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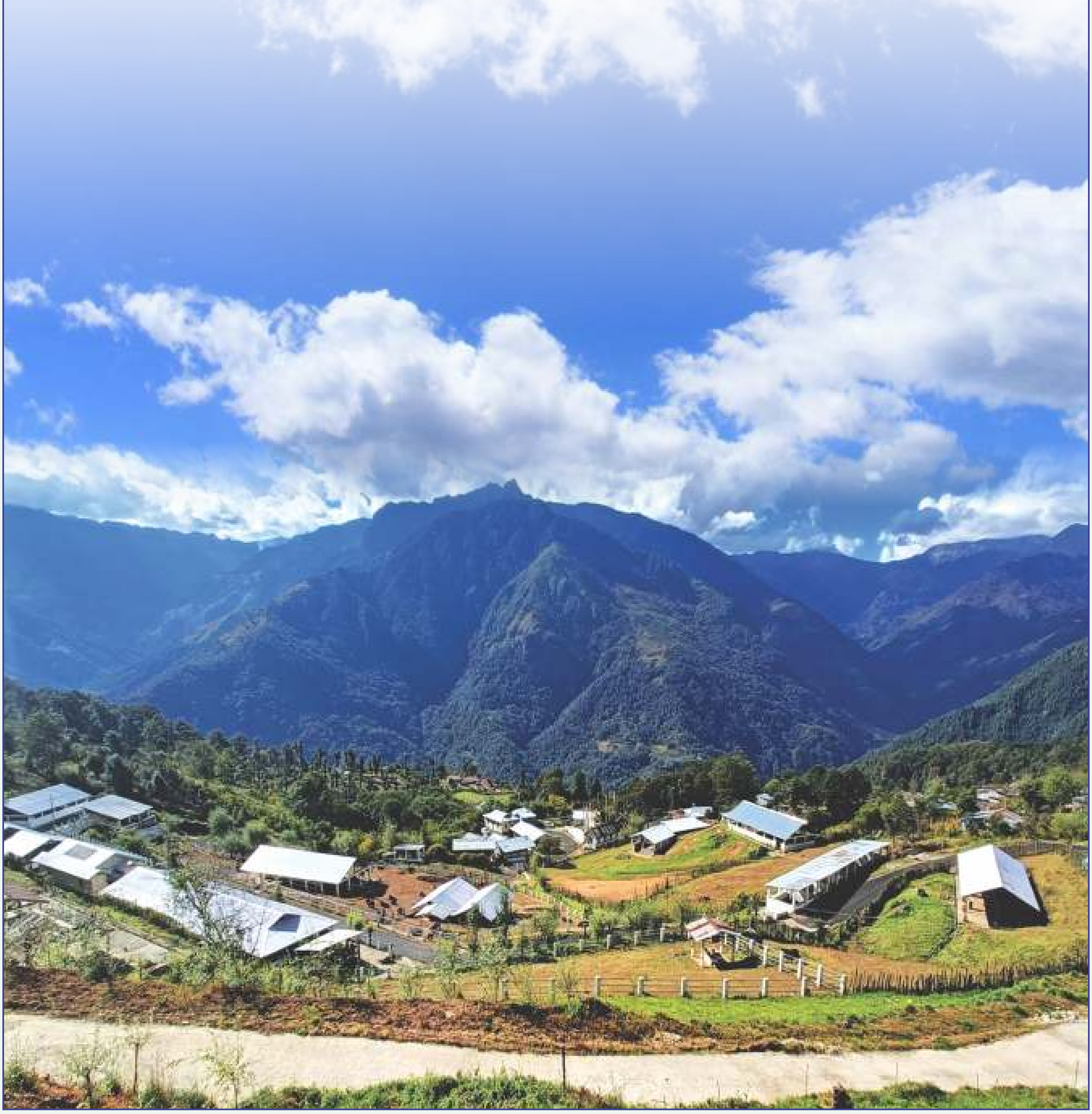
Footprints of ICAR in Northeast India-2



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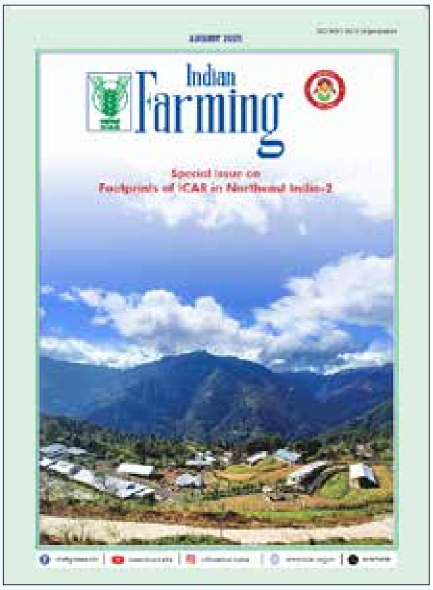

Cover I: Northeast India

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Advancing Farming Systems and Rural Prosperity in the North Eastern Hill Region

THE ICAR Research Complex for NEH Region, its regional centres, National Research Centres, Krishi Vigyan Kendras and other institutes have played a transformative role in advancing agriculture, ensuring food security, and empowering rural communities across the northeast. This special is brought with the help of NEH team to showcase how the institute has strengthened regional farming systems and enhanced livelihood opportunities through location-specific technologies and farmer-oriented programmes.

Protected cultivation of high-value vegetables such as capsicum, tomato, and cucumber under controlled environments offers sustainable income for hill farmers by ensuring year-round production and reducing weather risks.

Pond-based integrated farming models in Meghalaya demonstrated efficient use of water and land resources by combining fish culture with livestock and crop production, thereby diversifying income. Similarly, natural farming techniques and integrated organic farming systems reduce chemical dependence and further promote ecological balance, and improve soil health linking crop, livestock, and horticulture components to ensure nutritional and livelihood security.

Buckwheat cultivation has emerged as a climate-resilient crop option, is a robust stress tolerant crop, enhancing cropping intensity and income in marginal hill areas. Besides, livestock-based enterprises such as poultry farming contribute significantly to food and nutritional security, particularly for smallholders and women farmers. Disease management interventions were also done such as strategies to protect pigs from African swine fever to safeguard rural livelihoods.

Technological innovations like containerised nursery systems ensure production of quality planting materials, for crops like Khasi mandarin. Emerging aquaculture opportunities, including *Wallago attu* (freshwater shark) culture in Manipur, highlight new avenues for fish-based income. Likewise, quality cashew production in the Garo Hills offers potential for export-oriented growth, while farm mechanization helps reduce labour drudgery and increase efficiency in hill agriculture.

