is flower regulation using chemical regulation by application of ethrel (25ppm) + urea (2%) + calcium carbonate (0.4%) in all months, whereas, in March-May Ethrel 10 ppm (2.5 ml/100 litres of water) + 2% urea + 0.04% sodium carbonate is applied and in September-January 10-20ppm NAA (Palnofix (1-2ml/4.5 L water) + 2% urea. Solution of 3.2 ml of 39% ethrel+ 1kg urea+ 20g calcium carbonate in 50 L water is prepared for 1000plants @ 50 ml/plant poured at the central core of the plant during evening time at 35-40 leaf stage of plant i.e., 15-17 months old. Flowering initiates within 30-40 days and fruits matures within 130-140 days. Fruits available during September-November and February get good price in local market.

3. Dragon fruit cultivation technology under integrated nutrient management (INM): Dragon fruit (*Hylocereus* sp.) also called Pitaya is a tropical climate and has very good potential for Tripura. This fruit is highly nutritive and contains antioxidant value. It has three types of fruit variety: Red colour fruit with white colour flesh, Red colour fruit with red colour flesh, and Yellow colour fruit with white colour flesh. Cultivation of this fruit in Tripura started in 2016-17. Two varieties namely Red fleshed and White Fleshed have been evaluated under Tripura agro climatic conditions, and both have been found to be very much suitable for the state. INM with planting at spacing 2 m x 2 m with plant density of 1.0 lac plants/ha with four plants per cement pole has been standardized under weed mat/black poly ethylene or straw mulching. Foliar application: N:P:K (19:19:19) (@2g/litre water) in First week of January and August; three sprays of Micronutrient especially Zn (0.1%) and Boron (0.5%) at each three

fruiting developing stages (i.e. in June, July and August). Production is 45-50 MT/ha and market rate in Tripura is Rs. 400-500/kg. ICAR Tripura Centre has organized trainings and demonstration in farmer's field and is also distributing quality planting materials. Directorate of Horticulture, Govt. of Tripura is implementing dragon fruit cultivation projects in different parts of the state.

4. Standardization of rejuvenation techniques of old mango trees: Rejuvenation of old and senile mango trees var. Himsagar was standardized under Tripura conditions. Pruning at 2.5-3.5m during December-January. Top grafting of old pruned seedling trees during April-May with Amrapali scions gave maximum grafting success and early fruiting. Training and demonstrations were organized.

5. Fruit quality improvement of Litchi var. Shahi through shoot pruning and foliar feeding: Pruning of 20-30 cm shoot on 10-12 years bearing litchi trees after harvesting was performed in combination with single spray of zinc (0.1%) at one month before panicle emergence followed by boron (0.5%) at one week before flowering was effective for better flowering and fruit set, and single spray of urea (1%) at green fruit stage, again boron (0.1%) at fruit maturity stage was effective for fruit growth and quality. Foliar sprays of zinc, boron and urea significantly reduced fruit cracking (5.1-5.6%) in comparison to control (15%) and increased yield/tree (34.6-37.8 kg). Rejuvenation of old litchi trees and shoot pruning along with foliar feeding was found to be very effective in improving production and fruit quality on old trees.

6. Standardization of HYV of vegetable based annual cropping sequence: Vegetable cultivation is one of the most preferred agricultural practices in Tripura for higher income. However, vegetable growers of the state always faced difficulties in selecting the suitable high yielding varieties of vegetable crops which is suitable for soils and agro-climatic conditions of Tripura and variety specific packages of practices for these crops were also not available. Considering this, adoptive evaluated trails were conducted at ICAR Tripura Centre since 2014 for many high yielding vegetable varieties and suitable HYV vegetable varieties for the state. On the basis of long-term evaluation trial of newly developed high yielding varieties highly productive annual cropping sequence was standardized. Around 500 farmers were selected for cultivation of HYV vegetable crops in seasonal (winter and summer) cropping sequence and vegetable productivity was increased by 35-45%, cropping intensity was increased, and BC ratio ranged from 2.5-3.4 in comparison to traditional local varieties.

7. Standardization of multi-storeyed vegetable cultivation model for upland conditions of Tripura: A highly profitable and sustainable multi-storeyed vegetable cropping system was standardized for upland conditions of Tripura, comprising of various commercial important vegetable crops. In winter season, French bean, peas and brinjal were recorded to be better performer with BC ratio of 3.6, 3.5 and 3.1, respectively. Whereas, Coriander as leaf harvesting gave 4.0 BC ratio. In Summer season, Swamp taro (caudex + stolon type), Amaranthus (Leafy), cowpeas and okra with BC ratio of 3.2, 3.1, 2.7 and 2.5 were better performer under Teasle Gourd and ridge gourd. Nutrient combination of FYM (5t/ha) + INM with 75 RFD + Rhizobium + PSB gave better response.

8. Collection, evaluation and conservation of teasel gourd and Hyacinth bean germplasm in Tripura: A wide range of variability is found in teasel gourd and Hyacinth bean in Tripura. Some superior types are widely cultivated by the local farmers and demand is very high. IC number from NBPGR, New Delhi have been received for Total 17 hyacinth genotypes. Superior selections are being cultivated commercially by the farmers.

9. Demonstration of Horti based Integrated Farming System: IFS components: Horti. + agri.+ Piggery+ Fishery + Poultry, and Horti.+agri.+ goat+poultry+ Fishey gave higher returns with BC ratio of >3.0. Horti based IFS has been found to be very suitable for small and marginal farmers in Tripura.

10. Evaluation of Onion and Garlic varieties under Tripura conditions: Onion varieties namely Bhima Shakti, Bhima Subhra, Arka Pragati, Arka Kirtiman, Arka Kalyan, Pusa Red as short day rabi and var. Bhima Super as Late Kharif were found to be promising along with few more Short-day rabi onion varieties under Tripura condition with yield range of 27-30 T/ha. Garlic variety Bhima Purple with yield range of 32-35 q/ha was better performer under Tripura condition. Onion production technology was standardized. Onion storage under ambient conditions were also studied and high rainfall and humid conditions negatively affected the storage life of onion. Thrips population was high during February to March.

11. Production technology of gladiolus for Tripura condition: Gladiolus varieties evaluated are Prescilla, Red Ginger, Pusa Suhagan, Suvenior and Summer Sunshine. Suitable planting time of corms is August-October-November. Staggered planting or planting at 10-15 days interval during August to December may extend the availability of spike without any glut harvest at one time.

Conclusions

Considering the agro-climatic suitability, pineapple, jack fruit, citrus fruits are the major crops for Tripura. Mango, banana, litchi, ber, papaya and other minor tropical fruits are also grown. Adoption of improved production technology and scientific management of the orchards are very much essential for production of quality fruits. Vegetable cultivation is very much profitable and farmers have adopted cultivation of HYV vegetables in annual cropping sequence. Farmers are advised to adopt INM and IPM for better production. Among the cut flowers, marigold, gladiolus, anthurium, gerbera and Dendrobium orchid cultivation have been widely adopted by the farmers. Future potential crops namely, dragon fruits and avocado have been introduced and are being popularized among the farmers.

Parasitic infections and infestations in poultry of North Eastern Hill Region of India- An overview

R. LAHA
Joint Director (Incharge), ICAR Research Complex for NEH Region, Sikkim Centre
Tadong, Gangtok, Sikkim-737 102

Poultry farming is a mean of subsidiary income for poor and landless farmers and a profitable business for commercial poultry farmers/ entrepreneurs. One of the constraints in poultry farming in both backyard and commercial poultry farming is outbreak of various diseases that leads to economic losses to poultry farmers, where viral and bacterial diseases of poultry are mainly taken into consideration and parasitic diseases of poultry is generally remain under considered in such economic losses. It may be due to lack of awareness about parasitic diseases among poultry farmers and may be due to the fact that parasitic diseases may not cause mortality among birds to that extent as compared to viral or bacterial diseases which are very much visible. As a result, economic losses due to mortality and morbidity due to parasitic infections and infestations in poultry remained unnoticed. Somewhere economic losses to the extent of more than half of annual profit due to poultry coccidiosis have been reported. Keeping in view of such economic losses due to parasitic infections, it is very much essential to know about the prevalence of parasitic infections or infestations in poultry of north eastern region of India. Mostly eight different species of gastrointestinal parasites have been reported from poultry of north eastern region like *Ascaridia galli, Eimeria* sp. (Coccidia), *Raillietina* sp., *Syngamus trachea*, *Capillaria* sp., *Strongyloides avium*, *Choanotaenia infundibulum* and *Heterakis gallinarum. Dermanyssus gallinae (*red mite*), Liponyssus* sp. (feather mite), *Chrysomya bezziana* (causes urogenital myiasis) infestations in poultry of north eastern region of India have been reported. Anticoccidials, anthelmintics and insecticide agents have been used for prevention and control of both parasitic infections and infestation.

Emerging diseases of pig and poultry in the North eastern scenario and transboundary context

ARNAB SEN, LAHA. R.G., GHATAK.S, DAS.S, MILTON A.P., PURO.K., V.K. MISHRA

Division of Animal and Fisheries Sciences, ICAR Research Complex for NEH, Barapani, Meghalaya-793103

Introduction

Rapid globalization leading to increased trade and thus continuous movement of humans and animals, climate change, increased concentration of animals and humans pose an ever increasing threat of infectious diseases crossing the borders and leading to huge outbreaks. Outbreaks of exotic viral and bacterial diseases have become a real threat to animal populations worldwide in recent years. Outbreaks of FMD in UK in 2001 and 2007, Blue tongue in 2007, equine influenza in Australia in 2007 and India in 2008-09, highly pathogenic avian influenza (H5N1) are some of the glaring examples of the amount of devastation they can cause in terms of economic losses and damage to the industry. The scars from these outbreaks are stark reminders which make us sit and probe our capabilities to work towards creating technologies and garner our scientific knowledge in pursuit to overcome these infections. Theoretically, sealing our borders and stopping the movement of all human and animals can help us achieve the task but its sheer magnitude and enormity certainly make us ponder upon some better scientific means to find a sensible solution to this enigmatic problem of transboundary diseases. The sole mandate of this endeavor is to work on a roadmap to build our capabilities and strengths in the direction of developing latest diagnostics and organize rigorous surveillance for the highly contagious and ravaging (selected) diseases so as to have complete vigil on the disease situation of emerging and exotic infections and build a formidable defense to guard our territories, thus saving the livestock wealth and livelihood of millions of human beings involved with it.

The North Eastern Region of India has a diverse population of domestic livestock and wild fauna. This region is most favorable for livestock farming, as 60% grazing land is unfit for crop production and 40% people living below poverty line are dependent on micro and macro livestock farming for their economic support. The contribution of different livestock population to the total animal population of the nation is – cattle-6.20%, buffaloe-0.85%, sheep-0.36%, goat-3.51%, pig-28.22%, horse-3.72%, yak-24.61% and mithun-91.36%. Besides, there are sizable numbers of semi-domestic animals and large numbers of wild fauna. High rainfall and humid condition of this region probably favors rapid multiplication and maintenance of most of the infectious agents. In addition, there is close interaction between human, domestic and wild animals Moreover; the location of the eight northeastern Indian States itself is part of the reason why it has always been a hotbed of militancy with trans-border ramifications. This region of 263,000 square kilometers shares highly porous and sensitive frontiers with China in the North, Myanmar in the East, Bangladesh in the South West and Bhutan to the North West. The region's strategic location is underlined by the fact that it shares a 4,500 km-long international border with its four South Asian neighbours, but is connected

to the Indian mainland by a tenuous 22 km-long land corridor passing through Siliguri in the eastern State of West Bengal, appropriately described as the 'Chicken's Neck. 'The North Eastern Region shares approximately 4500 km international boundaries with Myanmar, Bangladesh, Bhutan, Nepal and China. Uncontrolled migration of animals from neighboring countries, therefore, can be great threat for spreading of emerging and transboundary diseases to this region. Analyzing total animal health scenario following weaknesses are evident:

- The framework for animal health lacks adequate systems and tools for analyzing and managing risk, and planning for outbreaks.
- Efforts to develop and validate diagnostic assays needs to occur more rapidly.
- No road map is established about prevalence of infectious diseases of livestock and poultry in entire NE states.
- The workforce on the front lines of animal care is not adequately educated and trained to deal with animal disease issues, and there is a shortage of veterinarians in the workforce for animal disease prevention, detection, and diagnosis.
- Collaboration between public health, state animal health officials and University scientists is lacking, although strong networking can accelerate the detection and diagnosis of animal diseases.

Bacteriology (Antimicrobial resistance)

Environmental pollutions with antimicrobial residues are assumed to promote resistance among non-target bacteria and horizontal gene transfer (WHO 2004). Residues in the micro-environment of the bacteria are thought to influence the development of resistance through horizontal gene transfer mechanisms (Aminov 2011). This understanding has been central to the various antibiotic control policies that aim at reduction of resistance burden of the environment and through reduction in circulating residues in various ecological niches.

Horizontal gene transfer is a key phenomenon for spread of resistance among bacteria (Aminov 2011). Transfers happen across various classes of bacteria (Tenover 2001, Aminov 2011). While there are documented evidences of such transfer between bacteria of human origin there are hardly any report of resistance transfer between plant and animal origin bacteria and human pathogens (Okeke and Edelman 2001). Therefore, this knowledge gap needs to be bridged by investigation on the transferability between animal – plant – human origin bacteria to comprehend the magnitude of such horizontal transfer of resistance genes.

Tracking bacteria with defined traits to their origin is a necessary prerequisite in understanding the epidemiology of spread of bacteria from one source to other (Singh et al 2006). In the continuum of the bacteria world transfer of antimicrobial resistance may be due to transfer of a resistant bacteria as such from one host to another representing clonal spread with ecological connectivity or through transfer of resistance genes to other bacteria that in turn colonize their

regular hosts (horizontal gene transfer). While horizontal gene transfer has received much attention (Aminov 2011), clonal spread of resistant bacteria at the interface of animal-human-plant bacteria is also important, especially in the agrarian socio-economy of India. To delineate these two modes of transfer it is important to study the relatedness among bacteria originating from various sources so that a conclusive epidemiological model of transfer of antimicrobial resistance can be built.

Virology (Porcine and poultry viruses)

Viruses are by their genetic nature obligate parasites. Consideration of developments in diagnostic methods and vaccines in general and animal viruses in particular, has to recognize the tremendous ability of viruses to rapidly produce mutations which, through selection, can exploit biological "niches". Thus, there is a constant evolution of potential "strains" which can exploit both there "normal" and also more "foreign" species. Indeed, such exploitation can often result from direct intervention strategies, e.g., vaccination and from more indirect changes concerning human patterns of endeavor This contributes to the harmonization of methods of surveillance and control of important animal diseases and standard methods are described for laboratory diagnostic tests and the production and control of biological products (principally vaccines) for veterinary use in laboratories across the world. The availability of such standards should increase the effectiveness of measures undertaken to improve animal health worldwide. The OIE Manual has been written and revised by experts of established international standing and is unique in that each chapter has been approved by the Veterinary Services of all the OIE Member Countries.

The Manual contains general information on sampling methods, Good Laboratory Practice (GLP), validation of diagnostic assays, sterility tests, laboratory safety, vaccine production and biotechnology, as well as chapters on specific diseases. The area of Good Laboratory Practice in the context of laboratory recognition (certification by outside authorities) is taking on a higher significance in the context of World trade.

The subject of "emerging diseases" caused by viruses has been developed for human diseases, (Morse and Schluederberg, 1990; Morse, 1993), but is no doubt also highly relevant in both the zoonotic diseases and those affecting only animals. Viruses are humanity's only real competitors, acting as both parasites and genetic elements in their hosts. They show considerable genetic plasticity, enabling them not only to evolve in new directions, but also to produce genetic and metabolic relationships with cells, uniquely positioning them to mediate subtle, cumulative evolutionary changes in their host. This poses problems in vaccine design and strategies as well as to diagnostic methods. Virus diseases are also able to rapidly destroy large proportions of populations and the mere fact that long term natural selection favours mutualism offers only limited encouragement to our species, with millions of people and animals suffering before equilibrium can be reached.

New patterns of human movement and practices, leading to new contacts across what had once been geographic boundaries, have been seen to give rise to a variety of emergent infections.

Most emergent viruses are zoonotic, with natural animal reservoirs a more frequent source of new viruses than from spontaneous evolution. Rodents and arthropods are most commonly involved in direct transfer, and changes in agricultural practices or urban conditions that promote rodent or vector multiplication favour increased incidence of disease.

Other animals, especially primates, are important reservoirs for transfer by arthropods. Approximately 100 of the more than 520 known arthropod borne viruses (arboviruses) cause human disease. At least 20 of these might fulfill the criteria for emerging viruses, appearing in epidemic form at generally unpredictable intervals. These viruses are usually spread by the bites of arthropods, but some can also be transmitted by other means, for example through milk, excreta or aerosols. The arbovirus infections are maintained in nature principally, or to an important extent, through biological transmission between susceptible vertebrate hosts by blood-sucking insects; they multiply to produce viraemia in the vertebrates, multiply in the tissues of the insects and are passed on to new vertebrates by the bites of insects after a period of extrinsic incubation. The names by which these viruses are known are often place names such as West Nile or Rift Valley, or are based on clinical characteristics like yellow fever.

Most arboviruses are spherical, measuring 17-150 nm or more, a few are rod-shaped, measuring 70 x 200 nm. All are RNA viruses. Many circulate in a natural environment and do not infect man. Some infect man only occasionally or cause only a mild illness; others are of great clinical importance causing large epidemics and many deaths. Specifically, these belong to the Togaviridae, the alphaviruses, flaviviruses, the Bunyaviridae, nairoviruses, phleboviruses and other subgroups. Vertebrate hosts can be defined according to their role in maintenance or amplification of virus. Maintenance hosts are essential for the continued existence of the virus and there is usually no actual disease, but the development of antibodies. These include migrating birds which travel over long distances carrying these and other similar viruses; rodents and insectivores such as rats, hedgehogs, lemmings and chipmunks are known to carry louping ill and Colorado tick fever; primates such as monkeys which carry Dengue fever; Leporidae (rabbits and hares) which carry Californian encephalitis; Ungulates (cattle and deer) which are implicated in the transmission of European tick-borne encephalitis; bats which carry Rio Brava virus; and marsupials, reptiles and amphibia such as kangaroos and snakes which also harbour encephalitis-causing viruses.

Incidental hosts become infected, but transmission from them does not occur with sufficient regularity for stable maintenance. Man is usually an incidental host, often, but not always, being a dead end in the chain. These hosts may or may not show symptoms. Link hosts bridge a gap between maintenance hosts and man, for example, between small mammals and man by goats (via milk) in tick-borne encephalitis. Amplifier hosts increase the weight of infection, as is the case with pigs which act between wild birds and man in Japanese encephalitis.

Viruses are thus adapted to extremely diverse niches. Arthropod-borne viruses are spectacular examples of emergence and re-emergence resulting from innocent environmental manipulation or natural environmental change. Important aspects of ecological change and their relation to arbovirus life cycles are: 1) Population movements and the intrusion of humans

and domestic animals into new arthropod habitats, particularly tropical forests; 2) Deforestation, with development of new forest-farmland margins and exposure of farmers and domestic animals to new arthropods; 3) Irrigation, especially primitive irrigation systems, which are oblivious to arthropod control; 4) Uncontrolled urbanization, with vector populations breeding in accumulations of water (tin cans, old tires etc.) and sewage; 5) Increased long distance air travel, with potential for transport of arthropod vectors; 6) Increased long-distance livestock transportations, with potential for carriage of viruses and arthropods (especially ticks); and 7) New routing of long-distance bird migration brought about by new man-made water resources.

The areas of priority with regard to disease detection and control, in the north eastern region are as detailed below

- Molecular epidemiology of economically important animal viruses like FMD (Foot and Mouth Disease), arboviruses, PCV (Porcine circo virus), PPV (Porcine parvo virus), CSFV (Classical swine fever virus), IBD (Infectious Bursal Disaese Virus), NDV (New Castle Disease Virus) and PRRS (Porcine respiratory and reproductive syndrome), Nipah Virus, Avian Influenza (H5N1 and H7N9), Swine Influenza (H1N1).

- Development of antigen cartography models for surveying antibody variant status against CSFV, PPV and PCV.

- Development of models for correlating antibody status and pathogen load in cases of persistent /chronic infections by Real time PCR.

- Studies on cytokine cascades and role of gamma interferons in CSFV and NDV.

- Development of virus isolation facilities under containment.

- Development of primer repositories and rapid PCR based protocols both conventional and real time for prevalent and emerging diseases.

- Development of alternative methods of prophylaxis and therapeutics. Like exploration of unconventional antiviral agents including plant extracts/molecules, non specific immunopotentiators.

- Molecular taxonomy of indigenous animal viruses and bacteria based on phylogenetic data

- To provide services in diagnostics and surveillance for emerging animal diseases to different provincial agencies.

- Training and further education as well as consultancy in the field of animal disease diagnosis

Parasitology/ Hemoprotozoal Diseases (Babesiosis, Theileriosis, Anaplasmosis and Trypanosomosis)

Transboundary movements of living animals are responsible for spread of these haemoprotozoan diseases. Babesiosis caused by different spp. of *Babesia* are transmitted through the vector ticks. Movement of animals from enzootic area may spread the infections to non-enzootic area along with spread of ticks. This is applicable in case of Theileriosis and Anaplasmosis also. Trypanosomosis caused by *Trypanosoma evansi* induces clinical signs like fever, anaemia and oedema and transmitted through fly. Its immunosuppressive effects can interfere with other diseases. *T. evansi* infections could be responsible for vaccination failure in FMD and HS in cattle and buffaloes and FMD and Classical Swine Fever (CSF) in pigs. Another issue is that chemoresistant strains of haemoprotozoa may spread through transboundary, as it has been observed in case of *T. evansi*. Numerous Chinese isolates of *T. evansi* exhibit chemoresistance to a number of trypsnoside drugs).

- ***Cysticercus cellulosae infections* in Pigs.** The larval stage of adult human tapeworm *Taenia solium,* developed in the muscles of pig known as *Cysticercus cellulosae.* Thus, it is a disease of zoonotic significance. Human beings are infected when they eat undercooked pork containing cysticerci (*Cysticercus cellulosae*).

- **Mange infestation in pigs -** Pig owners are generally concerned with internal parasitic infections of their pigs and ignored the external parasitic infestations. Sarcoptic mange in pigs caused by the mite *Sarcoptes scabies* var. *suis* is one of the external parasitic infestation of pigs which pig owners generally ignored. But it has economic importance. Firstly, this parasite has negative effect on growth rate and efficiency of feed conversion particularly in growing and finishing pigs. Secondly, the damaged skin may be invaded by secondary bacterial infection, which aggravates the condition. Thirdly, sarcoptic mange infestation may cause decrease fertility of sows, responsible for economic losses to the pig owners. Hence, mange infestation in pig is very much important.

- **Gastrointestinal Parasitic infections in animals.** Different GIP infections like Ascaris suum in pigs, Haemonchus contortus in goats, infections with different species of Amphistomes and Fasciola in Cattle, Buffaloes and pigs may be transmitted through transboundaries

Descaling & Containment of Diseases

A number of basic approaches may be used to control and eliminate epidemic livestock diseases. They are usually used in combination. The weighting that is given to the different approaches will be determined by the nature of the disease in question, the epidemiological circumstances and their acceptability and cost. The approaches to be used are summarized below.

Denial of access of the disease agent to susceptible host animals

This may be achieved by:

Applying good hygiene and sanitary practices when handling livestock. This includes disinfection of all personnel and equipment. In this context, veterinary services should note that there have been several well-documented cases of highly contagious diseases such as FMD being spread from farm to farm by veterinarians on their rounds.

Removing potentially contaminated materials from the environment, by disinfection, destruction and/or safe disposal. This includes cleaning and disinfection of premises that have housed infected animals, destruction of contaminated feedstuffs and other materials and burial or burning of the carcasses of infected animals.

Preventing the feeding of contaminated materials to livestock. Many diseases can be transmitted in this way. The classical example in recent years has been bovine spongiform encephalopathy (BSE). However, entry into the food chain is an important method of perpetuation and spread of other important animal pathogens, particularly by swill feeding.

These include FMD, African swine fever, hog cholera (classical swine fever) and swine vesicular disease. These diseases have spread not only from farm to farm but from continent to continent. Controls on swill feeding by either enforcing strict bans on swill feeding of animal tissues to animals or allowing only the feeding of heat-treated swill to animals should be an integral part of the prevention and eradication of a number of epidemic livestock diseases including those mentioned above. Swill feeding is a common source of transmission of animal diseases.

While the other approaches to be described could be considered as subsets of denying access of the disease agent to susceptible hosts, they are conveniently considered separately.

Avoiding contact between infected and susceptible animals

This is one of the most important approaches and may be achieved by:

Quarantining of infected or potentially infected farms or areas: A ban or appropriate animal health restrictions are placed on the movement of susceptible species animals into or out of the quarantined area until infection is considered to have been removed. Restrictions may also be placed on the movement of people, potentially contaminated animal products and other materials. Imposing livestock movement controls. These are usually imposed over a wider area around the immediate quarantined or infected area, as part of a zoning policy (for example, within surveillance or control zones). With such controls the movement of susceptible species is only permitted under strict, designated conditions when it is deemed safe. This may include the transport of livestock direct to abattoirs for immediate slaughter for those diseases that are not transmitted by meat or other animal products. There may also be bans or restrictions placed upon congregations of susceptible animals such as at livestock markets or race meetings. In some cases, through erecting large-scale fencing or other physical

barriers. However, potential adverse effects, such as disruption of wildlife habitats and of traditional movements of people and their animals, should first be evaluated.

Removing infected and potentially infected animals: This is often referred to as an eradication policy. Susceptible species on infected farms or in designated infected areas are immediately slaughtered on site and their carcasses disposed of safely, usually by burial or burning. It is often combined with cleaning and disinfection procedures for the infected premises. Because of the rapid spread of epidemic diseases, all susceptible animals are slaughtered, whether obviously infected or not. For some infectious disease control programmes, such as for brucellosis and tuberculosis, it is possible only to slaughter animals that have been tested positive, but this is not appropriate for rapidly contagious epidemic diseases.A component of an eradication policy may also be selective reduction of susceptible wild and/or feral animal populations in infected areas, but before embarking on such a programme a careful evaluation should be made.

Reducing the number of susceptible animals: This is an important approach used in many countries. In emergency disease control it is usually achieved by vaccination of susceptible animals. Vaccination may be done selectively (for example as "ring vaccination" around infected areas) or as "blanket" vaccination programmes in susceptible animal populations. Depending on the nature of the disease and of available vaccines, it may be possible to eliminate infection completely. More usually vaccination is used to reduce the level of infection in animal populations to an acceptably low level where other disease elimination policies are more feasible. In fact, in some cases routine vaccination may mask underlying infection in animal populations.

Reducing access of vectors to susceptible animals: This may be appropriate for insect-borne diseases and, in some cases, may be achieved by reducing vector numbers in an area by treatment and/or elimination of potential breeding sites. Large-scale insecticide spraying is generally too costly, ineffective in the long term, and/or environmentally unacceptable. Other approaches might be to treat susceptible animals with long acting insecticides during critical periods or remove animals from high-activity insect vector areas either continuously or during times of the day or year when insect vectors are most active.

Biological control: To date, there has been only one emergency disease situation for which biological control has proved effective. This has been for the New World screwworm fly (Cochliomyia hominovorax) in the Americas and North Africa using the sterile insect release method (SIRM). SIRM techniques are also currently under evaluation for the Old World screwworm fly (*Chrysomia bezziana*).

Conclusion

Early reaction is to carry out without delay the disease control activities needed to contain the outbreak and then to eliminate the disease and infection in the shortest possible time frame and in the most cost-effective way, or at least to return to the status quo that existed previously and to provide objective, scientific evidence that one of these objectives has been achieved.

It is far too late to leave the planning of an emergency disease eradication or control programme to the time when a disease outbreak has actually occurred. There will then be intense political pressure and pressure from livestock farmer groups for immediate action. In such a climate mistake will be made, resources misused, deficiencies rapidly highlighted, and there will be unavoidable delays resulting in further disease spread and higher costs-unless there has been adequate forward planning and preparation.

Soil degradation in North East India- reality and concerns

SAMARENDRA HAZARIKA AND MAHASWETA CHAKRABORTY
Division of System Research and Engineering, ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya

The north eastern Himalayan region of India is highly susceptible to soil degradation hazard, mainly because of its fragile environment, high degree of slope, large scale deforestation and unsustainable utilization of land resources. The hilly terrains along with high rainfall makes the area vulnerable to severe soil erosion. Apart from natural causes like water erosion, anthropogenic activities like shifting cultivation (jhum) with short cycle of 3-4 years and deforestation accelerate the process of soil erosion. Human interference in the ecosystem, both for their need and greed, play a major role in exploiting the soil resources and degrading it. Although this problem persists all over the world, cropland areas under hill agriculture are eroding faster than natural processes and have been significantly degraded. Challenging problems in soil conservation arise mainly from the rapid growth of the population which results in increasing requirement for food production on one hand and further industrialization and urbanization on the other hand causing deterioration, destruction, contamination of the environment by industrial fumes and various other xenobiotics. In addition to these, climate change in the region including atmospheric warming accompanied with changes in precipitation can induce soil acidification through intense leaching of basic cations from soil and also increase soil organic carbon decomposition. This implies gradual reduction in the proportion of labile carbon fractions i.e., loss in soil organic matter, reduction in nutrient cycling processes that may further lead to gradual decline in soil health and crop productivity in the region.

Assessment of gravity-fed drip irrigation system for mid-hills of Meghalaya

B.K. SETHY[1], H. DAYANANDA SINGH[2,] V.K. VERMA [2], DEBASISH CHAKRABORTY[2], NASEEB SINGH[2], H. JITEN SINGH[2], K. AJAY KUMAR[2]
[1]ICAR-Indian Institute of Water Management, Bhubaneswar-751023, [2]ICAR Research Complex for NEH Region, Umiam, Meghalaya-793103
Corresponding email: bsethy088@gmail.com

Meghalaya state receives higher rainfall than most parts of the country from the southwest monsoon season. Considerable amount of rainfall occurs for seven months (April to October) in a year but leaving the dry months (November to March) with lots of water scarcity. The mean annual rainfall varies from about 12,000 mm in the southern slopes of the state (Mawsynram) and close to 2000 mm in the northern-most slopes. Rainfall is the main source of water in Meghalaya that fills the dams, lakes and reservoirs which are vital for irrigation and it also recharges the ground water. Moisture is the major limiting factor for cultivation of high value crops on hilly ecosystem during post-monsoon to winter seasons. There is large scope of harvesting desired quantity of rainwater at valley lands and hill slopes of the NEH region. The harvested rainwater can be used for multiple purposes like piggery, fish rearing, cultivation of *rabi* vegetables or high value cash crops. But, energy is the main constraint to lift the harvested water to hill slopes or tops. Heavy seepage loss at hill tops and slopes restricts for multiple use of water. Rainwater can be harvested on hill tops and stored in poly lined ponds for multiple uses. Use of modern irrigation techniques can help to achieve an optimum and economizing consumption of harvested water which can bring many areas under cultivation and will ultimately result in increasing the cropping intensity. Drip or trickle irrigation is one of the latest proven methods of irrigation, which is becoming increasingly popular in areas where there is water scarcity and salt problem. Gravity fed drip irrigation may be encouraged for efficient use of harvested water for cash crop growing in the hill slopes. Hence, assessment of such a system where runoff water is harvested and utilized through solar operated pump and distributed by gravity-fed drip irrigation at different land use systems is the need of the hour.

In order to address the issue, two sites one at the experimental field of *ICAR RC NEH Umiam, Agricultural Engineering* and second field at Umktieh Village, RiBhoi District which is 10.5 kms away from ICAR RC NEH, Umiam were selected for field evaluation of the whole system. The soil was sandy loam and sandy clay loam type with acidic in nature. The field capacity ranged between 29.1 to 33.4% with permanent wilting point from11.0 to 15.1% and average bulk density of 1.32Mg/m^3. For the experimental field of the Agril Engg. one pond (Capacity: 1169 m^3) was renovated to store runoff water which was lifted to an overhead tank (elevation between pond and tank: 7 m) and for the farmer's field at Umktieh Village the water was taken from wells to a storage tank using 0.5 hp solar operated DC pump. The area at experimental field of Agricultural Engineering was 500 m^2 with elevation difference of 7.8 meter.7 nos. of bench terraces were constructed (width: 1.2 to 2.5 m, length: 28 to 38.5 m) due to steep slope (51.3%) as soil and water conservation measure at the experimental field. Raised beds were prepared in the terraces. Strawberry saplings were planted in two-rows in each terrace with the spacing of 30cm x 30 cm from plant to plant and row to row. For the farmer's

area at Umktieh Village, the total area for strawberry cultivation is 712.6 $m^{2.}$ A total of 29 beds were prepared having a bed width of 60 cm and inter bed width of 60 cm and plant to plant spacing at 30 cm x 30 cm. Fields were prepared and added with manure to facilitate rich growth of the seedlings. Black plastic mulching was laid over the prepared beds (width of plastic 1.2 m, thickness of plastic 20µ) to maintain soil moisture, reduce weed growth and improve strawberry quality. Holes were made through the plastic mulch and seedlings (Strawberry: Sweet Sensation variety) were planted at a spacing of 30 cm by 30 cm in two rows over the prepared beds. Regular monitoring of the experiment was made with approved package of practices for strawberry cultivation. Periodical harvesting of strawberry was done over the period of five months. On observation, it was found that Around 143.1 kg and 319 kg of strawberry were harvested from the experimental field and farmer field with productivity of 13.79 t/ha and 13.28 t/ha and water use efficiency (WUE) of 33.12 ,Kg/ha-mm and 30.45 Kg/ha-mm respectively. Average overall efficiency of the solar pumping system (including solar panel, charge controller, DC motor and water pump) was 7.02 % and average solar intensity achieved was 512.94 w/m^2. The system can be adopted in all the hilly ecosystem for sustainable higher income by cultivation of cash crops like strawberry.

Identification and characterization putative immunogenic peptides from field isolate of *Campylobacter coli* through microbiological, proteomic, genomic and immuno-informatics approach

SANDEEP GHATAK*, AAP MILTON, SAMIR DAS, SOURABH DEORI, ARNAB SEN, K. PURO, SRINIVAS KANDHAN, DADIMI BHARGAVI, KASANCHI M. MOMIN
Division of Animal and Fisheries Sciences, ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Corresponding email: ghataksnd@rediffmail.com*

The present study was conducted to identify the putative antigenic components of *Campylobacter coli* bacterium which is a major pathogen causing zoonotic infections in humans and production loss to swine husbandry as well. *C. coli* field strain (NEH) was isolated previously from pig faecal sample following standard microbiological techniques as per ISO 10272-1:2017 method. Following molecular and genomic confirmation the strain identity, whole genome sequencing was undertaken on Illumina Nextseq platform. Moreover, whole proteome of the bacterium was also resolved by SDS-PAGE. Proteome and WGS data were first quality checked (FastQC), and were subsequently analysed with a variety of tools and methods to identify potential peptides with vaccigenic potential. Our results from proteome study revealed two potential peptides of 45kDa and 29kDa that could be targets for vaccine development. Analysis of WGS data, on the other hand, identified 51 cell wall and capsule associated genes and 49 genes associated with virulence, defense and disease causation. Of these, there were 21 highly antigenic fractions and 9 very highly antigenic fractions with mean antigenicity score of 0.9389 ± 0.0309. To understand the chromosomal organization, these very promising peptides were also mapped to the whole genome of *C. coli*. The mapping results showed that these peptides were encoded by genes located in the regions between 100 - 600 kbp and 2300 - 2500 kbp indicating future possibility of recombinant peptide synthesis. In order to assess the exposure of the peptide to host immune system to evoke a protective response, we estimated the trans-membrane domains of each peptides. Our initial results revealed that of the 30 peptides, 4 peptides were most promising with 2 - 5 trans-membrane domains implying that these segments would be exposed to host immune system eliciting an immune response. Among the three peptides, two peptides had their -NH_2 end exposed indicating an amide mediated interaction with the host immune apparatus while another had -COOH functional end exposed across the membrane. Taken together, our results identified 4 putative peptides with vaccine potential from the field isolate if *C. coli* through a combination of microbiological, proteomic, genomic and immuno-informatics approach.

THEME-1

Natural Farming and Ecosystem Services

Response of organic amendments on yield and economics of radish cultivation (*Raphanus sativus* L.) cv Japanese white

LUNA BAROOAH[1], NANDEESH J[2], SIBANI DAS[3]
[1]*Assistant Professor, College of Horticulture & FSR, Nalbari, Assam Agricultural University,* [2]*MSc student, Department of Horticulture, Assam Agricultural University, Jorhat,* [3]*Junior Scientist Stage III, Assam Agricultural University, Horticultural Research Station, Kahikuchi, Guwahati, Assam, India*
** Corresponding email: luna0123@gmail.com*

Radish (*Raphanus sativus* L.) under the family Cruciferae is a popular root vegetable grown all over the world. Radish is grown for its tender roots which are eaten as raw as salad or cooked vegetable. Abundant use of chemical fertilizers coupled with continuous cropping results in deterioration of innate soil fertility as well as crop quality. The present investigation was carried out to find out suitable organic amendments to improve yield and economics of radish cultivation. The experiment was carried out at experimental farm, Department of Horticulture, Jorhat during the year 2018-20. Pooled data over two years revealed that T_8 (80:60:60 kg NPK + 10 t FYM/ha) recorded the yield of Radish 191.45 q /ha which was followed by 169.73 q/ha under T_7 (Enriched compost 5 t/ha). The cost economics indicated superiority of T_8 (RDF 50:50:100 kg NPK/ha) + FYM @10 t/ha) with 2.58 benefit-cost ratio followed by 2.50 in T_6 [T_1 + Enriched compost (2.5 t/ha)]. Hence, considering the positive effect on yield and cost of cultivation, T_7 is considered the best organic treatment to earn good economic yield.

Evaluation of different potential rhizospheric isolates and assessment of the impacts utilising based on their biochemical and PGPR methods

PARIJAT DE[1]*, ACHYUTA BASAK[1], BAPPA PARAMANIK[2], BASABDUTTAA BHABAI[3], ASHOK CHOUDHURY[1]
[1]*Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbeha, West Bengal-736165,* [2]*Dakshin Dinajpur Krishi Vigyan Kendra, Uttar Banga Krishi Viswavidyalaya, Patiram, Dakshin Dinajpur, West Bengal-733133,* [3]*Central Seed Research Station for Jute and Allied Fibre, ICAR-CRIJAF, Bud Bud, Purba Bardhaman, West Bengal-713403*
** Corresponding email: parijatsoil@gmail.com*

Screening potential rhizospheric isolates through biochemical like Indole test, Methyl red test, Vogues Proskeur test, Citrate utilization test (IMViC test) and PGPR (nitrogen assimilation in microbes, phosphate solubilisation etc), based assays is a common approach to identify beneficial bacteria that can enhance plant growth and provide various benefits to plants. The study explored the correlative relationships between different biochemical tests and PGPR properties, specifically focusing on phosphate solubilisation. In this study, the correlative relationships between different biochemical tests and PGPR properties, with a focus on phosphate solubilisation, were investigated. The results revealed the following correlations: Methyl red test was found to be positively correlated with phosphate solubilisation and tryptophanase assay (by indole test) were found to be negatively correlated with phosphate solubilisation. Vogues Proskeur and Citrate utilization tests were negatively correlated with

phosphate solubilisation. Moreover, scatter plot analysis was employed to identify a unique group of rhizobacteria. This group exhibited low acid production (possibly indicated by low positive results in the methyl red test) but high phosphate solubilisation. This specific group of bacteria with this characteristic combination was visualized and identified through scatter plot analysis.

Isolation and characterization of native phosphorus solubilising microorganisms from rhizospheric zone of different crops in acid soil

CHRISTY B.K. SANGMA[1]*, ROKOZENO CHALIE-U[1], L.J. BORDOLOI[1], RAJESHA G.[2], A. RATANKUMAR SINGH[1], B.U. CHOUDHURY[1], S. HAZARIKA[1], V.K. MISHRA[1]

[1] ICAR Research Complex for NEH Region, Umiam, Umroi road, Meghalaya 793 103, [2]ICAR -IIMR, Rajendranagar, Hyderabad, Telangana 500 030

** Corresponding email: christysangma@gmail.com*

The phosphorus (P) content in soil is about 0.05% (w/w) but only 0.1% of the total phosphorus is available to plant because of poor solubility and its fixation in every type of soil. Phosphorus solubilizing microorganisms (PSMs) through their various mechanisms of solubilization and mineralization are able to convert the unavailable form into bioavailable form facilitating increase uptake by plant roots. Although, several of these bacterial or fungal strains *etc*. have been identified as the potential PSM, their performance under different soil conditions is not reliable and therefore, needs the region specific native and compatible strains for increase efficiency. So, the present study focuses on the isolation and characterization of native PSM(s) from rhizospheric zone of different plants and crops grown in acidic soils of North Eastern Hill Region. For isolation, rhizospheric soil samples were collected from different crops: *viz*. bamboo (*Bambusa vulgaris*), tree bean (*Parkia roxburghii*), alder (*Alnus nepalensis)*, Khasi mandarin (*Citrus reticulata*), upland and lowland rice and *jhum* rice (*Oryza sativa*), *jhum* millet (*Setaria italic*), maize (*Zea mays*), turmeric (*Curcuma longa*), sesame (*Sesamum indicum*), French bean (*Phaseolus vulgaris)*, groundnut (*Arachis hypogaea)*, greengram (*Vigna radiata*), soybean (*Glycine max*) and lentil (*Lens culinaris*). Altogether, 18 nos. of native phosphorus solubilizing strains were isolated by serial dilution method and plating in the sterilized Pikovaskaya's (PVK) media (Pikovskaya, 1948) supplemented with insoluble tri-calcium phosphate (TCP)/hydroxyl apatite as the phosphorus source. These strains were PPS-01, PPS-02, PPS-03, PPS-04, PPS-05, PPS-06, PPS-07, PPS-08, PPS-09, PPS-010, PPS-011, PPS-012, PPS-013, PPS-014, PPS-015, PPS-016, PPS-017, and PPS-018. After isolation, the strains were pure cultured and screened in Pikovskaya's media for halo formation and morphologically characterized. Most of the strains isolated were Gram positive, *Cocci* and *Bacilli* types. P solubilizing index (in plate) ranges from 2.295 to 3.20 and solubilization in broth (Av. P) mg/L ranges from 247.1 to 571.8 mg/L. Solubilizing index was found to be highest in strains isolated from maize and rice crops. The strains isolated from leguminous crops *viz*. *Rhizobium* sp. (miscellany, PPS-015), *Rhizobium sp.* (miscellany, PPS-018), *Bradyrhizobium japonicum* (PPS-017), *Rhizobium leguminosarum* biovar *phaseoli* (PPS-013, PPS-014) from greengram,

groundnut, soybean and Frenchbean respectively, were found to be dual purpose *i.e.*, they are both phosphorus solubilizing as well as the nitrogen fixing types.