New commercial crops like dragon fruit represent high-value options with growing market demand. Further Lakadong turmeric, a GI tag crop from Meghalaya, is a high curcumin quality turmeric which can elevate the livelihood security of the farmers with value addition through farm machinery. Finally, the role of Farmers Producer Organizations is crucial in aggregating smallholders, strengthening market access, and ensuring better price of their produce.

Together, these innovations reflect a holistic approach with the collaborative efforts of scientists, government, farmers and other organisations to create agriculture more resilient, profitable, and sustainable in northeast India.

AAgrawal

(Anuradha Agrawal)

Indian Farming 75 (08): 03-05; August 2025

ICAR Research Complex for NEH @50:

Advancing agriculture and empowering the northeast

Vinay Kumar Mishra* and Veerendra Kumar Verma

ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya 793 103

The north eastern region of India consists of eight states: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura covering an area of 262,179 km² and are home to more than 45.58 million people according to the 2011 Census, which is about 3.77 percent of the total population of India. The region is unique in its social, cultural and political diversity. More than 200 major tribes and numerous sub-tribes live across the region, each with their distinct traditions, customs and ways of life. This article highlights the various interventions done by ICAR Research Complex for NEH, its regional centres and KVK's in the northeast India.

Keywords: Agricultural interventions, Cultural diversity, Tribal farming

AGRICULTURE is the backbone of the north eastern economy, supporting livelihood of majority of the population, more than eighty percent of whom live in rural areas. Jhum, or shifting cultivation, remains the dominant land use system in these hilly areas. At the same time, the region is blessed with extraordinary natural resources. It is one of the world's recognized biodiversity hotspots, containing species-rich tropical rainforests that support a wide variety of plants and animals. The region is also considered centre of origin for several important crops, including citrus fruits, cereals and orchids. Its water resources are equally significant. About one-third of India's total surface runoff originates here through the mighty Brahmaputra and the Barak river systems. The northeast alone accounts for about 34 percent of the country's water wealth and nearly 40 percent of its hydropower potential. Floods and soil erosion frequently damage land and livelihoods, while groundwater resources remain largely untapped.

In addition, forests dominate the landscape of the region, covering almost 65.6 percent of its total geographical area, which is far higher than the national average of just 21.34 percent. However, forest cover has been under pressure. The India State of Forest Report of 2015 recorded a decrease of about 628 km² in forest cover across the northeast, mainly because of shifting cultivation and other human pressures. The soils, climate and biodiversity of the region are well suited for a wide range of crops, livestock, fisheries and forestry-based activities.

Thus, Indian Council of Agricultural Research established the ICAR-Research Complex for North Eastern Hill Region in 1975 with an objective to provide scientific and technological support for agricultural development tailored to the unique challenges and opportunities for the north eastern region. Over the years, it has grown into a multidisciplinary research centre covering a wide range of fields, including natural

ICAR-Research Complex for NEH Region, Headquarter at Umiam, Meghalaya

Rice variety: NICRA Aerobic Dhan-1

Turmeric cultivar: Megha Turmeric-1

Production of gerbera under open condition

Production of lilium and gerbera under low-cost polyhouses

resource management, crop sciences, horticulture, animal husbandry, fisheries and agricultural engineering.

The institute is committed to developing location-specific technologies that are sustainable, climate-resilient and culturally compatible with the tribal societies of the region. Its headquarter is located at Umiam, Barapani in Meghalaya. Four divisions operate at the headquarters, supported by six regional centres located at Basar in Arunachal Pradesh, Lamphelpat in Manipur, Kolasib in Mizoram, Jharnapani in Nagaland, Tadong in Sikkim and Lembucherra in Tripura. In addition, the institute coordinates twenty Krishi Vigyan Kendras distributed across all eight states of the region, which serve as vital links for transferring technologies from research stations to farmers' fields.

The institute has been playing a leading role in promoting agricultural development and improving tribal livelihoods in the region. It provides customized livelihood options in agriculture and allied fields, supports skill development and builds rural social capital. It is also active in human resource development, providing teaching and research opportunities for postgraduate and doctoral students in agricultural and allied sciences in collaboration with universities from across the country. Being hub of agricultural research in the northeast, the institute has implemented numerous competitive projects supported by national and international agencies. The institute has built strong linkages with other ICAR institutes, universities and international organizations while also working closely with NGOs, farmers' organizations and cooperatives for outreach programmes. It continuously provides technical advice, consultancy and modern technologies to stakeholders across the region. Its contributions cover many aspects of agriculture, natural resource management and rural development.

One of the greatest challenges to agriculture in the north eastern hills is soil acidity. About twenty-one million hectares in the region are affected by acidic soils, and around sixteen million hectares suffer from high levels of acidity with pH below 5.5. In such soils, essential nutrients such as phosphorus, calcium, magnesium, zinc, boron and molybdenum are deficient, while toxic elements like aluminium, iron and manganese occur in harmful concentrations. Traditional liming practices require 2–10 tonnes of lime per hectare, which is far too costly for resource-poor farmers. To overcome this problem, institute developed an alternative technique of furrow application of lime at much lower rates of 2–4 q/ha, making the practice affordable and effective.

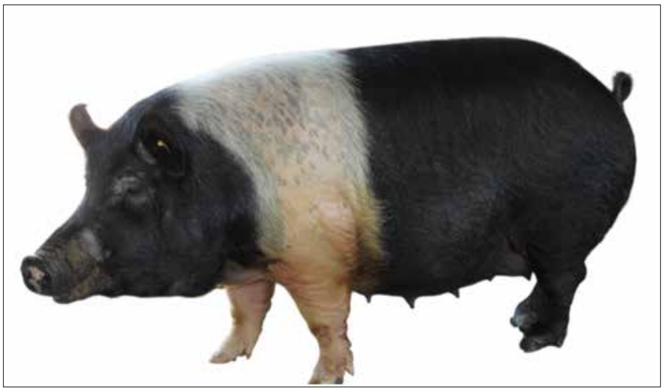
The institute has also standardized organic production technologies for about fifty crops, including cereals, pulses, oilseeds and vegetables, under a cropping system approach for hill states. It has standardized technologies for year-round production of high value crops under naturally ventilated polyhouses/rain shelter and developed package of practices for management of the citrus decline in Khasi mandarin. It has developed integrated farming system models that combine crops, livestock, fisheries and other components to ensure year-round food, income and employment security for farmers. Integrated farming system and integrated organic farming system have been widely adopted and are helping to reduce dependence on shifting cultivation. They have enhanced productivity of crops by 20–40 percent, livestock by 20–30 percent and fish by 30–50 percent. The institute's work on integrated organic farming was recognized at the global level during the United Nations Climate Change Conference in 2021. Besides, the integration of mushroom cultivation, bee keeping, fish farming and farmers' friendly tools into these systems has improved soil conservation and significantly enhanced the economic conditions of tribal farmers.