Screening of *Citrus* rootstock germplasm for aluminium toxicity tolerance suitable to acid soil under natural farming

PANCHALI UZIR*, DWIPENDRA THAKURIA, CHAYANIKA CHALIHA, L. MOMO SINGH

School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Central, Agricultural University (Imphal), Umiam, 793103, Meghalaya
**Corresponding email: panchaliuzir@gmail.com*

Citrus productivity in acid soils suffers greatly from citrus decline. North-Eastern India is regarded as one of the main gene centres and reservoirs for a variety of citrus species in India. The main factor limiting citrus productivity in acidic soil is Al toxicity. At present, citrus rootstocks species commonly used were identified based on their disease resistance abilities. Studies from the past seldom never mentioned the ability of citrus rootstock germplasm for Al toxicity tolerance in acid soil. So, we screened 7 different citrus germplasm (wild: *C. latipes* Tanaka; semi-wild: *C. macroptera* Montr, *C. aurantium* Dulcis; and domesticated species: *C. grandis* L. Osbeck, *C. jambhiri* Lush, *C. sinensis* L. Osbeck, *C. reticulata* Blanco) against Al-toxicity tolerance for future use as potential rootstock under natural farming. Each of 7 citrus species was grown in nursery bags containing an acid *Inceptisol* (pH 5.3) spiked with 4 Al levels (0, 50, 100, and 150 mg Al kg^{-1} soil). Five replicate nursery bags were maintained per treatment and the plants were grown up to 120 days. Increased levels of Al in the treated soils elevated the concentration of readily soluble Al (RSAl). Soil pH, soil organic carbon (SOC), and soil available nitrogen and phosphorus (Avl.N and Avl.P) were all significantly reduced along with the amount of chlorophyll-a, chlorophyll-b, and total chlorophyll in leaves at higher Al levels. The Malondialdehyde content of the leaves increased with increasing Al levels, indicating that the plants were under stress. The root length, root area, number of root tips, root dry weight decreased significantly and root diameter increased significantly at higher Al level. Root exudate profiling in reverse-phase C18 column indicated five most common organic acids namely oxalic acid, malic acid, maleic acid, citric acid and succinic acid across citrus species and Al level as a defence response against Al toxicity. Maleic acid was dominant among all other organic acids. The relative abundance of organic acids varied within a plant species depending on the level of Al. This study for the first time could identify *C. latipes*, *C. macroptera* and *C. aurantium* as potential wild, semi-wild and domesticated rootstocks, respectively showing higher degree of Al toxicity tolerance in terms of rhizospheric soil attributes, plant physiological stress and organic acids in root exudates. Hence, these citrus species can be grown well in acidic soil.

Impact of natural farming on rural economy-evidence from Sonitpur District of Assam, India

ANGANA SARMAH, NAMITA DUTTA, PALASH DEBNATH

[1]Subject Matter Specialist, Horticulture, Krishi Vigyan Kendra, Sonitpur, Assam Agricultural University, Napam, Tezpur -784028, Assam, India, [2] Subject Matter Specialist, Soil Science, Krishi Vigyan Kendra, Sonitpur, Assam Agricultural University, Napam, Tezpur -784028, Assam, India, [3] Head, Department of Plant Pathology, Assam Agricultural University, Jorhat -785013, Assam, India

** Corresponding email: angana.sarmah@aau.ac.in*

Natural Farming now-a-days is becoming increasingly popular among the smallholder farmers of Sonitpur district of Assam. The state has 272 lakhs farming households out of which 85.59 farming households are small and marginal having operational land holding of less than 1-2 hectares (Agricultural Census, 2010-11). So, to obtain desirable changes in socio-economic life of its esteemed farming population, there must be adoption of all sustainable and profit earning technologies for boosting production and productivity in due space and time (Sarmah *et.al.*, 2023). Natural farming practices are cost savings from not using chemical fertilizers and pesticides, as well as higher benefit from intercrops. Under natural farming system, three to four crops are cultivated or grown together on the same area, along with leguminous crops as intercrop in order to ensure that no piece of land is wasted and utilized properly. This article highlighted the activities of Mrs. Dipali Mandal, a lady farmer engaged with vegetable and flower cultivation since last fifteen years. By converting her entire farm (less than 1ha) under natural farming system since last three years, she could able to increase production by 36.71% over conventional farming by focusing mainly on the different cropping systems of natural farming and comparing the economics of natural farming (NF) with conventional farming (CF) systems. It is found in study that intercropping with leguminous crops is considered as one of the most important components of natural farming as it increases crop productivity and soil fertility through the atmospheric nitrogen fixation. The analytical results from soil samples collected from different locations of her farm reflected that there was incredible enrichment of soil in terms of organic carbon (0.56-0.89), available nitrogen (265.6 -288.5 kg/ha) and available potash (222.5-239.8 kg/ha). These studies revealed that the farm soils where natural farming practices were adopted, were exuberantly loaded with bacterial population ($45x10^7$ CFU/ml) in comparison to conventional farming ($16x10^7$ CFU/ml). The increase in soil organic carbon content might be attributed to the exuberant multiplication of microbes in the soil under natural farming system.

Evidence for the impacts of agroforestry on soil properties

KABERI MAHANTA*, KUSUM KUMAR DEKA, SEEMA BHAGOWATI, SIBANI DAS

AAU – HRS, Kahikuchi, Guwahati - 17

** Corresponding email: kaberi.jorhat@gmail.com*

Agroforestry plays a vital role in the Indian economy by way of tangible and intangible benefits. In fact, agroforestry has a high potential for simultaneously satisfying three important

objectives *viz.*, protecting and stabilizing the ecosystems; producing a high level of output of economic goods; and improving income and basic materials to the rural population. Agroforestry has helped in the rehabilitation of degraded lands on one hand and has increased farm productivity on the other. It has traditionally been a way of life and livelihood in India for centuries. Soil health is a key indicator of natural capital, that reflects the capacity of soil to respond to agricultural management by maintaining both agricultural production and the provision of ecosystem services. The integration of trees into agricultural landscapes has the potential to generate a number of improvements in the soil as a habitat for soil organisms and also for crop growth. Soil improvements by trees can also occur by increased supply and availability of nutrients for crops and soil biota. This mechanism can also recycle fertilizer applied by farmers, thus improving nutrient use efficiency and the returns as a result of fertilizer application. Therefore, a study was carried out with the aim to examine soil physical-chemical properties under the existing agroforestry systems of AAU-HRS, Kahikuchi, Guwahati-17 leading to higher productivity and profitability with treatments comprised of T1 – Sole *Acacia mangium*, T2-Sole Jackfruit, T3-Sole Gmelina arborea, T4-*Acacia mangium*-based AF system, T5-Jackfruit-based AF system, and T6-*Gmelina arborea*-based AF system with repetition of four and RBD as the statistical design. Soil sampling was done from a depth of 0-20 cm to analyze physical and chemical properties including bulk density, total porosity, microporosity, macroporosity, CEC, mean weight diameter, moisture content, and pH while in the case of total organic carbon (TOC), total nitrogen (TN) and C/N ratio sampling was done from two depths viz. 0-10 cm and 10-20 cm by following standard protocols. Significantly higher total porosity, microporosity, macroporosity, CEC, mean weight diameter, moisture content, pH, and a significantly lower bulk density were recorded in AF- based systems as compared to the sole AF systems at 0-20 cm surface soil. However, a significantly increased TOC and TN were associated with surface soil as compared to sub-surface soil in AF- based systems as compared to the sole AF systems. Differences between the agroforestry systems in regard to soil physical and chemical properties are improved mostly in AF-based systems than the sole AF systems.

Potassium forms and their contributions toward yield and potassium uptake in rice as influenced by nutrient management practices

SEEMA BHAGOWATI[1], KULENDRA NATH DAS[2], INGUDAM BHUPENCHANDRA[3], KABERI MAHANTA[1], SIBANI DAS[1]

[1]AAU – Horticulture Research Station, Kahikuchi, Guwahati – 17, [2]Dept. Of Soil Science, AAU, Jorhat-13, [3]ICAR-KVK, Tamenglong, ICAR-RC for NEH Region, Manipur Centre, India.

**Corresponding email: seema.bhagowati@aau.ac.in*

A field experiment was carried out in winter rice for two consecutive growing seasons at demonstration farm of Krishi Vigyan Kendra, Nagaon, Assam Agricultural University, Simaluguri in the Nagaon district of Assam, North East India. Various forms of potassium (K) and their contribution toward K uptake were found to be affected by chemical fertilizer as well as organic manure use. The treatments included for the study were, T_1- Absolute control, T_2- Microbial consortia (Azospirillium + PSB + KSB) @ 4 kg/ha, T_3- RDF (60:20:40:: N: P_2O_5:

K_2O), T_4- T_3 + KSB @ 4 kg/ha, T_5- ½ RDF of K as basal + ¼ at 40 DAT + ¼ at 60 DAT, T_6- Potassium nano-fertilizer @ 100 ml/1.2 L of water (10ml/100g), T_7 - T_6 + 50% RDF as top dressing at 40 DAT, T_8- ½ RDF of K as basal + Spraying 3% K solution at maximum tillering and PI stage, T_9- INM Package (50% NP + Full K + 5t/ha Enriched Compost), T_9- INM Package (50% NP + Full K + 5t/ha Vermicompost). The concentration of water-soluble K in the studied soil was the lowest among all four fractions followed by exchangeable, non-exchangeable and lattice K. Maximum amount of lattice was recorded in plot receiving 100% K fertilizer along with N & P fertilizers and INM components while lowest was recorded in plots which did not receive any fertilizer. Treatments where 100% K fertilizers were applied alone or in combination with INM components for 2 years continuously observed an increase in total K, highest being observed in T_{10} = 100% NP + Full K + 5 ton/ha Vermicompost) (11015.50 mg kg^{-1}). Highly significant positive correlation values among various forms of K implied the existence of dynamic equilibrium. Yield was always better in INM package plots. Grain yield exhibited significant positive correlation with NPK uptake (r = 0.891**, 0.946** and 0.970**), water soluble K (r = 0.785**) exchangeable K (r = 0.897**) and available K (0.867**), suggesting their availability to rice crop. The highest potassium use efficiency (PUE) of 51.96% was found in the plot receiving 50% NP + Full K + 5 t/ha Vermicompost (T_{10}) while the lowest of 40.49% in the plot receiving potassium nano-fertilizer @ 100 ml/1.2 L of water (T_6) treatment.

Ecosystem services and environmental advantages of agroforestry in context to NEH Region

SUBRATA DAS*, T. AMRUTHA, A.K. MOHANTY, A.K. SINGHA, R. BORDOLOI, WANPHRANG KHARKONGOR, HEJBINA M. HUSSAIN, EMIDAKA SUTING, MANENDRA SINGH

ICAR-Agricultural Technology Application and Research Institute, Zone-VII, Umiam, Meghalaya, India
**Corresponding email: dsubrata6@gmail.com*

Agroforestry, an integrated land management approach that combines trees with agricultural crops and/or livestock, has gained significant attention due to its potential to provide a wide range of ecosystem services and environmental advantages. This study highlights the various ecosystem services associated with agroforestry systems and their positive environmental impacts. Recent advancement in agroforestry sector through scientific, technological and government interventions is leading it towards better landuse system in near future. The scientific reports are scanty for ecosystem services flow provided by agroforestry. Moreover, multifunctional working landscape, agroforestry is increasingly seen as delivering ecological services, environmental advantages, and economic goods and services. Many ecosystem services are being provided by agroforestry systems for agro-ecosystem enrichment and environmental stability like, carbon sequestration, biodiversity conservation, soil carbon and nutrient enrichment, and air and water quality. As part of a multifunctional working landscape, agro forestry is a sustainable landuse system and alternative for mono-cropping system. However, it is recognised for reducing poverty and increasing production efficiency through its

provisioning services. In order to address the issues associated with shifting cultivation in North Eastern Hill (NEH) region, suitable alternative land use systems for horticulture, agriculture, forestry, and agroforestry have been established through proper utilization of region's natural resources. These systems have essentially identical hydrological behaviour as under the natural system. As a result, agroforestry may be a viable choice for land use in this area, as it may offer a range of ecosystem services, environmental benefits, and employment opportunities.

Development of floral calendar in natural farming system of Kyrdemkulai, Meghalaya

NGANGOM UMA DEVI*, DWIPENDRA THAKURIA
College of Agriculture, Central Agricultural University (Imphal), Kyrdemkulai – 793105, Meghalaya
**Corresponding email: ngangom.uma@gmail.com*

Apis cerana himalaya which is native to North East state are the most important group of pollinators. Pollinators are a diverse group of insects. It provides an important service in our environment by pollination of cross-pollinated plants and ensures the growth of seeds and fruits. Varieties of plants grown under natural farming system provide important food resource for honey bees. Native plants are undoubtedly the best source of food for bees. All foraging plant species do not contribute equal amount of food source for beekeeping. Some supply both nectar and pollen abundantly and some produce plenty of nectar but little or no pollen and called honey plants. Some plants produce plenty of pollen but only a trace or no nectar are known as pollen plants. In order to survive, prosper and be productive, honeybee colonies must have a supply of both nectar and pollen in adequate quantities. Plant species and blooming period varies from place to place due to variation in topography, climate and other cultural practices (Harugade and Chaphalkar, 2013). Honey flow period refers to the time when bees get abundant blossoming floral plants while floral dearth refers to that time when honeybee suffers from scarcity of nectar and pollen due to unavailability of blooms of flora. The extensive knowledge about local floral calendar is a key for successful beekeeping and play vital role to make profitable entrepreneurship. Every region has its own honey flow and floral dearth periods. Since the practice of modern beekeeping is relatively new in India, the compilations of bee-flora list are still far from complete. Study on bee flora, honey flow period and floral dearth have been neglected. Hence, the present study has been undertaken to develop a floral calendar by studying the bee flora in natural farming system of Kyrdemkulai, Meghalaya. A survey was carried out to identify prevailing bee-flora resources which serve as nectar and pollen sources to *A. cerana himalaya* and their blooming period. The study was accomplished at Kyrdemkulai, Meghalaya. The visual observations were made on the basis of collection of nectar or pollen or both from flowers by *A. cerana himalaya.* The observations were recorded at weekly interval during January 2020 to December 2022. Data were collected as per visual observation, especially during plants blooming periods where the plants were visited by honeybees. The natural farming sites of Kyrdemkulai, Meghalaya is endowed with diverse flora; 63 flora of *A. cerana himalaya* with various blooming period which show great promises for beekeeping. The present study can be concluded as, month of January to May and December (Honey Flow);

June to August (Dearth period) and September to November (Build up) season. Therefore, the month of February, March and April was identified as most suitable time for honey harvesting in this region.

Exploring the potential of natural farming for transforming food system: An epistemological approach

SNEHAL ATHAWALE[1*], RAM SINGH[2], SINGYALA CHIPHANG[3], BROTA SING BEY[4]
[1&4]Ph.D Scholar, [2]Professor and Head, [3]Assistant Professor (Agricultural Economics), School of Social Sciences, College of Post Graduate Studies in Agricultural Sciences, (Central Agricultural University, Imphal), Umiam-793103, Meghalaya, India.
**Corresponding email: snehalathawale98@gmail.com*

A sustainable food system encompasses the principles that supports food security, make optimal use of natural and human resources, upholding cultural acceptability and accessibility, maintaining environmental integrity and fostering economic prosperity. However, the complexity and lack of transparency in food chains necessitate an epistemological examination for achieving long-term sustainability in the food system. To achieve sustainable development goals (SDGs), agroecological approach such as natural farming is a novel solution that promote food security and sustainability while maintaining food safety. Natural farming is not a panacea to cure the illness of the food system but it is an inclusive approach to food systems that seeks to create a sustainable and regenerative agricultural system. Therefore, it gives igneous outlook to transform current food systems. In this scenario, we have highlighted the need of key elements that can contribute to form natural farming-based food system *i.e.* one health approach, indigenous knowledge and ecological restoration, leading to integration, harmony for sustainability and transforming civilizations. The article acknowledges interconnectedness of human, animal, and environmental health as an integral part of one health, the value of indigenous knowledge that advocates the harmonious coexistence of humans with nature and importance of ecological restoration for sustainability of food system which leads to integration of ecological, social and economic principles into agriculture, maintaining the balance of the ecosystem by working with its natural cycles hence creating harmony. The study attempted to showcase the multi-prolonged approach to form natural farming-based food system to promote sustainability.

Underutilized local horticultural crop component for diversification of natural farming system under hill ecosystem

MAYENGBAM PREMI DEVI[1]*, PRANABJYOTI SARMA[2], D. THAKURIA[3]
[1] Assistant Professor, College of Agriculture (CAU, Imphal), Kyrdemkulai, Meghalaya, [2]Professor, College of Agriculture (CAU, Imphal), Kyrdemkulai, Meghalaya, [3]Dean, College of Agriculture (CAU, Imphal), Kyrdemkulai, Meghalaya*
**Corresponding email: mpdhort69@gmail.com*

Lack of agricultural diversity has led to severe consequences on global biodiversity and the natural environment. Majority of the commercially cultivated crop species contribute in draining inputs and resources to get expected maximum yield in a wide range of environment, which leads to loss of ecosystem services and global emissions. In this aspect and in consideration of the urgent climate crisis, the highly under-valued and resilient local underutilized species will be one of the alternative solutions for nutritional and food security. The current trend of natural farming system approach is an opportunity to create general awareness and acceptance towards inclusivity of these species as a crucial component of the farming system. The state Meghalaya has an advantage being endowed with wide diversity of wild edible fruits and herbs. Considering the urgent importance, an attempt was made to identify potential local underutilized horticultural genetic resources to incorporate in the natural farming system model in Kyrdemkulai area of Ri-Bhoi district Meghalaya. Information was recorded through local as well as market surveys, and confirmed using existing records and literatures. The most frequently used underutilized fruits in the region belonged to Euphorbiaceae, Fagaceae, Musaceae, Rosaceae, Rutaceae, Solanaceae, Zingiberacea, Arecaceae and Elaeocarpaceae. The majority of the species were trees, followed by herbs, shrubs and climbers/ramblers. Habitats of these species included dense forest areas, open areas, river-side, forest undergrowth and some were cultivated at homesteads or farms. Some potential underutilized local horticultural crop includes *Emblica officinalis, Myrica esculenta, Castanopsis indica, Musa* spp., *Artocarpus chaplasa, Elaeagnus latifolia, Artocarpus chaplasa, Averrhoa carambola, Morus australis, Citrus grandis, Spondias pinnata, Momordica dioica, Sechium edule, Solanum* spp., *Begonia roxburghii*, *Curcuma angustifolia*, *Hibiscus sabdariffa, Phlogacanthus thyrsiflorus, Houttuynia cordata, Eryngium foetidum,* etc. Other multi-utility species like *Dendrocalamus* spp., *Hibiscus mutabilis* and local edible mushrooms can also be an important part of the farming system to enhance the agro-ecosystem. Taking account of the diverse edible plants in the region, there is a huge opportunity for expanding the utilities of these crops through scientific inventions and studying the growth and interaction pattern with the existing ecosystem.

Integrated farming systems of foot hills of Jammu for sustaining production and productivity-An exploratory study

KOHIMANOOPUR[1], N. RAVISANKAR[1], M.A. ANSARI[1], M. SHAMIM[1], A.K. PRUSTY[1], SUNIL KUMAR[1*], N.P. THAKUR[2], A.K. GUPTA[2], VIJAY KHAJURIA[2], ANIL KUMAR[2], RAGHUVEERSINGH[1], RAGHVENDRA, K.J.[1]AND PURSHOTTAM KUMAR[2]

[1]-ICAR-Indian Institute of Farming System Research, Modipuram, UP, [1]- Director, ICAR-Indian Institute of Farming System Research, Modipuram, UP, [2]- SKUAST, Jammau, J&K.*

Slopping land along with small, marginal farming and rain-fed agriculture is the characteristic feature of hill farming in J&K. Undulated topography coupled with prodigious climatic disparities makes the farming system extremely diverse and labour intensive. The rainy season receives more than 70 per cent of the total annual rainfall, of which 90 percent goes waste as runoff. The study was conducted during 2022-23 in three Districts *i.e.* Jammu, Kathua and

Sambha of J&K to assess the status of IFS in sustaining the production and productivity response of 59 farmers in 3 blocks and 6 villages in Jammu District, 37 farmers, in one block and 11 villages of Kathua district and 87 farmers from 4 blocks and 12 villages in District Samba. The data was collected through google survey form and analysed using "R" statistical tool. It was evident that most of the farmers (92.48 %) grow cereals and nearly 75 per cent of the cropped area is under rice, maize, wheat, millets, while remaining area is under oilseed, pulses vegetables and fruits. The productivity of crops is very low due to prevalence of local cultivars with low input- rainfed cultivation. Vegetables are grown in kitchen garden for self-consumption in 38.25 % households and commercial cultivation (12.45 %) for economic return. Improvement in vegetable yield (25-35 %) was observed due to introduction of improved cultivation methods and use of quality seeds as well as better management practices (35-65 %) under integrated farming system. Livestock also provide economic and livelihood security for the majority of farm households and may sometimes known as Integrated bio-system. Majority (94.68%) of farmers has one of two cattle and/or buffalo and consumes milk. The indigenous breed of cattle and buffalo are smaller in size with poor feed conversion ability and hence milk yield is about 3-4 litter /animal/day. The up-gradation of local cattle through cross breeding with Sahiwal or Gir has given new dimensions in dairy farming. Backyard poultry farming has been adopted by most (18.35 %) of the farmers for household consumption; however, few (2.58 %) farmers adopted commercial poultry farming for better economic return. The introduction of Gramapriya breed of poultry has helped to increase egg production which was 350-500 per cent higher than local breed. Farmers (2-4 %) residing nearer to permanent water harvesting structure are having fishery component. In the farming system mode, family members are gainfully employed due to the production and maintenance of a number of components which may be the special feature of utilization of family members. It was estimated that small and marginal farmers utilize 610-624 man days for farming activity out of which 595 man days comes from family labour. It was also observed that women's (63.45 %) participations are more in farming system rather than that of man and hence family farming system provide more opportunities to women engaged in farming system in Jammu region of J&K. It can be concluded that after adoption of improved cultivars, improvement and introduction better performing breeds with good agricultural practices realized more production, higher income and employment generation round the year, which play a significant role in increasing production, return and nutritional requirement under agro-climatic conditions in Jammu region of J&K.

Impact of applied pollination with Indian Honey bee, *Apis cerana himalaya* on the yield of mustard

RUMKI H. CH. SANGMA*, SANDIP PATRA, K. KOUTSU, A.R. SINGH, H. TALANG, C. AOCHEN, B. BHATTACHARJEE

ICAR-Research Complex for NEH Region

**Corresponding email: rumkisangma@gmail.com*

The study on the impact of Indian honey bee, *Apis cerana himalaya* in pollination and yield of mustard crop variety, TS-67 was carried out from November, 2021-February, 2023 at the Entomology farm, ICAR-Research Complex for NEH Region. The treatments that were evaluated include pollination with Indian honey bee, *Apis cerana Himalaya* under caged conditions, open pollination and control (pollinator exclusion). Pollination Efficiency Index (PEI) was worked out based on the foraging activity, relative abundance and loose pollen grains adhering to the body of the insect pollinators. Their impact on yield were also assessed. Results revealed *Apis cerana* and *Apis florea* as the most efficient pollinator of mustard based on PEI, respectively. A number of insect visitors belonging to different families and insect orders were found visiting and foraging on mustard flowers at different times of the day under open pollination conditions. The main insect pollinators in decreasing order of per cent relative abundance were *Apis cerana*, *Eristalis tenax*, *Apis florea*, *Halictus* sp., *Ceratina* sp., *Nomia* sp. and a number of syrphid flies. Among them the most frequent visitors were *Apis cerana*, *Eristalis tenax* and *Apis florea*. *Apis cerana* and *Eristalis tenax* was found foraging throughout the day. Per cent increase of 80-104 % in yield was obtained with honey bee pollination over control. Under open pollination conditions per cent increase in yield varied from 110-150% over control, respectively.

Natural farming for ecosystem restoration and sustainable livelihood-An experience in Mon District of Nagaland

RIKYNJAI NANGBAH, A. K MOHANTY, R. BORDOLOI, E. RENBOMO NGULLIE, AZRIEL M. TARIANG, FENESTELLA DKHAR, HEJBINA M HUSSAIN, SUBRATA DAS, EMIDAKA SUTING, WANPHRANG KHARKONGOR

ICAR-ATARI, Zone-VII, Umiam, Umroi Road, 793103, Meghalaya, INDIA

**Corresponding email: affygineanangbah@gmail.com*

Natural farming is an ecology-based sustainable farming system aiming at conserving biodiversity, combating climate change, and improving the livelihood of people and the ecosystem as a whole. This study was designed to assess the performance, level of satisfaction, and suggestions of the practicing farmers on natural farming. In conventional chemical farming practice, indiscriminate use of chemical fertilizers and pesticides destroy the beneficial soil micro flora, change the soil nature and also contribute to the high crop production cost. The essence of natural farming is to minimize the external inputs to the farm land, and nurture the soil fertility naturally. It was shown that enrichment of soil occurs through propagation of beneficial soil microbes. It encourages the natural symbiosis of soil micro flora and crop plants. In order to address the problem and restore the ecosystem, the concept of natural farming, also known as Zero Budget Natural Farming (ZBNF), is used. Natural farming techniques have been shown to enhance soil structure and increased microbial activity over time. Natural farming systems are seen to be more climate resilient than conventional farming systems. The present study based on field demonstration conducted by KVK, Mon of Nagaland on 'Natural farming in Cabbage Cultivation' under Project "Out Scaling of Natural Farming through KVKs", as it is a most prevalent cole crop practiced by the majority farmers in the district. The growth and

yield response of cabbage to application of liquid fertilizer, Jeevamrit, and mulching for natural nutrients approaches shown positive impact. Application of Jeevamrit a resulted in more leaves per plant and overall increase in yield parameters like head diameter, head circumference, head weight etc. On an average a yield of 198.23 q/ha with a BCR of 2.0 with net income of Rs.98882/- was observed from the demonstrated plot as compared to 167 Q/ha from control plot with a BCR of 1.5 with net income of Rs.51550/-.Understanding the perception and awareness of farmers and other local stakeholders remains a challenge for the adoption of agricultural sustainability.

Plant-available micronutrients in rice growing soils of Meghalaya

M. CHAKRABORTY*, A. BALUSAMY, S. HAZARIKA, B.U. CHOUDHURY
Division of System Research and Engineering, ICAR Research Complex for NEH Region, Umiam, Meghalaya-793103
**Corresponding email: mahasweta00@gmail.com*

Rice is one of the major staple food crops of Meghalaya occupying more than 80 percent of the area and constitute a major share of the food grain production. However, the average productivity of rice in the state (1.91 t/ha) is much below the national productivity (2.06 t/ha). The state is still in deficit of about 2.63 lakh tons of rice grain annually. Thus, characterization of rice growing fields in respect to soil quality parameters is very essential for preparing any management plan for increasing productivity of rice in the state. Considering the importance of micronutrients in crop growth and enhancing crop productivity, a study was undertaken to assess the plant available micronutrients concentration in both lowland and upland rice ecosystems. Low land rice is cultivated in the valleys with poor to moderately well drained soils with slope varying from level to gently sloping (0-8%) and upland rice are grown mainly on the shifting cultivation areas or by making terraces on the hill side slopes. Results of the study conducted with soils from different rice fields of Ri-Bhoi district, Meghalaya showed that soils of lowland contained more oxidizable organic carbon over that in upland soils, thereby increasing the micronutrient availability. Considering the critical limits of 4.5, 2, 1.0 and 0.2 mg kg^{-1} for available (DTPA-extractable) Fe, Mn, Zn and Cu, respectively, Zn was found to be limiting in substantial area of rice soils. Variation in soil micronutrients was found to be more in upland rice soils, whereas with respect to concentration of nutrient availability in general, upland soils were found to be lagging behind. Thus micronutrient management measures especially with respect to Zn must be adopted to overcome these soil fertility problems in the deficient areas.

Different organic nutrient sources' effects on the growth and yield of the potato (Kufri Pukhraj) in Arunachal Pradesh

PAVANKUMAR GOUDAR[1], MAHESH KUMAR[1], NAVYA V. BHAT[2], A.K. TRIPATHI[1]
[1] College of Agriculture, Central Agricultural University (I), Pasighat, Arunachal Pradesh, [2] Department of Fruit science and Horticulture technology, OUAT, Bhubaneswar, Odisha,

One of the nation's most significant cash crops and a proud member of the vegetable kingdom is the potato. The potato, also referred to as the "king of vegetables," is a temperate crop grown in subtropical temperatures in India. After rice, it is the country's second-most significant food crop. Farmers in the study's target region in Arunachal Pradesh's East Siang district are interested in natural farming and organic farming, yet intensive crops like potatoes necessitate enormous quantities of inorganic fertilisers or alternatively organic nutrient sources to meet crop demand. The experiment was designed and carried out in College of Horticulture & Forestry, CAU, Pasighat, Arunachal Pradesh during the Rabi season of 2020, 2021, and 2022 to study the Influence of various organic nutrient sources on growth and yield of potato (Kufri Pukhraj) in Arunachal Pradesh in order to address the issue of supplementing the inorganic nutrients from the organic sources. The randomised block design (RBD) was used to set up the experiment, which was replicated four times using the following treatments: {$T_{1:}$ Absolute control, T_2: Inorganic practices standard technology, T_3: Crop residue based compositing of available cheaper crop/weed residues (like NADEP method)+Crop residue incorporation (Main crop/catch/green manuring/bio-fumigation crop)+biofertilizer (*Azotobacter* and Phosphobacteria) + microbial culture to decompose crop residues, T_4: T3 + FYM @ 25 t/ha, T_5: T3 + Vermicompost 7.5 t/ha, T_6: T3 + Neem cake @ 5 t/ha + soil application of *Beauveriabassiana* @ 4 kg/ha* + seed treatment with Trichoderma formulation @ 8 g/kg seed + foliar spray of neem oil @ 3 ml/l (on appearance of insects) + foliar spray of copper oxychloride @ 3 g/l (for management of foliar diseases). The combined data showed that, among the six treatments, T6 had the largest output of marketable tubers (16.35 t/ha), whereas T1 had the lowest yield of non-marketable tubers (11.47 t/ha).

Millet cultivation in natural farming system for climate resilience and nutritional security in North East India

JAYANTA LAYEK, KRISHNAPPA R, AMIT KUMAR, SANDIP PATRA, K.M. REDDY, B. MAKDOH, C. SANGMA

ICAR Research Complex for NEH Region, Umiam

Corresponding email: jayanta.icar@gmail.con

Due to nutritional superiority, climate resilience and short growing season, millets get prominent place in cropping sequence around the world. Experiment was conducted under natural production system in degraded and fragile hill ecosystem of North Eastern Region (NER), India to identify the millets suitable towards resilient farming and nutritional and food security of local inhabitants. Besides, high yielding varieties (HYVs) of different millets *viz.*, finger millet, foxtail millet, little millet, barnyard millet, proso millet and browntop millet, local landraces of finger millets from Himalayan foothills (*Sikkim -1* & -2, *Nagaland -1* & *-2*) were also evaluated for three consecutive three years to identify the stable high yielding and nutritionally superior genotypes suited for the region. Among the various millets, finger millet followed by little millet and foxtail millet had proven their superiority in terms of productivity

as compared to other millets. Among different germplasms of finger millets, VL Mandua 352 recorded highest average grain yield (1.43 Mg ha^{-1}) followed by *Nagaland-2* (1.31 Mg ha^{-1}) and *Sikkim-1* (1.25 Mg ha^{-1}). The different types of millets were found to be rich sources of protein with 12.3% in foxtail millet variety namely, SiA3088, 11.5% in Proso millet and 8.7% each for local landraces of finger millets *viz.*, *Sikkim-1* and *Nagaland-2*. Local landraces of finger millet namely, *Sikkim-1* also recorded the highest amylose content (17.2%) followed by *Nagaland-2* (16.8 %) as compared to the HYVs. Similarly, finger millet landrace *Nagaland-1* recorded highest amylopectin content (17.1%) as compared to the other germplasms of millets. Saturated fat concentration ranged from 0.3% (Finger millet germplasm, *Sikkim-2*) to 1.32% (foxtail millet germplasm, SiA3088). Finger millet, *Sikkim-2* recorded the highest omega-6 content (1.16%) followed by barnyard millet, VL 207 (1.09%). However, among different genotypes of finger millets evaluated, local landraces viz., *Sikkim-2* (1.01%) followed by *Nagaland-2* (0.79%) recorded significantly higher PUFA against best HYVs like VL Mandua 324 (0.63). Finger millet genotypes, *Sikkim-1* and *2* recorded highest histidine (0.41%) and tryptophan (0.12%) content respectively. Local finger millet lines, *Sikkim-1* and *Nagaland-2* recorded higher thiamine (0.32%) compared to the HYVs. It can be concluded that finger millet has a great potential in this hilly ecosystem and apart from HYVs like VL Mandua 352, local germplasms from Nagaland and Sikkim states of India should also be promoted for ensuring food and nutritional security.

Revitalizing traditional potato strains: Incorporating local landraces into seed production

CLARISSA CHALLAM*, N. SAILO, T BUCKSETH[1], P. JANANI, BAPI DAS[2], YVONNE A. LYNGDOH, BRAJESH SINGH[1]

ICAR-Central Potato Research Station, Shillong, Meghalaya, India, [1]ICAR-Central Potato Research Institute, Shimla, Himachal Pradesh, India, [2]ICAR Research Complex for NEH Region, Tripura Centre, India

**Corresponding email: Clarissa.Challam@icar.gov.in*

Potato cultivation in the Khasi Hills of Meghalaya began in 1830 with the introduction of the 'Khasi' variety. To address susceptibility to late blight, new varieties were introduced from England and Australia between 1892 and 1902. This continued until 1946, resulting in multiple introductions. Promising varieties like Arran Consul, Kerr's Pink, Royal Kidney, Up-to-Date, and Great Scot were commercially cultivated until the late 1970s. With the intention of replacing the old varieties which are riddled with plenty of problems, improved and high yielding varieties like Kufri Khasigaro, Kufri Jyoti, Kufri Megha, Kufri Himalini, Kufri Girdhari etc. were introduced. The local landraces presently grown in the Meghalaya hills are survivors of the early introductions and may include chance selections from natural seedlings. Conserving and cultivating local potato varieties plays a vital role in preserving biodiversity and cultural heritage. Landraces or indigenous varieties, exhibit resilience to local conditions, require fewer resources, and offer unique flavors and nutrition. Local landraces account for 30% of the potato cultivation area in the state. However, ensuring the availability of high-quality seeds for popular and widely grown landraces has been neglected. To address this issue, a local survey collected landraces from farmers' fields, resulting in the identification of 14 distinct landraces. Four prominent landraces—Lah Lhew, Lah Saw, Lah Taret, and Lah Shidieng-were prioritized for virus

elimination. Uniform tubers of these landraces were selected and tested for viruses using ELISA and PCR techniques. Meristem tip culture was employed for virus elimination, resulting in successful production of meri-clones of the four landraces. Healthy mother cultures were multiplied using micropropagation, while clean seed tubers were multiplied through aeroponics, apical rooted cuttings, and field multiplication. Conserving these landraces not only promotes sustainable agriculture but also maintains genetic diversity. This initiative marks the first step in revitalizing popular local landraces into the "Seed Production System", ensuring the availability of high-quality seeds and preserving genetic diversity.

Assessing plant diversity and carbon stock in traditional grassland and silvipasture systems of the Western Himalayas

PEMPA L. BHUTIA[1,2*], B. GUPTA[2], R.P. YADAV[3], KARMA G. BHUTIA[4], H. KALITA[1]
[1]ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema-797106, Nagaland, India, [2]Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-173230, Solan, Himachal Pradesh, [3]India Rani Lakshmi Bai Central Agricultural University, Jhansi- 284003, Uttar Pradesh, India, [4]Rain Forest Research Institute, Jorhat-785101, Assam, India
**Corresponding email: pempadenzongpa66@gmail.com*

In the Western Himalayas, traditional grassland and silvipasture systems play a crucial role in ensuring livelihood security of the rural population amidst climate change. These systems not only provide a sustainable source of fodder, fuelwood, timber and other non-timber forest products, but also actively contribute to biodiversity conservation, carbon sequestration and climate regulation. Considering this perspective, the study aimed to evaluate the plant species composition and carbon stock of grassland and silvipasture systems across various elevations in the western Himalayas. The traditional grassland and silvipasture systems exhibited diverse floral spectrum, with wide range of plant species (114 species), predominantly herbs (69.30%) and shrubs (30.70%). The diversity index was higher in silvipasture than grasslands for herbaceous species, while it was in a similar range for shrubs in both systems. The silvipasture system reported a total above-ground and below-ground biomass carbon stock of 40.63 Mg C/ha, while the grassland exhibited a carbon stock of 2.92 MgC/ha. The total vegetation carbon stock increased with elevation in silvipasture, while it decreased in grassland. This study highlights the significance of silvipasture systems in the Western Himalayas due to their greater plant species diversity and enhanced carbon stock in vegetation compared to grasslands, with important implications for the conservation and management of traditional forage-based systems in the face of climate change.

Quantifying the effect of spacing on growth performance of different bamboo species in mid-hills of Arunachal Pradesh

R.A. ALONE*, DONI JINI, THEJANGULIE ANGAMI, AMPEE TASUNG, L.K. BAISHYA
ICAR Research Complex for NEH region, Arunachal Pradesh centre, Basar 791 101
**Corresponding email: rajesh.scientist@gmail.com*

Arunachal Pradesh has a very rich bamboo diversity and it holds an important position among the bamboo bearing states of India. Bamboos have become integral part of the local culture and day to day life of the tribal communities in the rural areas of Arunachal Pradesh. Bamboo forms a major component of Agroforestry systems of Arunachal Pradesh. An experiment conducted at Agroforestry section of ICAR research farm, Basar in mid-hills of Arunachal Pradesh in order to quantify the effect of spacing on the growth parameters of 10 bamboo species. The 10 bamboo species *viz. Dendrocalamus sikkimensis, D. hookerii, D. hamiltonii D. sahnii, Bambusa pallida, B. balcoa, B. cacharensis, B. tulda, B. nutans* and *B. arundinacea,* were planted at 3 different spacing viz. 5m x 5m, 6m x 6m and 7m x 7m in 3 replications in the year 1999.After 24 years of planting, the following results were obtained. At 5m x 5m spacing, the maximum clump circumference was recorded in *B. cacharensis*, (11.32±0.06m) followed by *D. hamiltonii* (10.2±0.04m). In this spacing, the highest number of culms per clump was recorded in *D. hamiltonii* (64±0.34) followed by *D. sikkimensis* (52±0.23). At 6m x 6m spacing, the maximum clump circumference was recorded in *B. cacharensis* (13.1±0.06m) followed by B. nutans (10.2±0.08m). In this spacing, the highest number of culms per clump was recorded in *D. sahnii* (66±0.7) followed by *D. sikkimensis* (51±0.5). At 7m x 7m spacing, the maximum clump circumference was recorded in *B. nutans* (13.4±0.06m) followed by *B. pallida* (10.8±0.2m). In this spacing, the highest number of culms per clump was recorded in *B. pallida* (82±0.8) followed by *D. sikkimensis* (71±0.72). It is concluded that performance of *D. hamiltonii* is better than other bamboo species at 5m x 5m spacing in terms of number of bamboo culms per clump. *D. sahnii* is performing better at 6m x 6m spacing and *B. pallida* is performing better at 7m x 7m spacing.

Effect of spacing on tree biomass and carbon sequestration potential of ghamari (*Gmelina arbora*)

R.A. ALONE*, DONI JINI, THEJANGULIE ANGAMI, AMPEE TASUNG, JOKEN BAM, L.K. BAISHYA

ICAR Research Complex for NEH region, Arunachal Pradesh centre, Basar 791 101
E mail: rajesh.scientist@gmail.com

Carbon fixation through forestry is a function of the amount of biomass in a given area. Plantations are a very efficient way of promoting biomass and carbon accumulation. Ghamari (*Gmelina arborea Linn*.) is an important multipurpose tree producing timber, fuelwood, fodder, pulp, honey etc. An experiment was conducted at ICAR Resrerch Farm, Basar, to quantify the effect of spacing on biomass and carbon stock of Ghamari. The Ghamari plantation was established in the year 1999. The Girth at Breast Height (GBH) of trees in sample plots was recorded in plantations at different spacing viz. 2x3m, 3x3m, 4x3m, 5x3m, 6x3m, 2x4m, 3x4m, 4x4m, 5x4m and 6x4m. The tree component wise biomass was estimated by using the allometric equations relating to the tree GBH. The carbon concentration of tree components was estimated using standard procedures. The component-wise carbon stock was estimated by multiplying biomass with respective carbon concentration. The planting design 2 x3m of

Ghamari recorded the highest bole biomass (101.77 t ha^{-1}), branch biomass (123.86 t ha^{-1}), foliage biomass (11.46 t ha^{-1}), root biomass (111.56 t ha^{-1}) and total biomass (348.65 t ha^{-1}) followed by 3 x 4m spacing having bole biomass (90.25 t ha^{-1}), branch biomass (111.38 t ha^{-1}), foliage biomass (9.87 t ha^{-1}), root biomass (101.5 t ha^{-1}) and total biomass (313.0 t ha^{-1}). The 2 x 3m spacing also recorded the highest carbon stock in bole (44.26 t ha^{-1}), branch biomass (56.55 t ha^{-1}), foliage (5.35 t ha^{-1}), root (39.86 t ha^{-1}) and total carbon stock (146.02 t ha^{-1}) followed by 3 x 4m spacing having carbon stock in bole (39.25 t ha^{-1}), branch (50.85 t ha^{-1}), foliage (4.60 t ha^{-1}), root (36.26 t ha^{-1}) and total carbon stock (130.96 t ha^{-1}). This study concludes that closer the spacing, more will be the biomass and carbon stock per unit area.

Unleashing profitability and reducing market dependency through integrated organic farming systems

M.A. ANSARI[1], N. RAVISANKAR[1], M. SHAMIM[1], A.K. PRUSTY[1], RAGHVENDRA K.J.[1], RAGHUVEER SINGH[1], SUNIL KUMAR[1], JAYANTA LAYEK[2], C.K. THANGAMANI[3], L.J. DESAI[4], G. SUJA[5], S.K. DAS[6], R. KRISHNAN[7]

[1]ICAR- Indian Institute of Farming Systems Research, [2]ICAR-RC for NEH Region, Umroi Road, Umiam, 793 103

[3]ICAR-Indian Institute of Spices Research, Kozhikode (Calicut)-673 012, [4]Dantiwada Agricultural University, Sardarkrushi nagar - 385 506, Banaskantha, [5]ICAR-Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram, 695 017, [6]ICAR-RC for NEH Region, Sikkim Centre, Tadong, Gangtok (AI-NPOF) 737102, [7]Sustainable Organic and Agriculture, Tamil Nadu Agricultural University, Coimbatore-641 003

Integrated organic farming system (IOFS) offers a promising solution for reducing the environmental burdens associated with input-intensive agricultural practices. However, a significant challenge in organic agriculture is the limited availability of organic inputs necessary for crop nutrition and soil health maintenance. These challenges can be overcome by efficiently recycling the existing on- and off-farm resources and integrating various components tailored to specific locations. By implementing practices like composting, green manuring, and crop rotation, organic farmers can effectively recycle organic residues and by-products, transforming them into valuable nutrient sources for crops. Integrating livestock, agroforestry, and cover crops within the farming system further contributes to nutrient recycling and soil improvement. This approach allows IOFS to address the challenge of organic input availability while promoting sustainable and location-specific agricultural practices. Therefore, seven number of Integrated Organic Farming Systems (IOFS) models developed for 6 States (Gujarat, Kerala, Meghalaya, Rajasthan, Sikkim and Tamil Nadu) to reduce the cost of production and ensure quality inputs for organic farming. After long term implementation of this IOFS model, IOFS model of Meghalaya, ensures Rs 69,462 net returns from 0.43 ha area and also reduce the market driven nutrients due to meet out the demand (N, P and K) from recycling of available farm by products/residues. IOFS model of Sikkim ensures Rs 37,300 net returns with 2.25 benefit cost ratio from 0.60 ha area. Similarly, SK Nagar, Gujarat IOFS model ensure total net profit of Rs 39,656 from 0.4 ha area. In IOFS model (Cassava + vegetable cowpea, Taro, Maize, Napier grass, greengram, blackgram, groundnut, Lemon, Karonda, Lemon grass, Vermicompost, 2 cows) of Thiruvananthapuram, Rs 30402 net returns ensure

from 0.3 ha area. The highest net returns of the system indicates that under integrated organic farming system at Calicut, Kerala (Spice based system (Turmeric, ginger, fodder, vegetable cowpea, tapioca, banana, vermicompost, 2 cows), a net income of 2.29 lakhs per acre (0.4 ha) can be obtained from the spices based organic farming systems. These findings can align with government aims to bring 10% of the net cultivated area under certified organic farming by 2030 which is currently only 3%.