Further, water scarcity during the dry season, especially from November to March, remains a major

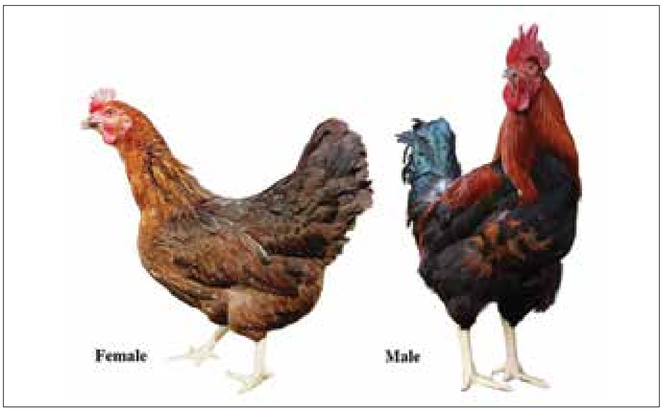
Ginger and turmeric washer and slicer

problem in the hills despite abundant rainfall in the monsoon. To address this, the institute developed Jalkund, a low-cost rainwater harvesting structure for storing rainwater. Jalkund has enabled farmers to irrigate crops during dry periods, raising cropping intensity from 100 percent to 200 percent and generating additional income. In crop improvement, NICRA Aerobic Dhan 1, a rice variety that requires 60 percent less water than traditional; puddled rice and emits up to 85 percent less methane, has been developed. Another significant development is Megha Turmeric 1, which is valued for its high curcumin content. Its adoption has increased production, created employment opportunities and encouraged entrepreneurship among tribal farmers.

In horticulture, the institute has developed 4 varieties of guava (Megha Wonder, Megha Supreme, Megha Magenta, and Megha Seedless) that are in high demand among farmers. It has also developed improved cultivars of papaya, pineapple, tomato, brinjal, French bean, taro, yam, gerbera and other crops suited to the region. There is a huge demand of the ornamental crops, for that institute has developed package of practices for the production of the gerbera, lilium and anthurium for open as well as under protected conditions.



Lumsniang: An improved breed of pig



Tokbari: An improved breed of poultry

Farm mechanization is a major challenge in the hill agriculture; the institute has developed several tools and farm tools and implements suitable for the marginal and small farmers of the region. Among them, the recently developed ginger and turmeric washer, slicer and drier are most popular among the farming communities.

In animal husbandry, the institute developed the Lumsniang pig variety, which is well adapted to the hill ecosystem and preferred by consumers for its growth rate and meat quality.The breed reaches body weights of 90–100 kg in twelve months and has higher litter sizes compared to local pigs. Artificial insemination in pigs, developed and standardized by the institute, has been widely adopted and has produced about fifty thousand piglets in Nagaland alone in recent years. The institute has also developed the Tokbari chicken, a dual-purpose bird with better scavenging ability and egg production rates 133 percent higher than native birds. To address animal health issues, the institute has created affordable diagnostic kits. A simple Mastitis Detection Card has been developed to help dairy farmers identify mastitis early and reduce economic losses. For pig farmers, an indigenous ELISA kit for Classical Swine Fever (CSF) virus has been developed using a freeze-dried antigen. This is the first indigenous kit for detecting CSF antibodies in India and provides a cost-effective alternative to imports.

Looking to the future, the institute emphasizes that food grain productivity in the region must increase from the present level of about 1.9 t/ha to nearly 4 t/ha, while cropping intensity must rise from 135 percent to 240 percent. This will require improvements in every aspect of crop production, including seeds, soil fertility management, irrigation, pest and disease management and mechanization. In the meat sector, piggery and poultry will continue to be priority areas. Efforts will focus on improving local breeds, developing suitable crossbreeds and reducing the high cost of feed by utilizing locally available materials. In animal health, the institute aims to develop next-generation vaccines, including edible and DIVA vaccines, as well as companion diagnostic tests for major livestock diseases.

SUMMARY

Through these diverse initiatives in the last 50 years of its journey, the institute has transformed agriculture and allied sectors of the region significantly and continues to play a vital role in supporting sustainable agricultural growth, improving rural livelihoods and ensuring nutritional security in one of the unique and resource-rich regions of India.

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Protected cultivation of high value vegetable crops for sustainable production in north eastern hill region

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Due to increasing population, urbanization and rapid industrialization, achieving food security has become a major challenge in our country. It is estimated that by the year 2050 about 342 million tonnes of vegetables will be required to meet the consumers demand. Keeping in view the scenario, protected cultivation of vegetable crops especially the high value ones would be promising technology for improved productivity and cropping intensity. This technology may be promising for north eastern hill region due to unpredictable weather and prevalence of more congenial natural environment requiring minimal or no cooling as compared to other northern plains of India. Protected cultivation is carried out under protected structures like net house, shade house, polytunnel, polyhouse, etc. which are given different names depending on the cladding and other materials used during construction.

Keywords: Cropping intensity, Industrialization, Protected structures

THE basic concept of protected cultivation implies to the growing of high value crops under protected structure providing ideal microclimate for obtaining maximum growth with minimal or least stress. Thus, this technology provide substantial opportunity to obtain maximum benefit of growing the low volume and potential vegetable crops irrespective of environmental factor and to get off-season vegetables. Scattered and small land holdings, difficult terrain, fluctuating and unpredictable weather, prevalence of extended monsoon during rainy season especially in Meghalaya affecting the produce in terms of both quality and yield, thereby, reducing profit margin of northeast hill regions'farmers in cultivation under open environment. Protected cultivation technologies are commercially adopted in some of states of India like Maharashtra, Andhra Pradesh, Chhattisgarh, Madhya Pradesh, etc. The area under protected cultivation is likely to increase in hilly regions due to unpredictable weather and prevalence of more favourable natural environment which requires lesser or no cooling as compared to adjoining northern and southern plains. Commonly used protected structure for cultivation of vegetables are fully automated climate controlled or high tech greenhouses, partial climate controlled or modified naturally ventilated greenhouses, walk in tunnels, insect proof net houses and plastic low tunnels. There is a vast potential for increasing the area under low cost polyhouses manifold in north eastern hill regions for production of high value vegetables during off-season to harness the benefit of the premium price of the produce and also early and delay harvest period.

Protected cultivation has a tremendous scope in north eastern hill regions, considering the increase in consumer preference for off-season and high quality produce of vegetable crops. This technology promise higher production not only in commercially grown high value vegetable crops but also in some vegetables such king chilli, bird eye chilli, dale chilli as which are endemic to north eastern region even under adverse agro-climatic conditions.

Selection of crop, varieties and crop calendar

For cultivation under protected structure, high value low volume crops such as capsicum, tomato, parthenocarpic cucumber, cherry tomato, etc. are the most suited and hence, widely cultivated to secure maximum yield per unit area. Some of the private sectors hybrids promising for protected cultivation are tomato: Naveen 2000 Plus, Avtar; capsicum: Indra, Bharat, Mahabharat, california Wonder, Orobelle, Tanvi Plus; parthenocarpic cucumber: Kian, Nun-9729 and

Nun 3019. Besides these private sector hybrids, recently many hybrids/varieties are developed and released by research organizations under public sector, such as Pusa Seedless Cucumber-6, Him Palam Khira-1 in cucumber; Arka Basant and Arka Gaurav in capsicum; and Pusa Rakshit, Arka Meghali, Arka Saurav in tomato. These cultivars are reported to be promising for protected cultivation.

For the north eastern hill region where the farmers are mostly marginal with poor income, low cost naturally ventilated polyhouses or partially controlled polyhouses would be the most feasible structure. Under such protected structure, the climatic conditions of the cultivation area are the most important determinant for the crop cycle or harvest duration. The time of sowing and transplanting could be made flexible. Citing tomato as example, its transplanting under north eastern hill region could be done from mid-August to first week of September and achieve harvesting till March to April. Similar harvest duration could also be achieved in off season. Capsicum being more climate sensitive, its transplanting should be done earlier by mid of July till early August so that the plant attain proper vegetative stage before the prevalence of low winter temperature. Likewise, king chilli, one of the potential chilli species endemic to the region is mostly cultivated during spring summer in open conditions but under naturally ventilated polyhouse, its year round cultivation is possible. With 40% shade net intensity on the roof during peak summer, reduce

Table 1. Production technology of high value vegetable crops under protected conditions

Vegetable	Variety	Planting time	Seed rate	Spacing	Inter-culture operation	Fertigation	Plant Protection	Crop duration (months)	Yield
Tomato	Big fruited tomatoes: Naveen 2000 Plus, Avtar 7711, Arka Vardan, Arka Vishal, BSS 366 Cherry tomatoes: Cherry 1, Cherry 2, BR-124 and H A-118	Jan and Feb May and June	150–200 g/ha	70 × 30 cm	Training, Pruning, Mulching,Topping, Cluster thinning of fruits to attain proper sizes	Fertigation @5–8 L/m^3 (5: 3: 6 ratio of N: P: K) according to growth and season of the crop.	Whitefly, Thrips, Aphids: Yellow and blue traps; metasystox spray @1.5 ml/L water 10 days after transplanting Mite: Spray dicofol @2.0 ml/L	8–9	Big fruited tomato: 250–300 t/ha Cherry tomatoes: 100–150 t/ha
Capsicum	Red: Bharat, Mahabharat, Indira, Tanvi Plus, Mekong Yellow: Orobelle, Tanvi and US 26 Green: Mekong and California Wonder (OP)	Jan-Feb and July-Aug for two crops in a year; March for raising single crop	50 g/1008 m^2	45–60 × 30 cm	Topping after 1 month; Training for keeping 2 leader or 4 leader system; Thinning of fruits to attain proper sizes	Fertigation with Polyfeed (19:19:19) or application of any water soluble fertilizer @2.22 g/m^2 by dissolving 7g/10 litres of water, two times from 3rd week post-transplanting and terminating 15 days before harcesting.	Use of sticky yellow traps or yellow water traps and regulation of humidity through fogging to minimize the incidence of insect vectors; Integrated management for powdery mildew and collar rot diseases	9–12	8–10 kg/m^2
Cucumber	Parthenocarpic: Kian, Akameer, Nun-9729 (Summer), Saintis (Winter) Others: Japanesh Long Green,Poinsett, Malin, Pusa Sanyog	Feb, June, Oct	60 g seed/1000m^2	70–150 × 30–60 cm	Training, Trellising avoid fruits upto 1.5 to 2.0 feet above the ground removing dry leaves	A basal application of 50–100 kg NPK/ha with The polyhouse soils should be analyzed for the nutritional status for ensuring judicious and economic use of liquid fertilizers, water soluble fertilizers like Samadhan or polyfeed (19:19:19) with the irrigation water	Use of sticky yellow traps or yellow water traps and regulation of humidity through fogging to minimize the incidence of insect; Integrated management for powdery mildew and downey mildew	3–3.5	4–5 kg /m^2
Lettuce	Butter head: Boston, Butter crunch, Dark Green Boston, Red Butter head Crisp head: Garishma, Dublin and Salinas Loose Leaf: Oak leaf, Revolution, Dark Ruby Red	Nov-March	375–500 g/ha	45×30 cm	Weeding, earthing up and mulching	Fertigation @2 g/L of water twice a week.	Use of sticky yellow traps or yellow water traps and regulation of humidity through fogging to minimize the incidence of insect; Integrated management for powdery mildew and downey mildew	3–3.5	30–40 kg/m^2

blossom and fruit drop,a major issue in this chilli species, is also observed. The cultivation of other crops such as parthenocarpic cucumber, gherkins, zuchini, and cherry tomatoes under protected cultivation needs to introduce amongst the farmers of north eastern region for crop diversification.

Design and dimension of protected structure

Efficient designing and construction of location specific polyhouses is the pre-requisite for success of protected cultivation technology by making use of appropriate and need based cladding material that combines the desirable characteristics of various materials. An ideal polyhouse may be standardized as per agro-ecological situation for harnessing the real potential of greenhouse technology. There are three types of polyhouses, viz. low cost polyhouse, medium cost polyhouse and high tech polyhouse.

High tech or fully automated or high cost greenhouse: In this type of polyhouse, there is higher automation for getting maximum climate control so as to extend the cropping season. This protected structure is provided with heaters and fan-pad cooling system to maintain ideal temperature in winter and summer, respectively. An operator, comparator and sensor form the basic part for running the structure. Cultivation of bell pepper and tomato with extended harvest duration is possible under this type of structure. It is constructed with plastic in normal places but glass houses or rigid plastic are used for construction under colder climate.