Theme – 2

Hill Agriculture

Sustainability & Economics

Changes of farming system in North Eastern Himalayan region: An ex-post facto review

RAJESH KUMAR[1*], BAGISH KUMAR[1], ABUL K. AZAD[1], M. THOITHOI[1], G. KADIRVEL[1], A.K. MOHANTY[2]

[1]ICAR-Agricultural Technology Application Research Institute, Zove-VI, Kahikuchi, [2]ICAR-Agricultural Technology Application Research Institute, Zove-VII, Umiam

**Corresponding email: rajeshk3022@gmail.com*

The North Eastern Region is known for its in-famous farming system Jhum cultivation leads to the destruction of forest land and the cultivation of crops. This primitive farming system follows by the tribals for decades. They have traditionally lived mainly in forests, hills, and undulating inaccessible terrain in plateau areas, no other form of cultivation was possible to mitigate their food supply demand. Their per capita food availability was limited with nutritionally unbalanced. But due to the advancement of the National Agricultural Research System and its committed work to reach the un-reach through Krishi Vigyan Kendra (KVK), the cropping pattern, cropping intensity, farming system, and farm income changes. Now, the tribal are producing surplus food grain and commercializing. In line with this, a study conducted by ICAR-Agricultural Technology Application Research Institute, Zone VI, Guwahati on impact assessment of technological interventions through KVK in tribal areas. A total of 2 ATARI (Zone-VI & VII) was taken for the study purpose and 760 farmers both from adopted and non-adopted areas were interviewed separately. The study revealed that there is a change in cropping patterns, cropping intensity, crop diversification, and farming system. Earlier, the Eastern Himalayan Region is primarily known for agriculture through the jhum cultivation method, however, change to an agriculture and horticulture-based farming system. The area under mono-cropping area decreased by 10.13 percent and increased multiple cropping and intern cropping by 16.97 percent and 4.60 percent respectively. The Simpson Crop Diversification index is 0.89. The scientific use of hybrid rice area increased by 18.0 percent and maize by 43.0 percent. The study revealed that in the non-intervene area, the average farm income was Rs. 74381.20 per year, whereas, in intervened area, it was Rs. 415875.30. There is a change in BC ratio from 1.3 to 1.9. The major contribution in changing the farm income through KVK was specific region wise supplying of quality planting material (38.50%), advisory services in crop & animal production (22.50%), training and awareness (16.00%), demonstration (14.50%) and field visit exposure (8.50%). So, it can be concluded that the various interventions through KVKs has significant impact in farming system and enhancement of socio-economic condition of the tribal farmer.

The Hidden treasures of the forest: Promoting forest conservation through non-timber forest products in Eastern Himalayan region

LIMASUNEP OZUKUM[1], SANJOY DAS[1*]

[1]Department of Agricultural Economics, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus (Nagaland), PIN – 797106, [2]Department of Agricultural Extension, School of

Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus (Nagaland), PIN – 797106
**Corresponding email: das_san1@rediffmail.com*

NTFPs are products derived from forest resources other than timber, such as fruits, nuts, seeds, and medicinal plants. These products provide valuable income to forest communities and can help incentivize sustainable forest management practices. The proposed study was conducted in the Eastern Himalayan states of Meghalaya and Nagaland where two districts from each state were selected purposively i.e., East Khasi Hill and Ri-bhoi districts from Meghalaya and Mokokchung and Peren districts from Nagaland. One block from each district was selected purposively based on villages involved in NTFP collection. A total of 250 respondents from twenty villages from 4 block were selected proportionately based on the number of households. About important and commercial 17 plant-based and 5 animal-based NTFPs were collected from Meghalaya and about 16 plant-based and 9 animal-based NTFPs were collected from Nagaland. The NTFPs collected from Meghalaya where a majority of the NTFPs collected comprised nourishment (35%), therapeutic and alimentary supplements (26%), fuelwood (26%), housing material (5%), and ornate products (2%) respectively while the NTFPs collected from Nagaland, the majority of the NTFPs collected comprised nourishment (37%), therapeutic and alimentary supplements (22%), fuelwood (28%), housing material (5%), and ornate products (8%) respectively. Binary logistic in the regression model was used to check whether the hypothesis of 'increasing the income of local people derived from the extraction of NTFPs will be an incentive for local people's participation in forest conservation activities. The study showed that income from NTFPs influenced positively and significantly four forest conservation models in Meghalaya and three forest conservation models in Nagaland. Overall, the study confirmed that income from NTFPs positively and significantly influences at least five forest conservation activities from either or both the study areas and that extraction of NTFPs disparages local people from collecting the critical parts of the plants that affect their growth or reproduction.

Evaluation of different *Citrus* species as rootstocks of *Khasi* mandarin under mid hill altitude of Meghalaya

H.D. TALANG*, H. RYMBAI, M.B. DEVI, S.R. ASSUMI, VANLALRUATI, B.U. CHOUDHURY
Division of System Research and Engineering
ICAR Research Complex for NEH Region, Umroi Road, Umiam

Khasi mandarin (*Citrus reticulata* Blanco) is one of the most popular citrus species throughout the NEH region. Most of the mandarin orchards in the region are of seedling origin, however in recent years budded and grafted plants of *Khasi* mandarin is in demand for commercial orcharding. The effect of rootstocks on fruit production and quality has been extensively mentioned in literature. The utilization of rootstocks help to reduce the adverse effects of abiotic stresses including drought, salinity, water logging and alkalinity, as well as conferring tolerance to biotic stresses such as Phytophthora *sp*, nematodes and citrus tristeza virus. There is no dispute about the vital influence of rootstock with respect to vigour, precocity, fruit quality,

longevity of tree, resistance and adaptability to the biotic and abiotic stresses of Citrus. Several trials on rootstock of citrus have been conducted in different part of the World since 1900 A.D. using mandarins, sweet oranges, acid lime, lemon, grapefruit and pummelo as scion. In case of *Khasi* mandarin, however, little information is available on rootstock studies. Keeping the above in view, we made an attempt to evaluate different *Citrus* species as rootstocks for *Khasi* mandarin. Rootstocks used are: *C. karna* (T1), *P. trifoliate* (T2), *C. jambhiri* (T3), *C. limonia* (T4), *C. latipes* (T5), *C. taiwanica* (T6), *C. volkameriana* (T7). Result indicated that minimum nos. of days taken to first sprout (15.05), days taken to 50% sprouting (26) with maximum percentage of graft success (93.58) and plant survival (96.25) was observed in *C. jambhiri* (T3). At 180 days after wedge grafting, maximum plant height (35.80cm) and rootstock diameter (0.37cm) was recorded with *C. jambhiri* (T3) whereas maximum nos. of leaves per plant (17.33) and nos. of branch per plant (3.23) was observed in *P. trifoliate* (T2). *C. jambhiri* (T3) rootstock showed better graft and survival percentage as well as vigorous effect on Khasi mandarin as compared to *C. karna* (T1), *P. trifoliate* (T2), *C. limonia* (T4), *C. latipes* (T5), *C. taiwanica* (T6) and *C. volkameriana* (T7) rootstocks.

Examining the effects of Jalkund adoption, a hilltop rainwater harvesting technique, on the livelihoods of tribal farmers in Meghalaya

CHIKKATHIMME GOWDA H. R.[1*], N UTTAM SINGH[2], PAMPI PAUL[1], V. K. MISHRA[3], KAMNI P BIAM[1], ANJOO YUMNAM[1], ANIRUDDHA ROY[4], AMRUTHA T.[5], A.K. TRIPATHI[6]

[1] Scientist, Division of Technology Assessment and Capacity Building, ICAR-RC for NEH Region, Umiam
[2] Sr. Scientist, Division of Technology Assessment and Capacity Building, ICAR-RC for NEH Region, Umiam
[3] Director, ICAR-RC for NEH for Region, Umiam, [4]Sr. Scientist, Head (i/c) Division of Technology Assessment and Capacity Building, ICAR-RC for NEH Region, Umiam, [5]Scientist, ICAR-ATARI Zone VII, Umiam, [6] Dean ,College of Agriculture, Pasighat, CAU
**Corresponding email: chikkathimme.hr@icar.gov.in*

A study was conducted to evaluate the effects of Jalkund technology on water productivity, farm income, and employment in tribal dominant villages of East Khasi Hills and Ribhoi districts of Meghalaya during 2021. The study involved crop diversification, cost-benefit analysis of various farm activities, and estimation of water productivity for each activity. The findings indicated that the adoption of Jalkund allowed farmers to cultivate additional high-value vegetable crops on an area of 450m², resulting in an extra income of Rs. 27,000. The cultivation of vegetables also produced 22.21 kg per 1000 liters of stored water, while water productivity for poultry and piggery operations was about 16.67 kg/1000L and 26.67 kg/1000 L, respectively. The benefit-cost ratios for vegetable cultivation, piggery, poultry, and fish growing were 2.32, 2.70, 2.04, and 5.00, respectively. After implementing Jalkund technology, the total income of farm households increased from Rs. 1,45,000 to Rs. 1,91,125. All the farm components significantly contributed to the income through the use of stored water, with livestock components (poultry and piggery) contributing Rs. 58,125. Additionally, livestock rearing generated an extra 20-man days of employment, while fish farming provided four more days of employment and an income of Rs. 3,125. Piggery experienced the highest increase in

income (36.21%), followed by crop (vegetable) production (26.73%), and poultry (24.17%). Overall, Jalkund adoption resulted in a 31.81% increase in farm household income compared to non-adoption, with farmers generating an average of 46 additional days of employment. Jalkund technology proved to be essential in enhancing the livelihoods of hill agricultural households by providing water during the post-monsoon dry months.

Development of DRIS-based nutrient diagnostic technique for Khasi Mandarin (*Citrus reticulata* Blanco)

H. RYMBAI*, N.A. DESHMUKH, T. RAMESH, H.D. TALANG, V.K. VERMA, J. MAWLEIÑ, B.U. CHOUDHURY, S. HAZARIKA

Division of System Research and Engineering
ICAR Research Complex for NEH Region, Umroi Road, Umiam
**Corresponding email: rymbaihort@gmail.com*

Mandarin is the most common citrus fruit grown globally, particularly in India's eastern Himalayas, which is a major hotspot for citrus diversity. Khasi mandarin, an ecotype of mandarins found in Meghalaya and other north eastern India is the most significant commercial fruit crop in the area. For higher yield, it is essential to use leaf tissue analysis to identify any potential nutritional imbalances. There is currently no information available regarding the nutritional diagnosis of Khasi mandarin plants, notably in the acidic soils of the mountainous ecosystem of the Eastern Himalayas, India. Determining nutrient limitations and developing leaf-based diagnostic recommended and integrated system (DRIS) norms and nutrients relationships with fruit output from 144 orchards were the goals of the current study. The findings indicated that the DRIS indices predicted an ideal nutritional value for Khasi Mandarin: 2.26-2.83% N, 0.11-0.16% P, 1.86-2.07% K, 1.85-2.12% Ca, 0.33-0.48% Mg, 170.10-225.10 mg kg^{-1} Fe, 74.03-83.43 mg kg^{-1} Mn, 1.24-2.45 mg kg^{-1} Cu, and 19.84-21.28 mg kg^{-1} Zn. The DRIS norms identified the nutrients; Zn, P, Ca, K, N and Mg as deficient to low levels (14.15→2.14), while Fe, Mn, and Cu were at high to excessive levels (5.50→18.25). The nutritional balance index had a significantly negative relationship with the fruit yield. Leaf nutrient concentrations of N (0.909**), P (0.827**), K (0.867**), Zn (0.833**), Ca (0.827**) and Mg (0.592**) had a significant positive correlation with fruit yield. The finding facilitates the correct interpretation of leaf nutrient analysis, and the norms developed will enable a precise intervention through nutrient management for higher yield in mandarin citrus.

Performance of king chilli under different nutrient combinations in acid soils of Meghalaya

L. JOYMATI CHANU*, S. HAZARIKA, B.U. CHOUDHURY, T. RAMESH, A. BALUSAMY, M.B. DEVI

Division of System Research and Engineering, ICAR-Research Complex for NEH Region, Umiam, Meghalaya (793 103), India
**Corresponding email: joymati.loit@gmail.com*

King chilli (Capsicum chinense *Jacq.*) is an indigenous potentially high-value crop of northeastern (NE) region, traditionally grown on hill slopes, rice fields and vegetable gardens by farmers in the region. The crop is known for its pungent taste and high capsaicin content, thus earns high value in market. Traditional way of cultivation without periodic nutrient inputs lead to sub-optimal productivity and quality of the crop. With this background, in order to study the responds of king chilli to different nutrient combinations, an experiment comprising of twenty seven nutrient combinations of N, P, and K, taking 120:50:50::N:P_2O_5:K_2O kg ha^{-1} as base nutrient combination. The experiment was conducted in soil of pH-4.91, N-351.23 kg/ha, P-21.12 kg/ha, K-580 kg/ha and SOC-2.24%. The result of the study revealed that nutrient managements of N:P_2O_5:K_2O application @150:65:65 kg ha^{-1} recorded the highest Capsaicin content of 4.28% , and was 103% higher than the crops grown under natural fertility condition i.e. without external inputs (capsaicin of 2.1%). Furthermore, the application of NPK in the above doses has significantly enhanced the yield (no. of fruits per plant, 50.6% over the control) and other phytochemicals parameters such as chlorophyll and carotenoids contents of the crop. Therefore, the nutrient combination of 150:65:65 kg N, P_2O_5, K_2O per ha can be suggested to increase the quality and productivity of the crop and to improve the livelihoods of king chilli producers in the region.

Effect of different seedling growing media on growth, quality and vigour of tomato and cabbage seedling and subsequent performance in the main field

MAINU HAZARIKA[1*], JUMI SAIKIA[2], SAILEN GOGOI[2], PRAVEEN KUMAR[3]
[1]Arunachal University of Studies, Namsai-792103, Arunachal Pradesh, India, [2]Assam Agricultural University, Jorhat-13, Assam, India, [3]Agriculture Research Station, Mandore, Jodhpur, Rajasthan-342304, India
**Corresponding email: hazarikamainu@gmail.com*

Quality seedling can ensure higher crop yield. The present investigation was carried out at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat-13, Assam and at Farmer's Field (Karangakhat gaon, Dhekiajuli, Jorhat, Assam) during rabi season of 2018-19 and 2019-20 to access the impact of different seedling growing media on growth, quality and vigour of tomato and cabbage seedling and subsequent performance in the main field. The treatments consisted of four different nursery media composition viz. M_1: Cocopeat (60): Vermiculite (20): Perlite (20), M_2: Cocopeat (50): vermicompost (50), M_3: Cocopeat (50): vermicompost (50): Microbial consortium, M_4: Conventional nursery (soil: sand: FYM), two Crops viz. C_1: Tomato (Arka Rakshak), C_2: Cabbage (Rare Ball) and two growing conditions viz. G_1: Experimental Farm, Dept of Horticulture, AAU, Jorhat; G_2: Farmer's field (Karangakhat gaon, Jorhat). The effect of different seed sowing media on seedling quality and their performance in the main field was found to be significant. Tomato seedlings raised in plug trays with seed sowing media coconut (50): vermicompost (50) i.e M2 recorded higher seedling emergence percentage (98.42), seedling height (15.47 cm), seedling vigour index (2268.54), dry matter accumulation (24.18%), total chlorophyll content (1.61 mg g^{-1} fw), palisade ratio (1.27) and mesophyll layer thickness (82.88 µm). In case of cabbage seedlings raised in plug

trays with seed sowing media coconut (50): vermicompost (50) : microbial consortium *i.e* M3 recorded higher seedling emergence percentage (92.67), stem diameter (3.12 mm), root length (12.01 cm), seedling vigour index (2358.43), seedling fresh weight (1.72 g), seedling dry weight (0.38 g), total chlorophyll content (0.99 mg g^{-1} fw), palisade ratio (1.23) and mesophyll layer thickness (95.26 µm). Similar positive performance was also recorded in the main field of horticultural Experimental Farm, Dept of Horticulture, AAU, Jorhat and farmer's field. Computation of production economics resulted in the higher B:C ratio in tomato and cabbage in seed sowing media - cocopeat (50): vermicompost (50) i.e M2 and cocopeat (50) : vermicompost (50) : microbial consortium i. e M3, respectively. From the present investigation it can be concluded that M2 [cocopeat (50) : vermicompost (50)] is the best seed sowing media for tomato and M3 [cocopeat (50) : vermicompost (50) : microbial consortium] is best for cabbage.

Farmers friendly machine learning model for agricultural sustainability in the Papum Pare District of Arunachal Pradesh, North-East, India

SAMIKHYA BHUYAN[1], SUMPAM TANGJANG[2], SIMANTA JYOTI MEDHI[3]

[1] *Faculty of Agricultural Sciences ,Department of Soil Science & Agril Chemistry , Rajiv Gandhi University, Arunachal Pradesh, 79112,Email : samikhyabhuyan5@gmail.com,* [2] *Dean, Department of Agricultural Sciences, Rajiv Gandhi University, Arunachal Pradesh, 79112, Email : Sumpam.tangjang@rgu.ac.in,* [3] *Senior Software Engineer , Volvo Group, India, 560122, Email : simmedhijyoti@gmail.com*

The study was conducted in Papum Pare District which is situated in the North Eastern part of Arunachal Pradesh. Its mainland extended between 26°55′ and 28°40′ North latitude and 92°40′ and 94°21′ East longitudes with covering an area of 3462 sq km. A total of 180 no of soil samples (0-20 cm and 0-70 cm depth) were collected from four land use system which were rice, millet, plantation and forest respectively. The soil quality index (SQI) of different land use system were calculated and found to be ie. forest (0.96) and (0.76), millet (0.79) and (0.73), plantation (0.77) and (0.66), and rice (0.74) and (0.67) in 0-20 cm depth and 0-70 cm depth respectively. The selected minimum data set indicators which affecting soil quality index were soil organic carbon, clay, pH, base saturation and available iron. The dataset was trained using the machine learning algorithm and predict the SQI using the equation: SQI = SOC*0.1+ pH *0.0054+C *0.0547+BS*0.0027+Av Fe *0.0075+0.0006789 (Where, SOC = Soil organic Carbon, C= Clay, BS=Base saturation, Av Fe = Available iron). It was found that the predictive model showed high level of accuracy. The crop recommendation system was developed using "decision tree classifier model." To connect the model, a web application is being designed. This application presents the model to the user. A QR code was developed for the farmers so, that they will scan and get the information of soil quality.

Fruit quality of Khasi Mandarin (*Citrus reticulata*) growing in different altitudes of Meghalaya

ANGSHUMAN KAR*, NG TOMBISANA MEETEI
Plant Molecular Biology & Biotechnology, School of Crop Improvement, CPGS-AS (CAU-I), Umiam, Meghalaya
**Corresponding email: angshumankr@gmail.com*

The North-Eastern Region of India is renowned for its rich diversity of citrus species, including the economically significant Khasi mandarin (*Citrus reticulata* Blanco.). This citrus crop holds immense importance in the socio-economic development of the region. Meghalaya, often referred to as the "Abode of Clouds," benefits from its diverse topography and varying altitudes, creating favorable conditions for citrus cultivation. However, despite the widespread cultivation of Khasi mandarin in this region, there is a pressing need for high-yielding, superior quality, and pest and disease-resistant planting material to support commercial cultivation. Hence, this study was done to identify the best plants in terms of yield and fruit quality for commercial cultivation of Khasi mandarin which will ultimately help in increasing the farmers' income in the North Eastern region. Fruits from Khasi mandarin plants were collected from 3 different altitude ranges (<500 m, 500-1000 m, >1000 m) in different districts of Meghalaya. Tree morphology and fruit physical characteristics such as fruit weight, diameter, and peel thickness were measured. Biochemical composition, including total soluble solids (TSS), titratable acidity (TA), vitamin C content, and sugar content, was determined using standard methods. The results indicated significant variations in fruit quality attributes across different altitudes. As the altitude increased, there were variations observed in TSS levels, acidity, ascorbic acid content, and sugar content. Khasi Mandarin fruits grown at higher altitudes exhibited smaller size, thicker peel, higher TSS, lower acidity, and higher ascorbic acid content compared to those from lower altitudes. The highest total sugar and reducing sugar content was found at 900-1000 m (11.14 % and 6.06 % respectively). Titratable acidity decreased with altitude, with the lowest acidity found at 1200-1400 m (0.63%). Ascorbic acid content was highest at 1000-1200 m (55.69 mg/100 ml). These findings suggest that the climatic conditions associated with different altitudes influence the metabolic processes and biochemical composition of the Khasi Mandarin fruit. By understanding the relationship between altitude and fruit quality, we can pave the way for sustainable and efficient citrus production in Meghalaya, ultimately benefiting the farmers, consumers, and the citrus industry as a whole.

Influence of nitrogen and sulphur application on yield parameter of Indian mustard (*Brassica juncea* L.) grown under rainfed conditions in Arunachal Pradesh

DANA ONA
Department of Agronomy, Rajiv Gandhi University, Rono Hills, Doimukh, Arunachal Pradesh

During the rabi season of 2021-2022, a field experiment entitled "Influence of Nitrogen and Sulphur Application on Yield Parameter of Indian Mustard (Brassica juncea L.) Grown under Rainfed Conditions in Arunachal Pradesh" was conducted at an Agricultural farm in Karsingsa, Papum Pare district. An uneven and inadequate nutrient supply is one of the most important

causes of mustard yield loss. As a result, the study focused on determining the optimal dose for enhancing total output in mustard in Arunachal Pradesh. The experiment included twelve treatments with three replications, each with four levels of nitrogen as N1, N2, N3, N4 (0, 30, 60, and 90 kg N ha-1) and three levels of sulphur as S1, S2, S3 (0, 30, and 60 kg S ha-1). Compared to N3, N2, N1, the maximum yield was obtained with 90 kg N ha-1. Similarly, 60 kg S ha-1 produced the most significant growth and yield compared to S2, and S1. The combined application of N and S at a rate of 90 kg N + 60 kg S ha-1 (N4S3) significantly increased the maximum number of siliqua per plant (130.43), number of seeds per siliqua (15.21), stover weight (15.22 g/plant), test weight (5.68 g), seed yield (14.20 q ha-1), stover yield (39.95 q ha-1) and harvest index (24.30%). In light of our findings, it was found that the application of N and S had a substantial effect on mustard yield and may be recommended as the optimal dose of application.

The impact of soil amendments on rapeseed yield and soil fertility in acidic hill soil of Manipur

LEISHANGTHEM MOMO SINGH[1*], PANCHALI UZIR[1], AK SINGH[2], T. BASANTA SINGH[3]

[1]School of Natural Resource Management, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, 793103, Meghalaya [2]Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema Campus-797106, Nagaland [3]Division of Natural Resource Management ICAR Research Complex for NEH Region, Manipur Center

**Corresponding email: momoleishangthem1@gmail.com*

Soil acidity has been highlighted as a key agricultural concern that has a detrimental influence on crop productivity, either directly or indirectly, and the issue is especially serious in hilly states of the North Eastern region. Therefore, it's advisable to supply the required doses of lime requirement to the soil to sustain its fertility also as productivity. So, a field experiment was carried out during Rabi season of 2020-2021 at Langol Farm, ICAR Research Complex for NEH Region, Manipur Centre in Randomized Block Design consisted of nine treatments with three replications. The 9 treatments were T1-Control (no application), T2-RDF, T3-RDF+Lime, T4- RDF+Sulphur, T5- RDF+Boron, T6- RDF+Lime+Sulphur, T7-RDF+Lime+Boron, T8- RDF+Sulphur+Boron, T9- RDF+Lime+Sulphur+Boron to evaluate the yield and soil fertility of rapeseed. The results revealed that combined application lime, sulphur and boron recorded maximum yield of rapeseed compared to rest of other treatments. T9 (RDF+Lime +Sulphur + Boron) gave highest number of siliqua plant-1 (142), number of seeds siliqua-1 (15.00), grain yield (1,315 kg ha-1), stover yield (3,068 kg ha-1) and oil content (35.83%). Results further indicated that in soil fertility, the available nutrients (N, P, K, Ca, S and B) has found significantly enhanced with combined application of RDF, lime, sulphur, and boron over other treatments at harvest. Increased in yield and yield attributes of mustard may be due to different roles played by calcium, sulphur and boron in plant metabolic activity and its regulatory effect on other element and also helped in improvement of physico-chemical properties of soil which ultimately improved the availability of macro-micronutrients to the

crop. It is inferred that the combined application of lime, sulphur and boron under the present investigation is beneficial for increasing productivity and soil fertility status of rapeseed under acidic soil of Manipur. However, the results are of one season. Further experimentation is needed to have the right recommendation of lime, sulphur and boron nutrition for rapeseed for a particular soil and climatic situation.

Assessment of the effect of nitrogen, phosphorous and rhizobium application on pea (*Pisum sativum* L.) yield in the Arunachal Pradesh Region

CHUPPA WANGSU
Department of Agronomy, Rajiv Gandhi University, Rono Hills, Doimukh, Arunachal Pradesh

The study was undertaken in Karsingsa, Arunachal Pradesh during the rabi season of 2021-2022 to assess the effects of nitrogen, phosphorus, and rhizobium culture treatment on Pea (*Pisum sativum* L.). The experiment contained three levels of phosphorous (P1, P2, P3 @ 0, 30, and 60 kg P_2O_5 ha^{-1}) and two levels of nitrogen (N1, N2 @ 0 and 20 kg N ha^{-1}) as well as rhizobium culture (R1, R2 @ 0 and 300 g ha^{-1}). In three replications, 12 treatment combinations were tested using Factorial Randomised Complete Block Design (FRBD). The KK-10 pea variety was sown at 40 cm x 10 cm spacing. The results showed that combining nitrogen and phosphorus with rhizobium culture greatly boosted pea production. Among the treatments, T12 [i.e., 20 kg N ha^{-1}+60 kg P_2O_5 ha^{-1}+300 g Rhizobium culture (N2R2P3)] application differed significantly, increasing yield contributing attributes such as number of pods per plant (7.85), number of seeds per pod (12.62), dry weight (5.95 g), seed yield (37.25 q ha^{-1}), stover yield (79.85 q ha^{-1}) and harvest index (32.07%). N2R2P3 may be appropriate application rates for optimizing pea production while minimizing environmental effect. This finding can help Arunachal Pradesh address local agricultural difficulties, promote food security, ensure sustainability, and promote economic development.

Trends analysis of sugarcane status in the hill zone of Assam

BROTA.S. BEY[1*], SNEHAL ATHAWALE[2], RAM SINGH[3], SINGYALA CHIPHANG[4]
[1&2]Ph.D. Scholar, Professor[3], Assistant Professor[4] (Agricultural Economics), School of Social Sciences, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya, India.
[*]Corresponding email: brodbey@gmail.com

Sugarcane being one of the important cash crops of Assam occupy an area of 29 thousand ha with an average productivity of 37 t/ha. The sugarcane cultivation plays a vital role in rural economy by mobilising rural resources and generating income and employment opportunity. The major sugarcane growing districts in the state of Assam are Karbi-Anglong, Nagaon, Dima Hasao, Sonitpur and Golaghat where Karbi Anglong and Dima Hasao districts comprise the Hill Zone in Assam where sugarcane is grown by and large under upland condition with the

requirement of intensive labour. The highest area under sugarcane cultivation was found in Karbi Anglong district with 7639 ha whereas, Dima Hasao district with 3420 ha. Although, sugarcane covers most of the area under cultivation but the productivity is slightly on a lower side though found significant. It is to be noted that most of the farmers in Karbi Anglong and Dima Hasao grow mainly the local varieties viz., *Nok k-er, Nok kelok* due to which their production is slightly lower. Moreover, the overall productivity growth of Assam was found declining in some of the district as a consequence of replacement of sugarcane area by tea crop owing to greater influence of large tea industries and the switch over from sugarcane to tea cultivation mainly due to higher labour requirement in sugarcane cultivation. Rapid urbanisation and migration of labour from rural to urban areas in search of better opportunities are also major contributing cause for the same. Therefore, in order to improve the productivity of sugarcane in the region it is recommended to disseminate the improve varieties of sugarcane with better management strategies to the Hills district farmers and improved post-harvest processing of sugarcane and develop alternative use of cane juice and other by product in the context of dwindling market scenario of sugarcane and jiggery along with enhancing the storability of Jaggery using low-cost methods.

A study on cultivation of gladiolus using organic liquid fertilizers for sustainable floriculture

M. JANGYUKALA[1*], HEMANTA LAISHRAM[1], LIMASUNEP OZUKUM[2]
[1]Dept. of Horticulture, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema -797106, [2]Dept. of Agricultural Economics, School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema -797106

The present experiment was conducted during the year 2021-22 in the Research farm of Horticulture Department, NU:SASRD to find out the effect of organic liquid fertilizers viz., Effective micro-organisms (EM), Indigenous Effective micro-organisms (IEM) and Jeevamrutha on the growth, flowering, corm production, soil fertility status and plant nutrition behaviour of gladiolus (*Gladiolus grandiflora* L.). The experiment was planned in a Randomized block Design (RBD) with 8 treatments. The results revealed that the maximum spike length (89.62 cm), number of florets per spike (10.47) and number of corms per plant (1.76) were received under Treatment T_3, i.e. application of IEM (500 ml activated IEM m^{-2}). Application of EM recorded the earliest days to sprouting (6.83 days), for spike initiation (68.48 days), first floret opening (74.24 days) and harvesting of spikes (7.91 days). Maximum plant height (108.09 cm), shelf life (9.35) and vase life of spike in distilled water (11.17) was recorded in Treatment T_6, i.e. 50% RDF + 50% IEM. The nitrogen and phosphorus content (4.33% and 0.011%) in index leaves was highest in T_2 (EM) and T_3 (IEM) respectively. In corms, highest nitrogen content (3.08%) was in RDF and phosphorus content (0.016%) was in T_3 (IEM). Highest available N (961.71 kg ha^{-1}), available P (61.96 kg ha^{-1}) and available K (516.50 kg ha^{-1}) in soil after harvest was obtained with T_2 (EM). The highest organic carbon content (2.81%) was recorded in T_5 i.e., 50% RDF + 50% EM. The maximum benefit:cost ratio was observed under treatment T_3 i.e. application IEM in comparison with the other treatments.

The results proved that EM and IEM are promising organic liqiud fertilizers. It is a solution for cost efficient intergrated nutrient management for sustainable floriculture.

Soil moisture conservation measures: A strategy towards double cropping in jhum ecosystem of Arunachal Pradesh

BADAPMAIN MAKDOH[1]*, LETNGAM TOUTHANG[2], AMPEE TASUNG[3], RAJESH KHAN[4], THEJANGULIE ANGAMI[5], L.K BHAISHYA[6], RAGHUVEER SINGH[7], B.U CHOUDHURY[8]

ICAR Research Complex for NEH Region, AP centre, Basar, Arunachal Pradesh-791101
**Corresponding author: bmakdohicar@gmail.com*

Jhum cultivation is one of the predominant traditional systems of cultivation in most parts of Arunachal Pradesh. But, it is a very tedious practice and economically unviable system of farming as far as profitability is concerned. As per the trend of the rainfall pattern during post rice harvest (August-January) the region received over 800-1000mm which could possibly support water requirement for post *kharif* crops alongside soil moisture conservation. Considering the problems of low system productivity and economic output of jhum farming, the idea of taking double cropping in jhum was hypothesized. A field experiment was conducted in jhum field at the Research farm, Gori, ICAR RC, Arunachal Pradesh centre, Basar. Immediately after harvest of jhum rice, various soil moisture conservation (SMC) measures were imposed. The experiment was laid out in factorial RBD with five (5) SMC measures *viz*., T_1: No residue with no land modification, T_2: Paddy straw mulching after harvests @ 2t/ha, T_3: Double mulching using weed biomass (fresh @10 t/ha) at growing stage+ S_1, T_4: Conservation furrows after 2 rows interval+ in-situ paddy straw retention, T_5: Contour trenches at 2 m intervals + in-situ paddy straw retention, followed by three (post *kharif*) crops *viz*., C_1-Frenchbean, C_2-Green gram and C_3-Buckwheat. The results revealed that SMC measure retained more moisture which was up to the tune of 17% or more when compared to control. With respect to yield performance, frenchbean (green pods) yield was 21-45% higher in SMC measures over the control. Similarly, yield of greengram and buckwheat was 7-25% and 6-24% higher over the control treatment, respectively. The highest grain yield of greengram was observed in T_4 (4.94 ±0.38 q/ha) and least in control (3.94 ±0.03 q ha^{-1}). The rice equivalent yield was highest in T_2 (3630.4 kg/ha) which was at par with T_3 (3605.2 kg/ha) and T_4 (3524 kg/ha) and least in T_1 (2762.8 kg/ha). The highest value of number of pods/plant in frenchbean and greengram was observed in mulching. The per cent increase in WUE in frenchbean was 41.14 %, 38.86% and 36.26% in T_2, T_3, and T_4 over the control. In green gram the highest WUE value was registered in T_4 which was 25% higher over control. As indicated from the study, it can be concluded that mulching and conservation furrows could be the effective SMC measures for taking subsequent crops for double cropping in jhum ecosystems in the mid-hills of Arunachal Pradesh.

Effect of pruning on yield and quality of King Chilli (*Capsicum chinense* Jacq.) inside naturally ventilated polyhouse

M BILASHINI DEVI*, V.K. VERMA, H.D. TALANG, H. RYMBAI, L. JOYMATI, B.U. CHOUDHURY
ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Corresponding email: bilashini1712@gmail.com*

The present investigation was undertaken at Horticulture Farm, ICAR Research Complex for NEH Region, Umiam, Meghalaya with the main objective of studying the influence of pruning on vegetative, fruiting, yield and quality trait of three King chilli (*Capsicum chinense* Jacq.) local lines viz., ML-3, ML-5 and ML-7. The experiment consisted of three intensities of pruning i.e. two shoots, four shoots and un-pruned (control) replicated thrice in factorial RBD. The results revealed that the tallest plant (183.33 cm) and significantly early flowering (55.03 days) was recorded in four shoots pruning system followed by two shoots pruning system. The number of fruits per plant (140.33) was recorded highest in the plants when left unpruned however maximum average fruit weight (8.18 g) was recorded in two shoots pruning system. The highest fruit yield per plant (2.53 kg) was recorded in four shoots pruning system followed by two shoot (2.38kg) and unpruned (1.82kg). However, it was also observed that there was negligible influence of pruning system on Capsaicin content of the lines under study.

Mechanical and manual Increase productivity of direct seeded organic rice in acidic soil of Meghalaya

AMIT A. SHAHANE[1]*, H. KENCHARADDI[2], U. K. BEHERA[3]
Assistant Professor, College of Agriculture (CAU-I), Kyrdemkulai, Meghalaya, India, 793105 Dean (Former), College of Agriculture (CAU-I), Kyrdemkulai, Meghalaya, India, 793105
**Corresponding email: aashahaneagro@gmail.com*

A field experiment was conducted at Instructional Farm of College of Agriculture (CAU-I), Kyrdemkulai, Meghalaya, India in 2022 (wet season- June to November, 2022) to evaluate manual and mechanical weeding in rice (Ariz Gold) for their capacity to influence the growth and yield. The experiment was planned in randomized block design involving seven treatment viz., T1: Control (farmer practice); T2: Manual weeding at 25-30 DAS and 45-50 DAS; T3: Manual weeding at 25-30 DAS,45-50 DAS and 60 DAS; T4: Mechanical weeding at 23-25 DAS and 45-50 DAS; T5: Manual weeding at 25-30 DAS followed by (fb) mechanical weeding at 45-50 DAS; T6: Mechanical weeding at 23-25 DAS fb manual weeding 45-50 DAS and T7: Weed free. Sowing of rice (Arize gold) was done in upland condition with direct seeding under rainfed organic production system. The growth and yield attributes studied (plant height, tiller/m2, filled and unfilled spikelets length and weight of panicle) was unaffected due to applied treatment except control (which found statically inferior to all other treatments). The tillers production at harvest varies from 129 to 231 per m2 with lowest and highest control and

weed free plot. The rice growth was suboptimal which can be seen from values for growth and yield attributes. Low soil fertility, washing of manure and delayed sowing are some of the important reasons for poor growth and yield. The grain yield varies from 596 kg/ha to 1064 kg/ha; while for straw yield it varies from 1806 to 3223 kg/ha. The yield advantages was 457.3, 463.3 and 396.6 kg/ha with two time manual weeding, three time manual weeding and two time mechanical weeding, respectively. On statistical terms, all treatment remains on par for grain yield (except control); while for straw yield, three times weeding and weed free treatment found statistically superior over Mechanical weeding at 23-25 DAS fb manual weeding 45-50 DAS. In nut shell, two times manual weeding will be best treatment considering yield achieved; while it is conditioned by weed population dynamics and crop growth response.

Assessment of growth, yield attributes and economics of king chilli grown under protected condition in mid hills of Meghalaya

UTPAL BARUA*, MOKIDUL ISLAM
KVK Ri Bhoi, ICAR RC for North Eastern Hill Region, Umiam, Meghalaya - 793103
**Corresponding email: ubarua@rediffmail.com*

'Bhut Jalokia' or 'Ghost chilli' is one of the types King Chilli (*Capsicum chinense* Jacq) grown in entire North Eastern states. It is used for various culinary preparations, which is preferred due to its pungency and aroma. King chilli is one of the hottest chillies in the world, which once occupied the number one position among the hottest chillies of the world. The unique climatic condition of Meghalaya favours the cultivation of this crop, which could contribute to the economic upliftment of the tribal farmers due to its high value and demand. Due to long rainy season, the cultivation of king chilli under open condition proves to be less remunerative. The present demonstration was carried out in five villages of Ri Bhoi district of Meghalaya. King chilli was cultivated inside naturally ventilated low cost polyhouses as well as under open field condition at farmers' field during 2020-2023. The horticultural traits studied viz. plant height, number of primary branches, fruit length, fruit width, number of fruits per plant, average fruit weight, number of seeds per fruit, 100 seed weight, average yield per plant and yield showed significant increase than that of cultivation under open field condition. The number of days to first flowering (61.35 days) and days to first harvest (85.50) was less than that of crop under open condition. This resulted in early crop maturity (161 days) with more yield (78.40 q/ha) and larger fruit size inside polyhouse. The benefit cost ratio of king chilli cultivated inside polyhouse recorded to be 1.06, 2.95 and 3.06 in the first, second and third year of demonstration. The extension gap, technology gap, technology index and increase over farmers practice were 25.65 q/ha, 11.60 q/ha, 12.89% and 48.63% respectively. Thus, it can be concluded that cultivation of king chilli under low cost polyhouse is remunerative.

Molecular characterisation of Bt from Manipur region

MANJU MATHEW, KENNEDY N., GURUMAYUM ROBERT DANIEL,

MAHESH PATHAK, EKHUPAR GARY SUTING
School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya-793103

Bacillus thuringiensis (Bt) is a naturally occurring gram positive, rod-shaped, motile, facultative anaerobic, spore-forming soil bacterium widely used as an eco-friendly bio-pesticide against pests in agriculture and forestry. During unfavourable conditions, the bacterium sporulates producing spore and parasporal body, the latter composed mainly of one or more insecticidal proteins in the form of crystalline inclusions. Different subspecies of Bt can be effectively used against various insect pests such as Helicoverpa armigera, Spodoptera litura, Achaea janata, Plutella xylostella and Pieris brassicae. But many insect pests have developed resistance against existing Bt strains. North Eastern region of India is an unexplored and undisturbed area which may possess a diversity of Bt. Bt was isolated from 10 districts of Manipur from different ecological niches ranging from forests, hills and plains. Enrichment method and sodium acetate method was used to isolate the bacterium from the soil and water samples. Sodium acetate method yielded a greater number of Bt like colonies than the former method. These colonies are selected on the basis of the white to creamy colour and fried egg like morphology, the colonies can be raised or flattened too having a dried and rough appearance. Such colonies are selected and are examined under the phase contrast microscope for the crystal-like structures. The crystal-like structures are the confirmation for the bacterium selected to be Bt. 12 such colonies were selected which showed parasporal bodies under microscope. The further confirmation was done by PCR based detection using different universal primers like Cry I, Cry II, Cry III and with specific primers like Cry1Ac. The 12 samples showed positivity in this molecular characterisation. So, it can be concluded that these are having Cry I genes which is Lepidopteran specific. The development of resistance to Bt impose a major threat in the successful deployment of Bt. Therefore, our study will help in isolating and identifying novel Bt strains of NE region which may carry potent insecticidal proteins. Further, the native strains will perform better as they are adapted to the local climatic conditions and crop settings.

Faunistic analysis of fruit fly species in horticultural fruit crops in mid-hills of Meghalaya

HISSAY C. BHUTIA, KENNEDY N., K.J. DAVID, N. UMA DEVI, MAHESH PATHAK
School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University, Umiam (Meghalaya) - 793103

India with its diverse climatic conditions and other favourable factors is consistently making progress in production of horticultural crops. However, pests and diseases are an utmost barrier to the growth of the horticultural sector. Among many of the known pests, fruit fly (Diptera: Tephritidae) is recognized worldwide as a major threat to the horticultural industry including India. These flies are abundant in the tropical, subtropical and temperate region of the globe and known as the largest family of order Diptera. The attack of fruit flies reduces the yield and quality of the fruit while also making them vulnerable to secondary infections. As fruits are

export oriented horticultural commodity, there is also an increasing fear of human mediated migration of fruit fly pest species causing serious concerns for international and domestic quarantine agencies. In order to formulate the pest management plans, it is important to correctly identify and understand the diversity of the local fruit fly fauna. The north-eastern states of India have an exceptionally rich biodiversity of insect pests and their natural enemies. Despite of existence of huge biodiversity of insects, very little information is available on species composition of fruit flies in the NE region including Meghalaya. Therefore, considering the importance of fruit fly, the present study has been conducted in Ri-bhoi district of Meghalaya to collect and identify various fruit fly fauna from horticultural fruit crops and to study its diversity, richness, and abundance. Parapheromonic traps (Methyl eugenol and Cue-lure) and food baits (ProteineX and Yeast) were used for sampling. Fruit fly fauna collected at weekly intervals were identified by using standard protocol based on established taxonomic keys and unidentified specimens were sent to NBAIR, Bangalore. A total of 20 species belonging to 5 genera of tephritid fruit flies were recorded from the study area viz., Bactrocera, Zeugodacus, Acroceratitis, Themara and Trypeta. The most dominant genus observed was Bactrocera. Methyl eugenol and Cue-lure attracted more fruit flies from the Bactrocera and Zeugodacus genus respectively, whereas food baits attracted more fruit flies from the Zeugodacus genus. As a result, it is highly recommended that fruit flies should be monitored and managed using a combination of traps and baits. Therefore, adequate knowledge of the different lures and traps and the factors affecting their efficiency is important for successful use of lures and traps as a tool for IPM and ecological studies.