Medium cost greenhouses: This type of protected structure is similar with fully automated greenhouse but here the temperature and humidity control is achieved by exhaust fans with evaporative cooling pads. In northern India mostly the mid and low hills this type of protected structure offer promises for cultivation of many vegetable crops. The main advantage of this type of polyhouse is its cost effectiveness as compare to the fully automated one.

Naturally ventilated low cost polyhouse: The main advantage of this type of protected structure is the involvement of low initial investment. This type of polyhouse structure is constructed with GI pipe or steel pipe, logs or bamboo or any material which are available locally. There is no provision of heating or cooling pads in this polyhouse structure. A UV stabilized plastic is used to cover the roof and insect proof nets with proper mesh or thickness form the sidewall. This type of polyhouse require about half of the initial cost for construction of semi-automated polyhouse. Modified naturally ventilated polyhouses offer great scope not only for cultivation of high value vegetables crops but also raising of disease free pro-tray seedlings. Since climate in north eastern hill region is mild, low cost polyhouse can be successfully used for production of both off season vegetables and round the year production providing opportunity for the farmers to earn premium prices. Farmers of this region use polyhouse with bamboo frame to meet both the demand of local market and also for domestic consumption.

Plastic low tunnels: Plastic low tunnels or row covers are simple and cost effective structures that provide protection from climatic variation. This type of portable structure is often used for vegetable crops during off season in open field. This type of structure can be installed over one or many rows of vegetable crops to provide ideal microclimate during cool and rainy season. The plastic covering not only provide protection from abiotic factors such as rain, hail and storm but also raises the soil temperature for optimum plant growth. Provided with the location specific modification, this type of protected structure are promising for vegetable cultivation in hilly regions and cold deserts.

System of production based on growing media under protected cultivation

Soil cultivation: This is the traditional method of cultivation where plants are cultivated in soil. This is the most widely adopted system in the current time in north eastern hill region though there are disadvantages of soil borne pest and pathogens.

Cultivation in growing media/substrate (Hydoponics/Aeroponics): Soilless cultivation where vegetables are cultivated in growing media under protected conditions is gaining popularity amongst the farmers and agri-enterprenuers in the country. For such type of cultivation, growing media such as cocopeat, rock wool, vermicompost, perlite, vermiculite, etc. are utilized, thus keeping the crop free from soil borne infections. This type of cultivation system is still very new to the farmers of north eastern hill region and needs popularization by creating awareness and skill development by expertise. In this regards, ICAR Research Complex for NEH Region, Umiam, Meghalaya hasimparted awareness amongst the hill farmers and human resource development through demonstrations and training programme in its demonstration units of hydroponics. Other research institute in the region such as Central Potato Research Institute, Upper Shillong Centre, Meghalaya is working on soilless cultivation of potato through aeroponics. However, limited resources such as power supply, heavy initial investment, growing media, quality seedlings, mechanization, etc. are some of the lacuna in wide scale adoption of such type of cultivation system in the region.

Healthy nursery production under protected condition

Most of the farmers of the region prepare seedlings in soil under open field conditions where biotic and abiotic stresses are major constraints in raising healthy and time bound seedlings. Among the biotic stresses, soil borne fungi, nematodes and different viruses are the major limiting factors in growing healthy seedlings of vegetables like tomato, chilli, sweet pepper, etc. Among abiotic factors, unfavourable microclimate, especially temperature restricts raising off-season nursery under open field conditions. Most of the farmers cultivate vegetables in the normal growing season by raising seedlings in open fields. At the time of harvest, the

Production of King-chillies under naturally ventilated polyhouse

Soil less cultivation of lettuce under hydroponic system

market become oversupplied with these vegetables resulting in poor returns or losses. However, the same vegetable can fetch higher or premium prices when produced in off season through soil or growing media. Raising nursery inside protected conditions not only offer promise for production of healthy, disease free and off-season vegetable nursery but also provide scope for vertical space utilization.

Protected cultivation and vegetables' grafting

Grafting of vegetable crops is becoming popular in recent times to combat biotic and abiotic stresses in addition to modifying growth and yield characteristics. As the grafted plants are more sensitive to biotic and abiotic stress in particulars, it requires proper protection in the initial phase. So, protected cultivation offers promise in providing optimum growing environment for grafted vegetable plants. In north eastern region, grafting of fruit crops is practise by farmers but grafting of vegetables is a new technology and need to be introduced. Some of the research institute such as ICAR-IIHR, Bengaluru, ICAR-CAZRI, Jodhpur, ICAR-IIVR, Varanasi, CSKHPKV, Palampur, etc. are working in grafting of solanaceous and cucurbitaceous vegetables.

Benefits of protected cultivation technology

Some of the benefits obtained through protected cultivation technology are summarised below:

- Environment control allows raising vegetables throughout the year independent of climatic factor which otherwise is not possible under the open field conditions.
- Protected cultivation provide optimum yield per unit area/input.
- The production of chemical, insect-pest and disease free premium products.
- Production of export quality crops.
- Provide opportunity to farmers with small and the marginal land holdings to enhance their income by cultivating vegetable crops targeted for the international markets.
- Provide employment generation for the educated youth of rural areas in agriculture.

SUMMARY

Indigenous technological database need to be developed to make adoption of protected cultivation sustainable in north eastern hill region. Cost effective and location specific design of the protected structure needs to be developed. Systematic efforts are needed for development of suitable hybrid/varieties for protected cultivation; package of practices including fertigation specific to north eastern region need to be worked out. Protected cultivation has huge initial investment and labour intensive. Therefore, locally available suitable design of tools, devices and equipments are required to reduce the cost of cultivation.

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Integrated organic farming system

for livelihood and nutritional security

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A key limitation in organic farming is the insufficient availability of bulk organic inputs. This challenge can be addressed through effective recycling of both on-farm and nearby resources, along with integration of different farm components. To overcome this, an Integrated Organic Farming System (IOFS) model was designed, incorporating cereals, pulses, oilseeds, vegetables, fruits, fodder crops, dairy, fish pond, duckery, and a vermicomposting unit. The model aims to fulfill the diverse needs of farm households while conserving resources and protecting the environment. Vertical intensification was achieved by growing climbing vegetables on bamboo structures built above water bodies. Solid wastes from cattle sheds were processed into farmyard manure (FYM) and vermicompost, while wash water from dairy and duck units was channeled into fish ponds to stimulate plankton growth. Rainwater harvesting further supported critical irrigation during winter. On a 0.43 ha farm (near 1.0 acre), the IOFS model yielded a net return of ₹88,820 annually (equivalent to ₹2,06,558/ha/year), substantially higher than conventional farmer practices such as rice-fallow or rice-vegetable rotations. Nutrient recycling within the system was highly efficient, meeting about 95.4% of nitrogen, 83% of phosphorus, 98.2% of potassium, and most micronutrient demands internally. Demonstrations of this model on farmers' fields gained popularity, showing marked improvements in crop and livestock productivity under organic management compared to traditional approaches.