Effect of land use on phosphorus fixation in acidic soil of Mizoram

LUNGMUANA*, Y.B. KUMAR, S. DOLEY
ICAR RC NEH Region, Mizoram Centre, Kolasib, Mizoram-796081

Soil acidity in north eastern hill region (NEHR) is one of the main reason for lower crop productivity. The extend of soil acidity in the region may differ across locations depending on the topography, climate etc ranging between 4.5 to 6.5. Soil acidity reduces the availability of phosphorus and therefore, assessment and knowledge on soil properties related to P fixation is important for P management. In this experiment, six land use system from three depths (0-15, 15-30 and 30-45 cm) in the foothills of Kolasib district has been collected. Mean of three soil depth results revealed that the soil pH was highest in lowland rice (LR; 6.1) to teak (5.06), available P from LR (8.3 mg kg^{-1}) to oil palm (O; 3.81 mg kg^{-1}), total P from rubber (R; 468.09 mg kg^{-1}) to T (409 mg kg^{-1}). The acid phosphatase activity ranges between 300 to 900 µgPN $g^{-1}h^{-1}$ and F exerted significantly higher activity 754 µgPN $g^{-1}h^{-1}$ followed by A (587.27 µgPN $g^{-1}h^{-1}$) and least by LR (316 µgPN $g^{-1}h^{-1}$). The quantity of P fixed decrease with the increase in added P. The P fixation was highest for Teak (86.63%) and lowest for rice (71.03 %). Across the soil depth, the adsorption maxima through the Langmuir isotherm (Lmax) was highest for T (415.7 ug g^{-1}) to LR (212.03 ug g^{-1}) and constant related to the bonding energy (K) varies between 0.3 to 0.56 mL ug^{-1}. The bonding energy (K) has significant positive relationship with

dithionite-Al_2O_3 and oxalate-Fe_2O_3 and SOC implying that these soil properties govern the P sorption.

Technological intervention for sustainable ginger production in the hill's ecosystem of the Eastern Himalayas range

HEIPLANMI RYMBAI*, V.K. VERMA, T. RAMESH, H.D. TALANG, VANLALRUATI, M BILASHINI DEVI J. MAWLEIÑ, ANUP DAS, B.U. CHAUDHURY
Division of System Research and Engineering
ICAR Research Complex for NEH Region, Umroi Road, Umiam
**Corresponding email: rymbaihort@gmail.com*

Ginger (*Zingiber officinale* Rosc.) is an important commercial spice cultivated for its aromatic rhizomes, which are used both as spices and as medicines. Ginger has been grown under shifting/Jhum cultivation practices which are an age-old inherited skill adopted by hilly farmers. The presents investigation was carried out to study the comparative performance of the improved and traditional farming practices on yield and quality of the ginger, and their economics. Result showed a significant ($p< 0.05$) effect of ginger production practices and slope gradients on soil quality, available nutrients, nutrient and soil microbial biomass. A higher uptake of ginger for N (47.90±0.62 $kgha^{-1}$), P (9.43±0.38kg ha^{-1}) and K (72.88±0.39$kgha^{-1}$) was noted under integrated production system (IPS). The interaction of organic production system (OPP)* Gentle Slope (GS) had the highest SMBC, SMBN and SMBP, which was at par with IPS*GS for SMBC and SMBP. A strong positive correlation of soil pH with SMBC (0.942**), SMBN (0.831**), and SMBP (0.938**); and SOC with SMBC (0.956**), SMBN (0.881**), and SMBP (0.947**). Our result also indicated a negative correlation between SOC and slope gradients (-0.652**). Similarly, Yield and quality traits of ginger were significantly ($p< 0.05$) affected due to cultivation practices and slope gradients in ginger cultivation. Ginger grown under IPP produced the highest fresh rhizome yield (17.06±0.35tha^{-1}), dry matter (20.28±0.33%) and oleoresin (6.76±0.02%). However, crude fibre was noted to be the highest under farmer's practices (6.45±0.04%). Similarly, among the slope gradients, gentle slope (<20%) had the maximum fresh rhizome yield (16.40±0.36 tha^{-1}), dry matter (20.09±0.15%) and oleoresin (6.95±0.01%). However, the lowest value for all the traits was recorded at steep slope (>40%), exception of crude fibre (6.39±0.02%), which is the highest. The IPP improved the soil quality and ginger yield and quality. In addition, the net energy (36552.47 MJ ha^{-1}), energy use efficiency (2.49), energy productivity (0.69 Kg MJ^{-1}) and energy profitability (1.49) were also found to be the highest under IPP.

Performance of short duration improved paddy (cv. RC Maniphou-13) for enabling early planting of rabi crops to escape terminal drought

AZRIEL M. TARIANG[1*], A.K. MOHANTY[1], A.K. SINGHA[1], N.A. SINGH[2], F. DKHAR[1], R. NANGBAH[1]

[1] ICAR-ATARI, Umiam, Meghalaya, [2]SMS, KVK, Ukhrul, Manipur
*Corresponding email: azrieltariang@gmail.com

Paddy (*Oryza sativa*) is a staple crop in most North Eastern Hill states, accounting for 2.27% of total paddy acreage in the country. Rice productivity in the region is just 2.0 t/ha, which is lower than the national average productivity of 2.5 t/ha. It has been observed that, due to the fragile hill ecosystem and severe climatic anomalies in the North Eastern region, the majority of rice cropped acreage is left fallow after harvesting due to restricted soil moisture availability to go for second crop in the *Rabi* season. Without disrupting the region's rice productivity trend, there is a need to increase unit area productivity by including a second crop (*Rabi*) followed by rice, so that the terminal drought phase can be avoided. The present study evaluates the effectiveness of the short duration paddy variety RC Maniphou-13 as a climate resilient technological intervention which was conducted in the farmers' fields of Ukhrul District, Manipur. The result indicated that the variety had a short growing period (90-105 days), which is excellent for early summer and pre-kharif. The crop was sown in May and harvested during August to early September. As per the data, it was observed that the average yield of the improved variety was 34.15 q/ha whereas the average yield of the farmers' variety was 25.4 q/ha which is 34.45 percent increase over the local varieties cultivated by the other farmers, and the returns in terms of benefit cost ratio were 2.03 and 1.52, respectively. Through this intervention, the farmers were able to proceed towards early planting of rabi crops like field pea and garden pea in the month of August itself in order to utilise the residual soil moisture available in the field and to avoid the terminal drought period. This practice allowed the farmers to reduce the frequency of irrigating *Rabi* crops, which otherwise would have increased the cost of cultivation and thereby have an impact on the farmer's overall net income. The demonstration of paddy var. RC Maniphou-13 was therefore proved to be a suitable climate resilient technological intervention for managing improved production and returns per unit area each year in the region.

Dynamics of rainfall and temperature in Lepa Rada District of Arunachal Pradesh, India

N. UTTAM SINGH, NIVETINA LAITONJAM*, PAMPI PAUL, KAMNI P. BIAM, C. GOWDA, D. CHAKRABORTY, A. ROY, ANJOO YUMNAM, V. K. MISHRA
ICAR-Research Complex for North Eastern Region, Umiam, Meghalaya
**Corresponding email: nivelaitonjam@gmail.com*

Analysis of climatic variables is now essential for the detection and attribution of climate change, and researchers from all over the world, including India, have given it a great deal of attention. The present study used station data for the last thirty-nine years (1983-2021) in analyzing variation of rainfall and temperature in Lepa Rada district of Arunachal Pradesh. Parametric (linear regression) and non-parametric (Mann-Kendall and Sen's Slope) methods were used. The study observed that annual minimum temperature decreased at the pace of 0.033^{o}C per year while annual maximum temperature increased at the rate of 0.115^{o}C per year.

Lepa Rada also experienced significant increasing trend in seasonal (i.e., spring, summer, autumn and winter) maximum temperature during the study period. On the contrary, significant declining trend in winter rainfall was observed in the study area at the pace of -2.809 mm per year. The analysis of trend and variability in rainfall may be useful for planning the efficient use of water resource and management in the study area. Further, the analysis of variability in temperature may help researchers to extend work on effect of temperature on yield of major crops in the study area.

Long term impact of diverse land use system on soil carbon and microbial biomass carbon in hill ecosystem of Meghalaya

NONGMAITHEM RAJU SINGH*, B.U. CHOUDHURY, ASHISH SINGH
ICAR-Research Complex for North Eastern Hill Region, Umroi Road, Umiam, Meghalaya
Corresponding email: rajuforestry@gmail.com

The conversation of primary pine forest to the cultivated land use systems brings a significant change in the soil carbon. In the uplands of North Eastern Hill region of India (Meghalaya), such practices are very prevalent. So, therefore, we have made an attempt to evaluate the long term response of converting primary pine forest to different agroforestry systems (AFSs), cropland (seasonal cultivation) and traditional shifting cultivation on the soil organic carbon (SOC) and soil microbial biomass carbon (SMBC) up to a soil depth of 0.30m. We took the nearby primary pine forest as a reference site. Agroforestry systems were further classified as multipurpose trees (MPTs) which include Alder, Grevillea, and Som while in the fruit trees based agroforestry systems (FBAFSs) include peach, pear, plum, guava, Assam lemon and Khasi mandarin. Result revealed that after >30 years of conversion of primary pine forest to MPTs based AFSs and FBAFSs recorded a marginal increase 8.5% to 13.6% SOC concentration respectively over pine forest (1.72%) in the surface soils (0.0-0.15m). In contrast, the SOC concentration declined in seasonal cultivated lands (Shifting cultivation and cropland) from 5 % to 18.6% in the surface soils (0.0-0.15m). Similarly, MPTs and FBAFSs recorded 31.6 to 31.8% higher SMBC over the pine forest (509.6µg/g) in the surface soils (0.0-0.15m). While SMBC declined in the cultivated land uses (8 to 21%), more particularly in the shifting cultivation (-21%) compared to the pine forest in the surface soil. There was overall trend of decreasing SOC and SMBC concentrations across the different land use systems in sub-surface layer (0.15-0.30 m) and more intense decrease was observed in cultivated land use (SOC 17.9 to 29.9%; SMBC 23 to 26%). Profile sum stock of SOC (up to 30cm) ranged 51.2 to 66.7 Mg ha^{-1} across the different land use systems. The severity of soil acidity also increased due to the traditional and seasonal cropping, a 0.75 to 0.85unit decline in the surface and 0.79-0.85 units in the subsurface soils under shifting cultivation (lowest soil pH: 4.36) compared to the agroforestry systems (MPTs and FBAFSs). So, we suggest that the adoption of agroforestry systems (MPTs and FBAFSs) as a replacement of shifting cultivation and seasonal croplands to not only restoring the soil carbon and microbial biomass carbon but also ensuring the food security of the north eastern hill region and similar ecosystems of India.

Performance of French bean variety Arka Sharath in East Garo Hills

T.A. SANGMA[1], B.S. RAJAWAT[2]
[1]SMS, Horticulture, KVK, East Garo Hills, [2]Senior Scientist & Head, KVK, East Garo Hills
*Corresponding email: trudytengse@gmail.com

Considering the hilly terrains, horticultural crops occupy prime position with the agricultural spectrum. The region's agriculture system is predominantly traditional and organic by default. Cultivation of pulses is gaining importance all over the world due to their increasing demand and high market value. In India, pulses are grown mostly on marginal and sub-marginal lands without proper inputs. French bean is a short duration, non-traditional legume and one of the precious and highly relished pulse crop of North East India. The agro-climatic conditions in Meghalaya is favourable for the cultivation of French bean throughout the year in the higher altitudes of Khasi hills, while in Garo hills it is mostly cultivated during winter. Although its cultivation is widely done, the local variety gives a low productivity. Hence this trial was conducted using a HYV Arka Sharath, a dwarf variety developed by IIHR, Bengaluru to compare against the local variety for two years 2019-2020 and 2020-2021 at the farmer's field, Megagre, Megapgre, Nengmandalgre and Chachatgre of East Garo Hills district with 04 demo plots in 01 hectares. The details of the technology were mainly, seed Rate: 50-60kg/ha, Sowing time: October, Spacing: 40X10cm and Fertilizer Dose: FYM @ 10 t/ha + vermicompost 2.5 t/ha + neem cake 150 kg/ha. This demo unit was compared against the framer's practice. The economic analysis indicated that Arka Sharath, on an average resulted in 118 q/ha production while the local variety was only 93 q/ha. The benefit cost ratio of Arka Sharath was 3.49 on an average for two consecutive years, while the local variety acquired a benefit cost ratio of only 3.05. From the present trial, it can be suggested that a scientific and organic technology needs to be adopted by the farmers and opt for a HYV French bean for cultivation inorder to meet the growing demand for the crop. Farmers are satisfied with the variety Arka Sharath compared to local due to better productivity and short duration.

Morpho-Biochemical characterization of Khasi Mandarin (*Citrus reticulata*) for future sustainability and livelihood

DR. D.P. DUARAH[1*], DR. R.P. DAS[2], DR. S. SAHA[3], DR. D. BORDOLOI[4], DR. M. NEOG[5], DR. D. N. KALITA[6]
[1,6]Krishi Vigyan Kendra, Kamrup, Assam Agricultural University, Kahikuchi, Guwahati, [2]Department of Horticulture, Assam Agricultural University, Jorhat, [3]Department of Horticulture, SCS College of Agriculture, Assam Agricultural University,Chapar, Dhubri, [4]Krishi Vigyan Kendra,Karimganj, Assam Agricultural University, Akbarpur, [5]Directorate of Extension Education, Assam Agricultural University, Jorhat
*Corresponding email: dorodipriyomduarahaau@gmail.com

Khasi Mandarin (*Citrus reticulata*), commonly known as '*Komola tenga*" or is a commercially popular subtropical citrus species in the North Eastern Himalayan region of India including Assam exhibiting common reproductive trait polyembryony. It exhibits a tremendous variation in morpho-biochemical traits among its population due to traditionally propagated through

seeds. People follow this variation to identify different ecotypes of Khasi mandarin. Facts of genetic diversity is essential for betterment of fruits in future. Therefore, an investigation was undertaken during 2017-2019 on to study the variability of Khasi Mandarin by cluster analysis and Principal Component Analysis. Five Khasi Mandarin trees between 10-20 years of age were selected in each district comprising of thirty five (35) numbers of trees in seven districts. Each tree was given a number for future identification. The accession number consisted of letter "AKM" for Assam Khasi Mandarin, 01 to 07 for districts eg. Tinsukia, Lakhimpur, Jorhat, Golaghat, Karbi Anglong, Dima Hasao, Kamrup and T_1 to T_5 for plant number. Wide range of variability was observed among the selected Khasi mandarin accessions for qualitative and quantitative characters of tree, leaf, flower, fruit and seed. The maximum fruit weight (145.29g) was recorded in AKM03T2 and minimum (110.80g) was in AKM01T4. In terms of biochemical constituents, the highest TSS was recorded in AKM07T2 (11.9 ^{0}Brix) and lowest in AKM06T2 (6.22 ^{0}Brix). Some morphological traits *i.e.* fruit volume, fruit length, fruit seeds per fruit, juice percentage showed significant variation among different districts. Three different fruit shapes were recorded viz. spheroid, pyriform and oblate. Variations in pulp colour *i.e.* orange, light yellow and dark orange were recorded in in the selected mandarin oranges. No groups were formed based on geographical location indicating that qualitative traits were largely influenced by genetic factor. The principal component analysis of quantitative traits gave 33 principal components, but in our study eigen values of the principal component for quantitative traits indicated that first 4 components accounted for 91.7% of the total variation. On the other hand, eigen values of the principal component for qualitative traits indicated that first 16 components accounted for 90.2% of the total variation.

A study on the performance of different rapeseed-mustard varieties under late sown condition of Jaintia Hills of Meghalaya

KHRAWBOR DKHAR[1*], T. GOHAIN[2], GADE RAMANA REDDY[3], LEISHANGTHEM MOMO SINGH[4], NORBU TAMANG[5]
Department of Agronomy, SASRD, Nagaland University, Medziphema-797106
**Corresponding email: khrawbdkhar2007@gmail.com*

A field experiment entitled "A study on the performance of different rapeseed-mustard varieties under late sown condition of Jaintia Hills of Meghalaya" was conducted in The District and Local Research Station, Jowai, Meghalaya, during *rabi* season of 2020-2021. The experiment consisted of eight rapeseed-mustard varieties namely PM-26, PM-27, NRCHB-101, SURBHI, BULLET, ANMOL, LOCAL (Meghalaya), LOCAL (Assam) which were laid out in Randomized Block Design (RBD) with three replications, to study the growth and yield performance of different rapeseed-mustard varieties and as well to find out the best suitable variety under late sown condition of Jaintia Hill of Meghalaya. The results revealed that there was a significant difference among all the rapeseed-mustard varieties for all the growth and yield attributes studied. Among the eight rapeseed-mustard varieties, it is found out that the variety NRCHB-101 perform the best and very suitable to the condition, followed by the variety SURBHI, BULLET and ANMOL. The variety (NRCHB-101) showed significantly higher

plant height (151.77 cm), number of branches^{-1} (13.25), number of siliqua plant^{-1} (159), seeds siliqua^{-1} (13.25), seed yield (1631.04 kg ha^{-1}), stover yield (4261.84 kg ha^{-1}) and oil yield with 442.56 (kg ha^{-1}). Further, mean result of the study revealed that highest gross returns (Rs 75841.51), net returns (Rs 52561.51) and B:C rartio (3.25) was recorded in the variety NRCHB-101. Therefore, NRCHB-101 can be recommended for cultivation under late sown condition of Jaintia Hils of Meghalaya.

Small Millets: Promising crop with nutrient powerhouse in hill farming

MAHESH KUMAR*, PAVANKUMAR GOUDAR, ANIL KUMAR TRIPATHI
College of Agriculture, Central Agricultural University (I), Pasighat, Arunachal Pradesh
** Corresponding email: maheshbiochem@gmail.com*

Millets are regarded as climate smart crops because of their ability to grow in adverse condition as nutrient poor soil, lesser irrigation condition and an easily be grown in hilly terrain. They are short duration crops with high photosynthetic efficiency and C4 carbon fixation ability. Finger millet (*Eleusine coracana*), foxtail millet (*Setaria italic*), little millet (*Panicum sumatrense*), proso millet (*Panicum miliaceum*), kodo millet (*Paspalum scrobiculatum*), pearl millet (*Cenchrus americanus*) and barnyard millet (*Echinochloa* spp.) are some of the commonly cultivated small millets in India. They are loaded with health important minerals (calcium, phosphorus, magnesium, Zinc etc.), vitamins (β-carotene, Thiamine, Riboflavin, Niacin etc.), proteins, essential amino acids, fatty acids, dietary fibers, and other bioactive phytochemicals. Even though, small millets are nutritionally & therapeutically rich and climatic resilient crop, still presently, they are marginally cultivated crops. There is a need to popularise small millets consumption as food and their cultivation. The small millets can be one of the valuable crops of future agricultural system.

THEME - 3

Crop improvement and protection challenges

The efficacy of specific insecticides, in conjunction with various okra cultivars were studied, for the management of *Earias vittella* (Fabricius) (Lepidoptera: Noctuidae) in Assam, India

CHADA ANU REDDY*, ANJUMONI DEVEE, MANISHA URANG, DILIP KUMAR SAIKIA
Department of Entomology, Assam Agriculture University, Jorhat, Assam, India.
**Corresponding email: anureddychada@gmail.com*

The objective of the research conducted was to determine the efficacy of particular insecticides and three widely grown okra cultivars against *Earias vittella*, the principal insect pest that affects okra crops. The experiment was conducted at the Experimental Farm of the Department of Horticulture, Assam Agricultural University, Jorhat, Assam, during *kharif*, 2020 and *spring-summer*, 2021. The results showed that the trichomes present on both the adaxial and abaxial sides of the leaves in the okra cultivars Arka Anamika, Pusa Sawani, and S-51 played a significant role. The study revealed that the insect pest population and the percentage of fruit infestation increased over time in the control plots. The treatment lambda cyhalothrin 5% EC @ 15gm *a.i.*/ha + S-51 demonstrated the highest percentage of fruit infestation (12.33 and 10.33 per cent in *kharif* and *spring-summer* respectively). In contrast, treatment chlorantraniliprole 18.5% SC @ 25 gm *a.i.*/ha + Arka Anamika had the highest average yield (58.70 q/ha) and high benefit-cost ratio (3.08:1). The findings of the study revealed that there was no significant variation among the cultivars concerning trichome density, except in the case of Arka Anamika. However, there was a significant difference in the insecticidal treatments for managing *Earias vittella*, and the insecticide chlorantraniliprole 18.5% SC @ 25 gm *a.i.*/ha proved to be the most effective, followed by emamectin benzoate 5% SG @ 8.5 gm *a.i.*/ha. In summary, the study indicated that the use of appropriate insecticides (chlorantraniliprole 18.5% SC @ 25 gm *a.i.*/ha) and the selection of the right cultivar (Arka Anamika), can significantly enhance the management of *Earias vittella* in okra crops. Moreover, the study provided valuable insights into the critical role played by trichomes in controlling insect pests in okra. The findings of this study can help farmers and researchers to improve the quality and yield of okra while minimizing the impact of insect pests.

Canopy architecture of bael tree influenced fruit quality and understory fodder production

R.K. PATEL, SUNIL KUMAR, MANJANAGOUDA, S.S., AVIJIT GHOSH, AMIT K. SINGH, DEEPAK UPADHYAY
GSM Division, ICAR-IGFRI, Jhansi-284003, UP
**Corresponding email: rkpatelicar@gmail.com, ram.patel1@icar.gov.in*

Bael cultivation in India has bright prospects owing to indigenous fruit of the country and gaining momentum among fruit growers as well as in Govt scheme due to its some unique quality like medicinal value, ability to grow well in the wasteland and problematic soil conditions. The canopy architecture management is one of the essential orchard management procedures which mould the tree for optimum light utilization and efficient cultural processes in the upcoming years. Plant growth, yield, fruit quality and crops cultivated beneath the shade of trees are all enhanced by improved light penetration into the canopy. Efficient canopy

management in bael orchards with proper utilization of their under storey spaces for fodder production assumes greater significance to decrease the fruit and forage scarcity. Present study conducted in bael cvs. CISHB-2 and NB-9 with four canopy architectures i.e., central leader system, modified central leader system, open centre system and untrained tree during 2021-22 to see the influence of bael tree canopy architecture on fruit and fodder production. Guniea grass grown as understory of bael tree recorded higher yield under open centre system (17.0 t/ha FW & 5.27 t/ha DW) than untrained tree (15.0 t/ha FW & 4.35 t/ha DW) whereas grass yield in sole pasture recorded 15.33 t/ha as fresh fodder and 4.91 t/ha as dry matter. Tree growth, yield and fruit quality attributes were significantly influenced due to different bael canopy architectures. Bael tree canopy developed as open centre system recorded higher fruit yield, yield efficiency and productivity efficiency followed by central leader system than modified leader system and untrained tree. The open centre system of canopy management also produced better quality fruit in terms of higher TSS, ascorbic acid, total sugar, total phenol and lower acidity than other system of canopy management.

Teasel gourd: Genetic diversity, population structure and strategies for crop improvement in North Eastern states of India

VEERENDRA KUMAR VERMA*, NIHARIKA DUTTA, AMIT KUMAR,
M. BILASHINI DEVI, H. RYMBAI
ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya
**Corresponding email: verma.veerendra@gmail.com*

Teasel gourd (*Momordica subangulata* subsp. *renigera*) is an important dioecious, vegetatively propagated, underutilized cucurbit vegetable crop of India. Based on agro-morphological traits and polypoidy (allotetraploid, 2n = 4x = 56), it differs from other *Momordica* species of spine gourd. The fruits of the teasel gourd is rich in nutritional values like β-carotene and polyphenols content and also possesses hypoglycemic properties. It also protects and regenerates pancreatic β-cells. Additionally, it enhances both insulin secretion and insulin sensitivity, helping to manage Diabetes at all levels. The crops is grown most widely under the Legume (Indian bean) – Cucurbits (Teasel gourd) cropping system in the Brahmaputra and Barak valleys of the region. Due to wider adaptability, it is grown from plains to up to mid-hills. Genetic polymorphism amid plant species is a crucial factor for plant improvement and maintaining their biodiversity. Evaluation of genetic diversity amongst plant species is significant to deal with the environmental stress conditions and their effective involvement in the breeding programs. Hence, present investigation was undertaken during 2018-20, to assess the genetic diversity in teasel gourd based on morphological traits and microsatellite makers using 70 accessions including 8 males, collected from different parts of north eastern states of India. Wide variations were recorded for leaf, flower and fruit characteristics. Fruit weight ranged from 22.8 g to 129.3 g; fruit length 4.76 to 11.23 cm; number of fruits/plant 3.67 to 25.33 and yield per plant 0.15-2.65 kg, number of seeds per fruits 23 to 51.33 and 100 seed weight 12.60 to 36.3 g and vitamin-C content 44.80 to 79.68 mg/100g. Among the accessions, high yielding lines were RCTG-8 (2.6 kg) followed by RCTG-26 (1.79 kg), RCTG-20 (1.77 kg) and RCTG-15 (1.63 kg). Under

molecular analysis, out of 43 SSR markers 40 were found polymorphic and the polymorphism information content ranged from 0.08 (Sed-09) - 0.68 (McSSR-5). Cluster analysis based on Nei's genetic distance ranged from 0.25-0.69, indicating the presence of wider diversity in population. Among the individual the genetic diversity was 76.0% while within the individual it was 24%. Among the accessions, the proportion of accessions with admixture in male and females were few due to the different geographical origin and clonal propagation. Being a dioecious crop, it can be improved through mating by induction of hermaphrodite sex form using silver nitrate (500 ppm) in female accessions.

Screening of ricebean [*Vigna umbellata* (Thunb.) Ohwi and Ohashi] cultivars against pulse beetle [*Callosobruchus chinensis* (L.)] and correlation with physico-chemical parameters

KHRIEKETOU KUOTSU[1*], PANKAJ NEOG[1], IMTINARO L[1], RUMKI H. CH. SANGMA[2]
[1]*Department of Entomology, SASRD, Nagaland University, Medziphema Campus- 797106, Nagaland, India,*
[2]*Entomology Section, ICAR RC for NEH Region, Umiam- 793103, Meghalaya, India.*
**Corresponding email: khrieketoukuotsu@gmail.com*

Ricebean [*Vigna umbellata* (Thunb.) Ohwi and Ohashi] is an important food legume grown in Nagaland, India. It is a versatile underutilized pulse crop grown as a dry pulse and also used as green manure and fodder. Insect pests are one of the major constraints encountered and the pulse beetle, *Callosobruchus chinensis* (L.) is an important pest that causes considerable damage to *Vigna* seeds. An experiment was conducted during January-June 2019 and 2020 at the laboratory of the Department of Entomology, *School of Agricultural Sciences and Rural Development (SASRD)*, Nagaland University in a Completely Randomized Design (CRD) with three replications to determine the basis of resistance among different ricebean cultivars against pulse beetle. A total of 16 local ricebean cultivars were used for screening against pulse beetle, *C. chinensis* using no choice test. Correlation studies between different biological parameters of *C. chinensis viz*., oviposition, adult emergence, development period, growth index, per cent infestation and per cent weight loss and physico-chemical parameters of different ricebean cultivars were worked out. In the study the physical characteristics *viz.*, seed size and seed index and biochemical contents *viz.*, protein, starch, phenol and tannin were found to be significantly influencing the host preference of the pest. Cultivars with higher protein and starch content were more susceptible while cultivars with higher phenol and tannin content were less susceptible. Based on the growth index, 3 cultivars *viz*., *Rhüjo, Akixi Anila* and *Manyhü Rhi* were found to be moderately resistant. These are potential bruchid-resistant cultivars and can be use in future ricebean improvement programs.

Breeding strategies of mustard for biotic stress resilience

ACHYUTA BASAK[1*], MOUMITA CHAKRABORTY[1], VICTOR SARKAR[2], PARIJAT DE[1], BAPPA PARAMANIK[3], MALAY KANTI MODAK[4]

[1] Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, W.B.- 736165, [2] Malda Krishi Vigyan Kendra, Uttar Banga Krishi Viswavidyalaya, Ratua, Malda, West Bengal, Pin-732205, [3] Dakshin Dinajpur Krishi Vigyan Kendra, Uttar Banga Krishi Viswavidyalaya, Majhian, Patiram, Dakshin Dinajpur, West Bengal, Pin-733133, [4]Institute of Agricultural Science, University of Calcutta, W.B.- 700073
*Corresponding email: achyutabasak51@gmail.com

Mustard [*Brassica juncea* (L.) *Czern*] is an important oilseed crop with high economic and nutritional value. However, it is frequently affected by biotic stresses such as insect pests, diseases, and weeds, which significantly reduce yield and quality. In recent years, various breeding strategies have been developed to enhance mustard's resilience against biotic stresses, including conventional breeding, marker-assisted selection (MAS), and genetic engineering.
Conventional breeding methods, including mass selection, pedigree selection, and hybridization, have been widely used to improve mustard for biotic stress resilience. These methods involve selecting the best-performing plants based on their observable traits, such as resistance to pests and diseases, and then crossing them to create offspring with desired traits. Although effective, these methods are time-consuming and rely on phenotypic selection, which may not capture all the underlying genetic architecture contributing to biotic stress resilience. Molecular Assisted Selection (MAS) is an effective molecular breeding approach that allows breeders to select plants with desirable traits based on molecular markers linked to stress tolerance. Several studies have reported the successful use of MAS in improving stress tolerance in mustard, particularly in resistance to diseases and pests. However, the success of MAS depends on the availability of high-density genetic maps and markers associated with stress tolerance. The use of genome editing and transgenic approaches in mustard breeding has the potential to introduce new and desirable traits into mustard rapidly. Transgenic mustard plants expressing various genes, such as those encoding insecticidal proteins or pathogenesis-related proteins, have shown improved resistance against pests and diseases. Several studies have reported the successful use of these approaches to improve stress tolerance in mustard. Quantitative trait locus (QTL) mapping and genome wide association study (GWAS) are genome wide molecular breeding strategies that allow the identification of genomic regions and candidate genes associated with stress tolerance. These approaches have been used to identify QTLs and genes linked to biotic stress tolerance in mustard. Omics technologies such as association mapping, introgressive breeding & NGS-based Bulked Segregant Analysis (NGS-BSA) are molecular breeding strategies that allow the identification of genes and proteins associated with stress tolerance also identify stress-responsive genes and proteins in mustard. These studies have led to the discovery of several genes and proteins involved in stress response pathways and provided insights into the molecular mechanisms underlying stress tolerance in mustard. This presentation aims to provide an overview of the different breeding strategies used to improve biotic stress resilience in mustard. The current understanding of mustard stress & stress tolerance mechanisms and the identification of stress-responsive genes and markers are also discussed here.

Influence of intercropping of French marigold (*Tagetes patula*) with gladiolus (*Gladiolus grandiflorus* L.) with varied levels of spacing and fertilizer levels on vegetative and flowering traits

KARISHMA BORAH[1*], SUNIL BORA[2], SARAT SEKHAR BORA[3]
[1,2]*Department of Horticulture,* [3]*Department of Agronomy, Assam Agriculture University Jorhat, Assam 785013*
**Corresponding email: kkborah28@gmail.com*

Gladiolus and marigold are two important commercial flower crops of Assam and cultivating these crops on same piece of land can aid in the enhancement their per capita income. The trial was conducted to analyze the effect of varied levels of spacing *viz.* 40 cm × 20 cm (S_1), 50 cm × 20 cm (S_2), 60 cm × 20 cm (S_3) and Nitrogenous fertilizer *viz.* 130 + 220 + 200 kg NPK/ha (F_1), 160 + 220 + 200 kg NPK/ha (F_2), 190 + 220 + 200 kg NPK/ha (F_3) when French marigold is intercropped with Gladiolus on their growth and flowering attributes. Sprouts per plant in T_9 (S_2F_3) and maximum plant height and leaves per plant in T_{12} (S_3F_3) attained superior results on gladiolus' vegetative traits. French marigold's growth parameters, such as plant height, number of branches, number of leaves and plant spread, were significantly affected by the application of 190 + 220 + 200 kg/ha NPK and 60 cm × 20 cm spacing. Flowering characters of both crops was found to depict significant outcomes on application of optimum level of spacing and fertilizer dose. Days to spike emergence, days to bud initiation and days to opening of first floret took least time with application of treatment T_{10} (S_3F_1). Spikes per corm, rachis length, internodal length, spike length and floret diameter of spike, fresh weight, dry weight, self-life and vase life recorded maximum in treatment T_{11} (S_3F_2). French marigold recorded minimum days to bud visibility, days to full bloom and days to 50% flowering in T_{10} (S_3F_1). Intercrop flowering productivity recorded maximum number of flowers per plant, flower diameter, fresh weight, self-life, loose flower life and yield per plant in spacing of 60 cm × 20 cm (S_3) and NPK supplied at 160 + 220 + 200 kg/ha (F_3). When French marigold and gladiolus were intercropped, the treatment combinations of 60 cm x 20 cm (S_3) and 160 + 220 + 200 kg/ha NPK (F_3) were found to be the best for achieving superior flowering characteristics in both crops, while 190 kg per ha N showed superior results on vegetative parameters of both crops.

Management of invasive pest, *Spodoptera frugiperda* (J. E. Smith) in maize under Meghalaya condition

SANDIP PATRA[*], R. H. CH. SANGMA, R. AKOIJAM, K. KUOTSU, B. BHATTACHARJEE, P. BAISWAR
ICAR Research Complex for NEH Region, Umiam, Meghalaya-793103.
**Corresponding email: sandippatra47@gmail.com*

Maize (*Zea mays* L.) is third most important cereal crops in India after rice and wheat and second most important cereal in Meghalaya only after rice. Recently, maize has been suffering from massive attack by an invasive pest, fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) throughout the country. Considering the economic importance of this pest, present experiments were conducted during kharif season of 2021 and 2022 to develop effective

management practices against fall armyworm in maize under Meghalaya condition. Therefore, two sets of experiments *viz*. (i) evaluation of different dates of sowing along with treatments schedules to assess the incidence level of the pest and (ii) evaluation of some bio and chemical pesticides against this pest were carried out at ICAR Research Complex for NEH Region, Umiam, Meghalaya in 2021 and 2022. The field trails were carried out in randomized block design with three replications for both the experiments. Dead heart caused by fall armyworm was recorded from each replication for both the experiments. Results revealed that out of five sowing, maize sowing second fortnight of April along with two soil application at 20 & 40 DAS and two spray with *Bt* @2g/l recorded 4.12% dead with highest grain yield. Among the treatments, chlorantraniliprole@0.3ml/l, emamectin benzoate @0.4g/l, *Bacillus thuringiensis (Bt)* @2g/l and *Metarhizium anisoplae*@5ml/l were effective against FAW with less than 5% dead heart.

Genetic variability analysis and molecular characterization in M_5 mutant lines of Indian mustard [*Brassica juncea* (L.)] for yield and its component traits

RICHA BORA[1*], RUMJHUM PHUKAN[1], PURNA K. BARUA[1], S. J. JAMBHULKAR[2]
[1]*Department of Genetics & Plant Breeding, Assam Agricultural University, Jorhat, Assam 785 013, India,*
[2]*Nuclear Agriculture & Biotechnology Division, Bhabha Atomic Research Centre, Trombay, Mumbai 400 085, India*
**Corresponding email: richabora98@gmail.com*

Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] is an important oilseed crop grown in India under diverse agroecological conditions in the temperate and subtropical regions during *the Rabi* season. Farmers in Assam grow rapeseed Toria (*Brassica rapa*) because of its low duration; however, the crop yields less as compared to Indian mustard. The development of short-duration, superior Indian mustard cultivars are necessary to increase the average yield of rapeseed-mustard in Assam. Some Indian mustard genotypes were produced at the Assam Agricultural University in Jorhat by inducing mutations. In the current study, 115 M5 lines produced by gamma irradiation from the parent variety of Indian mustard var. NRCHB-101 were evaluated in *Rabi* 2021–2022 to ascertain genetic variability and relationships between yield component metrics. The analysis of the data revealed sample induced genetic variation for all the variables. A significant genotypic coefficient of variation was reported for stem thickness, siliqua density, oil yield per hectare, and seed yield per hectare. High genetic heritability was observed characters such as number of days to maturity, stem thickness, seed yield per hectare, oil yield per hectare, oil content, thousand seed weight, and plant height. High estimates of genetic advance as a percent of mean were reported for the seed yield per plant, number of secondary branches, number of primary branches, and thousand seed weight. These traits can be used to develop high-yielding, short-duration Indian mustard cultivars. Molecular analysis was carried out by simple sequence repeat assay in 40 of the 116 genotypes including the parent. 18 of the 36 randomly chosen SSR primers that were tested displayed polymorphism. The value of the PIC varied from 0.021 to 0.638. Based on the Jaccard's

coefficient of similarity, clustering was carried out. The 40 genotypes were sorted into two distinct clusters, each of which had two sub-clusters, highlighting the diversity of the clusters. The SSR markers could be used to tag important traits. Further evaluation and selection of these lines could result in the required short duration high yielding varieties of Indian mustard for Assam and Northeast India.

A study on Okra and Blackgram intercropping system as influenced by plant geometry under rainfed condition

SIBANI DAS[1*], LUNA BAROOAH[2] , RANJITA BEZBARUA[1], ABU SALEH NIZAMUDDIN AHMED[1], SEEMA BHAGOWATI[1], KABERI MAHANTA[1]
[1]AAU – HRS, Kahikuchi Gauwahati-17, Assam, [2]College of Horticulture & FSR, Nalbari, Assam
**Corresponding email: sibani.das@aau.ac.in*

Intercropping has multifaceted advantages consisting of yield enhancement, more efficient use of resource, resource conservation, soil health improvement, crop diversification and superior ecosystem services and agricultural sustainability.Okra is a extensively cultivated vegetable crop and is planted with wide row spacing during rainy season and so it offers the scope of intercropping. Intercropping is the practice of growing more than one crop in the same field simultaneously and considered for increasing and stability of yield per unit. In this regard, a field experiment was conducted at the Horticultural Research Station Kahikuchi to study the effect of black gram and okra intercropping system. The experiment consist of five cropping systems namely C_1: sole black gram, C_2: sole Okra, C_3: okra + blackgram (1:1), C_4 : okra :blackgram (1:2), C_5 : okra:blackgram (2:2). Okra was grown as main crop with Blackgram as intercrop. Line sowing of Okra var Arka anamika was grown with a spacing of 45 cm x 30 cm in sole okra. Blackgram var SBC – 40 was sown with 30 cm x 10 cm spacing. As per the treatments, single and double rows of intercrops were grown in between okra. The result indicated that all the growth and yield parameters were relatively higher under sole cropping which ultimately registered the higher fruit yield as compared to intercropping treatments. The maximum fruit yield (133.34 qha^{-1}) was noted with sole okra and sole black gram (15.56 qha^{-1}). Then it was followed by okra:blackgram with 1:2 ratios (102.16 qha^{-1}) and (10.74 qha^{-1}) respectively. Further, it was observed that, highest land equivalent ratio (1.46) was registered under okra:Blackgram at 1:2 row ratio indicating higher total productivity. Thus, intercropping had a significant effect on all treatments and was best performed in okra and black gram (1:2) treatment. Sole okra yielded more than intercropped okra, however, extra yield obtained in intercropping black gram and okra (1:2) was quite satisfactory as it enhanced its growth and yield and appeared to be the best configuration for these crops that indicated advantage of intercropping system.

Identification of low P-tolerance rice genotypes

LETNGAM TOUTHANG[1*], DEBOJIT SARMA[2], AMIT KUMAR[2], PHILANIM W.S.[2]
[1]Genetics & Plant Breeding, ICAR RC NEH Region, Umiam, Meghalaya, Division of Crop Science,
[2]Genetics & Plant Breeding, Assam agricultural University (AAU), Jorhat
*Corresponding email: letngam111@gmail.com

A set of 80 rice genotypes were screened with 7 *Pup1* linked markers Pup1-K-41, Pup1-K-42, Pup1-K-43, Pup1-K-46-1, Pup1-K-46-2, Pup1-K-52 and Pup1-K-52 using Kasalath as check. Highest amplification frequency across the genotypes was observed in K-46-2 (65%) and K-46-1 (57.5%) markers respectively. Based on *Pup1* data, the genotypes were grouped into 6 clusters wherein 26 genotypes were *Pup1* positive, 25 with partially positive and 25 genotypes completely devoid *Pup1* locus. Core set of 32 genotypes were selected for field validation under three graded levels of phosphorus (P). The genetic variability for *Pup1* locus, P-uptake and P-use efficiency were significantly high among the genotypes. Except for days to flowering and maturity, all the agro-morpho and physiological traits under study exhibits significant difference of G x P interactions. This indicates that the impacts of P-levels on growth and development were highly depended on the genotypes. Using the sensitive parameters of P-stress indices, PUE and grain yield, the genotypes were grouped into highly tolerant, moderately tolerant and non-tolerant to low P. The study identified eight rice landraces *viz.* Kolong, Balighungoor, Banglami, Sadakra, Koimurali, Gopinath, Ikhojoi and Kasalath as highly efficient to low P.

Synergistic effect of different insecticides with entomopathogen *M. anisopliae* against sucking pests of rice

BIMAL KUMAR SAHOO[1]*, MAHESH PATHAK[2], HIA KALITA[3], SIKHA HARITHA[4], KENNEDY NINGTHOUJAM[5], PRANAB DUTTA[6], R.K. PATIDAR[7], N.S.A. THAKUR[8]
[1,3,4]M. Sc. Research Scholar, [2]Professor (Entomology), [5] Assistant Professor (Entomology), [6]Associate Professor (Plant Pathology), [7]Associate Professor (Nematology),[8]Professor (Entomology), School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya -793 103
*Corresponding email: bimalsahoo.1996@gmail.com

Rice (*Oryza sativa* L.) is the world's leading food crop, cultivated over an area of approximately 167.1 million hectares and yielding approximately 782 million tonnes (paddy). But from last two decades, globally rice yield has become almost stagnant or declining due to various causes among which insect pest infestation is the major one. In the present investigation, the compatibility of chemical insecticides with entomopathogen *Metarhizium anisopliae* was evaluated both *in vitro* and *in vivo* for managing sucking pests of rice. Compatibility was done for six different insecticides at lethal (L) and sublethal (SL) dosages with *M. anisopliae* by adopting food poison technique. Among all chemicals Imidacloprid (SLD) @ 0.1-0.15ml/L showed best compatibility result with *M. anisopliae* with lowest per cent inhibition of radial growth of 29.70 % followed by Pymetrozyne (31.48 %) and Thiamethoxam (41.62 %). Potter's tower bioassay was conducted for evaluating synergistic effect of compatible insecticides with *M. anisopliae* and it was revealed that per cent reduction in white leaf hopper (WLH), green

leaf hopper (GLH) and gundhi bug (GB) population over control was highest in Imidacloprid (LD) @ 0.2-0.3 ml/L (80.65 %, 50.00 % and 67.51 %) followed by followed by Imidacloprid (SLD) @ 0.1-0.15 ml/L + *M. anisopliae* (77.11 %, 42.86 % and 63.27 %) respectively. The corrected mortality percentage of WLH, GLH and GB were recorded highest (76.12 %, 50.00 % and 36.99 %) in Imidacloprid (LD) @ 0.2-0.3 ml/L followed by Imidacloprid (SLD) @ 0.1-0.15 ml/L + *M. anisopliae* (62.69 %, 42.86 % and 28.77 %) in field condition respectively. Highest grain yield was recorded (3.36 t ha^{-1}) in Imidacloprid (LD) @ 0.2-0.3 ml/L followed by Imidacloprid (SLD) @ 0.1-0.15 ml/L + *M. anisopliae* with 3.14 t ha^{-1} as superior over control with 2.00 t ha^{-1}. So, this study concluded that imidacloprid was best compatible with *M. anisopliae* at sub-lethal (SL) dosage and as sole and combined application of Imidacloprid with *M. anisopliae* showed at-par result, therefore Imidacloprid in combination with *M. anisopliae* can be recommended as a component of IPM. Furthermore, it can be popularized among the farmers for managing sucking pests.