Keywords: Hill ecosystem, Integrated organic farming system (IOFS), Nutrient balance, System productivity

AGRICULTURE in northeast India, particularly in Meghalaya, is largely traditional, characterized by minimal use of chemical fertilizers and pesticides, reliance on local crop varieties, subsistence-oriented practices, and generally low productivity. The state's geography is predominantly hilly and mountainous, with over 70% of the area under sloping terrain, while less than one-third comprises valley lands 2019. To address these challenges, an Integrated Organic Farming System (IOFS) model was initiated in 2005 on 0.43 ha of valley land at the ICAR Research Complex for NEH Region, Umiam, Meghalaya (21.5°N–29.5°N latitude, 85.5°E–97.3°E longitude, 950 m above sea level). The IOFS concept builds upon the foundations of both organic farming and integrated farming systems. It represents a sustainable and holistic strategy that merges crop cultivation, livestock rearing, and agroforestry to establish a mutually supportive and ecologically balanced system. Central to this model is the efficient use of local resources, reduction of external inputs, and enhancement of biodiversity. Organic farming principles are applied through practices such as the use of organic manures, bio-pesticides, and crop rotations, all aimed at sustaining soil health and fertility. By adopting a circular approach to agriculture, waste generated in one component is recycled as input in another, thereby strengthening resilience, minimizing dependence on synthetic inputs, and reducing the adverse impacts often associated with conventional farming.

Development of IOFS model in institute farm

Proper farm design is essential for optimizing resource use within a production system. The IOFS model was established on 0.43 ha (1 acre), scientifically integrating field and horticultural crops with livestock units, fodder blocks, a central water body, leguminous

IOFS model developed at ICAR Research Complex, Umiam, Meghalaya

hedgerows, farmyard manure (FYM) pits, and vermicomposting structures. A 500 m^2 pond with an average depth of 2 m was included, serving as both an irrigation source and a site for aquaculture. Composite fish culture was followed, combining surface, column, and bottom feeders in a 40:30:30 ratio. A dairy component with one crossbred cow and a calf provided milk as well as manure for crops and the fish pond. The cowshed was strategically placed on the pond embankment so that wastewater drained directly into the pond, promoting growth of plankton that functioned as natural fish feed. To supply organic fodder, perennial grasses such as broom grass, Congo signal, hybrid napier, and guinea grass were cultivated. Solid cattle waste was processed into FYM and vermicompost.

The cropping system incorporated cereals (rice, maize), pulses (lentil, pea), oilseeds (soybean, rapeseed), vegetables (tomato, French bean, carrot, okra, brinjal, cabbage, potato, broccoli, cauliflower, chilli, coriander), spices (ginger, turmeric, chilli), and fruits (papaya, guava, banana, peach, pineapple, Assam lemon). A nutritional kitchen garden was also developed, using crop rotation, diversification, and intercropping with legumes to ensure continuous vegetable supply. In low-lying zones, raised and sunken beds were created—vegetables like tomato, carrot, and French bean were grown on raised beds, while rice-pea/lentil was cultivated in sunken beds. Crop residues were returned to the soil as mulch or compost. Hedgerows of *Tephrosia candida* were planted along bunds to supply nitrogen-rich biomass, which was used as mulch or green manure. Climbing vegetables such as pumpkin, bottle gourd, cucumber, chow-chow, and ridge gourd were trained on bamboo structures (machans) built above pond dykes and FYM pits to intensify production vertically. Nutrient supply was managed entirely through organics like FYM, vermicompost, and rock phosphate while pest and disease management relied on biological and cultural measures.

The system achieved high internal nutrient recycling, meeting about 95.4% of nitrogen, 83% of phosphorus, 98.2% of the total potassium and most of the micronutrient needs from within the farm. The 0.43 ha model generated an annual net return of ₹ 88,820 (equivalent to ₹ 2,06,558/ha), substantially higher than farmers' prevailing practices in the region.

IOFS models developed at farmers' fields of Meghalaya

The dissemination of IOFS technology was carried out through a cluster-based approach with the objective of enhancing the livelihoods of tribal farming communities. Priority was given to areas where farmers either avoided or used very limited amounts of synthetic fertilizers and pesticides. The central premise was that integrating IOFS with scientific organic practices would not only sustain yields but also enhance productivity. The programme was first implemented in three villages of Ri-Bhoi district, Meghalaya—Mynsain, Pynthor, and Umden Umbathiang, covering about 340 households, of which more than 95% belonged to tribal communities. Building on the initial success, organic farming initiatives were later expanded to other districts of Meghalaya through projects such as the Network Project on Organic Farming, the Tribal Sub-Plan, and the National Mission on Sustainable Agriculture for Hill Regions. A large-scale effort was subsequently launched in partnership with the Government of Meghalaya and the School of Livelihood and Rural Development (SLRD) to bring nearly 200,000 ha under organic certification. To formalize collaboration, aMoU was signed with SLRD, Shillong, focusing on organic farming promotion and certification processes.Water management interventions were a major component of the programme. Numerous farm ponds were either established or renovated, and low-cost rainwater harvesting structures known as Jalkunds were introduced. These structures, constructed using 250 GSM silpaulin sheets, enabled collection of monsoon rainwater for supplemental irrigation of high-value crops during dry spells. The use of Jalkunds significantly enhanced crop productivity, facilitated diversification into more profitable crops and livestock systems, and contributed to food and livelihood security throughout the year. To reduce drudgery and improve efficiency, small-scale mechanization was promoted, and farmers were trained in organic farming techniques, including recycling of crop residues. Additional enterprises such as mushroom cultivation and apiculture (beekeeping) were introduced to diversify income sources. These activities not only supported nutritional security but also generated supplementary income, ensuring better utilization of available on-farm resources.