Eco-friendly management of pest complex of brinjal *Solanum melongena* L. in Meghalaya

SUSHRUTA BORUAH[1]*, MAHESH PATHAK[2]

School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya-793103

**Corresponding email: sushrutaboruah96@gmail.com*

Brinjal (*Solanum melongena* L.), is a major vegetable crop with high productivity and high nutritive value. Despite the vegetable's popularity among poor farmers, it requires high inputs, particularly insecticides, because it is infested by a huge number of insect pests. Brinjal is highly prone to damage by insect pests from seedling to harvesting stage. In Meghalaya, Brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) is reported as the major pest. The present study on "Eco-friendly management of pest complex of brinjal, *Solanum melongena* L. in Meghalaya" was conducted in experimental farm of College of Post Graduate Studies in Agricultural Sciences (CPGS-AS), Umiam, Meghalaya from April to July, 2021. A total of 22 insect species and 3 non-insects were recorded from the brinjal ecosystem, out of which 15 species were observed as insect pests, 6 species as predators, 1 species as pollinator and 3 species of predatory spiders from the brinjal ecosystem. The Brinjal shoot and fruit borer (BSFB) was found to cause the maximum damage (22.40% shoot infestation and 38.84% fruit infestation). The correlation studies of the major pests (aphids, jassids, hadda beetle and BSFB) with weather parameters (maximum and minimum temperature, maximum and minimum relative humidity and rainfall) revealed that temperature and R.H. had significantly positive relationship with population fluctuation of the pests. The evaluation of bio-pesticide (Um-Comb) and synthetic pesticide showed that Chlorantraniliprole 18.50 SC was most effective against Brinjal shoot and fruit borer and hadda beetle and Dimethoate 30 EC was most effective against sucking pests i.e., aphids and jassids. Seed treatment with Um-Comb gave hundred per cent germination as compared to 84% in untreated seeds. The seed treatment and soil treatment followed by foliar spray with Um-Comb resulted in increased height, no. of branches, length

of fruits and yield of the Brinjal crop. Among the different Um-Comb treatments, seed treatment and soil treatment followed by foliar spray was found to be the most effective in managing the major pests. The highest marketable yield was achieved from the chemically treated plots; however, the benefit cost ratio was highest (2.74:1) in seed and soil treatment followed by foliar spray with Um-Comb.

Study of gene action governing NCLB resistance in maize (*Zea mays* L.) populations

BIPASHA DATTA, SUGUMAR S., DEVYANI SEN*

School of Crop Improvement, College of Post – Graduate Studies, Central Agricultural University (Imphal), Umiam, 793103

**Corresponding email: devyani.sen@gmail.com*

In the context of crop improvement programs, plant foliar diseases pose persistent yield challenges. To counter this, host plants have over time evolved genetic mechanisms of resistance which form the basis of resistance breeding. In maize currently the worlds most produced cereal crop, foliar diseases such as Northern Corn Leaf Blight (NCLB) lead to considerable yield losses in case of severe outbreaks. NCLB is highly common in North East Hill Region (NEHR) because of the moderate temperature and high humidity conditions prevalent in the region including Meghalaya. Since host plant resistance is the most cost efficient method of disease management, phenotyping three F_2 bi-parental populations Cross 1, Cross 2 and Cross 3 under artificial epiphytotics based on AUDPC scores was undertaken. The objective of the study was to elucidate the mode of gene action in these populations. The disease progress scores were subjected to generation mean analysis. The analysis revealed the importance of both additive and non-additive gene action in governing NCLB resistance in Cross 1 and Cross 3 whereas only dominance gene effect was significant in Cross 2. All the three types of epistatic interactions were implicated in Cross 1 and Cross 3. In Cross 2 an additive-dominance model was implicated. The highest narrow sense heritability for AUDPC was observed in Cross1 demonstrating presence of additive genetic action in this particular bi-parental population. These results indicate that the nature of gene action governing NCLB inheritance is under polygenic control and population specific.

Weed mat technology for pineapple cultivation

BISWAJIT DAS*, H. LEMBISANA DEVI, BAPPI DAS, ASHIMA S. BAIDYA, RAJIB DEB, MOJAMMIL ABEDIN, PRITHWIJIT DAS

ICAR Research Complex for NEH Region, Tripura centre, Lembucherra- 799210, Tripura

**Corresponding email: biswajitsom_dr@yahoo.co.in, Biswajit.Das@icar.gov.in*

Pineapple (*Ananus comosus*), the State Fruit of Tripura, is a very popular fruit crop. In recognition of the premium quality of variety Queen grown in Tripura 'Geographical Indicator

(GI)' has been awarded in 2015 under Geographical Indications of Goods (Registration & Protection) Act, 1999. However, over the years pineapple plantations have been facing problems due to lack of replantation with quality suckers, mismanagement, inaccessible due to over growth of leaves of old plants and unfertile soil due to surface runoff and unmanageable weed growth. To produce large size fruit with better taste scientific management is very much important. Moreover, under the changing climate conditions which is also noticeable in Tripura adoption of climate resilient technologies are essential for increasing production of premium quality fruits. Pineapple suckers were planted at spacing 30 x 60 cm + 90 cm/1 m on raised beds. Before planting different mulching materials namely weed mat, polyethylene black sheet and straw were used in different treatments including control (without b any mulch). Mulching was laid before sucker planting on raised beds. Foliar feeding with NPK mixture and Boron and Zn were also done in few designated treatments. Mulching with weed mat in combination with foliar sprays gave better plant growth and fruit size. Soil Preparation: Raised beds of dimension 100 m length x 1 m width and 15-20 cm hight are prepared and organic manure @ 300 g/plant and Urea, SSP and MOP 18 g, 25 g and 15 g/plant, respectively is applied. Mulching: Raised beds are covered with woven polypropylene black weed mat (1.5 m width and 100 m long). Edges are pressed with mud to protect from high wind blow. Planting system and Time: Suckers weighing 500-600 g are planted in the month of September. Raised Bed double row high density planting with spacing 40 cm (plant to plant) x 60 cm (Row to Row) + 90 cm/1.0 m (Bed to Bed). Irrigation: Pineapple requires less irrigation. However, during dry spell (November to mid-March) in the 1st year (Planting Year) at fort night interval and in the 2nd year and successive years sprinkler irrigation is beneficial during Dec-Jan. and Feb.-March (2-3 times). Foliar feeding: NPK (19:19:19) foliar sprays at 7th or 8th months after planting, and again at 30 and 60 days after fruit set. Trace element feeding: Zn (0.4%) + B (0.1%) sprays at 40 and 50 days after fruit set. Result: Plant growth was better compared to the control and fruit weight ranged from 1.2-1.5 Kg in queen with TSS 15.5-16.5 ^{0}B and in Kew weight ranged from 1.5-2.5 kg with TSS 13.5-14.5^{0}B. Whereas, in control, the respective values were 0.5-0.8 kg weight with TSS 11.5-13.5^{0}B in Queen and 0.8-1.2 kg with TSS 8.5-10.5^{0}B. Intended beneficiaries of the technology: Technology was demonstrated to the Agricultural officials of Directorate of Horticulture and Soil Conservation, Govt. of Tripura through interface meeting and other meetings/ field visits, SMS of Krishi Vigyan Kendra, Technology is being demonstrated to farmers in different parts of Tripura.

Genetic diversity and marker trait association analysis for grain, yield and yield contributing traits using Northeast Hill region rice landraces and SSR markers

HARENDRA VERMA[1], PURUSHOTAMA RAO[1], S.P. DAS[2], AMIT KUMAR[3], L.K. BAISHYA[1], C. AOCHEN[1], H. KALITA[1], V. K. MISHRA[3]

[1]ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema, Nagaland, 797106, [2]ICAR Research Complex for NEH Region, Tripura Centre, Lembucherra, Tripura, 799210, [3]ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya, 793013

Rice cultivation in the NEH region of India offers diverse and high-quality grain, making it attractive for breeding programs. In this study, 130 upland rice landraces collected from Nagaland and Manipur were directly planted in a randomized complete block design with three replications in upland ecosystem, Yield and grain quality traits were evaluated for two consecutive *kharif* seasons in 2019 and 2020 at the ICAR NEH Region, Nagaland. A UPGMA dendrogram grouped the 130 rice genotypes into eight clusters, with clusters 1, 2, and 3 consisting of solitary genotypes, while clusters 4, 5, 6, 7, and 8 had 5, 97, 5, 14, and 6 genotypes, respectively. The analysis of principal components (PCA) indicated that the first two components (PC1 and PC2) accounted for 38.37% of the variation in grain quality, yield, and yield attributes. The range of PIC values in this study varies from 0.19 to 0.80, with a mean of 0.518 across all accessions. A total of 237 alleles were detected, averaging 2.6 alleles per locus, indicating high diversity among the studied rice accessions. A Bayesian clustering model was employed to analyze the population structure of 130 rice landraces and population was divided into two subpopulations, P1 and P2, based on this optimal K-value (K=2). Subpopulation P1 consisted of 52 genotypes, with 48 (92.3%) classified as pure and 4 (7.69%) as admixtures. Subpopulation P2 comprised 78 genotypes, with 58 (74.35%) classified as pure and 20 (25.64%) as admixtures. Analysis of molecular variance revealed 13% of the total variation was among populations, while 86% was within individuals and 1% within individuals. An unweighted neighbor-joining tree was employed to determine the genetic relationship between the 130 rice genotypes, which were classified into two groups. Using the MLM model, marker trait association analysis identified six significant associations for grain quality and yield attributes in the upland ecosystem. These associations, with R^2 ranging from 3.55% to 11.91%, were determined using markers located on chromosomes 2, 3, 8, 9, and 12. The markers were associated with traits such as gel consistency, GT, plant height, maturity duration, days to flowering, and decorticated grain width.

Morphological and molecular screening of native *Bt* isolates from Meghalaya

V. NIROSHA, KENNEDY NINGTHOUJAM, GURUMAYUM ROBERT DANIEL, MAHESH PATHAK, GARY SUTING

School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya-793103

Biological control methods have been used for more than a century to manage insect pest species. Chemical control gives better results, but using synthetic insecticides should be the last resort as it is harmful to human beings, beneficial insects and natural enemies. *Bacillus thuringiensis* (*Bt*) is an important and well documented bioagent. It is a gram-positive rod-shaped soil bacterium characterized by a parasporal crystalline protein inclusion. The crystals are assembled as parasporal bodies expressed by the cry genes. Insecticidal crystal proteins or delta-endotoxin produced by sporulating cells are toxic to lepidopteran, dipteran and coleopteran orders of insects. Isolation of *Bt* has been done from soil/water samples collected through random sampling from 30 different locations of Meghalaya covering 02 districts

namely; Ri-Bhoi and West Khasi Hills. Out of two different methods used for isolation *i.e.*, Enrichment method and Sodium acetate method, in Sodium acetate method maximum number of *Bacillus* like colonies were observed on the growth media. Under the morphological characterization colonies which were circular, creamy-white, raised and dry-rough textured were selected and streaked on nutrient agar media. The microscopical characterization was done through commassie brilliant blue staining and observation under 100 X Phase Contrast Microscopy. From the samples, a total of 16 *Bt* isolates were isolated based on presence of parasporal bodies using Phase Contrast Microscopy. Almost all the selected 16 *Bt* isolates showed the presence of parasporal bodies with 04 *Bt* isolates showing typical bipyramidal crystals. Molecular characterization by detection of *cry* genes namely *cry1*, *cry2* and *cry3* genes was done using specific primers for *cry1*, *cry2* and *cry3* genes respectively. Out of the total 16 *Bt* isolates 12 isolates showed the presence of *cry1* gene and absence of *cry2* or *cry3* genes, 04 isolates showing bipyramidal crystals but negative for *cry1, cry2 and cry3* are sources of further interest as these native isolates could be harboring novel genes. Understanding diversity of *Bacillus thuringiensis* in the North East region for identification of novel insecticidal genes through morphological and molecular characterization can play a crucial role in resistance management against various insect pests and better understanding of the molecular mechanism of *cry* gene action in insects.

Yield performance study of Indian mustard (*Brassica junceac var.* NRCHB-101) through cluster front line demonstration (CFLD) in North Tripura

EMIDAKA SUTING*, A.K. MOHANTY, A.K. SINGHA, R. BORDOLOI, AMRUTHA T. SUBRATA DAS, HEJBINA. M HUSSAIN, WANPHRANG KHARKONGOR, SANTANU DAS, RANADHIR SARMA

ICAR- Agricultural Technology Application Research Institute, Zone-VII, Umiam, Meghalaya, India
**Corresponding email: emidakasuting22@gmail.com*

Indian mustard *(Brassica juncea* L.) is one of the significant oilseed crops in India, which accounts for 32 per cent of total oilseed production of the country, thus establishing India as the third-largest producer of rapeseed and mustard globally next to China and Canada with the production figure of 115.25 lakh tonnes (2022-23). However, the mustard cultivation in the NEH region with an area coverage of 0.46 lakh ha gives an average yield of 8.88 q/ha against the national average of 12.03 q/ha (2022-23) in which the state of Tripura covers an area of 7893 hectares under mustard, producing 6630 Mt with poor yield capacity of 8.4 q/ha. Various factor like lack of improved cultivars, faulty agronomic management practices, inadequate nutrient management, severe climatic aberrations, improper disease and pest management etc. are accountable for the lower yields of Indian mustard in this region. In order to address these concerns, the Cluster Frontline Demonstration (CFLD) programme on oilseeds has been initiated as an effective extension approach to enhance the productivity of the oilseed crops through large scale dissemination of improved package of practices. The present study has been undertaken to evaluate the yield performance of Indian mustard in field condition in Tripura over a period of 3 years starting from 2019 to 2021 with a purposive sample representing

different locations selected for the study. It was observed that the average seed yield in case of CFLD mustard (*var.* NRCHB-101) was 9.35 q/ha, which is significantly high as compared to farmers' practices (6.34 q/ha). The use of recommended package of practices showed an increased yield of 41.59 per cent over control with average net return of Rs. 50350 than the farmer's practice of Rs. 31450 and also higher B: C ratio (3.79) as compared to farmers' practices (2.74). The study thus concluded that the CFLD on Indian mustard (*var.* NRCHB-101) had a positive effect on boosting the productivity of mustard in North Tripura district ensuring the successful mission of CFLD Oilseeds.

To screen the fungal endophytes isolated from the banana species of Nagaland for their siderophore production and phosphate utilization

BENDANGSENLA*, SUSANTA BANIK
School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Nagaland.
**Corresponding email: bensen1144@gmail.com*

A total of 280 fungal endophytes were isolated from the wild and locally cultivated banana species of Nagaland and the isolates were screened for their ability to produce siderophore and for their utilization of phosphate *in vitro*. Out of the 280 fungal endophytes isolates, 96 isolates were found to be positive for siderophore production and only 40 isolates were found to show positive result for phosphate utilization. In the present investigation, it was also found that 30 isolates were positive for both siderophore production and phosphate utilization viz., FEB1, FEB11, FEB23, FEB50, FEB68, FEB71, FEB87, FEB106, FEB110, FEB120, FEB123, FEB141, FEB176, FEB210, FEB214, FEB215, FEB223, FEB229, FEB230, FEB245, FEB250, FEB254, FEB257, FEB260, FEB262, FEB266, FEB269, FEB270, FEB276 and FEB280.

Evaluation of pre-*kharif* (Aus) rice varieties for higher yield in transplanted lowland condition of North Tripura

SANTANU DAS*, SANKAR PRASAD DAS
KVK North Tripura, Panisagar, ICAR RC for NEH Region, Tripura Centre, Lembucherra, Tripura
**Corresponding email: santanudascau@gmail.com*

Agriculture in North Tripura district is mostly reliant on monsoon due to lack of sufficient irrigation facilities. Rice-vegetable cropping system is the major source of livelihood for small and marginal farmers of North Tripura district, especially for valley farmers. However, majority of the farmers grow only lowland rice as rainfed crop and keep the land fallow due to lack of water during succeeding season. Thus, paddy is one of the most important crops in this district and around 26.3 thousand hectare land is cultivated under paddy cultivation (District wise area target of North Tripura, 2023-24). Due to the lack of irrigation facility, farmers mostly prefer short duration paddy varieties. Utilizing the pre-monsoon rainfall farmers complete sowing/transplanting by the month of April-May and harvest the crop by the month of August-

September with an average low yield of 2.80 t/ha. There is a very good scope to enhance productivity of rice by adopting HYVs and improved production practices. An OFT (On Farm Testing) was conducted during the year 2022-23 to evaluate the performance of short duration paddy varieties in pre-*kharif* (*Aus/Ahu*) season under rainfed condition. OFTs were conducted in five different blocks of North Tripura district, covering 0.2 hectare each, with three short duration varieties namely "Hakuchuk-2, Tripura Aus and TRC-2015-5 (NICRA Aerobic Dhan 1)" along with one high yielding popular variety i.e. "Gomati" and compared with a local check - traditional varieties grown by the farmers. The result revealed that the maximum yield was obtained with the variety TRC 2015-5 (4.4t/ha) followed by Gomati (4.10 t/ha), Tripura Aus (3.90 t/ha) and Hakuchuk -2 (3.84 t/ha), however the average yield of local varieties were recorded was 3.40 t/ha. The average rice yields obtained with varieties Hakuchuk-2, Tripura Aus and TRC-2015-5 and Gomati were 13.0%, 14.7%, 29.4% and 20.6% higher than local varieties respectively. Among all these varieties tested in farmers' field, Hakuchuk-2 and TRC-2015-5 (NICRA Aerobic Dhan 1) was found highly acceptable to the farmers due to its higher yield and shorter duration with higher biomass (straw) for cattle feed. The longest duration was taken by Gomati (137 days) followed by TRC- 2015-5 (120 days) and Hakuchuk-2 & Tripura Aus (115 days). The highest B:C ratio (2.3) was achieved with the cultivation of paddy variety TRC-2015-5 (NICRA Aerobic Dhan 1) followed by Gomati (2.1), Tripura Aus (2.0), Hakuchuk-2 (2.0) as compared to local check (1.8). During the feedback collection farmers were shown more interest to cultivate TRC-2015-5 (NICRA Aerobic Dhan 1) due to its shorter duration and higher yield as compared to local check.

Kairomonal effects of *Corcyra cephalonica* and *Spodoptera frugiperda* on *T. pretiosum*

THOKCHOM TULLIKA, KENNEDY N., MAHESH PATHAK,
GURUMAYUM ROBERT DANIEL
School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya – 793103

Biocontrol programs using egg parasitoids, especially the Trichogrammatidae family, are widely used around the world. Researchers have demonstrated that the behavior of these entomophagous insects is influenced in various ways by chemicals produced by their host or prey. Such chemical cues help the parasitoids in the host habitat location, host location, host recognition, host acceptance, and foraging activities. Chemicals like kairomones emanating from host insects are used by the parasitoids to distinguish the host from the nonhost. Kairomones are the chemical substances released by one insect species that evoke behavioral and physiological responses in the receiver such that the subsequent actions are favorable to the receiver and not the emitter. Among the *Trichogramma* species, especially *Trichogramma pretiosum* has been exploited in the Americas, as a potential biological control agent for *S. frugiperda*. The Fall Armyworm (FAW) *Spodoptera frugiperda* is the most destructive pest of many economically important crops across the globe. It originates from America's tropical and subtropical region and it recently has invaded many nations including India in 2018, causing

enormous economic losses. There is a significant yield loss when larvae feed on vegetative and reproductive plant stages. Considering the invasiveness and spread of FAW, it is essential to prevent its infestation in the early stages in the field. Therefore, laboratory bioassay study of kairomonal extracts from whole body washes and egg wash of host insects viz., factitious host i.e., *Corcyra cephalonica,* and natural host i.e., *Spodoptera frugiperda* of *T. pretiosum* were carried out under laboratory conditions in a four-armed olfactometer and petri dish to check the parasitoid activity index and its increase in rate of parasitization. The present study will help in understanding the nature and role of kairomones emanating from the host insects on the parasitic potential of *T. pretiosum.* The use of kairomones, if found useful in the study, could be used as an important management tool in various biorational approaches in pest management.

Assessment of the genetic diversity using SSR markers and stability using AMMI model in rice bean landraces

PHILANIM W.S.*, AMIT KUMAR, LETNGAM TOUTHANG, CH. RUMKI SANGMA, KRISHNAPPA R., SANDEEP JAISWAL, N. RAJU SINGH
ICAR Research Complex for NEH Region, Umiam, Meghalaya-793103
**Corresponding email: philanim09@gmail.com*

Ninety rice bean genotypes representing a core set from collection of germplasms across different North eastern states were evaluated for yield and yield corresponding traits. The germplasms were assessed for genetic diversity and stability. Total of 14 polymorphic markers amplified for a total of 30 alleles with an average of 2.14 alleles per each polymorphic marker. Markers Cg18775c0 and cG29169c0 recorded highest Polymorphic Information Content (PIC) of 0.76 and 0.73 respectively. Major allele frequency ranged (MAF) ranged from 0.48 to 0.99 with an average of 0.72 where cG25619c0 (0.99) and cG11226c0 (0.99) had highest MAF. AMOVA showed that 98% of existing variation was from within population and 1.79% variation came from among populations. The high percentage showed how genotypes are greatly diversified within a population. F_{ST} index which helps to differentiate and decipher the probability by descendance obtained value of 0.01789 indicating a high F_{ST} to differentiate the groups. The matrix showed that the population pairs Manipur-Mizoram (F_{ST}>0.08), Mizoram-Meghalaya (F_{ST}>0.08) and NBPGR- Mizoram (F_{ST} 0.06-0.08) showed highest significant variation. The first two principal components axis (IPCA1, 90.4% and IPCA2, 9.6%) could explain 100% of the total of the interaction variation. Correlation study showed that the stability parameters are highly associated with each other ($p<0.01$). STRUCTURE based analysis of the multi locus genotype data estimated the true value of ΔK at 2 indicating two sub populations. Multi trait stability index and genotype selection of 30 accessions along with strength and weakness view of the genotypes to the traits inferred higher productivity of G29 (BSKB 28) for pods per plant and seed yield per plant and G17 (Ukhrul 15) for seeds per pod. Different stability measures (AMMI model) selected genotypes; G22 (Bete 6), G8 (IC002567), G13 (Ukhrul 6), G16 (Ukhrul 14), G17 (Ukhrul 15), G21 (Bete 4) and G28 (BSKB 3) as the most desirable and stable performing with good yield in all the years.

Molecular identification based on DNA barcoding of major insect pests infesting tomato crop in Nagaland

ARENSUNGLA PONGEN[1*], G.T. BEHERE[2], ALEMINLA A.O.[1],
RUMKI H. CH. SANGMA[3], BENDANGSENLA[1]
[1] School of agricultural sciences and rural development (SASRD), Nagaland University, Medziphema-797106, Nagaland, India, [2]ICAR- Central Citrus Research Institute (CCRI), Nagpur, Maharashtra- 440033, [3]ICAR-Research Complex for NEH region, Umiam-793103, Meghalaya, India
**Corresponding email: arensungpon@gmail.com*

Significant morphological similarities within or in between species of insects has made reliable taxonomic identification difficult. DNA barcoding has been appeared to be a useful tool in resolving the issues related to the identification of taxonomically difficult insect species. In the present study 3 major insect pest species were collected and identified *viz*., *Aphis spiraecola*, *Chrysodeixis eriosoma* and *Helicoverpa armigera*, DNA barcodes were successfully developed by sequencing partial Cytochrome oxidase I (COI) gene of mitochondrial DNA. The molecular identities of the insect species were established through BLAST NCBI. All the analyzed sequences have been deposited to International Gene Bank (NCBI) with accession numbers ON460288, ON461370 and ON496461. The present study has resulted in the quick identification of *A. craccivora* and *C. eriosoma.* in tomato ecosystem which has not been reported previously from Nagaland, India. The comprehensive molecular database developed in this study could be used as diagnostic tool for applied IPM research and on-farm decision making.

Diseases of important horticultural crops grown under mid hills of Meghalaya

TASVINA R. BORAH[1*], P. BAISWAR[1], A. BALUSAMY[1], T. RAMESH[1], V. K. VERMA[1], DEBASISH CHAKRABORTY[1], SHRUTI SINHA[1,2], OM PRAKASH[1,2], DEEPU KUMAR[1,2]
[1]ICAR Research Complex for NEH Region, Umiam 793103, Meghalya, [2]College of Post Graduate Studies in Agricultural Sciences, CAU-Imphal, Umiam 793103, Meghalaya

The different districts of the state of Meghalaya (the abode of clouds), experience temperate to subtropical climatic conditions according to the altitude of the places. The district of RiBhoi in the 25.9321°N latitude and 92.0665°E longitude with altitude of 858msl has climate conditions ranging from subtropical to tropical with hot humid summer and cold dry winters. Many of the agricultural crops are grown under different cropping systems. The agrian economy of the district is upheld by the production of cash crops like ginger and turmeric, while vegetable crops are grown in every household either on sustenance or commercial scale. However, the production and productivity of the crops are lowered by many pathogens over the years. In recent years the attack of soil borne fungal pathogens has been an emerging problem in crop production. Amongst the soil borne pathogens, *Sclerotinia sclerotiorum* attacks the rabi season crops like cabbage, broccoli, cauliflower and disease incidence was up to 20% with cold moist weather conditions favouring the pathogen build up at nursery and early crop stage. The kharif

crops tomato and French bean are infected by *Sclerotium rolfsii* up to 30%. Tomato and potato are affected by the late blight pathogen during March-April when low temperature coupled with sufficient moisture favoured disease. Ginger was mostly affected by the wilt pathogen (*Ralstonia solanacearum*) causing yield loss of 10%. Turmeric crop was attacked by the blight pathogen and also infection by *Alternaria* species was also found. The disease dynamics tend to shift with congenial weather conditions prevailing for longer durations.

Genetic diversity and population structure of *Ustilaginoidea virens* causing false smut of rice

MATHEW S. BAITE[1,2*], SHASWAT S. PRADHAN[1], PARAMESWARAN C.[1]
[1]ICAR- National Rice Research Institute, Cuttack 753006, Odisha, India, [2]Present address: ICAR – Research Complex for NEH Region, Nagaland Centre, Medziphema - 797106
**Corresponding email: mathew.baite@gmail.com*

False smut caused by *Ustilaginoidea virens* is an emerging disease of rice in India. The disease is causing economic loss to farmers through reduction of yield and quality of rice. To devise a suitable approach to manage the disease effectively, understanding of the genetic diversity and population structure of the pathogen is essential. Hence, a total of 34 isolates of *U. virens* obtained from different locations in India were characterized using 25 genomes specific SSR markers that produced 203 alleles with a mean of 8.12 per marker. The genetic diversity varied from 0.00 to 0.885 with an average of 0.673. SSR markers showing higher polymorphic information content (PIC) were used to analyze the genetic diversity of *U. virens*. Based on the phylogenetic tree, the 34 isolates of *U. virens* were grouped into two major clusters (Cluster I and Cluster II). Cluster I included isolates from Andhra Pradesh, Bihar, Kerala, Manipur, Mizoram, Punjab and West Bengal while cluster II included isolates from Assam, Manipur, Meghalaya, and Odisha. The isolates from same/nearby locations did not necessarily fall into the same cluster. The Analysis of molecular variance (AMOVA) showed highest variation of 86% found among the individuals while least variation of 14% was observed between the two populations. The population structures of 34 isolates of *U. virens* evaluated using STRUCTURE and Principal coordinated analysis (PCoA) separated the 34 isolates into two distinct sub populations. The findings will be helpful for management and breeding in rice genotypes resistant to false smut.

Evaluation of grass pea (*Lathyrus sativus* L.) landraces for genetic variability and character association for growth, yield and quality attributes

NIHARIKA DUTTA*, S. B. NEOG, P. K. BARUA
Assam Agricultural University, Jorhat-785013
**Corresponding email: dutta1014@gmail.com*

Grass pea has immense potential as a dual-purpose pulse-cum-forage crop in areas prone to adverse climatic conditions such as cold, heat, drought, salt-affected soils, submergence, and excessive rainfall, along with resistance to several diseases and pests. Despite several advantages, the presence of a neurotoxin, β-N-oxalyl-L-α, β-diaminopropionic acid (ODAP), in the foliage and seeds of this legume limits crop production and area expansion. ODAP has been reported to cause neurolathyrism, a non-reversible neurological disorder in humans and animals. To identify the genotypes higher in forage and seed yield, rich in protein, and low in ODAP content, the present investigation was carried out using a set of sixteen grass pea genotypes, evaluated during *Rabi* season (2021–22), using a randomized block design with three replications. Except for pod length and pod width, significant variations were observed for all the growth, yield, and quality traits. The variations for forage and seed yield varied from 11.27–20.67 g and 3.09–5.67 g per plant, respectively. ODAP content varied from 0.071-0.371% in leaves and 0.080-0.441% in grains. Similarly, crude protein content also varied from 13.30–20.12% in leaves and 23.62–28.82% in seeds. High GCV and PCV were observed for ODAP content in leaf and seed and dry matter yield per plant. High heritability coupled with high genetic advance was observed for leaf width, green forage yield, dry matter yield, crude protein content in leaves, and ODAP content in leaf and seed. High heritability and moderate genetic advance have been observed for seed weight and yield as well as protein content in seeds. Under principal component analysis (PCA), the first five principal components explained 81.98% of the total variance, and the first PC accounted for 29.53 percent of the total variations, which were contributed by growth and yield-related traits. Based on the mean performances, JCL-21-N-1, JCL-21-N-5, and JCL-10-4 were found promising for green fodder yield, and JCL-21-N-1, JCL-21-N-4, and JCL-10-4 for higher yield with low ODAP and high crude protein content. The only genotype with a combination of low ODAP content, high fodder, and high grain yield was JCL-21-N-1. Correlation and path analysis revealed the importance of number of leaves per plant, primary branches per plant, secondary branches per plant and dry matter yield per plant for improvement of green forage yield. On the other hand, the number of pods per plant and number of effective pods per plant were observed to be the most important traits for improving seed yield. ODAP content in leaf exhibited a significantly negative correlation with green forage yield per plant, dry matter yield per plant, and primary branches per plant, while ODAP content in seed showed a significant negative correlation with primary branches per plant, green forage yield per plant, and 100 seed weight. Therefore, selection for improvement in these traits would result in the isolation of genotypes with low ODAP content.

Dissipation of insecticidal residues having different modes of action in cabbage

ROMILA AKOIJAM*, ARATI NINGOMBAM, SONIA CHONGTHAM, DEVI C.P, TELEM R.S., SINGH T.B., I.M. SINGH, SEN A.

ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat 795004

**Corresponding email: romi.ak9@gmail.com (R. Akoijam)*

The dissipation study of residues of insecticides having different modes of action was studied in cabbage. The insecticides such as deltamethrin, chlorantraniliprole and fipronil residues were sprayed as foliar application twice at an interval of 7 days with the recommended doses of deltamethrin (@ 12.5 g a.i./ha), chlorantraniliprole (@ 30 g a.i./ha) and fipronil (50 g a.i./ha). The samples were taken randomly before application of any insecticides and 1 hour after second spray of insecticides. The residues were below detectable limit (BDL) for all the insecticides. The residues of fipronil was found to be more persistent than that of chlorantraniliprole and deltamethrin. Fipronil was found to be persisted upto 7th day with the residue of 0.01 mg kg^{-1}. However, the residues of chlorantraniliprole and deltamethrin was persisted upto 5th day i.e. 0.11 mg kg^{-1} and 0.03 mg kg^{-1} respectively. Observation revealed that the residues of chlorantraniliprole on cabbage dissipated with the course of time and equally high degree of dissipation was observed. The half-life of chlorantraniliprole was found to be 1.81 days as compared to 1.07 and 1.42 days respectively for fipronil and deltamethrin.

In vitro evaluation of native *Trichoderma* species against *Sclerotinia sclerotiorum* causing white mold of cabbage

SHRUTI SINHA[1,2*], TASVINA R. BORAH[2], P. BAISWAR[2], P. DUTTA[1], D. THAKURIA[1], M. PATHAK[1], OM PRAKASH[1,2], ABHISEK THAKUR[2], DEEPU KUMAR[1,2]

[1] College of Post Graduate Studies in Agricultural Sciences, CAU-Imphal, Umiam 793103, Ri Bhoi, Meghalaya, India, [2]ICAR Research Complex for North Eastern Hill Region, Umiam-793103, Umiam 793103, Ri Bhoi, Meghalaya, India

Agrochemical-based control measures of plant diseases cause residual chemicals to accumulate, with a heavy toll on the environment. To compensate for this the use of antagonistic microorganisms that are naturally present in the soil is indispensable. Vegetable production, be it in homestead gardens or commercial cultivation is one of the major activities of all farmers. Soil-borne fungal pathogens take a toll on vegetable production by causing diseases and total loss of production at times under favorable weather. Their management becomes an arduous task due to their wide host range, scarce resistant source, and long period survival in the soil through resting structures. *Sclerotinia sclerotiorum* causes infections in cabbage (white mold), causing heavy losses. In this context, experiment was conducted to evaluate (*in vitro*) antagonistic potential of native *Trichoderma* spp. against *Sclerotinia sclerotiorum* causing white mold of cabbage. Evaluation of eleven *Trichoderma* spp. isolated from different rhizospheric soil samples against mycelial growth of *Sclerotinia scletiorum* using dual culture method in three replications, found the best two *Trichoderma* spp. with the mycelial growth inhibition of MT7(83.29%) and MT11 (81.55%). *In vitro* evaluation of the potent *Trichoderma* spp. showed correlated growth rate of MT7 (1.91mm/hr) and MT11 (1.87mm/hr), biomass production of MT7 (7.87g/100ml) and MT11 (6.49g/100ml). Similarly, their functional attributes were evaluated for production of siderophore MT7 (88.16%) and MT11 (86.01%), IAA MT7 (0.425µg/ml) and MT11 (0.242µg/ml), Zn solubilising ability MT7 (74.33%) and MT11 (73.20%) and PO_4 solubilising ability MT7 (68.48%) and MT11 (60.94%) and HCN

production (positive). These findings would be relevant for holistic management of *S. sclerotiorum* causing white mold disease of cabbage in an integrated approach.

Agro-morphological characterization of *Coix lacryma-jobi* L.: An important potential crop from North-east India

SUBARNA HAJONG[1*], REGINAH PHEIRIM[2], SARA PRADHAN[1], CHUBASENLA AOCHEN[3] TIATEMSU PUNATEMJEN[4], JULIUS UCHOI[1]

[1]ICAR-National Bureau of Plant Genetic Resources RS Umiam, Meghalaya-793103, [2]Lovely Professional University, Punjab-144411, [3]ICAR Research Complex For NEH Region Nagaland Centre, Jharnapani, Medziphema, Nagaland – 797106, [4]Fazl Ali College, Mokokchung, Nagaland-798601

**Corresponding email: subarna.hajong@gmail.com*

Coix lacryma-jobi L. is popularly known as Job's tear due to its large, shining, pear shaped fruits showing remarkable resemblance to tear drops. The genus belongs to the grass family Poaceae. Coix is a potential grain crop, the seeds are rich in proteins, minerals and crude fat which can potentially benefit human health. The crop can thus, be used as an alternative to rice (contains more fat and proteins than rice and wheat). Coix is also used for preparing beverages, as feed, fodder, for making ornaments etc. Coix is also used in traditional Indian and Chinese medicines. Some Khasi tribes of Meghalaya also use it in their religious rituals. North-east India being one of the centres of diversity of coix has a high reservoir of this crop germplasm (both cultivated and wild). In the present study, 124 accessions of coix collected from different states of North-east India were studied for 20 quantitative agro-morphological traits. Analysis of variance showed that genotypes differed significantly for agro-morphological traits such as days to germination, first leaf unfolding, angle between leaf and stem, leaf blade length, 100 seed weight and seed length/width ratio. Genotypic and phenotypic coefficient of variation, heritability (bs) and genetic advance as per cent mean were also computed for the quantitative traits. The highest value for GCV was observed in number of tillers/plant (49.65%) followed by 100 seed weight (41.41%) and number of seeds per plant (34.96%). The lowest (19.14%) and highest (100%) broad sense heritability were estimated for total seed weight/plot and days to germination as well as days to first leaf unfolding, respectively. High heritability estimates coupled with high genetic advance as *per cent* mean were found in number of tillers/plant, number of seeds per plant, 100 seed weight and seed length/width ratio. High heritability paired with high genetic advance as percent of mean provides the most effective selection condition for a specific trait. Based on mean values of agro-morphological traits, superior performing genotypes SH/TM/2021-16 was identified for number of tillers/plant (4.67), number of seeds/plant (1461.60), SH/TM/2021-6 for 100 seed weight (75 g), IC-629198 for seed weight/plant (175 g) and seed weight/plot (1600 g), and SH/TM/2020-32 for seed length/width ratio (3.33).

Screening of Pigeonpea Genotypes & *in-vitro* evaluation of botanicals against Fusarium wilt disease

JYOTI KUMARI[1*], BIRENDRA KUMAR[2], SANGITA SAHNI[3]
M. Sc.Plant Pathology, Post Graduate College Of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa Samastipur-848125, Bihar, India
**Corresponding email: jyotiramathakur@gmail.com*

Pigeon pea (*Cajanus cajan*L.) Millsp), also known as tur or arhar in India is a valuable pulse crop predominantly cultivated in tropical areas and in India. Pigeon pea having a significant place among the family Fabaceae. The legume crop pigeon pea is kharif season crop and has wider adaptability requires low input in cropping practice. In India, pigeon pea is the 2nd most important pulse crop after chickpea. Among a few variables known to influence pigeon pea development, the most significant is the effect of diseases like Cercospora leaf spot, Fusarium wilt, collar rot, Phytopthara blight, dry root rot, Alternaria leaf spot, phyllody and sterility mosaic. It just so happens, a couple of them causes monetary misfortunes in India (Kannaiyan et al., 1984). Among the illnesses, Fusarium wilt, incited by *Fusarium udum*, is the main soil borne disease and was first revealed from Bihar state in quite a while (Butler, 1906).During the present study, the varietal screenings were conducted in a simulated environment under wilt sick plot. Genotypes found resistant to moderately resistant may either be used as donor parent in breeding program for resistant varieties or if yield level is comparable with existing varieties, it may be released for general cultivation. For an ecofriendly and sustainable management of Fusarium wilt, the effectiveness of botanicals were tested *in vitro* at 5, 10, 15, and 20% conc. against the pathogen by poisoned food technique. The botanical extract of ashoka leaves, eucalyptus leaves, garlic clove, marigold leaves, tulsi leaves, neem leaves, dhatura leaves, turmeric rhizome, ginger rhizome, onion bulb and moringa leaves were found effective in inhibition of *Fusarium udum*.

Development of modified screening platform for identification of aluminium toxicity tolerance of rice genotypes from North-Eastern India

SANDEEP JAISWAL[1*], AMIT KUMAR[1], PHILANIM SHIMRAY[1], LETNGAM TOUTHANG[1], BIJOYA BHATTACHARJEE[1]
[1]ICAR Research Complex for NEH region, Umiam, Meghalaya-793013
**Corresponding email: sandeepjaiswal110@gmail.com*

Soil acidity induced Aluminium (Al^{3+}) toxicity greatly affects the production potential of rice crop. Lack of a suitable screening platform for screening of rice genotypes under Al toxicity condition is also a limiting factor for identification of suitable parent for breeding for Al tolerance. Due to the inherent ability to grow under low pH, rice requires even higher Al concentration for toxicity screening. In our study, a modified formulation based upon Magnavaca solution which is free of Ammonium nitrate was developed. The modified formulation was found to have 161 µM of active Al^{3+} concentration when 550 µM of $AlCl_3.6H_2O$ is supplied at pH 4.1 in the solution. Plant growth experiment using ten rice

genotypes validated the effectiveness of new formulation for screening rice genotypes, especially under Al toxicity. Three genotypes Swarna, Nagina22, and Naveen were found comparatively tolerant to Al toxicity. Thus, the present experiment provided an important nutrient formulation suitable for screening of rice genotypes under Al toxicity conditions. Moreover, the selected tolerant and sensitive genotypes can further pave the way for studying the molecular mechanism of Al toxicity response in rice and their use in the breeding program.

An overview of insect-pests constraining pulse production in north eastern region of India

ANUP CHANDRA*, SUJAYANAND GK, ASISH KUMAR ROUT,
RAGHVENDRA SINGH, G.P. DIXIT
ICAR-Indian Institute of Pulses Research, Kalyanpur, Kanpur 208024, Uttar Pradesh
**Corresponding email: anup.ento@gmail.com*

The north east region of India is known for its rich biodiversity and agricultural productivity. Among the major crops cultivated in this region, pulses hold significant importance due to their high nutritional value and economic significance. Major pulses grown in the region are blackgram, greengram, pigeonpea, chickpea and field pea. Apart from these, the region houses a variety of beans like rice bean, french bean, cowpea, adzuki bean, winged bean, dolichos bean etc. The north east region experiences a diverse range of climatic conditions, making it vulnerable to a variety of insect pests. Emerged in late 90s in the region, the pod boring weevil, *Apion clavipes* Gerst still upholds the status of a major insect pest of pigeonpea causing 35 to 40 % pod damage. Pod fly [*Melanagromyza obtusa* (Malloch)] causes 35 to 37 % pod damage. The crop also faces key challenges by the pod borers [*Helicoverpa armigera* (Hubner), *Etiella zhinckenella* (Treitschke) *Euchrysops cnejus* (Fabricius)], blister beetles [*Mylabris pustulata* (Thunberg), *M. phalerata* Pallas], aphids [*Myzus persicae* (Sulzer)] whereas flea beetles [*Chaetocnema basalis* (Baly), *Monolepta signata* (Olivier)] are of minor importance. In Tripura, the major insect-pests of pigeonpea are reported as *Maruca vitrata* (Fabricius), *H. armigera*, *Nanaguna breviuscula* (Walker), *M. obtusa*, *A. clavipes*, *Aphis craccivora* Koch, *Empoasca kerri* (Pruthi) and *Megalurothrips* sp. Termites pose serious threat, particularly in upland conditions. Cutworm [*Agrotis ipsilon* (Hufnagel)] cuts the young plant at base, mainly in chickpea, beans and field pea, thereby directly affecting the plant population. Other insect-pests infesting field pea are pod borers (*E. zinkenella* and *E. cnejus*), aphids [*Acyrthosiphon pisum* (Harris)], pea semi-looper [*Thysanoplusia orichalsea* (Fabricius)] and pea leaf miner (*Phytomyza atricornis* Meigen). Larvae of Bihar hairy caterpillar, *Spilosoma oblique* (Walker) are voracious leaf feeders and skeletonize leaves when feed in gregarious form, especially on greengram and blackgram. Cowpea faces major infestation from aphids (*A. craccivora*) and stem-flies [*Ophiomyia phaseoli* (Tryon)]. The north east hilly region of India is, by default or other way, known for its pro-organic tends. Managing insect-pests while resorting minimum on insecticides, is a limitation in these states. IPM approaches like development of resistant varieties, cultural management practices; biological control through predators, parasitoids, entomopathogens and other eco-friendly approaches could fit well in the hilly agro-ecosystem.

There is sizeable scope to further increase the pulse productivity by suppressing these insect pests in this unique region of India.