Flow chart/ steps of technology

Site selection: Identify suitable land close to the homestead for establishing an Integrated Organic Farming System (IOFS)

↓

Water management: Construct rainwater harvesting structures such as jalkunds or small farm ponds to ensure water availability

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Animal husbandry: Establish units for dairy, piggery, or poultry to provide income, nutrition, and organic manure

↓

Nutrient recycling: Build compost pits and vermicomposting units to recycle animal dung, kitchen waste, crop residues, and weeds into organic manure

↓

Kitchen garden: Develop a nutritional garden with year-round vegetables of high demand

↓

Field crops: Grow maize followed by French bean to maintain crop diversity and soil fertility

↓

Fruit cultivation: Plant fruit crops like pineapple, Assam lemon, papaya, banana, and guava along field boundaries and corners

↓

Vertical intensification: Construct bamboo machans over jalkunds and cultivate climbing vegetables such as pumpkin and bottle gourd

↓

Fodder and multipurpose trees: Promote the cultivation of fodder grasses and multipurpose tree species for livestock and ecological benefits

↓

Market linkage: Develop strategies for marketing surplus farm produce to strengthen farm income and promote entrepreneurship

Impact

The economic benefits of IOFS were evaluated over a five-year period in Meghalaya to assess their impact on farmers' livelihoods. It was observed that IOFS substantially enhanced productivity and farm income by integrating multiple enterprises such as crop cultivation, livestock, fisheries, and on-farm nutrient recycling through composting and vermicomposting. Crop and vegetable yields showed notable improvements compared to traditional practices (use of local varieties, low inputs, and limited recycling). Productivity gains were recorded at 20–30% in maize, 40–45% in French bean, 33–40% in ginger, 45–50% in tomato, 37–50% in carrot, and 27–30% in chilli. Livestock contributed 41–49% to the total farm income, while fishery added 3.5–9.5%. Farmers also recycled large volumes of biomass, producing 0.4–1.25 tonnes of quality vermicompost, annually.

Case studies further highlighted the model's profitability. For example, Mr. Jrill Makroh and Mrs. Skola Kurbah achieved net annual returns of ₹ 46,695 from 0.27 ha (equivalent to ₹ 1,73,702/ha) and ₹ 31,100 from 0.21 ha (₹1,48,946/ha), respectively. These figures were considerably higher than the prevailing farmer practices of maize-fallow or maize followed by vegetables in partial areas during the winter season. Nutrient self-sufficiency within the IOFS was also remarkable, meeting 76–95.1% of nitrogen, 68.6–82% of phosphorus, and 85.5–96% of potassium requirements through internal recycling. Additionally, about 70% of seed needs were fulfilled from farm-saved seed. With organic certification, both income levels and livelihood security are expected to improve further. The successful demonstration of IOFS in Meghalaya has gained international recognition, with the initiative featured in the Compendium of Country Case Studies presented at the United Nations Climate Change Conference of the Parties (COP26) in Glasgow, United Kingdom, in November 2021.

IOFS models developed in different villages of Meghalaya

SUMMARY

Integrated Organic Farming System (IOFS) represents a sustainable and eco-friendly farming model that promotes entrepreneurship, particularly for small and marginal farmers. By combining crops, livestock, water management, and composting, the system diversifies farm income sources and reduces dependence on a single enterprise. The integration of high-value crops, vegetables, spices, fruits, and livestock enables farmers to respond to market demands, minimize risks linked with monocropping, and create new opportunities for agribusiness development. Field demonstrations of IOFS have shown that, under organic management, both crop and livestock productivity improved considerably compared to traditional practices. The models also generate a substantial proportion of nutrients internally, ensuring long-term sustainability while enhancing farm income and strengthening rural livelihoods.

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Livelihood improvement of rural farmers

through pond based integrated farming system model in Meghalaya

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The pond based integrated farming system model is an effective strategy for sustainable agriculture, promoting the integration of various farming activities. In northeast India, where smallholder farmers are prevalent, this model offers numerous benefits and has shown to increase system productivity by 7.5 times and profitability by 8.5 times compared to traditional farming practices. In addition, the model generates significant returns, with a total benefit-cost ratio of 2.70. Furthermore, this system contributes to environmental sustainability by improving soil fertility through agroforestry and enhancing water use efficiency with rainwater harvesting in farm ponds. The integration of livestock also helps recycle organic matter, reducing the need for external chemical inputs. Despite its benefits, the adoption of pond-based IFS faces challenges such as limited technical knowledge (80% of farmers), high input costs (70%), and marketing constraints like low product prices and transportation costs. However, the potential benefits of pond based IFS, particularly in terms of increased profitability, climate resilience, and resource efficiency, highlighting its importance for sustainable agricultural development in the region. Strengthening support systems, improving infrastructure, and enhancing farmers' knowledge will be the key to unlocking the full potential of this model in northeast India.

Keywords: Benefit-cost ratio, Constraints, Integrated farming system, Pond based IFS

THE Integrated Farming System (IFS) model is an innovative approach to sustainable agriculture that emphasizes the integration of multiple agricultural enterprises, including crop cultivation, livestock farming, fishery, agroforestry, and other farm-based activities, in a synergistic manner. This holistic approach is designed to maximize resource use efficiency, enhance productivity, improve farmers' income, and promote environmental sustainability. The IFS model helps mitigate risks by diversifying farm income sources and reducing the dependency on a single crop or activity. In the context of northeast India, the IFS model is particularly relevant due to the region's diverse agro-climatic conditions, varied farming practices, and socio-economic challenges faced by it's predominantly smallholder farmers which are backbone of the traditional agriculture. This region, consisting of states like Assam, Nagaland, Meghalaya, and Manipur, has a unique mix of agricultural practices that can greatly benefit from the diversification and resource optimization promoted by IFS model. In this region, farmers are generally practicing organic farming, therefore a farmer prefers to keep few livestock and fishery so that soil nutrient could be increased through animal excreta. Most of the people residing in this region are tribal and they are non-vegetarian in their dietary habits for which meat and fish products are very much in demand. As this region is a complex, diverse and risk prone region, farmers are essentially practicing both raising of crops and rearing of livestock and fishery. This region accounts for eight percent of the country's total land area and 3.8 percent of its total population. Approximately 30 percent of landless households and 48 percent of marginal households in the region engage in livestock farming. Various research indicated that agriculture, horticulture, animal husbandry and fishery production system individually at subsistence level but incorporation of all this system proves that these systems are not competitive rather complementary to each other and farm profitability can be increased through practicing this. Farm diversification through IFS has been recognized as a powerful strategy for achieving a range of objectives, including food and nutritional security, poverty reduction, employment creation, environmental enhancement, and the sustainable use of natural resources. The core principles of the IFS model include:

- ***Diversity in production:*** The integration of crops, livestock, aquaculture, agroforestry, and other activities within a farm system.
- ***Resource recycling:*** Efficient use of farm waste and by-products such as crop residues, animal manure, and agro-industrial waste to reduce external input costs.
- ***Sustainability:*** Reducing soil degradation, promoting biodiversity, and ensuring long-term ecological balance.
- ***Economic viability:*** Enhancing farm income through diversified and integrated activities, reducing dependency on monoculture farming.
- ***Risk management:*** Spreading risks associated with climate change, market fluctuations, and pests/ diseases through diversified farm activities.