Exploring the potential of epiphytic yeast as a natural antifungal agent against fruit rot disease in chilli

SUSHANTI THOKCHOM[1*], RAJKUMARI TOMBISANA DEVI[1],
AKOIJAM RATANKUMAR SINGH[2], KENNEDY NINGTHOUJAM[1]
[1]School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, Umiam-793 103, Meghalaya, India, [2]ICAR-RC for NEH Region, Manipur Centre, Lamphelpat-795 004, Imphal, Manipur, India
**Corresponding email: sushithokchom@gmail.com*

The majority of research in the field of biological control of plant pathogens has predominantly focused on investigating antagonistic properties exhibited by bacteria, actinomycetes, and filamentous fungi. Unfortunately, antifungal yeasts have received insufficient attention and have been subjected to limited exploration using cutting-edge technology and molecular-level investigations, despite their potential as microorganisms capable of controlling plant diseases. Taking this into account, the present study was undertaken to identify a bioactive compound derived from yeast that could effectively manage fruit rot disease caused by *Colletotrichum truncatum* in Chilli. A total of 160 epiphytic yeast strains were isolated from diverse genotypes of chilli cultivated in the North Eastern Region of India. Among these, six isolates demonstrated significant inhibitory effects on the growth and sporulation of the targeted pathogen, *Colletotrichum truncatum*. The inhibitory percentage ranged from 70% to 95% using various antagonistic techniques including Single streak assay, Co-cultivation, Volatile Organic Compound (VOCs) production, and Cell-free extract. Identification of VOCs through comprehensive GC-MS analysis revealed that 84% of the compound present in the cell-free extract was identified as 3-Methyl Butanoic acid, a novel compound previously reported to possess remarkable antagonistic properties. Molecular identification using ITS and NL gene sequencing confirmed the identity of the isolates as *Meyerozyma guilliermondii, Rhodotorula paludigena, Saturnispora silvae,* and *Rhodotorula taiwanensis*. The bioactive compound holds potential for further purification and standardization to enhance its efficacy in managing the disease under field conditions as well as during post-harvest stages.

Organic disease management of turmeric for future sustainability and livelihood in hill farming

MADHUSMITA KATAKY[1]*, D.N. KALITA[1], D.P. DUARAH[1], R. HELIM[1]
[1]Krishi Vigyan Kendra, Kamrup AAU, Kahikuchi Campus
**Corresponding email: madhusmitakataky@gmail.com*

Turmeric (*Curcuma longa*) is one of the most commercially important worldwide spice crop. In turmeric cultivation, major constraints are rhizome rot caused by fungal pathogen '*Pythium*

aphanidermatum'. For future sustainability and livelihood, Organic way of cultivation is the need to improve the quality of the spices against the inorganic practices specially in hilly region. Various organic treatments to improve the plant health for turmeric were carried out. Among the treatments evaluated against the disease, the rhizome treatment with *Trichoderma viride* (1:10) + application of *Trichoderma enriched FYM @ 2kg/sqm* + application of powdered Neem Cake @ 25g/pit at the time of planting + spraying of Panchygavya for both the crop shows the best result by lowering disease incidence (14.2 and 13.1) followed by Treatment 2 ie. hot water treatment of rhizome @ 450C for 20 min + Soil application of *Trichoderma* enriched FYM @ 3kg/sqm + Soil drenching of 1% Bordeaux mixture at one month interval. Yield increases in treated plots over control was significant. Bio-inputs application like *Trichoderma*, Neem cake, Neem seed powder, along with panchagavya application improved quality of rhizomes. Dry Matter content of turmeric (15.91%) & Curcumin content of turmeric (5.42%) were recorded significant increment over the control. Therefore, organic module by application of bio-inputs is the best approaches for safe and profitable turmeric cultivation in hill areas.

In vitro evaluation of biocontrol agents, botanicals and fungicides against *Fusarium* sp. causing stem rot of dragon fruit (*Hylocereus* spp.)

O.M. PRAKASH[1,3*], A. RATANKUMAR SINGH[1,2], TASVINA R. BORAH[2], PANKAJ BAISWAR[2], KENNEDY NINGTHOUJAM[3], DWIPEN THAKURIA[3], SHRUTI SINHA[1,3], SUSHANTI THOKCHOM[1,3], E. NONGTDU[1], ANKIT ALOK[3], DEEPU KUMAR[1,3]

[1] ICAR Research Complex for North Eastern Hill Region, Manipur Centre, Lamphelpat-795004, Imphal West, Manipur India, [2]ICAR Research Complex for North Eastern Hill Region, Umiam-793103 Umiam 793103, RiBhoi, Meghalaya, India, [3]College of Post Graduate Studies in Agricultural Sciences, CAU-Imphal, Umiam 793103, RiBhoi, Meghalaya, India

Dragon fruit (*Hylocereus polyrhizus*) is a herbaceous perennial climbing cactus species belonging to the family Cactaceae. Dragon fruit is more popular as worldwide due to its attractive colors, taste, sweet, juicy pleasant and nutritional richness with medicinal properties. Fruit is rich in vitamin B1, B2, B3, C, Iron, Calcium, Potassium and low carbohydrate and fat. However, dragon fruit is susceptible to various biotic (anthracnose, stem and fruit rot, pre and postharvest rot, Blight, bacterial soft rot, bacterial stem rot, viral disease and nematode disease), adversely affecting its yields and quality. The most destructive disease of dragon fruit is stem and fruit rot caused by *Fusarium* spp. with losses of up to 40%. Identification of pathogen causing stem rot of dragon fruit and *in vitro* efficacy of test of different biocontrol agents, botanicals and fungicides against *Fusarium* sp. were conducted. Evaluation of twenty-four *Trichoderma* spp. against mycelial growth of *Fusarium* sp. using dual culture method with three replication and found the best three *Trichoderma* spp. with the mycelial growth inhibition of T4 (91.48%), T6 (90.76%) and T5 (90%). *In vitro* efficacy test of six botanicals extract from *Allium sativum*, *Zingiber officinale*, *Curcuma augustifolia*, *Curcuma longa*, *Kaempferia rotunda* and NEH plant extract using food poison technique against *Fusarium* sp. revealed that

ginger extract (5%) and NEH plant extract (10%) recorded the maximum mycelial growth inhibition in tune of 100 %. Similarly, *in vitro* efficacy of six fungicides like Azoxystrobin 45% and chlorothalanii 40%, Kasungmycin 5% + COC 45% WP, Carbendazim 12% and mancozeb 63%, Hexaconazole 5% SC, Fluopicolide 5.56% WW+ Propamocarb hydrochloride 55.6% WW and Chlorothalonil 75% WP was evaluated and found Kasungmycin 5% + COC 45% WP (0.05%) and Azoxystrobin 45% + chlorothalanii 40% (0.25%) recorded the maximum mycelial growth inhibition of 100% and 87.77% respectively. The present study findings would be benevolent for integrated disease management development to control *Fusarium spp.* causing the stem rot of dragon fruit.

Host-plant expansion of *Aphis gossypii* Glover on patchouli [*Pogostemon cablin* (Blanco) Benth], population dynamics of major insect pests and their bioecological management

N.Y. CHANU[1*], HELEN SOIBAM[1], NANCY LEGO[1], T.S. MEHRA[3], T. SHANTIBALA[3], N. SURMINA DEVI[3] DENISHA RAJKHOWA[2], K.M. AJAYKUMARA[3], A.K. TRIPATHI[2]

[1]AICRP on MAP&B, College of Agriculture, Central Agricultural University (Imphal), Pasighat- 791102, Arunachal Pradesh, [2]College of Agriculture, Central Agricultural University (Imphal), Pasighat- 791102, Arunachal Pradesh, [3]College of Horticulture and Forestry, Central Agricultural University (Imphal), Pasighat- 791102, Arunachal Pradesh

**Corresponding email: naoremyaiphabichanu@yahoo.in*

Aphis gossypii which is a polyphagous sucking pest has expanded its hosts to *Pogostemon cablin* (Blanco) Benth, commonly known as patchouli, an aromatic crop which is a first report from India from the foothills of Arunachal Pradesh. The results from a study conducted on population dynamics for the major insect pests of patchouli i.e. *Aphis gossypii* and *Herpetogramma licarsisalis* for four consecutive years i.e., 2019, 2020, 2021 and 2022 revealed that the population of *A. gossypii* showed a significant negative correlation with total rainfall during all the four years (r = -0.77, r = -0.57, r = -0.56 and r = 0.39); a significant negative correlation with average relative humidity (r = -0.55) during 2021 and significant positive correlation with average maximum temperature (r = 0.66) and average minimum temperature (r = 0.57) during 2022. On the contrary, the population of *H. licarsisalis* showed a significant positive correlation with total rainfall during the four consecutive years (r = 0.61, r = 0.67, r = 0.66 and r = 0.37); a significant positive correlation with average relative humidity during 2019 (r = 0.63), 2020 (r = 0.49) and 2022 (r = 0.42); a significant negative correlation with average maximum temperature (r = -0.53) during 2019. Simultaneously, a study on bio-ecological management of these major pests was conducted during 2021 and 2022 and the results revealed that chlorpyriphos 20 EC @ 2.5ml/L to be the best treatment for management of *A. gossypii* (66.03% and 65.52% population reduction over control) during both the years which was followed by Spinosad 45SC @ 0.4ml/L (69.40% and 57.0% population reduction over control). During 2021, chlorpyriphos 20 EC @ 2.5ml/L proved to be the most efficient treatment against the *H. licarsisalis* (76.33% reduction over control) followed by Spinosad 45SC @ 0.4ml/L (69.40% reduction over control) but during 2022 Spinosad 45SC @ 0.4ml/L (70.29% reduction over control) was the best treatment followed by chlorpyriphos 20 EC @ 2.5ml/L (62.30% reduction over control). Mulching with paddy straw in inter-row spaces proved to be the most

beneficial treatment for the natural enemies giving highest oil yield (81.11 kg/ha and 118.06 kg/ha) and highest benefit cost ratio (1:2.19 and 1:5.48) during both the years 2021 and 2022.

Trend of Genetic diversity in Job's tear genotypes using agro-morphological, grain quality and SSR markers

AMIT KUMAR*, S.P. DAS, AVINASH PANDEY, KRISHNAPPA R., SHIV POOJAN SINGH, PHILANIM W.S., V.K. VERMA, V.K. MISHRA

ICAR Research Complex for NEH Region, Umroi Road, Umiam – 793103, Meghalaya

**Corresponding author email: amit4118@gmail.com*

The transformation of food production system from ensuring food security to enhancing healthy and highly nutritious diets has necessitates the cultivation of underutilized crops like Job's tear with better nutritive values. 34 Job's tear accessions collected over North Eastern Hilly regions of India were evaluated for agro-morphological traits, nutritive values and variability was assessed using morphological and molecular markers. Traits namely, test weight, yield per plant, leaf length and number of internodes per plant have shown high genetic advance over mean. Traits with significant positive relation with yield per plant were plant height, number of tillers per plant, leaf length, number of internodes per plant and test weight. Out of four major groups obtained by morphological clustering cluster II was found to have high aesthetic value. The first principle component contributed 40.746% of the total variance and dominated by the yield and growth related traits like yield per plant, test weight, plant height, number of tillers per plant, leaf length and number of internodes per plant. GBssrJT149 was found to be the most informative and useful marker for the analysis of Job's tears accessions. Both cluster analysis and principal coordinate analysis (PCoA) has grouped the accessions into three major groups. However, model based clustering, based on ΔK value has divided the entire population into two subgroups. Test weight and number of internodes per plant exerted very high positive direct effect on yield per plant. Based on AMMI analysis, accessions namely, IC 540181, IC 89393 and IC 89392 with large PC1 scores were the high performing ones for yield per plant. Accessions with high performance and stable performance as indicated by PC1 score of zero or nearly zero were IC 600638, IC 540181, IC 540256, IC 540279 and IC 486143. Based on MTSI, 5 accessions namely, IC 600638, IC 89392, IC 540181, IC 604098 and IC 540256 were found suitable for selection at 10 % selection intensity for yield related traits. The accessions with high yielding ability with better quality can be utilized for future breeding programme.

THEME-4

Innovations in Livestock and Fisheries

Sero-molecular investigation of lumpy skin disease virus circulating in the hill state of Meghalaya

SAMIR DAS[1*], L. WAHLANG[1], SABIA KHAN[1], A.A.P. MILTON[1], K. PURO[1], K. SRINIVAS [1], E.L. LYNGDOH[1], H. KYLLA[2], CHANDRIMA PEBAM[1], CAREEN L PAKYNTEIN, DANIAL PYNGROPE[1], S. GHATAK[1], A. SEN[1]
[1]ICAR Research Complex for North Eastern Hill Region, Umiam, [2] Department of Veterinary and Animal Husbandry, Govt. of Meghalaya
**Corresponding email: drsamirvph@yahoo.com*

The present study was done to study the introduction of LSDV in the state of Meghalaya. We were vigilant and investigating every suspected cases/ outbreak of LSDV since the first reports of the virus from the state of Orissa in 2019.The first positive cases from Meghalaya could be confirmed by our laboratory in the year 2022 through polymerase chain reaction (PCR) assays based on p32 and v117 genes of LSDV corresponding to envelope and fusion protein respectively. A total of 30 numbers of suspected tissue samples submitted by Department of Veterinary and Animal Husbandry, Govt. of Meghalaya between June 2021 to Jan 2023 were screened through PCR and 6 positives by both PCR (p32 & v117), 15 positives by either of the PCR (p32 or v117), 14 positives for v117 gene and 7 positives for p32 gene. Representative amplified PCR products were sequenced for the respective genes and were further put on nBLAST which confirmed it for LSDV. The sequenced products were further studied for their phylogenetic analysis along with other global and national strains of LSDV which showed that the circulating strains were close to reported Indian and Asian-African strains. Further, during the same period we have received 117 suspected serum and additionally we have collected 65 serum samples of cattle from Mawiong slaughter house, East Khasi Hill District, Govt. of Meghalaya from August 2022 to Dec 2022. The serum samples were put for indirect ELISA for presence of LSDV antibodies which showed 10/117 and 11/65 samples to be positive with overall sero-positivity as 11.54% (21/182). The molecular and serological positivity confirmed the presence of LSDV in the state of Meghalaya which warrants heighted surveillance of LSDV in the state for its effective control and prevention.

Identification and characterization putative immunogenic peptides from field isolate of *Campylobacter coli* through microbiological, proteomic, genomic and immuno-informatics approach

SANDEEP GHATAK*, A.A.P. MILTON, SAMIR DAS, S. DEORI, ARNAB SEN, K. PURO, K. SRINIVAS, D. BHARGAVI, K.M. MOMIN
ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Corresponding email: ghataksnd@rediffmail.com*

The present study was conducted to identify the putative antigenic components of *Campylobacter coli* bacterium which is a major pathogen causing zoonotic infections in humans and production loss to swine husbandry as well. *C. coli* field strain (NEH) was isolated

previously from pig faecal sample following standard microbiological techniques as per ISO 10272-1:2017 method. Following molecular and genomic confirmation the strain identity, whole genome sequencing was undertaken on Illumina Nextseq platform. Moreover, whole proteome of the bacterium was also resolved by SDS-PAGE. Proteome and WGS data were first quality checked (FastQC), and were subsequently analysed with a variety of tools and methods to identify potential peptides with vaccigenic potential. Our results from proteome study revealed two potential peptides of 45kDa and 29kDa that could be targets for vaccine development. Analysis of WGS data, on the other hand, identified 51 cell wall and capsule associated genes and 49 genes associated with virulence, defense and disease causation. Of these, there were 21 highly antigenic fractions and 9 very highly antigenic fractions with mean antigenicity score of 0.9389 ± 0.0309. To understand the chromosomal organization, these very promising peptides were also mapped to the whole genome of *C. coli*. The mapping results showed that these peptides were encoded by genes located in the regions between 100 - 600 kbp and 2300 - 2500 kbp indicating future possibility of recombinant peptide synthesis. In order to assess the exposure of the peptide to host immune system to evoke a protective response, we estimated the trans-membrane domains of each peptide. Our initial results revealed that of the 30 peptides, 4 peptides were most promising with 2 - 5 trans-membrane domains implying that these segments would be exposed to host immune system eliciting an immune response. Among the three peptides, two peptides had their -NH_2 end exposed indicating an amide mediated interaction with the host immune apparatus while another had -COOH functional end exposed across the membrane. Taken together, our results identified 4 putative peptides with vaccine potential from the field isolate if *C. coli* through a combination of microbiological, proteomic, genomic and immuno-informatics approach.

"Disease knows no boundaries and borders are porous to disease": Recent ingression of African swine fever into Meghalaya

A.A.P. MILTON[1*], SABIA KHAN[1], K. SRINIVAS[1], S. DAS[1], S. GHATAK[1], G. BHUVANA PRIYA[2], H. KYLLA[3], K. PURO[1], A. SEN[1]

[1]ICAR Research Complex for NEH Region, Umiam, Meghalaya, [2]College of Agriculture (CAU, Imphal), Kyrdemkulai, Meghalaya, [3]Animal Husbandry & Veterinary Department, Meghalaya

**Corresponding email: vetmilton@gmail.com*

African swine fever (ASF), which first emerged in India in 2020, is a deadly, highly transmissible, and transboundary viral disease that affects both domestic and wild pigs. It is characterized by hemorrhagic fever and has a case fatality rate of up to 100%. In June 2020, India experienced its first ASF outbreak in northeastern region. In the current study, ASF outbreak was investigated in six districts (Ri Bhoi, East Khasi Hills, West Khasi Hills, East Jaintia Hills, West Jaintia Hills and West Garo Hills) of Meghalaya. Tissue samples (blood, spleen, lymph node, and lung) were collected from pigs (n = 153) that died and were suspected for ASF from 2020 to 2023. p72 (or B646L) and p54 (or E183L) genes were amplified and sequenced from representative samples. Phylogenetic analysis was undertaken to decipher the prevalent genotype and genetic similarity between the previously analyzed global and Indian

strains. Molecular investigation using real-time PCR and SRCA assays confirmed the outbreak. A total of 53 animals were detected as positive for the ASF virus. Phylogenetic analysis revealed that the detected strains belong to genotype II, and the genetic similarities found between ASFV strains from Meghalaya, neighbouring states, and other countries demonstrate the disease's transboundary spread. The spread of ASF at alarming speed in India indicates that there is a greater chance for ASF to become endemic, particularly in northeastern India, which has a sizeable pig population. For the development of effective control strategies against the disease, continuous monitoring and surveillance are crucial in northeastern India.

Gastrointestinal parasitic infections in poultry of North Eastern region of India

R. LAHA*, M. DAS, S. DOLEY, B. SAILO, DONI JINI, V. SINGH, BRIJESH KUMAR, MAHAK SINGH, LALHRUAIPUII

ICAR Research Complex for NEH Region, Umiam, Meghalaya

**Corresponding email: rglaha@gmail.com*

Among various animal husbandry practices, poultry farming is considered as one of the low-cost farming among different animal husbandry practices. In recent years, poultry farming has developed tremendously. But frequent outbreak of diseases is a threat for poultry farming. It has been reported by several workers that gastrointestinal (GI) parasitic infections in poultry causes economic losses to the farmers. Keeping in view of that present study was undertaken to know GI parasitic infections in poultry of north eastern region of India. A total of 2247 numbers of faecal samples of poultry were collected from different north eastern states like Meghalaya, Manipur, Arunachal Pradesh, Tripura, Sikkim, Nagaland and Mizoram for detection of gastrointestinal (GI) parasitic infections. Out of these 920 (40.94%) faecal samples were found positive for different GI parasitic infections. State wise 42.60%, 42.57%, 60.93%, 37.56%, 31.70%, 31.42% and 18.94% infections were recorded in Meghalaya, Manipur, Arunachal Pradesh, Tripura, Sikkim, Nagaland and Mizoram respectively. *Eimeria brunetti*, *Eimeria tenella*, *Eimeria praecox*, *Ascaridia galli* and *Capillaria* spp. were recorded in faecal samples of poultry of Meghalaya; Eimeria spp. and *Strongyloides* spp. in Manipur; *Eimeria* spp. *Ascaridia galli* and *Capillaria* spp. in Arunachal Pradesh; *Eimeria* spp., *Ascaridia galli*, and *Strongyloides* spp. in Tripura; *Eimeria* spp. *Ascaridia galli*, *Strongyloides* spp. in Sikkim; *Eimeria* spp. *Ascaridia galli*, *Strongyloides* spp.in Nagaland and *Ascaridia galli*, *Eimeria* spp. in Mizoram were recorded in faecal samples of poultry. Post mortem examination of a total number of 598 GI tracts of poultry birds of both local birds and organized farms collected from butcher shops of Meghalaya revealed overall 21.23% (127/598) as positive for helminth infections. Indigenous poultry birds were found as 37.29% (113/303) positive where as 4.74 % (14/295) birds maintained in farm condition were found positive for GI parasitic infections. *Raillietina* spp. (Tape worm) and *Ascaridia galli* (Round worm) were identified after postmortem examination of GI tracts of poultry birds. Only *Eimeria* spp. were detected in intestinal scrappings of birds maintained in farm conditions. **Standardized molecular diagnosis of coccidiosis of poultry using PCR and five** different species of *Eimeria* i.e. *E. acervulina*, *E. praecox*, *E. mitis*, *E. maxima* and *E. tenella* were identified using PCR. Treatments of infected birds with suitable antiparasitic agents were advised.

Low-cost small scale intensive backyard poultry production system with improved germplasm

MAHAK SINGH*, N. PATTON, R.T. MOLLIER, H. KALITA, V.K. MISHRA
ICAR Research Complex for NEH Region, Medziphema, Nagaland
**Corresponding email: mahaksinghivri@gmail.com*

Backyard or family poultry rearing is practiced in NEH region since ancient time. Backyard poultry provides quality animal source food, enhance family income, generate employment, empower women and conserve biodiversity. In recent years, backyard poultry has gained attention for its role in food and nutritional security of vulnerable communities. There has been multi-prong approach to strengthen this system. One of the actions includes introduction of improved backyard poultry germplasm with better productivity. ICAR Nagaland Centre has developed a low-cost small scale intensive backyard poultry production system with improved germplasm. The characteristics of this system are i) raising more than 100-layer birds, ii) conventional housing system with low-cost materials, iii) have access to veterinary services and pharmaceuticals, iv) access to urban market, v) produces live birds, meat, eggs and vi) time devoted each day is more than one hour. The house is made up of bamboo, wood and CGI sheet with length and width of 50 ft and 20 ft. Height of side wall is 4 ft. Maximum height is 10 feet. The depth of bedding materials (rice husk, saw dust etc.) 0.5 to 1.0 ft. The capacity of house is 300 to 400 adult birds. The production performance of the system is presented in Table 1. The production performance of Vanaraja and Srinidhi birds in this system are better than intensive production system. Based on the production performances, this system is recommended for farmers' field.

Table 1. Production Performance of improved backyard poultry germplasm under low-cost small scale intensive production system (5 years average)

Parameters	**Vanaraja**	**Srinidhi**
Mortality (6-20 weeks)	2.55%	1.85%
Mortality (21-72 weeks)	7.8%	6.35%
Age at first lay	132 days	128 days
Peak production HDEP	64%	78%
Total egg production per hen (72 weeks)	162.52 ± 0.85	235.23 ± 0.98
Fertility%	86.87%	81.23%
Hatchability on total egg set	71.25%	70.24%
Hatchability on fertile egg set	82.35%	80.15%
Feed consumed (20-72 weeks)	44 kg	40 kg
Chicks produced per hen (up to 72 weeks)	114 nos.	152 nos.

Indigenous chicken production system in different agro-ecology of Indian Himalayan region: Implication on food and economic security

MAHAK SINGH*, NUNGSHITULA PONGENER, R.N. PATTON, RAHUL KATIYAR, VINAY SINGH, H. KALITA, V.K. MISHRA
ICAR Research Complex for NEH Region, Medziphema, Nagaland
**Corresponding email: mahaksinghivri@gmail.com*

The indigenous chicken production system (ICPS) has multiple use values and ecosystem services. In recent years, this system has gained attention for its potential to promote household food security, income generation, wildlife conservation, and the empowerment of women. This study aimed to collect, for the first time, comprehensive information about ICPS in three different agroecologies (tropical, sub-tropical, and sub-temperate) of the Indian Himalayan Region (IHR) and its role in food and economic security of the traditional communities. In this study region, ICPS is semi-extensive with a provision of homegrown feed and temporary shelter at night. In sub-temperate agro-ecology, females owned significantly ($P < 0.05$) higher indigenous chicken flocks. Households in sub-temperate agroecologies had significantly ($P < 0.05$) larger flock sizes and tropical livestock units (chicken-TLU). However, the livestock diversity index (LDI) was significantly higher ($P < 0.05$) in tropical and subtropical agroecologies. Significantly more households in the sub-temperate region valued indigenous chicken for its adaptability and survivability ($P < 0.05$). Mortality in adult birds constitutes approximately 9%, 14%, and 15% of the total flock in sub-temperate, tropical and sub-tropical agroecologies, respectively. In sub-temperate agroecology, larger flock size translated into higher ($P < 0.05$) egg production and subsequently higher egg consumption ($P < 0.05$) per household per month. The households' dietary diversity score was significantly higher ($P < 0.05$) in sub-temperate agroecology. The average annual income from the indigenous chicken was significantly higher ($P < 0.05$) in sub-temperate agro-ecology and accounted for 18% of household income. The marketing chain of ICPS was relatively shorter in the sub-temperate region. The demand for indigenous chicken and egg was significantly higher ($P < 0.05$) in the winter season in all the agroecologies. The litter from ICPS is used as farmyard manure, contributing to ecological resilience. Predators, non-availability of chicks, and diseases are the three most reported constraints to expand the indigenous chicken production system in all the agroecologies. The results indicate that ICPS contributes to food and nutritional security, economic security, and ecological resilience of marginalized communities in this hilly and fragile ecosystem. Even though the system is self-sustaining, there is potential to improve production and productivity through management and health interventions.

Global warming potential of poultry production in India: Evaluation using life cycle assessment approach

MAHAK SINGH*, N. PONGENER, REKHA YADAV, R.N. PATTON, R. TALIMOA MOLLIER, TRINAYANA KAUSHIK, RAHUL KATIYAR, VINAY SINGH, H. KALITA, V.K. MISHRA

ICAR Research Complex for NEH Region, Medziphema, Nagaland
**Corresponding email: mahaksinghivri@gmail.com*

An environmental assessment of the broiler chicken production in India from a cradle-to farm gate perspective was carried out using Life Cycle Assessment with the aim of identifying the environmental hotspots of the production system. To do so, broiler chicken production system in India was investigated in detail. The life cycle inventory included all inflows and outflows of the subsystems: feed-ration production and broiler grow-out, with system boundary from cradle to the farm gate, and the functional unit of the "1-kg live weight produced. Inventory data for the broiler chicken farms were collected from six different farms but typical of Indian broiler production system. Background data was taken from Ecoinvent database. The impacts categories evaluated were mainly: Global Warming Potential in hundred years (GWP), stratospheric ozone depletion, ionizing radiation, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, land use, mineral resource scarcity, fossil resource scarcity and water consumption. Results showed that the broiler chicken feed is the main factor responsible for the environmental impacts analysed followed by transport and electricity process. The total GWP for the broiler chicken production process was 3.77 kg CO2-eq per kg of live weight produced. Specifically, the energy component of feed viz. maize production was the main environmental hotspots. The process of transporting feed and chicks to the broiler farm also had a significant impact on the environment. The environmental results were compared with other published Life Cycle Assessment studies of chicken production in other countries and it was found that the environmental impacts of Indian broiler production system is on moderate level. A number of improvement actions are proposed to further reduce the environmental impacts of broiler chicken production system in India.

Genetic diversity analysis of native sheep population of eastern Indian Himalaya using microsatellite DNA markers

ARUNDHATI PHOOKAN[1*], GALIB UZ ZAMAN[1], BULA DAS[1], ARPANA DAS[1], MOMI SHARMA[1], PRANAB JYOTI DAS[2], SOURABH DEORI[3]

[1]College of Veterinary Science, Assam Agricultural University, Khanapara, Guwahati, [2]ICAR-National Research Centre on Pig, Rani, Guwahati, [3]ICAR- Research Complex for North Eastern Hill Region, Umiam, Meghalaya

**Corresponding email: arundhatiphookan@rediffmail.com*

A study was undertaken for genetic diversity analysis of three native sheep populations of eastern Indian Himalaya utilizing twenty-five Ovine microsatellite markers. A total of 150 sheep, 50 each from the states of Assam, Meghalaya and Arunachal Pradesh were genotyped through microsatellite. Polymorphism was revealed in most of the markers with a total of 242 numbers scored alleles. The average observed (H_o) and expected (H_e) heterozygosity estimates for Assam, Meghalaya and Arunachal Pradesh sheep were 0.311 and 0.396; 0.323 and 0.383; and 0.416 and 0.408 respectively suggesting that the genetic diversity of each population ranged from intermediate to high. The average polymorphism information content (PIC) estimates and Shannon's Information index were 0.357 and 0.70; 0.366 and 0.75; and 0.292 and 0.75 in

Assam, Meghalaya and Arunachal Pradesh sheep populations. Mean F_{IS} (within-population inbreeding estimate), F_{IT} (Between-population inbreeding estimate) and F_{ST} (Population differentiation measure) estimate for three populations under consideration were 0.149, 0.224 and 0.088, respectively. Significant deviations from Hardy-Weinberg equilibrium (based on Chi-square) were found in a total of 10, 13 and 6 alleles in Assam, Meghalaya and Arunachal Pradesh sheep population which indicated evolutionary force in operation at these loci in the respective population. Genetic diversity and phylogenetic relationship study using microsatellite markers revealed that Assam and Meghalaya sheep are the closest relatives, followed by Assam and Arunachal Pradesh sheep, and Meghalaya and Arunachal Pradesh sheep.

Livestock based natural farming

K. MERINA DEVI*, T. GYANESHORI DEVI, N. BHUMAPATI DEVI
College of Veterinary Sciences & Animal husbandry (CAU-I), Jalukie, Peren, Nagaland
**Corresponding email: merinadevi.90@gmail.com*

With the advent of new concepts, modernization, health and environment conscious, the concept of conventional farming has changed gradually towards natural farming during the past few decades. Natural farming has come into existence with the objectives to promote food security, food quality, sustainable farming by minimizing or eliminating the use of chemicals or synthetic products like growth promotors, feed additives and supplements, antibiotics, genetically modified feeds, vaccines etc. and thereby reducing their harmful effects on crops and livestock, promotes alternative methods of farming for freedom from external purchased inputs, cost reduction, soil health and crop growth, utilization of available desi livestock as valuable resources, water conservation, rejuvenation of croplands and ultimately increase income for farmers for better sustainable livelihood in an eco-friendly way. Under the alarming risk of harmful effects due to change in environmental conditions on agriculture and livestock, the practices of livestock based natural farming is the utmost necessary for sustainable agriculture and livestock and thereby creating green economy. Utilization of medicinal plants and herbs, indigenous micro-organisms (IMOs), Indigenous Technical Knowledge (ITK) towards livestock production is widely accepted in natural farming. Animal reared under natural farming are healthy, have minimal incidence of diseases and involves negligible cost of investment with zero inputs cost. Avoiding the freedom of movement (keeping animals tied inside the shed, keeping animals in shed throughout the year), sensory deprivation (environmental stimuli such as light, weather), and unsocial ways of husbandry, are strictly prohibited under natural livestock farming and thereby, the five pillars (5 P) that is Pusti, Prajanana, Parichalna, Pratishedhak and Parajibi Nashan of livestock rearing practices are to be addressed in an eco-friendly way. Natural farming becomes successful only when livestock production and its produces like dung, urine, droppings, milk, meat, egg etc. are produced chemical free and near to the nature. Therefore, natural farming involves all aspects of living harmony which includes agro-livestock-ecological aspects in context to creating the universal sustainable and environmental-friendly food systems and healthy life.

Reproductive performance of Khaki Campbell ducks under the agro-climatic conditions of Meghalaya

S. DOLEY*, S. DEORI, R. LAHA, K. PURO
ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Corresponding email: doleysunil@yahoo.com*

Reproductive performance of duck is most sensitive to environmental and genetic influences. Different factors like husbandry practices, seasons, mating systems, semen quality, incubation conditions etc. have been shown to influence duck egg production, fertility and hatchability of eggs. Therefore, the studies have been undertaken to evaluate the reproductive performance of Khaki Campbell ducks under semi-intensive system of rearing in the agro-climatic conditions of Meghalaya over a period of five years (2018-2022) under an institute funded project. Reproductive performance in terms of egg production, semen quality, fertility (%), hatchability (%) and dead in shell were evaluated under different seasons, mating systems, and incubation conditions. The overall age at first egg (days), egg weight at first egg (g), egg weight at 40 weeks of age (g), Hen Day Egg Production (%) at 40 weeks were recorded to be 168±1.38, 45.21±1.02, 62.15 ± 0.51 and 68.49±4.32 respectively. Irrespective of seasons, the fresh semen qualities of Khaki Campbell drakes were found to be optimum with overall mean values of 0.5 ± 0.01, 87.38 ±2.86, 6.66 ± 1.25, 90.96 ± 5.41 and 11.56 ± 2.35 for ejaculate volume (ml), initial motility (%), sperm concentration (x 10^9/ml), liveability (%) and sperm abnormality (%) respectively. The overall fertility rate of Khaki Campbell duck eggs was recorded higher during the winter (81.79±2.35%) compared to summer (76.94±3.27%) seasons in Meghalaya. The overall fertility rate of Khaki Campbell duck eggs was found to be better with male to female mating ratios of 1:4 (82.34±3.19 %) compared to 1:5 (81.13±3.28 %) and 1:6 (79.23±2.19 %). The overall hatchability (% FES) and dead in shell (%) were recorded to be 61.79± 3.45 and 17.24±3.10 respectively. The spraying of lukewarm water once daily in the setter during the first 18 days of incubation period under standard setting (Dry bulb: 99.50 ±0.5^{O}C; Wet bulb: 86.00±0.5^O C) conditions could improve the hatchability of duck eggs (5-6 %). The overall reproductive performance of Khaki Campbell duck in the agro-climatic condition of Meghalaya was found to be optimized under semi-intensive rearing system.

Evaluation of crossbred dual purpose birds under different management systems in the agro-climatic condition of Meghalaya

S. DOLEY*, S. DEORI, K. PURO, K.K. BARUAH
ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Corresponding email: doleysunil@yahoo.com*

The present study was conducted to evaluate the productive and reproductive performance of PB2 (♂) x RIR (♀) crossbred birds developed for dual purpose under intensive and backyard rearing systems in the agro-climatic condition of Meghalaya. A total of 1000 numbers of day-old chicks were brooded under standard battery brooder up to 4th weeks and were randomly divided into two groups of 500 chicks in each group. One group was reared under standard deep litter system in the institute poultry farm and

another 500 chicks were distributed to 10 farmers of Ri-Bhoi and 10 farmers of East Khasi Hill districts of Meghalaya with 25 chicks to each farmer for rearing under improved backyard systems. The chicks were vaccinated against Ranikhet and Gumboro diseases as per the schedules. The different productive and reproductive parameters were recorded up 72 weeks of age. The live body weight at 8th, 12th, 16th, 20th and age at sexual maturity were found to be significantly higher under deep litter system than backyard system. The overall FCR up to 8th week under deep litter system was recorded to be 2.52±0.25. The age at first egg was earlier and first egg weight was higher under deep litter (168.50±5.69 days and 41.81±0.48g) compared to backyard (175.00±4.95 days and 40.41±0.10 g) systems. The mortality rate of the birds up to sexual maturity was significantly higher under backyard system (17.84±0.81%) compared to deep litter system (9.33±0.24 %). Overall, Hen Day Egg Production up to 72 weeks was found to be good under deep litter system (39.49±0.51%), but was poor under backyard system (24.36±0.50 %). The study revealed that the performance of crossbred birds developed for dual purpose was found to be poor under backyard rearing system due to high mortality and poor egg production. However, the performance under deep litter system was found to be optimum.

Effect of feeding banana pseudostem (*Musa spp*.) and cassava tubers (*Manihot esculenta*) on the growth performance and nutrient utilization of cross-bred (Lumsniang) pigs in Mizoram

LALHRUAIPUII*, I. SHAKUNTALA, S. DOLEY
ICAR Research Complex for NEH Region, Kolasib, Mizoram
**Corresponding email: lhpuii@gmail.com*

Eighteen (18) numbers of cross-bred grower pigs (Lumsniang) were randomly divided into 3 treatment groups, consisting of 6 pigs in each group and allotted in individual pen with the provision of feeding and watering. A feeding trial was conducted incorporating Banana pseudostem (*Musa spp*.) and Cassava tubers (*Manihot esculenta*) (1:1 on DM basis) as a replacement to the standard commercial grower pig ration at 0% (G1), 15% (G2) and 25% (G3) for a period of 154 days. It was observed that the average dry matter intake was higher in G2 followed by G3 and G1 being the lowest. In the current study, no significant differences were observed among the control and treatment groups in terms of overall body weight gain, FCR and nutrient utilization. However, the ration incorporated with banana pseudostem and cassava tubers (1:1) reduced the feed cost resulting in increased total overall net income. Therefore, standard pig grower ration can be substituted with banana pseudostem and cassava tubers (1:1) up to 25% for economic small scale pig production system in Mizoram.

Enrichment of extender with Oxyrase preserves the *in vitro* quality of crossbred Hampshire boar spermatozoa during liquid storage

R. KATIYAR*, H. CHAKRAVARTY, S.N. ABEDIN, M. SINGH, S. DEORI, G. KHARGARIA
ICAR Research Complex for NEH Region, Umiam, Meghalaya-793105, India
**Corresponding email: rahul.katiyarvet@gmail.com*

Boar spermatozoa lose its quality as storage duration increases during liquid preservation. The high abundance of polyunsaturated fatty acids in the sperm plasma membrane makes it a sensitive candidate for lipid peroxidation. Generation of reactive oxygen species during liquid storage compromises the overall quality of boar spermatozoa. Therefore, the present study was designed to use the oxygen scavenging properties of Oxyrase to preserve the quality of boar spermatozoa during liquid preservation. A total of 18 ejaculates from 3 crossbred Hampshire boars (n=3, 6 ejaculates from each boar) were collected and diluted at 1:2 with BTS extender. Each diluted ejaculated was the divided into 3 aliquots. The first aliquot served as control, whereas, Oxyrase was added at the rate of 0.125 (T1) and 0.25 IU/mL (T2) in remaining two aliquots, respectively. The semen quality parameters like sperm motility, viability, mitochondrial membrane potential (MMP), lipid peroxidation (LPO) and DNA integrity were evaluated on 0, 3 and 5 d of incubation during liquid storage at 15 °C. The findings revealed that sperm progressive motility and viability were significantly ($p < 0.05$) higher in T2 group on days 3 and 5 as compared to other groups. Also, it was observed that sperm MMP was significantly ($p<0.05$) higher in T2 group on day 3 and in both the treatment groups on day 5 as compared to control group. The LPO was significantly ($p < 0.05$) lower in both the treatment groups as compared to control group on day 5. No difference in DNA integrity was observed following Oxyrase supplementation. In conclusion, supplementation of Oxyrase at 0.25 IU/mL extender improved the *in vitro* parameters of crossbred Hampshire boar semen.

Development of an eco-friendly heating system to manage cold stress during pre-weaning period in piglets reared under hill ecosystem of Meghalaya

R. KATIYAR[1*], C. GONMEI[1], N.S. SINGH[1], N. SINGH[1], G. KADIRVEL[2], K. PURO[1], B.U. CHOUDHURY[1], M. SINGH[3], S. DEORI[1]

[1]ICAR Research Complex for NEH Region, Umiam, Meghalaya, [2]ICAR-Agricultural Technology Application Research Institute, Zone - VI, Guwahati, Assam, [3]ICAR Research Complex for NEH Region, Medziphema, Nagaland

**Corresponding email: rahul.katiyarvet@gmail.com*

Pre-weaning mortality in piglet is one of the major managemental problem that affects herd productivity and economics in the swine industry. Cold stress during winter season is one of the main causes of pre-weaning mortality. Considering this fact, the study aimed to investigate the performance of piglets on exposure to "Briquette Fuel Animal Heating System (BFAHS). It consists of skeletal support, casing, top cover and wire mesh, designed to burn beehive briquettes (charcoal and mud in 2: 1 ratio). One briquette can produce heat up to two hrs. Thirty (n = 30) piglets were subjected to three groups viz, Incandescent bulb (T_1), Beehive briquettes (T_2) and Control (T_3) over a period of two months (January-February). During the study, the average minimum temperature recorded was 6.6 ºC. The body weight, mortality rate and body condition score (BCS) were recorded at 15 days interval. Results showed that, at weaning the growth performance of piglets in group T2 was significantly ($p<0.05$) higher than T1 and T3, i.e., 9.45 ± 0.09kg, 7.28 ± 0.65kg and 7.14±0.55kg respectively. At weaning, BCS revealed that

all the piglets in T_2 were healthy, whereas in T_1, out of 8 piglets, 5 were healthy, 2 moderately compromised and 1 very compromised, similarly, in T_3, out of 7 piglets, 3 were healthy, 3 moderately compromised and 1 very compromised. No mortality in was observed in T_2, although, T_1 and T_3 had 20% and 30% mortality rates. The findings of the present study indicate that BFAHS can be effectively utilized during winter to improve piglet's performance and avoid pre-weaning mortality from cold stress.

Augmented-OvSynch technique to improve oestrus resumption and conception rate in postpartum lactating cows under Indian field conditions

SURESH KUMAR[1*], M. PANDE[1], S. SAHA[1], N. CHAND[1], N. PRASAD[1], S. ARYA[1], A.S. SIROHI[1], S. MAHAJAN[1], C. SINGH[1], D. SAHU[2], S.K. DUBEY[3], U. SINGH[1]

[1]ICAR-Central Institute for Research on Cattle, Meerut, Uttar Pradesh, [2]Saroorpur Khurd, Sardhana, Meerut, Uttar Pradesh, [3]ICAR-Agricultural Technology Application Research Institute, Kanpur, Uttar Pradesh

**Corresponding email: suresh_vet079@rediffmail.com*

The present study was undertaken with the objectives to develop a hormonal strategy that may lead to early pregnancy in postpartum (pp) cows under tropical field conditions, to evaluate the effects of hormonal intervention on blood oestrogen and progesterone profiles, and to determine the effects of hormonal intervention on biomarkers of oxidative stress in the postpartum period. The study utilised pluriparous pp cows (n=219, 55±10 days' pp) to evaluate the effects of oestrus synchronization using the Augmented-OvSynch technique. Animals were divided into two groups, namely the control group (no hormonal intervention; n=82) and the treatment group (n=137, oestrus synchronization using Augmented-OvSynch protocol, day (d) 0, PGF2α; d 6, GnRH; d 13, PGF2α; d 15, GnRH) followed by artificial insemination (AI) after observation of standing oestrus. A third GnRH injection was administered five days post-AI for promoting the formation of accessory corpus luteum. Groups were further divided into pregnant control animals (C-P), non-pregnant control animals (C-NP), pregnant treatment animals (T-P) and non-pregnant treatment animals (T-NP). Observations were recorded for size of the dominant follicle, oestrus expression, time from PG to onset of oestrus, duration of oestrus and conception at 35±5 and 60±5 days. Blood samples were analysed for circulating oestrogen, progesterone on the day of AI (day 0) and 5-, 10- and 21-days post-AI and for oxidative stress biomarkers on day 0- and 21-days post-AI. Oestrus induction showed significant improvement in the treatment group (83.94%) compared to the control group (37.80%). The overall conception rates were also significantly higher in the treatment groups (68.61% versus 29.27%). Importantly, circulating midcycle progesterone levels were higher in the treatment groups and fertility was better in cows with higher superoxide dismutase (SOD) and total antioxidant capacity (TAC) and lower malondialdehyde (MDA) levels. In conclusion, oestrus synchronization with the Augmented-OvSynch technique improved conception rates and could be promoted as a viable technique to improve reproductive performance under tropical conditions in pp lactating cows.

Investigating the impact of nanoparticles on sperm ultrastructure and gene expression in cryopreserved buck semen

S.N. ABEDIN[1*], A. BARUAH[1], S. DEORI[2], K.K. BARUAH[2], G. KADIRVEL[2], R. KATIYAR[B], S. DAS[2], S. DOLEY[2], A. BORA[1], D.J. DUTTA[1], H. CHAKRAVARTY[2]
[1]College of Veterinary Science, Assam Agricultural University, Guwahati, Assam, [2]ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya
**Corresponding email: sayedna14@gmail.com*

Reactive oxygen species (ROS) have a strong association with the oxidative stress (OS) that arises during the process of cryopreserving sperm. In fact, the harmful impact of ROS on cellular integrity during cryopreservation has been identified as a key factor contributing to the decline in sperm quality. Fortunately, the use of antioxidant nanoparticles (NPs) has shown promising results in mitigating such damages. However, the exploration of NPs and their interaction with sperm cells in livestock species has received limited attention thus far. Therefore, the present study explored the effect of NP supplementation on sperm ultrastructure, potential interaction with sperm membrane (especially cellular uptake), heat shock protein (HSP) genes and semen quality in cryopreserved Assam Hill Goat buck semen. Thirty-two (32) ejaculates were collected from four (4) adult male bucks and then diluted in Tris- citric acid-fructose yolk (TCFY) extender containing the Zinc-oxide (ZnO) and Selenium (Se) NP treatments (T_0: Control; T_1: 0.1 mg/mL ZnO NPs and T_2: 1µg/mL Se NPs) after initial evaluation. Diluted semen was packed in 0.25 mL French mini straws and then stored in liquid nitrogen. Evaluation of the different treatment groups included the analysis of sperm parameters, lipid peroxidation (LPO) profile, classification of sperm head morphological ultrastructure through transmission electron microscopy (TEM), potential interaction between NPs and the sperm membrane, as well as the expression of heat shock protein (HSP) genes. Results revealed a significant (p<0.05) increase in percentage of spermatozoa with intact plasma membrane, intact acrosome in T_1 and T_2 in comparison to the frozen control group. TEM assessment revealed no internalization of both ZnO and Se NPs into the sperm structure. Few occasional contacts of ZnO NPs with the sperm membrane and few agglomerates of Se NPs around the area of damaged membranes were visualized. HSP70 and HSP90 mRNA levels were significantly (p<0.001) higher in the NP supplemented groups in comparison to the control. HSP70 and HSP90 mRNA levels had a positive association with sperm motility and weak to moderate association with other sperm parameters. In conclusion, NP supplementation ameliorates peroxidative damages during sperm cryopreservation and increases semen quality attributes possibly by increasing the expression levels of HSP (anti-freeze) genes in buck semen. Furthermore, NP supplementation may have a potential role in preserving sperm head ultrastructure by acting as an antioxidant and reducing OS during various degrees of cellular insults, which needs to be further explored.

Interventions for livelihood improvement by empowering tribal women through piggery production in villages of Meghalaya

K. PURO*, S. DEORI, S. DAS, A.A.P. MILTON, R. KATIYAR, S. GHATAK
ICAR-RC for NEH Region, Umiam, Meghalaya
**Corresponding email: akulepuro@gmail.com*

Livestock is generally considered a key asset for rural livelihood and women constitute a major workforce engaged in livestock rearing. Women play an important role in livestock management particularly pig rearing being feed gatherers, primary care providers and farrowing attendants in the rural areas of north east India. Identifying and supporting women's roles as livestock owners, processors and users of livestock products while strengthening their decision-making power and capabilities, are key aspects in promoting women's economic and social empowerment and consequently provides a way to enable rural women to break the cycle of poverty. The objective of the interventions was to impart scientific way of rearing improved varieties of pig for livelihood improvement. Two Women Self Help groups (SHGs) comprising of ten members each from NongTyrlaw Sohkhwai Village (Ialam Lynti Ban-i) and UndenLa village (UTylli) under Umling block in Ri-Bhoi district of Meghalaya were identified and selected for imparting three days training programme at ICAR-RC for NEH Piggery demonstration farm on two consecutive year 2021 and 2022, respectively. The scientific methods of housing, feed and feeding, breeding, health and disease management were taught and hands-on practical demonstration were also done besides field exposure visits to various scientific housing model and managemental practices. On satisfactory completion of 3 days training, each beneficiary was given three (03) numbers of improved varieties of weaned piglets. Other supporting inputs such as formulated pig feeds, mineral mixture, deworming tablet, Liver tonic, anti-diarrhoeal preparation and bleaching powder for sanitization were also distributed for the initiation of rearing pig in a scientific way. All the participants made a new housing made of bamboo, wooden or concrete as per scientific space requirement of pig. Feeds and feed formulation was also improved by integrating locally available feeds and sufficient quantity provided for feeding. The performance of the piglets was monitored and found satisfactory. The piglet production starts after a year that was recirculated amongst them rearing for fattening purposes. One of the major practical challenges was disease outbreak due to introduction of pig from local market harbouring infectious diseases that spreads the disease in the locality resulting in mortality of some piglets. The Women's Empowerment in Livestock Index (WELI) score was done to assess the impact of interventions. There is marginal increase in the score after the interventions suggesting the potential livelihood improvement. It will be beneficial to sustain the efforts for piggery production in the same line that will increase household productivity and improved health and nutrition.

Assessment of scientific pig farming in doubling farmers income: An explorative study in Lunglei district of Mizoram

HEJBINA M HUSSAIN[1*], D. MALSAWMDAWNGLIANA[2], A. K. MOHANTY[1], A.K SINGHA[1], R. BORDOLOI[1], T. AMRUTHA[1], S. DAS[1], W. KHARKONGOR[1], E. SUTING[1]

[1]ICAR-Agricultural Technology Application Research Institute, Zone-VII, Umiam, [2]Krishi Vigyan Kendra, Lunglei, Mizoram
*Corresponding email: mehzabinhezbina02@gmail.com

Pig Farming has emerged as a thriving Industry in India, especially in North-Eastern Region, playing a significant role in its economic growth and development. There are about 9.06 million pigs in India while estimated number of pigs worldwide is 784.20 million in 2022 (20th Livestock Census). India being the second largest pork producer globally, has witnessed a steady rise in Pig farming over the years. Owing to the favourable climatic conditions, availability of forest resources for pig rearing and local demand for pork, the North eastern states of India witnessed a remarkable growth in Pig production in recent years. Nearly 40% of the nation's entire pig population lives in the North-Eastern Region. Piggery occupies dominant position in the livestock economy in Mizoram as the number of pigs has accounted for more than 73% of the total livestock animal in the State, Mizoram. As per the 20th Livestock census, Mizoram Comprises of 2,83,021 Pig Population. Thus, Mizoram has the potential to take piggery to a more profitable enterprise with right approach with available resources. The present study attempts to highlight the importance and impact of scientific pig farming in doubling the income of the pig farmers. In this context, a study was conducted in Lunglei district of Mizoram, to determine the impact of scientific pig farming in improving the livelihood of tribal farmers. A random sampling technique was applied to draw the samples of 80 farmers from four villages, namely Rawpui and Tuipui-D (adopted village) and Thiltlang and Darzo Village (Non adopted Village) from Lunglei district of Mizoram. The study revealed that adoption of scientific method in rearing system, low-cost housing system, balanced feeding, biosecurity, artificial insemination, and a shift from non-descript local pig to improved breeds like Hampshire and Yorkshire helped the farmers increased their income by two-fold. The study also revealed that promotion of scientific pig farming resulted in employment generation, improvement in income and overall livelihood improvement of tribal farmers.

T-bar pole and rope restraining technique (TBP& RRT) for castration piglets

TILLING TAYO[1]*, MANISH KANWAT[2], TANMAY SAMAJDAR[3], HOMESWER KALITA[4]
[1]KVK Longding AP center Basar, ICAR for NEH Region, [2]KVK Bhuj ICAR-CAZRI, Gujarat, [3]KVK North Parganas, Kolkata, West Bengal, [4]ICAR RC NEH, Medziphema, Nagaland
*Corresponding email: tilling.tayo@gmail.com

T-Bar Pole and Rope Restraining Technique (TBP& RRT) for castration piglets is an innovative physical restraining technique for castrations of piglets, developed by SMS Animal Science, KVK Anjaw, which require only two pieces of rope (1 ft and 3 ft) long and T-bar pole (4-5 ft) tall, to mitigate the problem of manpower requirements for restraining piglets and post operative restraining complicacies in rural areas. It is an undeniable fact, that in field condition, chemical method of restraining piglets for castration is near to impossible, except for use of local anesthetic Lignocane, due to dart of available source of medicine, lack of infrastructure,

scattered pattern of village settlement with disperse population, along with road and telecommunications bottle neck. Therefore physical method of traditional way of restarting like hanging on hind leg by rope on fixed structure or restraining by applying pressure over piglet on floor is the option left and many a times leads to inequitable distributions of weight and pressure over piglet, which leads to postoperative restraining complicacies like Nerve damage, Hernia and Restraining shock. Moreover, many manpower, 3-4 men is required to control a single piglet, which is the major problems in carry out castration in village level at any given time. However, in contrast to traditional restraining technique, TBP& RRT requires only 1-2 men for restraining as well as carrying out castration of piglets, without any post operative restraining complicacies in more humanize ways.

Sperm functional attributes and fertility related transcripts alters during seasonal variation in Murrah Buffalo bulls

R.K. DEWRY*, T. K. MOHANTY, M. BHAKAT, S. NATH, D. NAIN, H.P. YADAV, D.K. YADAV

ICAR-National Dairy Research Institute, Karnal, Haryana
**Corresponding email: rajudewry@gmail.com*

Seasons have a significant impact on the quality of spermatozoa and the abundance of fertility-related transcripts in breeding bulls. Summer stress affects animal physiology in sub-tropical climatic region in India, resulting in reduced efficiency and fertility in breeding bulls. The objective of the study was to investigate the abundance of fertility-related transcripts in Murrah bulls at different varying seasons of the year. Eight (8) healthy sexually matured Murrah bulls aged between 4 and 6 years were classified into high fertile (HF, Conception rate, CR: 51.43 to 58.82 %) and low fertile (LF, CR: 23.47 to 34.35 %) groups based on field conception rate. The advanced *in-vitro* sperm functional attributes were evaluated from frozen semen in different seasons. The abundance of positively fertility-related transcripts (CRISP2, AQP7, and PRM1) and negatively fertility-related transcripts (CCT5 and CCT8) were compared in three different seasons (summer, rainy, and winter). The results revealed that the sperm functional attributes were more affected in the summer season, more in the LF group. Sperm velocities by CASA were found to be lowered in summer season in low fertile groups. The abundance of CRISP2, AQP7, and PRM1 genes were significantly ($P<0.05$) lower in the LF group than HF in the summer season as compared to rainy and winter seasons. In contrast, CCT5 and CCT8 genes abundance was significantly ($P<0.05$) higher in LF group than HF in summer than rainy and winter season. Our findings suggest that summer heat stress distresses more the abundance of fertility-related transcripts in Murrah breeding bulls than other seasons.

Alligator weed as potential poultry feed supplement to improve production performance in chicks reared under humid sub-tropical hilly ecosystem of Meghalaya

S. DEORI*, S.N. ABEDIN, J.B.M. WANKHAR, K. PURO, Z. HUSSAIN, S. DOLEY, B.U. CHOUDHURY, R. KATIYAR
ICAR Research Complex for North Eastern Hill Region, Umiam. Meghalaya
**Corresponding email: sourabhd1@rediffmail.com*

Alligator weed (AW) can have severe ecological and economic consequences by impacting water quality, flow and the growth of native flora and fauna. Majority of aquatic plants have little value as human food, therefore utilization of this resource as fodder for livestock and poultry has potential. Using this information, present study was aimed to investigate the possible effect of incorporating AW as a supplement on the production performance of improved variety chicks reared under deep litter system. Two hundred forty (n= 240; 35 days old) chicks were subjected to 4 experimental treatments over a period of 35 days during the study seasons (summer and winter). The experimental diet consisted of the following: Control diet without any supplements (C); basal diet + 1% AW (T1); basal diet + 2% AW (T2) and basal diet + 4% AW (T3). The average monthly temperature (°C) and humidity (%) fluctuations during the study period was 25.47± 1.17°C and 77.38±5.12% during summer & 16.57±1.37°C and 62.28± 2.56% during winters respectively. The production performance *viz.*, body weight (gms), average body weight gain (gms), weekly feed intake (g/wk/bird) and feed conversion ratio (FCR) were evaluated during both the study seasons. Results indicated that body weight average body weight gain and weekly feed intake in T1 group was significantly ($p<0.05$) higher in comparison to other groups. The weekly feed intake (gm/wk/bird) was significantly ($p<0.001$) higher during winter as compared to summer. The FCR was significantly ($p<0.001$) lower in group T1 in comparison to other treatments especially during winter. The results of our study suggest that AW has the potential to mitigate the negative effects of cold stress on growth and production performance in chicks. In conclusion, supplementation of I% AW to the diet of improved variety chicks enhance their production performance under deep litter housing system.

Sustainable turkey farming in Kolongpur village under Kamrup district of Assam: An alternate means of livelihood

ILAKSHY DEKA[1*], D.N. KALITA[1], G. KADIRVEL[2]
[1]Krishi Vigyan Kendra Kamrup, Assam Agricultural University, Kahikuchi campus, Guwahati, [2]ICAR, ATARI, Zone-VI, Guwahati

Kolongpur is a hilly village, 23 km south from Sonapur under Demoria Developmental Block of Kamrup district, bordering Meghalaya. The population of the village comprises the Karbi Tribe – a schedule tribe. Due to its hilly terrain and unreachable roads, till now no Government project is being implemented there. On realizing the suitability of Turkey farming both topographically and marketing potentiality this Turkey Village project was undertaken by Krishi Vigyan Kendra Kamrup, Assam Agricultural University, Kahikuchi Campus. After a benchmark survey of the village, 20 numbers of beneficiaries were selected for the project. The

beneficiaries were given 10 numbers of 15 days old Turkey poults and a bag of starter feed (Crum chick, Godrej and other medicinal inputs) each. Alongside, trainings as well as other extension activities were also imparted for management and feeding of turkey at different stages as and when required. The parameter recorded under the project were body weight at distribution (1wk age), adult body weight, early chick mortality, marketable weight of tom, dressing percentage, weight at onset of laying (7 months), dressing percentage, weight at onset of laying, age at onset of laying, no of egg laid in a year, Hatchability, FCR and B.C. The Turkeys have adapted well to the environment of Kolongpur. Keeping all the advantages of turkey rearing like low managemental activities, high disease resistance, faster growth rate with minimum feed expenditure, the scavenging nature of turkey leading to reduced feed expenditure etc., the farmers with zero previous knowledge on Turkeys have shown keen enthusiasm towards this venture. Being the leanest meat among poultry with nutritional and medicinal values of meat added to the acceptance by farmers as well as consumers. Earlier, very few know about turkey meat but now the demand for turkey meat at both farmer and consumer level is soaring high. Upon introduction of Turkey to Kolongpur, the economic benefits of the rearer have crystallized and showed encouraging horizontal expansion. Now, not only the people at Kolongpur but, the people around the adjutant villages have adopted turkey farming and have found an alternate means of sustainable livelihood.

Comparative performance analysis of backyard poultry farming as a viable option for empowering the rural youths in North Eastern Region (NER)

FENESTELLA DKHAR[1*], A.K. MOHANTY[1], R. BORDOLOI[1], H.M. SANGTUM[2], N. JYOTSNA[3], H. SAPLALEINLIANA[4], C.A. PARIAT[5], Z. TONGOE[6], A.M. TARIANG[1], R. NANGBAH[1]

[1]ICAR-ATARI, Zone -VII, Umiam, Meghalaya, [2]KVK, Wokha, Nagaland, [3]KVK, Senapati, Manipur, [4]KVK Lunglei, Mizoram, [5]KVK, Jaintia Hills, Meghalaya, [6]KVK, Wokha, Nagaland

**Corresponding email: fenest13dkhar@gmail.com*

Backyard poultry farming in India is traditionally followed by more than 50% of the rural families as a primary source of animal protein and supplementary income with little minimum capital investment. Today, poultry sector has been emerged as the fastest growing segment of Indian Agriculture with a growth rate of 8% per annum. But backyard poultry farming seems to be the most neglected and unorganized sector, even if it offers ample entrepreneurial opportunities and more than 30 million farmers are engaged in the sector. Though the poultry population in NER is not so discouraging as compared to National figure with 58.97 lakhs, 53.97 lakhs, 20.47 lakhs and 28.38 lakhs in Manipur, Meghalaya, Mizoram and Nagaland, respectively; but it is mostly predominant with backyard poultry with indigenous breeds having poor genetic potential of annual egg production of 70-80 eggs /bird/ annum and low body weight. It is because of the fact that in backyard poultry farming system, the indigenous breed has been favoured for their resilience in the face of challenging climatic aberration and their remarkable ability to survive. In this context, the present research has been taken in introducing improved backyard breed in NER hill ecosystem. This study presents a comprehensive analysis

of backyard poultry production performance using improved backyard breeds (like Vanaraja, Rainbow Rooster, Giriraja) in four different Districts namely Senapati District in Manipur, Lunglei District in Mizoram, Wokha District in Nagaland, and Jaintia Hills District in Meghalaya covered under ARYA Project. The study examines the performance and economic viability of improved backyard breeds under hill ecosystem and assess their productivity in terms of egg and meat production. It was recorded that average egg production of improved backyard breed/bird was 150 eggs / bird / year, whereas indigenous bird recorded at an average of 60 eggs/bird/ year. In terms of average meat production/ bird, the improved breed recorded 2.6 kg meat/ bird which is double that of indigenous breed (1.3 kg/bird). The average income of the rural youths before and after ARYA intervention was ₹ 35,740 and ₹ 1,10,809, respectively; showing a significantly difference.

Backyard poultry farming for livelihood improvement of farmers in Manipur: An Insight under Farmer FIRST Programme

WANPHRANG KHARKONGOR[1]*, A.K. MOHANTY[1], A.K. SINGHA[1], R. BORDOLOI[1], T. AMRUTHA[1], R.S. SINGH[2], H.M. HUSSAIN[1], E. SUTING[1], S. DAS[1], L. KJAM[3]

[1]ICAR- Agricultural Technology Application and Research Institute, Zone-VII, Umiam, Meghalaya, [2]Central Agricultural University, Imphal, Manipur, [3]ICAR Research Complex for NEH Region, Umiam, Meghalaya

**Corresponding email: wanphrangkharkongor@gmail.com*

Poultry rearing in rural areas is often considered as small-scale farming and exclusively meant for own family consumption or sale in local or other nearby informal markets, which does not provide enough income for sustainable livelihood. According to the Livestock Census 2019, the poultry population in the North Eastern Hills region is 6.9 Crore, with Manipur contributing 58 lakhs. Among the poultry population in Manipur, the indigenous breed accounts for 9.24 lakhs, while the improved variety accounts for 9.22 lakhs. Small-scale poultry farming usually involves rearing of few birds of indigenous breed, as a source of eggs, meat, or marginal income. Generally, the poultry rearing faces challenges like slow body weight gain, high mortality rate, non-availability of improved and high performing birds, poor financial support, and ignorance of technical knowhow which can limit its potential to contribute to rural development. The present study has been undertaken in Yairipok Top Chingtha and Yairipok Yambem Village under Imphal East district of Manipur to assess the impact of Backyard poultry intervened under Farmer FIRST Programme. A sample size of 26 beneficiaries were selected to study the impact of Backyard poultry farming over a period of four years on the livelihood improvement of beneficiaries following its implementation. Through a comprehensive analysis of the data, it was found that *after interventions* of the programme, the average number of poultry reared per farm family was increased to 86 as compared to 34 in case of *before intervention*, which indicated a boost in the production level. Similarly, the income from poultry farming also showed a substantial increase of 148 percent over the four-years period. This significant growth of income through poultry farming demonstrated the positive effect of the FFP program on the livelihood improvement of small-scale poultry farmers in these two villages. The findings also highlighted the importance of providing

technical and resource support to small-scale poultry farmers that created an impact in improving the economic conditions of rural farm holders and strengthened the poultry farming sector resulting in income enhancement and livelihood improvement.

Pig value chain analysis in Meghalaya

NIKITA CHANU[1]*, GOVINDASWAMY KADIRVEL[1], PAMPI PAUL[2], KESHAB JAMATIA[2]
[1]ICAR-ATARI, Zone-VI, Kahikuchi, Guwahati, Assam, [2]ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Corresponding email: nikitachanu121@gmail.com*

Pig farming plays an important role in the livelihood security of the inhabitants of the North-Eastern Himalayan region of India. The majority of the people in this region are tribal and they have been following the custom of pig rearing since time immemorial. Therefore, pork is considered an important meat source in the state. Hence, the present paper demonstrates status of piggery and the pork value chain by using both primary and secondary data in the Meghalaya, a North Eastern state of India. The study revealed that pigs constitute 34.66 percent of total livestock in 2019 and there was an increase of 150 per cent in pig population from the year 1988 to 2019. The per capita availability of pork has been observed to be of 5.66 kg/year in the state. Apart from the aggregators, producers in the study received the least profit margins amongst all actors in the value chain and reported of 32 per cent share in the final consumers' price. The average retail price of pork in the state was relatively high at around INR 350 per kg. The North eastern Region has immense scope for growth in the piggery sector; hence, piggery farming in the state must be supported through the governments' interventions via capacity building for the adoption of current scientific methods to enhance its production. Therefore, Adoption of improved breed and scientific breeding practices were also precedence in increasing productivity in this sector. Market intervention is critical as the pork value-chain is still unorganized and requires streamlining for improved marketing efficiency and just price distribution. Increasing production along with developing structured markets was vital for transforming piggery from subsistence farming to commercial enterprises in the state.

Influence of dietary supplementation of velvet bean meal on haemato-biochemical parameters in broiler chicks

PRAMOD SINGH*, K.P. MOHAPATRA, K. PURO
ICAR Research Complex for NEH Region, Umiam, Meghalaya – 793 103
**Corresponding email: praamodsingh@gmail.com*

Velvet or Bengal bean (*Mucuna pruriens*) is a highly productive tropical legume. Its seeds are rich source of protein and often used in human or animal food. But presence of incriminating factors, limits its use in poultry feeding. Moreover these possess antioxidant, anabolic and

growth hormone stimulating properties and have shown several health benefits, particularly as mood enhancer/stress alleviator in humans. The levo-dopamine stimulates release of growth hormone by pituitary gland (Mesko, 2002). These are also important in stimulating avian and mammalian immune system. In present study, an attempt has been made to study the effect of dietary supplementation of velvet bean meal (VBM) on haemato-biochemical parameters in commercial broiler chicks. Feeding experiment was conducted in day old *Vencobb* chicks (n=45; distributed into 3 groups having 3 replicates of 5 birds) during winter (December-January). Three diets with 20% CP and 3000 Kcal/kg ME (estimated) were formulated using yellow maize, soybean meal, groundnut cake, fishmeal, mineral mixture, DCP, and salt. The respective diets of G1, G2 and G3 contain VBM at a level of 0, 2 and 4%. Feed intake and body weights were monitored as per requirement. Blood samples were collected aseptically at 45d from wing vein and analyzed for various parameters using standard procedures. Average values for different parameters like hemoglobin, hematocrit, serum cholesterol and catalase were similar and remain under normal range across treatment groups of broiler birds at 45d. The average values of lymphocytes (%) were significantly higher in VBM supplemented birds in G2 (65.67) and G3 (63.33) than G1 (58.33) whereas, heterophils (%) were significantly lower in G2. The H/L ratio were significantly lower in G2 (0.33) and G3 (0.38), than G1 (0.43). The values for super oxide dismutase (SOD; U/g Hb) were higher in G2 (65.34) and G3 (71.61) than G1 (51.35). The ADG was significantly higher in G2 (31.44), followed by G1 (27.96) and G3 (26.40). The values of lower H/L ratio and higher ADG along with other parameters in G2 indicates better performance of birds on VBM supplementation at 2% of diet during the winter conditions of Meghalaya.

Efficacy of rubber mat in new born piglets in farrowing pen

DONI JINI*, JOKEN BAM, RAJESH A ALONE, L.K BAISHYA, B. PAIT
ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar
**Corresponding email: donoxini@gmail.com*

Floor of pig is made of cement concrete, bedding material, slatted floor. During the farrowing the new born piglets get abrasion during farrowing. Moreover, in piglets' soft pad might a susceptible to cut, brushes and wound which might cause lameness. During excessive cold especially during winter months, piglets (0- 7 days old) may susceptible to cold stress or hypothermia due to contact or loss of heat through the process of conduction from contact with floor during lying position. Thus, provision of bedding material in term of rubber mat will be beneficial to retain the heat loss, prevent from crush kill from sow and improved foot pads in order to assess the efficacy of rubber mats the study was carried in ICAR research farm gori. Six Yorkshire sows farrowed in the months of Dec, Jan and Feb. the floor space of each pen was floor 5 X 2.7m with covered space of 2 X2.3m housing. 04 sows were kept in concrete floor and 04 sows in rubber mat of dimension (7 feet X 4 feet with thickness of 23mm) in the covered space. In total 48 piglets were born with average litter size at birth 8.2 ±1.09. No mortality was found in rubber mat floor whereas in concrete floor it was 12.5% (3out of 24piglets) during winter months overall mean temperature December was Max 22.3° *C*- Min

6.7°.C Clinical examination of limb and claws of piglets were done on 7,14 & 21-days intervals. Injury score for (0,1,2,3) for no, mild, moderate and extreme lesion in selected anatomical region i.e., Sole. Soft heel. Coronary, fetlock, knee and teats. It was observed under rubber mats the injury score in sole, soft heel, coronary band (25,18,15) whereas in concrete (38,29,25) there was no much significant difference in fetlock, knee and teat region in both floors. Overall, 87.5 per cent skin abrasion in area around fetlock, knee and claws were found in cement concrete whereas 54.16% in rubber mats. Sole injury was more prominent i.e., 56% in concrete and only 32% in rubber matt. Thus, rubber mats can be used in farrowing pen of suckling of piglets effectively up to 30 days old to prevent form sole injury, lameness and mortality during extreme cold and reduces the crush kill from sows.

A comparitive study on the laying performance of Vanaraja, Rainbow Rooster and BND in Mizoram

LALHRUAIPUII, S. DOLEY, K. TAMILARASAN*, P.L. LALRINSANGA
ICAR-RC for NEH Region, Mizoram centre, Kolasib, Mizoram
**Corresponding email: arasankumar05@gmail.com*

Mizoram state has seen a 6.12% decrease in egg production from the previous year, with a total of 407.50 lakh eggs produced in 2021-2022. To address this issue, the study was conducted with the objective to evaluate the laying performance of some improved varieties of chickens such as Vanaraja, Rainbow rooster, BND at Poultry farm of ICAR, RC for NEH region Mizoram center. All the birds were reared under uniform and standard managemental practices. The data regarding body weight, egg production and egg weight were collected at various intervals to find out the age at first laying, body weight at first laying, total number of eggs produced in a day, average eggs produced by bird in a month, Hen day egg production, average number of eggs produced by bird for the period of one year, egg weight at different period etc. Age at first egg was lower in Rainbow Rooster (127days) and BND (134 days) compared to Vanaraja birds (169 days). Average annual egg production was highest in BND (191 eggs) followed by Vanaraja (142 eggs) and Rainbow Rooster (115 eggs). The average Hen Day Egg Production (HDEP) for BND, Vanraja and rainbow Rooster were found to be 53.15%, 39.57% and 32.04% respectively. The mean egg weight in 12 months was highest in Vanaraja (54.51±0.29 grams), followed by rainbow rooster (50.88±0.34 grams) and lowest in BND (41.14±0.34). The body weight at first laying was found to be 1.16 kgs, 2.30 kgs, and 2.50 kgs for BND, Rainbow Rooster and Vanaraja respectively. The egg weight at first laying was observed as 32.05g, 38.68g, and 45.52g for BND, Rainbow Rooster and Vanaraja respectively. It was concluded that the BND is higher in egg production, but lower in egg size and body weight. Vanaraja is a good dual purpose bird and it has better egg weight, body size and lower in production than BND. RR is average in production compared to BND and Vanaraja in Mizoram region. However, more trial is needed to evaluate the performance of these improved chicken varieties under field conditions.

Seasonal fluctuation of water quality and plankton diversity of subtropical Amkahoh River, Meghalaya

NINGTHOUJAM PEETAMBARI DEVI*
ICAR-Research Complex for North Eastern Hill Region, Manipur Centre, Imphal
**Corresponding email: peetambarining@gmail.com*

Water is essential to life, and even the slightest change in water quality can have serious effect on both human health and the aquatic ecosystem. For better understanding and generation of real time information of any aquatic ecosystem, regular assessment of water quality and plankton diversity is prerequisite one. We examined the seasonal fluctuations of water quality and plankton diversity in the subtropical Amkahoh River, Meghalaya (India), in 2021–2022. Collection of water and plankton samples were carried out during the selected months in the winter (December), pre-monsoon (March), monsoon (July) and post-monsoon (October) seasons. Results revealed that significant variation in different water quality parameters (pH, temperature, total dissolved solids, electrical conductivity, dissolved oxygen, turbidity, hardness, alkanity, free CO_2) across the seasons. pH ranged 7.8 (winter) to 8.25 (monsoon). Similarly, Dissolved oxygen (DO) ranged 8.2 mg/L (pre-monsoon) to 11.2 mg/L. More precisely, the water quality during the dry season have better quality than the wet season. We found that a notable seasonal variation plankton diversity across the seasons. Altogether 19 nos. of phytoplankton species were recorded across the seasons where Chlorophyceae-class plankton dominated during the winter, pre-monsoon, and monsoon seasons while Bacillariophyceae-class plankton prevails during the post monsoon. In terms of phytoplankton diversity index, highest values of Simpson's Index (1.22), Shannon Index (0.67) and Evenness Index (0.85) were recorded during the monsoon season indicating more plankton diversity during this period. On the account of the zooplankton diversity analysis, Rotifer zooplankton dominated during the winter, monsoon and post-monsoon seasons, while the Cladocera zooplankton dominated during the post monsoon. Unlike phytoplankton, the zooplankton diversity indices i.e. Simpson's Index (0.63), Shannon Index (1.05), and Evenness Index (0.95) were recorded highest during the pre-monsoon season, where the values of phytoplankton diversity indices were more in monsoon season. Comparatively, zooplankton contributed 14-37 % of the total plankton contribution. Overall, our study has observed the subtropical Amkahoh River in Meghalaya, India, has considerable seasonal change in water quality and plankton diversity and this information may help in forecasting long-term changes in fresh water ecosystems in the days to come.

Rebooting aquaculture in Northeast India: Harnessing plant-based solutions for sustainable fish health and production

CHANDAN DEBNATH*
ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Corresponding email: chandannath23@gmail.com*

Aquaculture is rapidly growing in Northeast India and has become a key sector for food production. As capture fisheries reach their peak, aquaculture is seen as the primary means to meet the rising demand for fish and fishery products. To increase fish production, aquaculture practices have shifted from extensive to semi-intensive and intensive modes in various regions such as Tripura, Assam, Manipur, and others. However, this expansion has also brought about the emergence of diseases as a major concern, resulting in a production penalty of 10-15%. Globally, fish diseases cause an annual loss of approximately US $6 billion, with India accounting for an estimated Rs. 1022.1 Crores. In Northeast India, the annual loss due to fish diseases is estimated to range from Rs. 14900 to 30770 per hectare, based on a study conducted in Assam. Efforts to combat these diseases have relied on chemotherapy using antibiotics and chemotherapeutics. Unfortunately, the indiscriminate and continuous use of such treatments leads to antimicrobial resistance, environmental pollution, and harm to non-target species. To address these challenges, there is a growing need to focus on phytotherapy, which utilizes plant-derived products. These products contain bioactive compounds, including alkaloids, flavonoids, pigments, phenolics, terpenoids, steroids, and essential oils, making them promising for managing fish health. Plant derivatives offer a cost-effective solution with broad-spectrum efficacy against diseases, without causing environmental toxicity. Several herbal products have shown potential in enhancing fish health and immunity. For instance, turmeric powder at 0.1% inclusion protects *Labeo rohita* from bacterial haemorrhagic septicaemia caused by *Aeromonas hydrophila*. *Rauvolfia tetraphylla* leaf extract at 0.5% concentration provides protection against *Aphanomyces invadans*, the causative agent of epizootic ulcerative syndrome (EUS). β-glucan at 15 mg/l safeguards *Anabas testudineus* from *Saprolegnia parasitica*, the causative agent of cotton wool disease. Lipopolysaccharide at 100 mg/kg protects *L. bata* from *Edwardsiella tarda*, the cause of Edwardsiellosis. *Sonneratia alba* leaf extract is effective against *Aphanomyces* infection, while *Eclipta alba* (Bhringaraj) leaf extract provides protection for *Heteropneustes fossilis*. *Withania somnifera* at 2 g/kg inclusion protects *L. rohita* from *A. hydrophila* infection and enhances immunity in *Macrobrachium rosenbergii* at concentrations ranging from 0.1% to 1%. Despite the potential benefits of these plant products, their full effectiveness remains untapped due to limited information on location-specific doses, duration, mode of administration, and their potential impact on non-target organisms. Additionally, there is a lack of awareness among farmers in Northeast India, who have limited resources and knowledge partners. To address these challenges and promote sustainable aquaculture practices, it is crucial to reboot the local aquaculture industry using available plant products. This approach can make fishery-based livelihoods safer, more secure, and sustainable in the region.

Evaluation of growth, survival and organoleptic score of *Catla catla* cultured in cattle wastewater

KOUBERI NATH[1*], ASIT CHAKRABORTI[1], SANJAY KUMAR DAS[2], BIKASH SHIL[1]
[1]ICAR Research Complex for North Eastern Hill Region, Tripura Centre, Lembucherra, Tripura, [2]ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya
**Corresponding email: kouberi914@gmail.com*

The growth, survival and organoleptic evaluation of *Catla catla* was assess after 90 days cultured in cattle wastewater. The experiment was conducted in 5 m^3 jalkund without soil base in duplicate. A control was maintained in duplicate without cattle wastewater. The wastewater was collected in jalkund and treated with quick lime @ 5g/L. After 15 days settlement the collected wastewater was diluted with bore well water for making 50% diluted solution. *Lemna minor* was inoculated after one week to remove the excess nutrients and BOD from the cattle wastewater. *C. Catla* was stocked @5000nos/m^2 in jalkunds after acclimatization and after 7 days of *L mimor* inoculation. The fishes were not feed with artificial feed and there was no aeration. The survival was recorded 100%, SGR 1.87, DWG 5.99 and productivity 2955 kg/ha in 8 months. There was no significant in difference in color, odour, and overall acceptability after 90 days of culture between the control and treatments. The results suggest that the cattle shed wastewater can be recycled in aquaculture after proper treatment and the productivity may achieve within national average.

THEME - 5

Farm mechanization, digitisation and secondary agriculture

Comparison between manual and photogrammetric measurements of anthropometric data for North-Eastern agricultural workers

ANUBHAB PAL*, THANESWER PATEL, RICKY DONALD SYIEMIONG, MIBOM MEGU

Department of Agricultural Engineering, North Eastern Regional Institute of Science and Technology, Nirjuli, Arunachal Pradesh

**Corresponding email: anubhabpaul@gmail.com*

The North-Eastern region of India is predominantly hilly and inhabited by tribal population. The overall working efficiency of human-machine environment and resultant discomfort has severe impact while using farm tools and machinery in hills. Thus, to achieve better performance and efficiency along with higher comfort and safety to the operator, it is necessary to design tools, equipment and workplaces keeping in view of the anthropometric data of the agricultural workers. 35 body dimensions of 100 people were measured both through manual and photogrammetric method. According to the result obtained both the methods were comparable to each other with an average percentage error less than 5%. It was found that photogrammetric method was better in terms of accuracy and speed as there was no human or instrumental error and because of the use of specialized software that can perform complex calculation. Manual measurement was a simpler method as compared to photogrammetric method.

Artificial Intelligence and IOT in precise evaluation of Citrus Canker disease suppression in Assam lemon due to application of organic formulations, botanicals and beneficial microbes

SWAGATA SAIKIA[1*], PRADIP K.R. BORAH[2]

[1]PhD Scholar, Dept. of Plant Pathology, AAU, Jorhat, [2]Prof, Dept. of Plant Pathology, AAU, Jorhat

**Corresponding email: swagata.saikia.adj19@aau.ac.in*

Citrus Canker caused by *Xanthomonas citri* pv. *citri* (Xcc) is one of the most destructive disease of citrus. The present study was aimed at managing the disease using beneficial microbes (Endophytes and rhizospheric microbes), botanicals (Aloe, Neem, Bael, Onion, Lemon grass, Garlic) and organic formulations (Panchagavya and Jeevamrut). The treatments were tested *in vitro* against the pathogen using dual culture assay. The results showed that endophyte (*Bacillus velezensis*), rhizospheric microbe (*Pseudomonas putida*), botanicals (*Cymbopogon citratus* and *Allium cepa*) and organic formulation (Panchagavya) were the most effective with inhibition percent of 54.14, 55.55, 52.66, 59.11 and 51.33 respectively which were later evaluated in field conditions. Assessment of percent disease severity, soil nutrients and yield enhancement of different treatments at different time intervals was done using AI and IOT technology. Manual observation of percent disease severity and yield was also done to check accuracy of both the datasets. Endophyte *Bacillus velezensis* applied both in soil and as foliar spray reduced the disease (81% in case of AI and 77.67% in case of manual observations) and also enhanced the

yield (120 no. of fruit/plant in case of AI and 130 in case of manual observations). Soil nutrients have also increased in rhizosphere highest after treating it with *Bacillus velezensis*, followed by *Pseudomonas putida*, *Cymbopogon citratus*, *Allium cepa* and Panchagavya. T-test analysis have revealed the efficacy of AI over manual observations and showed a positive correlation between both the data sets.

Effects of nanoparticles on morpho-histology of Eri silkworm, *Samia cynthia ricini* (Boisduval)

HIA KALITA*, MAHESH PATHAK, BIMAL KUMAR SAHOO, SIKHA HARITHA, PRANAB DUTTA, RAGHUBIR PATIDAR, KENNEDY NINGTHOUJAM, N.S. AZAD THAKUR

School of Crop Protection, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya.
**Corresponding email: hiakalita23@gmail.com*

Sericulture is the rearing of silkworms for the production of raw silk. Silk "the textile Queen" is secreted by the silkworms. Over the past 50 years, the use of synthetic pesticides for crop protection has rapidly expanded around the world. The need for innovative low-risk control methods and new chemical classes of pesticides has increased as a result of the increasing concern for the environment and human health. Recently, nanotechnology being embraced in the world of pest control has the potential to revolutionize modern day agriculture. The rapid development of nanomaterials in various fields of science results in the need of understanding their toxicity on development and physiology of non-target organisms. In this study, three nanoparticles (NPs) chitosan, silver (Ag) and zinc oxide (ZnO) at seven different concentrations (25, 50, 100, 200, 300, 400, 500 ppm) were used to study their effects on the morphology and histology of Eri silkworm (*Samia cynthia ricini*, Boisduval). The nanoparticles were incorporated in their diet by leaf dip method and applied once in each instar. In the larval and pupal stages, the length, girth and cocoon weight decreased with increased concentrations of the nanoparticles. At 500 ppm length of larvae treated with chitosan, Ag and ZnO NPs were 3.99, 4.37 and 5.98 cm as compared to control (7.12 cm), girth of larvae treated with chitosan, Ag and ZnO NPs were 1.67, 3.31 and 4.49 cm as compared to control (4.78 cm) and cocoon weight of pupae treated with chitosan, Ag and ZnO NPs were 1.94, 2.03 and 2.83 g/cocoon as compared to control (2.833 g/cocoon). The corrected larval mortality increased with increased concentrations, highest at 500 ppm with 22.18 %, 17.73 % and 12.18 % in chitosan, Ag and ZnO NPs, respectively. At 500 ppm deformities like absence of silken cocoon in the pupae, failed adult emergence, pupal death and deformed wings in the adults were observed in the morphology of the silkworms. The midgut tissues of the dead larvae treated at 500 ppm of the NPs observed under transmission electron microscope (TEM) exhibited alterations in the epithelial layer, basement membrane and muscle layer. In all the three nanoparticles absence of microvilli, empty cell contents and disruption of mitochondria was observed**.**

Development of weather-based statistical and machine learning models for pineapple yield estimation in Meghalaya

DEBASISH CHAKRABORTY[1*], MRINMOY RAY[2], JAYANTA LAYEK[1], HIJAM JITEN SINGH[1], HEIPLANMI RYMBAI[1]

[1]ICAR Research Complex for NEH Region, Umiam, Meghalaya- 793 103, [2]ICAR-IASRI, New Delhi- 110 012

**Corresponding email: debasishagri@gmail.com*

Yield estimation is very crucial for understanding the agricultural outputs, import-export policies, and most importantly the food security of the region/nation. Pineapple is one of Meghalaya's main fruits as well as cash/ commercial crops. As per recent Government of India data sets (2021-22), Meghalaya ranks 2nd in area and 4th in production, which are about 11.73 and 8.03% of the country's total share respectively. It is well known that crop yields are dependent upon so many factors starting from inputs (seeds/planting materials, manures/fertilizers, irrigation, etc.), their management (doses, times of application, mode of application, etc.), and the environment (soil, topography, and climate, etc.). But it has been seen that the year-on-year variability in yield is mostly due to the variability in the weather parameters as other factors remain almost stationary. Therefore, weather parameters are used for the prediction of crop yield. This study envisaged the development of a suitable model for the yield estimation of pineapple crops using different weather variables. We compared the performance of different conventional statistical models like multiple linear regression (MLR), least absolute shrinkage and selection operator (LASSO), elastic net (ENET), ridge regression, and machine learning techniques like classification and regression tree (CART), random forest regression (RFR), artificial neural network (ANN) and support vector machine (SVM). Results revealed that different models had different performance accuracies. Though various models were able to capture the variation in yield (having high R^2 values > 0.90), the error indicated by root mean square error (RMSE) and normalized RMSE (nRMSE) was comparable for ridge regression, LASSO, ENET, RFR, and SVM, all having very good accuracy (<5% nRMSE). Therefore, the results suggest that using weather variables, the pineapple yield of Meghalaya can be estimated with considerable accuracy and can be used for policy planning.

Status of farm mechanization and digitalization of agriculture in North Eastern region of India

RIZWAN AHMED[1], AISHWARYA P.[2]

[1]Ph.D Scholar, College of Post Graduate Studies in Agricultural Sciences, CAU(I), Umiam, Meghalaya, [2]Ph.D Scholar, Tamil Nadu Agricultural University, Coimbatore

Corresponding email: rizwan.mos@gmail.com

Agriculture is mainly of subsistence nature and organic by default in the North Eastern region (NER) of India. Farm mechanization involves the use of various machines, equipment and tools to automate and streamline farming operations which includes devices designed to reduce manual labour and improve the speed and accuracy of tasks such as planting, cultivating, harvesting and livestock management. Digitalization in agriculture involves the integration of digital technologies, data analytics, and information systems to enhance decision-making,

optimize resource utilization and improve overall farm management. The study was taken up with twin objectives to study the trend in adoption of farm mechanization among North East region farmers and to analyze its digitalization. The study was carried out with secondary data. The adoption and utilization of farm mechanization among farmers in the NER have been steadily increasing in recent years and are recognizing the benefits of mechanization in improving efficiency, reducing labor requirements and increasing productivity in their agricultural operations. Several factors have contributed to the growing trend. First, advancements in technology and availability of more affordable and efficient farm machinery have made it more accessible to farmers in the region such as tractors, harvesters, seeders and irrigation systems. Additionally, the changing demographics of the farming population have played a role in its adoption. Younger generations of farmers, who are often more tech-savvy and open to innovation, are increasingly taking over agricultural operations and are more inclined to invest in modern farming practices. Digitalization of agriculture has been gaining momentum globally, including farmers in the NER. Key areas where digitalization is making an impact among NER farmers are namely precision farming, farm management systems, smart irrigation, crop monitoring and pest management, market access and information. It is important to note that the adoption of farm mechanization can have both positive and negative impacts. While it can increase productivity and reduce labor requirements, it may also lead to job displacement in rural areas. Overall, the digitalization of agriculture among NER farmers is helping to bridge the technological gap, increase productivity, reduce input costs, and improve sustainability in agricultural practices. By leveraging digital tools and platforms, farmers in the region can enhance their agricultural operations, optimize resource utilization, and ultimately improve their livelihoods. Therefore, a balanced approach is necessary to ensure sustainable agricultural development.

The integration of IoT and AI for enhanced oyster mushroom cultivation: A comprehensive review

HUIDROM DAYANANDA SINGH[12], THANESWER PATEL[1*], HIJAM JITEN SINGH[2], NASEEB SINGH[2], ANUBHAB PAL[1]

[1]Department of Agricultural Engineering, North Eastern Regional Institute of Science and Technology (NERIST), Nirjuli – 791 109, Arunachal Pradesh, India, [2]Division of System Research and Engineering, ICAR Research Complex for NEH Region, Umiam,- 793103, Meghalaya, India

**Corresponding email: thaneswer@gmail.com*

Oyster mushrooms are a nutrient-dense food source, abundant in protein, minerals and fiber, while being cholesterol-free. Additionally, they possess medicinal properties. The popularity and consumption of oyster mushrooms have been steadily rising, yet their production falls significantly short of meeting the current demand. The objective of this review is to highlight the application of IoT (internet of things) and AI (Artificial Intelligence) in the cultivation of oyster mushroom and its performance. The materials were searched on the Scopus, Web of Science, and Pub Med database by using the combination of keywords “Oyster mushroom”, “Internet of thing”, “IoT”, “Artificial intelligence” and “AI”. The inclusion and exclusion of an

article in the present study were decided after reading the title and abstract by the reviewers. Reducing the yield of oyster mushroom cultivations are mainly due to two factors i.e., contamination of spawn and unable to provide suitable environment parameters to oyster mushroom. IoTs are mainly used in the controlling environment factors like temperature, humidity, irrigation and light in the oyster mushroom cultivation. IoT platforms, such as ThingSpeak, provide remote monitoring and control. Arduino microcontrollers are commonly used in temperature and humidity control systems for oyster mushroom cultivation, often employing fuzzy logic or fixed threshold methods. DHT11 and DHT22 sensors are popular choices for temperature and humidity measurement. The yield of the mushroom can be further improved by adoption of blue LED light, electrical and sound treatments. AI algorithms are used mainly in detecting spawn contamination, mushroom quality, yield prediction etc. Contamination of spawn by pathogens can lead to crop loss and requires manual segregation, which is time-consuming and prone to errors. Machine learning techniques, such as deep neural networks, have been used successfully to classify contaminated spawn with high accuracy. Manual assessment of mushroom quality is labour-intensive and inconsistent. Machine vision has been employed to assess oyster mushroom quality, achieving high accuracy using support vector machines and artificial neural networks. Machine learning techniques, such as long short-term memory, have been utilized for yield prediction in oyster mushroom cultivation with high accuracy. Even though there are various IoT and AI solution to improve the yield of oyster mushroom, the adoption of this technology in production site is still limited. To meet the global food demand there is need to implement of such technology in the field level.

Pulsing solutions: Effect on postharvest longevity and quality of cut gerbera (*Gerbera jamesonii* Bolus ex. Hook) flowers

VANLALRUATI*, S.R. ASSUMI, H. RYMBAI, B.U. CHOUDHURY
ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya
Corresponding email: maruathmar@gmail.com

An experiment was conducted on "Pulsing solutions: Effect on postharvest longevity and quality of cut gerbera (*Gerbera jamesonii* Bolus ex. Hook) flowers" at the ICAR Research Centre for NEH Region, Umiam during 2021-2022. The experiment was set up as Completely Randomised Design (CRD) including 7 (seven) treatments combinations, replicated thrice with five cuttings per replication. Uniform stems of gerbera at goose-neck stage were pulsed in 6 (six) different pulsing solutions. Pulsing treatments comprised of sucrose (3%) in combination with different levels of citric acid (100, 200 and 300 mg L^{-1}). Distilled water without any chemical served as control. After pulsing, gerbera cuttings were transferred into different vases containing distilled water for assessment of their various post-harvest attributes. Effects of citric acid as biocide on pulsing solution and its impact on vase life, water relation, increase in fresh weight, petal ion leakage and other physiological parameters such as chlorophyll degradation and anthocyanin concentrations were experimented. Results indicated that pulsing of gerbera stem cuttings in 5% sucrose with citric acid (300 mg L-^{1}) for 6 hours helped in improving the

flower turgidity, membrane integrity and vase life as compared to control. Increased pulsing duration positively improved the postharvest quality of gerbera.

Climate resilient fish cum raised floor poultry housing system for sustainable income

BANKITKUPAR MUKHIM*, MOKIDUL ISLAM, ELGIVA WANSHNONG, MEGHNA SARMA
Krishi Vigyan Kendra, Ri-Bhoi, ICAR RC for NEH Region, Umiam, Meghalaya
**Corresponding email: Bankitkupar.mukhim@icar.gov.in*

Technology demonstrations on climate resilient fish cum raised floor poultry housing system *viz*. kuroiler birds and IMC fish were undertaken during 2022-23 at Thadnongiaw village, Ri Bhoi district to study the growth, production and performance in comparison with single farming system along with indigenous birds to generate employment around the year. Raised poultry farming is a system constructed with floor space of 1sqft/bird/day. A total of 490 numbers of unisexed 2 weeks old Kuroiler chicks were distributed among 17 farmers. Data on body weight gain, egg production performance, mortality rate and economic return were taken as per standard method. The results of the demonstrations showed that the overall body weight was significantly higher in Kuroiler birds than in indigenous birds. The overall body weight gain of Kuroiler birds compared to indigenous bird at 18 months of age is 4.2 kg and 2.3 kg respectively. The overall mean annual egg production was higher in kuroiler birds i.e., 118 nos compared to indigenous bird i.e., 76 nos. Fish production with poultry was 168kg/ha and fish production without integration 90kg/ha. There has been a decreased in mortality rate of 16% in Kuroiler bird from 19 to 3% as compared to local bird of 19%. The economic analysis of poultry rearing revealed that gross return/bird was found to be Rs. 3603/bird for kuroiler and indigenous bird respectively. Therefore, in comparison to all the parameters, integrated system of poultry along with fish culture was proved to be more profitable with profit percentage of 214.15% with kuroiler and 195.8% with indigenous bird. Finally, it could be concluded that the performance of integrated system of fish and poultry was found to be better than single farming system in terms of body weight, egg production, fish production and profitability in Ri Bhoi district, Meghalaya.

Design and adoption of improvised poly-house solar bulk drying system for export potential spices of North East hill region

M.J. BAROOAH[1*], A. BORAH[2]
[1]Assam University, Silchar, [2]Assam Agricultural University, Jorhat
Corresponding email: mbarooah15@gmail.com*

In India, North-East hill region annually produces spices like ginger (373 thousand tons) and turmeric (87.65 thousand tons). Primary processing systems of these spices are scarce in North east region of India. Thus, the present study explored environment friendly drying system for process standardization

and value addition of produce. Considering climatic condition and physico-chemical properties of harvested spices, poly-house solar dryer is one of the cost effective bulk drying system, among various systems wherein the existing structural design dimension are improvised and system automated to attain higher hot air circulation, thermal efficiency and economic return with stability against annual wind storm. The existing structural system is standardized from segmented to hemi-cylindrical section of span 10.2m and radius 2 m of capacity 500 to 1000 kg (with racks), with moisture reducing silica gel embedded sponge fitted square air inlets during night and cloudy days, insulated heat storage, flat bed inlet air heating system during active drying, automatic humidity sensor based forced convection system and rubber cladding in outlet chimneys to withstand high rainfall condition. Preliminary trial under no load test exhibits that system generates hot air ranging from 42.70 to 54.32˚C at an ambient temperature of 28.50 to 34.60˚C. Sliced spice drying is accomplished in 14 to 26 hours, initial and final moisture content range of 78-89% to 10-11% respectively. At average solar radiation 521.46 watt/m^2, thermal efficiency was 24.89%. The dryer has payback period of 2.5 and 3.5 years for turmeric and ginger respectively. Thus, this dryer is techno-economically feasible for mass scale adoption in North-East India through demonstration and extension activities.

Value addition of minor fruits for livelihood security in Assam

SANCHAYEETA GOHAIN[1], KRIPAL BORAH[2], NEOG[3], P.KR. PATHAK[3]
[1]PhD Scholar, AAU, Jorhat, Assam, [2]Krishi Vigyan Kendra, Tinsukia, Assam, [3]Directorate of Extension Education, Assam Agricultural University, Jorhat-785013
Corresponding author email: sanchayeeta @ aau.ac.in

Assam is a biodiversity hotspot with many minor and indigenous fruits which has huge potential for livelihood and nutritional security through value addition as these fruits are rich in vitamins and nutrition and possesses medicinal and therapeutic properties also. Among the different indigenous minor fruits *viz*., Kordoi (*Averrhoa carambola* Linn.), Outenga (*Dillenia indica* Linn.), Bhimkol (*Musa balbisiana* L.), Rebab tenga (*Citrus grandis* L.), Mirika tenga (*Parameria polyneura* Hk.f.), Amlakhi (*Phyllanthus emblica* Linn.), Kujithekera (*Garcinia cowa* Roxb.), Bael (*Aegle marmelos* Correa), Roselle fruit (*Hibiscus sabdariffa* L.), Borthekera (*Garcinia pedunculata* Roxb.), Jackfruit (*Artocarpus heterophyllus* Lam.), Jamun (*Syzygium cumini* Linn. (Skeels), Nagatenga (*Rhus semialata* Murr.) have high potential for value addition. 'Ready to serve' (RTS) beverages can easily be prepared from ripe fruits of Outenga, Kordoi and Bael. Jam, jelly and squash may be prepared from ripe fruits of Kordoi, Outenga, Kujithekera, Roselle, Nagatenga and Bhimkol. Good quality pickles could be made available from Amlakhi, Kujithekera, Borthekera and Mirika tenga. Delicious juices could be prepared from Bael, Kordoi and Rebab tenga. Wines can also be prepared from ripe jackfruit, jamun and roselle. Sweet candy may be prepared from Amlakhi, Kujithekera and Mirikatenga. Value addition in minor and indigenous fruits could be one of the appropriate options to enhance farmer's income in Assam.

Site suitability analysis for pineapple cultivation in South West Khasi Hills of Meghalaya using Geospatial Technology

D.M. NONGHULOO*, C. GOSWAMI, F. DUTTA, B.K. HANDIQUE. K.K. SARMA, S.P. AGGARWAL

North Eastern Space Applications Centre, Umiam, Meghalaya

Meghalaya is one of the leading producers of pineapple (*Ananas Comosus*) in India which contributes to 8% of the total production in the country. Pineapple is a seasonal fruit and is rich in vitamins, enzymes, anti-oxidants and has a dense texture. Pineapple is a commercial crop which grows well in high rainfall and hilly areas of North Eastern Region (NER) of India. In Meghalaya the total production of pineapple is 138197 MT and South West Khasi Hills (SWKH) district contributes to 2.7% of the total pineapple production of the state. There is a scope for increasing the area and production of pineapple in the SWKH district and an attempt has been made to identify additional suitable areas for pineapple cultivation in SWKH district of Meghalaya using geo-spatial technology. Culturable wastelands *viz.* open scrub, dense scrub, current jhum and abandoned jhum were considered for the suitability analysis which contributes to around 18% of the total geographical area (TGA) of the district. Culturable wastelands were identified using Sentinel-2 satellite imagery and visual image interpretation technique. Multi criteria analysis was carried out in ArcGIS software to get the desired output. Eleven parameters were considered for the suitability study; average annual rainfall & temperature (climatic parameters), elevation & slope (physiographic parameters) soil depth, soil drainage, soil texture, pH, P_2O_5, K_2O and organic carbon (soil parameters). Appropriate weightage (0-100) was assigned to each layer and rank (0-10) to each suitability class while carrying out the weighted overlay operation in ArcGIS. An area of 21841.76 ha has been found to be suitable for growing pineapple in SWKH district out of which 1911.91 ha was highly suitable, 15717.05 ha was moderately suitable and 4212.79 ha was marginally suitable. Mawkyrwat Community & Rural Development (C&RD) block was found to have higher areas (14046.44 ha) suitable for growing pineapple. On the other hand, Ranikor C&RD block has been found to have more highly suitable areas (1134.61 ha) for growing pineapple. The outputs of the research study will be useful for the horticulture departments of Meghalaya in horizontal expansion of pineapple in SWKH district of Meghalaya.

Identification of potential sites for pineapple cultivation in East Jaintia Hills district of Meghalaya using Remote Sensing and Geographic Information System

T. KHARPHULI, C. GOSWAMI, F. DUTTA, B.K. HANDIQUE, K.K. SARMA, S.P. AGGARWAL

North Eastern Space Applications Centre, Umiam, Meghalaya

Horticulture sector in Meghalaya has emerged as the most profitable sector having potential for providing employment in rural areas and enhancing rural income. Pineapple (*Ananas Comosus*)

is one of the most important horticultural crops of Meghalaya in terms of area and production. The state contributes about 8% of the total pineapple produced in India. Among the fruit crops, pineapple occupies highest area in the state of Meghalaya (32% of the total area under fruit crops) and the total production of pineapple is 138197 MT out of which only 1770 MT is contributed by East Jaintia Hills (EJH) district. Therefore, an attempt has been made to identify potential areas for expansion of pineapple cultivation in EJH district using geospatial technology. Culturable wastelands *viz.* open scrub, dense scrub, current jhum and abandoned jhum were identified using Sentinel-2 satellite imagery and visual image interpretation technique. Theparameters that were considered for identification of potential areas for growing pineapple were temperature & rainfall (climatic parameters), elevation and slope (physiographic parameters), soil depth, soil texture, soil drainage pH, soil organic carbon, P_2O_5 and K_2O (soil parameters). The GIS database referring to these parameters were categorized into 4 classes according to the level of suitability i.e., highly suitable, moderately suitable, marginally suitable and not suitablefollowing standard criteria. Appropriate weightage (0-100) to each layer and rank (0-10) to each suitability class were assigned. After assigning weightage and rank, Weighted Overlay Analysis (WOA) was carried out in ArcGIS to identify the potential areas for pineapple cultivation in the study area. The potential areas were classified into 3 classes *viz.* highly suitable, moderately suitable and marginally suitable. An area of 27391.06 ha has been identified as potential sites for growing pineapple in EJHdistrict out of which 3006.79 ha is found to be highly suitable, 21573.04 ha is moderately suitable and 2811.24 ha is marginally suitable for growing pineapple. The evaluation of suitable sites of the study area indicates that the selected district has the potential for expansion of pineapple crop.

THEME - 6

Market oriented agricultural advisory services and agribusiness promotion

Supply chain of sponge gourd (*Luffa cylindrica*) in Meghalaya: A case study

BHABNA TALUKDAR[1*], RAM SINGH[2]

[1]M. Sc Scholar, [2]Professor and Head (Agricultural Economics), School of Social Sciences, College of Post Graduate Studies in Agricultural Sciences, Central Agricultural, University (Imphal), Umiam- 793103, Meghalaya

**Corresponding email: bhabnatalukdar@gmail.com*

Vegetables are the important component of balanced diet which plays key role in supporting food and nutritional security. They also help in uplifting the economy. Cucurbits are one of the large groups of vegetables cultivated widely in North Eastern states. Sponge gourd (Luffa cylindrica) is one such cucurbit which is consumed when it's tender and used as bath sponge or loofah when it's matured. The present paper demonstrated the supply chain of sponge gourd or luffa vegetable in Ri-Bhoi and East Khasi Hills districts of Meghalaya. Luffa being an underutilized vegetable crop grown in across the districts of Meghalaya. A sample of 16 supply chain intermediaries from market of Ri-Bhoi and East Khasi Hills districts have been selected. The standard analytical method of market margin, marketing cost and price received by growers as well as price spread was used. Paper demonstrates that the channel-III (Producer-Wholesaler-Retailer-Consumer) has been preferred more by the luffa growers as the highest quantity of the produce is disposed through this channel. However, channel-I was found to be more efficient than channel-II and channel- III. Channel-III has been followed by channel-II and channel-I for disposal of the produce. From the analysis it has been revealed that the channel-III needs to be strengthened by its technical and administrative interventions so that the crop may be popularly commercialized.

Navigating the mushroom industry through digitization: Assessing Meghalaya's small-scale enterprises amidst Covid-19

TH ONCHOILA MARING[1*], LOUKHAM DEVARANI[2], SNEHAL ATHAWALE[3], NILAY ADHIKARI[4]

[1]Ph.D Scholar (Agricultural Extension), [2]Associate Professor (Agricultural Extension), [3]Ph.D Scholar (Agricultural Economics), M. Sc Scholar4(Agricultural Economics), School of Social Sciences, College of Post Graduate Studies in Agricultural Sciences, (Central Agricultural University, Imphal), Umiam-793103, Meghalaya, India.

**Corresponding email: thoupongmaring@gmail.com*

Mushroom cultivation has gained recognition as a lucrative agribusiness that requires minimal investment and space. Meghalaya, one of the states in North-East India, boasts a rich variety of edible mushrooms abundant in its forested areas. The region's diverse agro-climatic conditions and ample agricultural waste provide an excellent opportunity to expand mushroom production. The COVID-19 pandemic has witnessed an increased reliance on Information and Communication Technology (ICT) tools, leading to heightened internet connectivity. Consequently, people have begun to embrace mushroom consumption due to its perceived immune-boosting and antiviral properties. However, pandemic-induced lockdowns and

associated restrictions have impacted the production and marketing activities of mushroom growers. Nonetheless, mushroom cultivators in Meghalaya have adeptly utilized ICT tools, warranting further in-depth exploration. In this context, a comprehensive study was conducted in the East Khasi Hills and Ri-Bhoi districts of Meghalaya from 2020-22 to analyze the situation of mushroom enterprises in the wake of the COVID-19 pandemic. The study captured the perceptions of 60 growers regarding selected strengths, weaknesses, opportunities, and threats (SWOT) elements with reference to ICT tools. The findings revealed that the utilization of mobile phones emerged as a strength, while trade digitalization presented an opportunity for small-scale mushroom enterprises. Based on these findings, strategic recommendations have been formulated to foster a robust mushroom ecosystem, enabling small-scale enterprises to harness substantial benefits.

Assessing the impact of block-level agro advisories on reducing farmers' input costs in Mizoram

SAMIK CHOWDHURY[1*], SAURAV SAHA[2], SUNIL DOLEY[1], I. SHAKUNTALA[3], S.B. SINGH[4], VANTHAWMLIANA[1], P. LALHMACHHUANA[1], D. CHAKRABORTY[5], S. HAZARIKA[5], S. LALLIANSANGA[6], LALMALSAWMI[7], LUNGMUANA[1], P.L. LALRINSANGA[1], LALHRUAIPUII[1], Y.B. KUMAR[1], TAMILARASAN K.[1], KRIPPAN GHOSH[8], S.C. BHAN[9]

[1]ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram -79608, [2]ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Sikkim 7371022, [3]College of Veterinary Sciences and Animal Husbandry, Jalukie, District Peren, Nagaland-797110, [4]Central Agricultural University, Imphal, Manipur 795004

[5]ICAR RC for NEH Region, Umiam, Meghalaya-793103, [6]Directorate of Agriculture, Govt. of Mizoram, Aizawl, Mizoram -796001, [7]Krishi Vighyan Kendra, Lengpui, Mamit, Mizoram – 796410, [8]India Meteorological Department, Shivajinagar, Pune-411005, [9]India Meteorological Department, Mausam Bhawan, Lodi Road,New Delhi–110 003

**Corresponding email: samikchowdhury33@gmail.com*

Biweekly block-level Agromet bulletins were distributed based on medium range weather forecast with the goal of assessing the effectiveness and usefulness of Block level Agro Advisory Services (AAS) and quantifying the economic benefits of adopting micro scale agromet advisory in their day to day agricultural operations at Kolasib. Based on agro-met advisory acceptance and non-adoption, four farmer groups were studied. These farmers were compared to nearby fields with the same crops where non-AAS farmers did not use forecasts. Sowing to marketing costs, yield, and net returns were computed. At Agro Met Field Unit (AMFU), Kolasib, the weather forecast and actual weather data from Regional Meteorological Centre, Guwahati were compared to verify rainfall forecasts for 2018-19, 2019-20, 2020-21 and 2021-22. Winter (84%) had a higher ratio score than pre-monsoon (80%), post-monsoon (79%) and monsoon (74%). Threat score was highest during the pre-monsoon (79%). In all four seasons, the wind direction correlation coefficient and RMSE values were too high to accept homogeneity in projected and observed values. Block wise verification of annual rainfall showed an accuracy range of 67–76%. This forecast directly boosted AAS adaptable farmers'

maize production profits by 12% to 19% due to irrigation costs during rabi season. The study also showed that AAS adaptable farmers earned more than non-adaptive farmers.

Role of agribusiness incubation (ABI) centre, ICAR Research Complex for NEH Region, Umiam, for entrepreneurship development in Northeastern, India

A. ROY[1], G. KADIRVEL[2], C. GOWDA, T.B. MARAK[1*], N.U. SINGH[1], H. NARESH SINGH[3], V.K. MISHRA[1]

[1] *Agribusiness Incubation Centre, ICAR Research Complex for NEH Region, Umiam, Meghalaya,* [2] *Director, ICAR-ATARI, Zone-VI, Kahikuchi, Guwahati, Assam,* [3]*Agribusiness Incubation centre, ICAR Research Complex for NEH Region, Manipur Centre*

**Corresponding email: thameri.marak@gmail.com*

The Agribusiness Incubation (ABI) centre, ICAR Research Complex for NEH Region, Umiam, Meghalaya, was one of the initiative of ICAR under the XIIth plan scheme of NAIF Component-2 in January 2016. This centre envisages facilitating incubation of new startups/entrepreneurs belonging to Northeastern India for innovative/commercial/potential technologies by providing the need based physical, technical, business and networking support. At present, ABI Centre, ICAR Research Complex for NEH Region, Umiam, Meghalaya along with its other regional centres across the Northeastern states has a total of 160 registered entrepreneurs performing well in different agribusiness ventures. Out of these members, 20 entrepreneurs have graduated successfully and 30 members are in acceleration stage. Continuous virtual/physical meetings/ workshops were organized to assess the impact of COVID-19 pandemic on MSMEs of Incubation centre. The pandemic has caused an immense effect among the MSMEs resulting in 13.02% to 36.36% of average loss in the monthly income with average operational capacity of only 15.00% to 49.28% of the total capacity. During these meetings/workshops, 4 (Four) major constraints being faced by the MSMEs were identified and prioritized in the order of logistic problem, lack of market access, low production volume and limited manpower. To address the constraints, the center facilitates various incubation support to the entrepreneurs such as training and skill support, pilot testing facilities, testing and validation of products/technologies, networking and linkage support, marketing and branding support, facilitates financial and legal supports etc. In order to provide the promotional facilities to the entrepreneurs, the centre has created an Exhibition hall, Training cum Conference hall and Incubatees Chambers besides facilitating a sales outlet (NARI) within the campus. ABI Centre has successfully made an achievement by generating over 4000+ of employments through start up entrepreneurs including FPOs/FPCs. More than 12000 farmers' lives have been benefitted from the entrepreneurs under ABI centre through forward and backward linkages.

Engineering sustainable agricultural growth through public investment in Manipur

ANJOO YUMNAM[1*], N UTTAM SINGH[1], ANIRUDDHA ROY[1], PAMPI PAUL[1], KAMNI P. BIAM[1], HR CHIKKATHIMME GOWDA[1], M. BILASHINI DEVI[1], NIVEDITA DEKA[2]

[1]ICAR Research Complex for NEH Region, Umiam, [2]Assam Agricultural University, Jorhat
**Corresponding email: anjooyumnam102@gmail.com*

Public investment has undeniable role in bringing transformative change in agricultural growth and sustainability. The present study aimed to examine the trend and pattern of public investments in agricultural sector in Manipur. The study also sought to examine the impact of public investments on agricultural production and estimate the efficiency in its utilization so as to engineer the allocation of the investment for sustainable agricultural growth in the state. The bounds test approach or Autoregressive distributed lagged model (ARDL) to cointegration was used to find the relationship between agricultural production as dependent variable and public investments in agricultural sector (agriculture and allied, irrigation and flood control, rural development and special area development programmes) as dependent variables. The annual data for the variables were collected for a period of 30 years (1990-91 to 2019-20) from RBI, State finances: a Study of Budgets. The public investments in agricultural sector had an absolute increase over the last 30 years with CGR of 3.88%. The highest increase was observed in major and medium irrigation. The ARDL model estimates showed that in the long run, investment in Agri & Allied had a significant negative effect on agricultural GSDP (-0.45) while impacts of investments in major and medium irrigation, Rural development and special area development were positive. The negative effect of investments in Agri & Allied implied unproductive expenditure in the many components which did not create positive returns. The efficiency of capital utilization was estimated using Incremental Capital Output Ratio (ICOR) which showed improved efficiency in capital utilization in the last decade. Considering the ICOR for the overall period, to maintain a sustainable agricultural growth of 4%, the public investment in agricultural sector should grow by 11%.

Is millet cultivation important for North East India? An analysis in the context of the local poultry feed industry

DIPANJAN KASHYAP[1,2*], KISHOR GOSWAMI [1]

[1] Indian Institute of Technology Kharagpur, India AND [2] Assam Agricultural University, Jorhat, India
**Corresponding email: dipankashyap@gmail.com*

Millets are essential crops for small and medium-scale farmers of North East India, thriving in hilly and dry areas. Millets are known as nutri-cereals, offering nutritional benefits such as high calcium, zinc, iron content, low glycemic index, and gluten-free properties. These resilient crops serve as natural insurance for farmers, ensuring income protection and food security in changing environment. Though various millet varieties like finger millet, foxtail millet, buckwheat, and pearl millet are sporadically cultivated mainly by the tribal farmers in parts of Assam and neighboring states, their production remains limited. The poultry industry in India has been rapidly expanding, with an annual growth rate of around eight percent. Feed

constitutes a significant portion (70-75%) of poultry production costs, with maize and soybean meal being the primary carbohydrate and protein sources, respectively. Poultry egg and meat production has been rising in Assam, Tripura, Meghalaya, and Manipur, leading to the emergence of several integration companies that collaborate with farmers of the region. To ensure a consistent feed supply, a few companies are establishing feed manufacturing facilities in Assam, reducing transportation costs and delays. Since North East India has limited soybean and maize production, local feed manufacturing plants either need to import raw materials from outside the region or utilize alternative feed ingredients available locally. Considering the region's preference for rice over millets for human consumption, millets can be strategically incorporated into poultry feed production. Millets offer a comparable protein composition to corn and soybean, providing valuable plant-based protein for poultry diets. It also contains essential amino acids, minerals, and antioxidants, contributing to bone development, egg production, and disease resistance. Feed manufacturers often substitute corn with millet when the crops have a considerable price difference. Incorporating millet into poultry feed formulations can enhance the nutritional value, cost-effectiveness, and sustainability of the industry.This paper examines the current state of millet cultivation in the region and its significance in the poultry feed sector. It emphasizes the economic advantages of expanding millet production, such as increased income and conservation of natural resources. The study underscores the need for research, development, and collaboration among stakeholders to harness the full potential of millet cultivation, promoting sustainable agriculture and rural development in North East India.

Dynamics of oilseeds production and decomposition of its output components in North-East India

A. ROY*, N.U. SINGH, A. YUMNAM, C.H. GOWDA, P. PAUL, K.P. BIAM, V.K. MISHRA

Division of Technology Assessment & Capacity Building, ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya

**Corresponding email: aniruddha.roy@icar.gov.in*

India is the fourth largest producer of oilseeds and accounts for about 15-20 percent of global oilseeds area and 9-10 percent of total edible oils consumption. Among different oilseeds, groundnut, rapeseed-mustard and soyabean accounts for about 80 percent of area and 87 percent of production of oilseed in the country during 2018-19. Currently, share of oilseeds are 14% of the total area under major crops. During the last decade (2010-11 to 2019-20) the compound annual growth rate of oilseed in North-East was 2.67% which was more than all India average (0.28%). In North-East, the production of oilseeds was 292 thousand tonnes in TE 2010-11 and it has increased to 372 thousand tonnes in TE 2020-21. This paper investigates the trends in area, production and yield of oilseeds in the North-eastern States of India. The study period was from 1990-91 to 2019-20 and it had divided into 3 periods: 1990-91 to 1999-2000, 2000-01 to 2009-10 and 2010-11 to 2019-20 to have an understanding of decadal performance. The results clearly showed that the growth rate performance of area, production and yield of oilseed in the

region declined sharply from period 1 to 3. The study witnessed that more than half of the area under the crop in the region suffered from low growth rate in production. The comparison of production growth rates in all the periods revealed that Nagaland show better performance followed by Arunachal Pradesh, Meghalaya, Mizoram and Sikkim while Assam, Manipur and Tripura are running behind. Performance of Nagaland was even better than the north east total and national level. Area growth was also best achieved by Nagaland followed by Arunachal Pradesh, Meghalaya and Sikkim. The decomposition analysis of growth suggests that sources of output growth in north east were the same in all the three periods as the major contribution was yield effect followed by area effect. In all the eight states for all the period the relative contribution to the change of output was either yield effect or area effect. Reduction in yield gap and adoption of new technology may increase the production of oilseeds in Northeast make this region self-sufficient in oilseeds production and consumption.

AMIU-AAU: A crop advisory on market intelligence

UDESHNA TALUKDAR*, SANGITA BORAH, SUJATA BARUAH, NIVEDITA DEKA
Department of Agricultural Economics & FM, Assam Agricultural University, Jorhat, India
**Corresponding email: udeshna.talukdar@aau.ac.in*

In a country like India, agriculture plays a crucial role in meeting the food and nutritional needs of the society. Agriculture has always been the backbone of India and 58 per cent of the population is still engaged in agriculture. But the fluctuation of market prices of agricultural commodities has remained a concern for the farmers for many years. The high post harvest losses, high market arrivals and low prices leads to decrease in producers share in consumer's rupee. The study was therefore an attempt to outline the role of market intelligence in marketing of agricultural commodities. Market intelligence is an unit for collection of market information (prices, trends, arrivals etc.), interpretation and dissemination of market intelligence, crop advisory etc. to the farmers and other value chain players. The present study was undertaken in different districts of Assam where major wholesale markets of the key commodities were used for collection of market prices and arrival data. The collected and analyzed market information were disseminated to farmers through different channels which includes web portal of AMIU, voice mail etc. The study concludes that market intelligence should focus on linking market linkages between farmers, farmer producer groups and markets which would make agriculture a more viable venture. It would therefore serve as the source of commercialization for farmers who are doing subsistence farming only.

Farm Income Enhancement through species diversification by incorporating *Pabda* as bottom feeder fish in polyculture system in Tripura

BISWAJIT DEBNATH[1*], BISWAJIT DAS[2], AMULYA KUMAR MOHANTY[3], VINAY KUMAR MISHRA[4]

[1]Krishi Vigyan Kendra, South Tripura, [2]ICAR Research Complex for NEH Region, Tripura Centre, [3]ICAR-Agricultural Technology Application Research Institute (ATARI), Zone VII, [4]ICAR Research Complex for NEH Region, Umiam, Meghalaya
*Corresponding email: debnath_biswajit@rediffmail.com

This paper analyses the economics of incorporating *Pabda* as a bottom feeder fish in pond fish farming as evidenced by the *'On farm trial (OFT)'* conducted by KVK, South Tripura. The *OFT* was conducted on 'Growth and production performance of high value fish, Pabda in Polyculture for income generation' for two consecutive years (2021-22 & 2022-23) in agro-climatic situation of South Tripura district. Considering the importance of farmers' income enhancement in recent past, this OFT was planned to incorporate high value fish species i.e. *Pabda* in carp polyculture system. Three combination of bottom fish diversification was followed in pond fish farming viz. Catla: Rohu:Mrigal (termed as Mrigal System), Catla: Rohu:Pabda (Termed as Pabda System), and Catla:Rohu: Mrigal & Pabda (Termed as Mrigal-Pabda dual system). Mean Values of Productions (in kg per acre) were 577.43 (SD = 65.43) in Mrigal system, 555.83 (SD = 76.83) in Pabda system and 597.00 (SD = 60.19) in Mrigal-Pabda system respectively. The net returns (in Rs. per acre) were Rs. 72,602 (SD = Rs. 15,334) in Mrigal syatem, Rs. 1,15,026 (SD Rs. 17,141) in Pabda system and Rs. 80,254 (SD = Rs. 14,645) in Mrigal-pabda system respectively. Results of one-way ANOVA showed that there was no significant difference ($p = 0.107$) in the level of production per acre among these three farming combinations. However, high level of significant difference was observed among these three farming system when we consider Gross return ($p = <0.001$) and Net return ($p < 0.001$). While carrying out the post hoc using Turkey's HSD, Net return from *Pabda* system was observed to be a different subset keeping other two farming systems in same subset. Finally, the *Pabda* system showed significantly different in net profit contribution. If we cross validate the result with mean values of net return, it is established that incorporation of *Pabda* as bottom feeder fish in pond fish farming has significantly contributed towards net income enhancement among the farmers of Tripura.

Quality Protein Maize (QPM): An option for income, food and nutritional security of tribal farmers of Meghalaya

MEGHNA SARMA*, MOKIDUL ISLAM
Krishi Vigyan Kendra, Ri Bhoi, ICAR Research Complex for NEH Region, Umroi Road, Umiam-793103, Meghalaya, India
Corresponding email: meghnasarma3@gmail.com

Meghalaya being an agrarian state about 80 percent of its population depends on agriculture for their livelihood. Maize, queen of cereals is the second most important food crop of Meghalaya after rice occupies about 18000 ha area (8% of total area) with an average yield of 2150 kg/ha .The area of maize has remained stagnant for the last five years and per unit productivity is lagging behind the national average (6105 kg/ha) of India. The constraints in achieving are cultivation of low yielding variety, local land races in acid soils with Al toxicity and non availability of improved variety of seed. In spite of several important nutritious use, maize has

a drawback with two essential amino acids *viz.*, Lysine and Tryptophane which leads to poor net utilization and low biological value of traditional maize causing malnutrition. Quality Protein Maize (QPM) has been developed by incorporating ***opaque 2*** gene to overcome this problem which contains twice the quantity of essential amino acids. Thus, QPM cultivation provides an opportunity to the tribal farmers for producing nutritionally superior maize grains. Hence, KVK, Ri-Bhoi introduced and demonstrated QPM (Var.HQPM-1) in 6 villages covering 10.0 ha area in Ri-Bhoi district of Meghalaya during Kharif season of 2021-22 with an objective to increase the production, productivity of the district. The results of the demonstration revealed that an average QPM yield was enhanced by 48.13 percent to 43.7 q/ha from 29.5 q/ha without application of any fertilizer. The incidence of disease and insect-pests attack was recorded at farmers' field. The enhancement of net return fetched from Rs.28,780 to Rs.66,476/ ha with a profitability ratio of 2.86. The reduced feeding cost for pig and poultry was also observed at the tribal farmers' field. The horizontal spread was very fast in few pockets but non availability of quality seeds in remote areas hindrance further spread though it might help to raise income, food and nutritional security significantly for the tribal farmers.

Technology dissemination mechanism in technology adoption in hill agriculture

PAMPI PAUL[1], K.P. BIAM[1], M.B. TENGLI[2], N. UTTAM SINGH[1], A. ROY[1], A. YUMNAM[1], C. GOWDA[1]

[1] Division of Technology Assessment and Capacity Building, ICAR RC NEH, Umiam, Meghalaya, [2]Assistant Professor, School of Social Sciences, CPGS-AS, CAU(I), Umiam, Meghalaya

**Corresponding email: pampindri@gmail.com*

Small-marginal farmers and their scattered-fragmented landholdings predominantly occupy the farming system of Meghalaya. In reality, most farmers practice traditional farming at the subsistence level. In contrast, agricultural science has advanced by developing new technologies like quality inputs such as hybrid seeds, improved agronomic practices, and scientific structural development like micro water harvesting structures. However, factually speaking technology cycle is only possible with technology adoption by the farmers at their field level. ICAR Research Complex for NEH Region, Umiam, has developed certain agricultural technologies over time, such as the hybrid maize variety Megha Maize-1, Megha Turmeric (Turmeric variety), and Jalkund, a micro water harvesting structure. Apart from this, Artificial Insemination (AI) in pigs is one of the most popularized technologies in the hilly pockets of the state. The technology dissemination mechanism used has a vital role in adopting the same. This paper has critically analyzed the different technology dissemination mechanisms used to popularize the technologies, and the study found that training and demonstrations were the most helpful dissemination methods used by scientists. In the case of Megha maize1, on average, demonstrations (4 no.) and training (2 no.) were conducted in a year since 2017-18. Through krishi vigyan Kendra (KVKs) and the line department of agriculture, seeds are distributed to users in a trial at the farmer's field; the highest 300 kg of seed were given to the district agriculture office (DAO), Ri-Bhoi district in 2021-22. Apart from this, with the active

involvement of the farmer's participatory seed production model was operating in 5 districts, where 210 quintal seeds were produced with coverage of 924 farmers from 22 villages. Further, in the case of Megha Turmeric, the training method has been most useful since its release and development. For jalkund, another prominent technology in 2017-18, training was mainly used, but later in 2018-19, demonstration at the farmer's field became the most useful method. Further, for Artificial Insemination (AI) in pigs, other than training, scientists have developed a few models of AI delivery at the farmer's door through direct linkage to tribal farmers, through trained, educated youth, oestrus synchronization, and fixed-time and mobile van-based AI delivery system through which Ri-Bhoi and East khasi hills districts were covered. Further, the study suggests working on the effectiveness of various technology dissemination methods.

Development of user friendly hydroponics model

SUBHANKAR SAHA[1], SUBHAJIT SINHA[2], DORODI PRIYOM DUARAH[3]

[1]Assistant Professor, Department of Horticulture, SCS College of Agriculture, Assam Agricultural University, Rangamati, Chapar, Dhubri, [2]Founder & CEO – 4CLIMATE (NatureX Technologies LLP), [3]Subject Matter Specialist (Horticulture), Krishi Vigyan Kendra, Kamrup, Guwahati

**Corresponding email: subhankar.saha@aau.ac.in*

With the rise of health consciousness among the people, the importance for healthy and nutritious diet has amplified. Moreover, the harmful effects of insecticides and pesticides used in vegetables have put the urban populace in dilemma. As an alternative, many people are now opting for organic food and some even try and grow vegetables in the little space they have in cities. Since, the space is limited in flats and apartment's people are opting hydroponics as an alternative as there is no requirement of soil and can be easily setup. In hydroponics as we know, the plants absorbs the nutrients dissolved in water which gets depleted in time with the plants growth and needs to be replenished at regular intervals. The growers face problem in maintaining the nutrient status of the solution using EC meter. Further, the pH also needs to be checked at regular interval and corrected. The nutrient solutions available in the market are also exorbitantly priced and often under perform due to limited scientific study. These hurdles faced by a layman with limited knowledge in hydroponics have hindered the adoption of this technology by many. Looking at the above problems, it is felt necessary to create an user friendly hydroponics system where the pH and EC are automatically read and corrected. Along with this, crop specific nutrient solutions with thorough research could be developed for the peoples benefit. Moreover, this can also lead to entrepreneurship development in urban areas where entrepreneurs can provide consultancy services and also assist in setting up of hydroponics facility.

An Impact Analysis of Front-Line Demonstrations on Adoption of Improved Practices in Finger Millet Cultivation in the Hill tracts of Arunachal Pradesh

PREMARADHYA, N.[1*], A.K. TRIPATHI[1]., SANGAPPA[2], PAVAN KUMAR GOUDAR[1], AJAYKUMARA K.M.[3]

[1]*College of Agriculture, (Central Agricultural University-Imphal), Pasighat, Arunachal Pradesh,* [2]*ICAR-Indian Institute of Millets Research, Hyderabad,* [3]*College of Horticulture and Forestry, (CAU-Imphal), Pasighat, Arunachal Pradesh*

**Corresponding email: premaradhya@gmail.com*

Finger millet (*Eleusine coracana*) is among the major crops cultivated in the undulating terrains of Arunachal Pradesh, India. It is consumed as a staple food and drink by the local tribal communities in the state. However, over the years there has been rapid decline in cultivation leading to reduced grain availability for household consumption due to seed colour, drudgery in processing and generation gap. With a view to increase the productivity and considering the above facts, a frontline demonstration was proposed and conducted in the farmers' holdings to demonstrate the performance of high yielding variety with improved package of practices in finger millet along with its nutrition awareness initiatives in Shi-Yomi and Siang districts over 2 years (2021–2022). The study focused On-farm trial with the Improved Crop Management practices viz., high yielding and short duration finger millet variety 'GPU-67' integrated nutrient management, timely weed management technologies were demonstrated and compared with the farmers practice practiced in jhum areas by the tribal farmers in 2021-2022. Results from both the districts were indicated that demonstration of finger millet variety GPU 67 with an improved crop management practices recorded higher mean grain yield of 2013.33 kg ha^{-1} and 2540 kg ha^{-1} respectively) and farmers practice recorded lower yield of 1141.66 kg ha^{-1} and 1385.5 kg ha^{-1} respectively. Adoption of high yielding variety with improved management practices in 2021–2022 showed increase in the grain yield of finger millet to the tune of 56.71 and 54.54% higher grain yield and 1.79 and 2.31 times more profit than that of farmers' practice in both the locations (₹15692 ha^{-1} and ₹30812 ha^{-1} of net income earned, respectively) and Cost was counted as a recommended cultivation package. Besides, farmers realized higher benefit cost ratio (1.42 and 2.46, respectively) through the demonstration compared to farmers practice (2.29 and 2.1, respectively). Thus, the demonstration of improved variety GPU 67 with crop management practices increased the grain yield and net income of the farmers growing finger millet under hilly tracts. In the present study, potential of the new high yielding variety and technologies were demonstrated systematically and scientifically in the farmers field along with farmers practice (broadcasting in the steep hilly slopes without any management practices) for further adoption by farming community in large scale in the state.

A case study of adopting vermicomposting technology as enterprise at Tinsukia District, Assam

KRIPAL BORAH[1], SANCHAYEETA GOHAIN[2], PRIYANKA AMONGE[3], MRINMOY CHETIA[4], SARODEE BORUAH[5], GAYATRI DEORI BHUYAN[6], GAUTOMI DUTTA[7]

Vermicomposting has gained popularity in both industrial and domestic settings because, it treat organic wastes more quickly compared to conventional composting and also due to the simpler , natural & less mechanised operations which make the technique easier to adopt. The economic and human health benefits associated with this production technology is making it more farmers friendly. The by-products of Vermicomposting i.e., vermicompost, vermiwash are nutrient-rich organic fertilizer and soil conditioner in a form that is relatively easy for plants to absorb. In the present study, the success of vermicomposing in two villages of Tinsukia District as an enterprise has been studied.The technology of bamboo made low cost vermicomposting unit was effectively adopted in these villages with an output of total of 216 ton of vermicompost, 43,200 lits of vermiwash and around 40 lakh of earthworm (*Eudrilus eugeniae*) altogether. The average income from one unit is Rs 1, 28430 per year with a B: C ratio of 3.5:1. With proper support of training and handholding this technology can transform life of more farmers in future.

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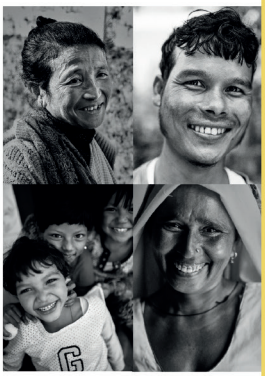

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