In northeast India, IFS model can significantly contribute to the region's agricultural development by promoting sustainable practices while addressing the challenges of food security, climate change, and economic inequality.

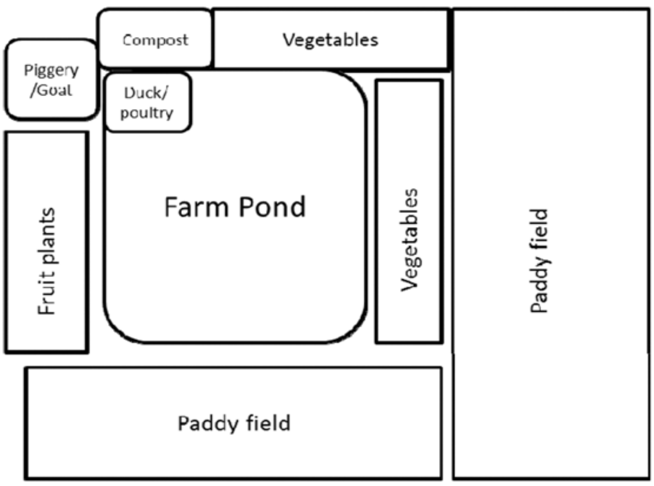
Importance of IFS in northeast India

The agricultural system in northeast India is diverse, with a significant number of smallholder farmers practicing traditional farming methods. These farmers primarily rely on shifting cultivation (also known as Jhum cultivation), a practice that has been linked to deforestation and soil erosion. This region has a significant portion of its land under forests, with over 54% of its geographical area designated as notified forests (reserve, protected, and unclassified) managed by the Forest Department. However, states like Assam (34.21%) and Meghalaya (42.34%) have less forest cover, while Sikkim has the highest forest land under governmental control. Agricultural land in this region spans 4.12 million hectares of net cultivated area and 5.7 million hectares of gross cultivated area, with Assam leading in cultivated area. Cropping intensity is highest in Tripura (184%) and lowest in Mizoram (106%), and the share of land under food grain production is highest in Manipur (78.7%), suggesting scope for diversification in cropping systems. The NER consists of various agro-climatic zones, from subtropical to alpine, with each state having distinct agricultural practices. Rice is the dominant crop in the region, with varying practices such as double cropping in Assam and Tripura, and terrace farming in Sikkim. States like Sikkim focus on crops such as maize and cardamom, while Tripura grows pineapple and arecanut, alongside rice. Given the region's hilly terrain, erratic rainfall, and limited access to modern farming inputs, IFS model presents an opportunity to improve farm productivity while also preserving the environment which includes:

- ***Soil conservation and fertility improvement:*** The combination of crop cultivation with agroforestry and livestock farming helps maintain soil health. For example, agroforestry systems involving tree species that fix nitrogen can improve soil fertility, which is particularly beneficial in the nutrient-poor soils of the region.
- ***Economic stability:*** The integration of different farming components such as dairy, poultry, fish farming, and vegetable cultivation ensures a steady income flow, reducing the dependency on a single crop and protecting farmers from market and climatic uncertainties.
- ***Climate resilience:*** Northeast India is vulnerable to the impacts of climate change, including erratic rainfall, floods, and droughts. The IFS model promotes climate-smart agriculture by diversifying farm activities and providing farmers with multiple coping strategies in the face of unpredictable weather conditions.
- ***Labour efficiency:*** IFS helps in the efficient use of labour by balancing seasonal workloads. While crop production can be labour-intensive during planting and harvesting periods, activities like livestock management, agroforestry, and fish farming provide alternative sources of work during the off-season.

Pond based integrated farming system

There are various models of IFS practiced in the north eastern region, viz. pond based IFS, pig based IFS, fish-cum-livestock IFS, horticulture cum fish culture IFS, agriculture-livestock-poultry IFS and agriculture-horticulture-piggery-fishery IFS. Pond based IFS is one of the most traditionally practiced model and served as a primary livelihood source for farmers in the region. Pond based IFS involves the integration of various agricultural components such as agriculture, horticulture (vegetables, fruits, and plantation crops), and animal husbandry (including poultry, piggery, goat farming, and duck farming), with aquaculture as the central activity. This system integrates fish farming in dugout ponds, which can be located in either the corner or the center of the farm, depending on the land's topography, alongside other farming practices like livestock, crops, vegetables, and fruits, with provisions for recycling on-farm resources.



Layout of pond based IFS
Source: Das *et al.* 2021

The NER experiences high rainfall (over 2000 mm annually), ensuring an ample supply of water. However, most of this precipitation occurs between June and October, leaving the region very dry from November to April. As a result, farmers have practiced rainwater harvesting in farm ponds for centuries, using the stored water for fish farming and to provide lifesaving irrigation during the dry season. The availability of harvested water helps mitigate the risks of crop failure during drought years, and farm diversification ensures steady income even if one or more components underperform. Consequently, pond based IFS offer resilience against climate variability and is recognized as a viable technology for promoting climate-resilient agriculture. According to the earlier researchers, this model is found to increase system production efficiency by 7.5 times and profitability by 8.5 times compared to traditional practices in the humid eastern Himalayas.

Fish farming component contributes the highest returns in the system, with B:C ratio of 4.37 followed by the egg and fruit component (B:C ratio of 3.40 and 3.05, respectively). Rice farming has the lowest B:C ratio of 1.80, suggesting the least profitable component in the system, though it still generates a positive return. The total benefit-cost ratio of the entire pond-based farming system is 2.70, depicting for every ₹1 invested, ₹2.70 is returned in net profit. This indicated that the pond based IFS model as a whole is profitable, with the highest returns coming from fish and egg.

Table 1. Economics (₹/unit) of pond based IFS

Components	GR	NR	B:C
Fish	17500	13000	4.37
Egg	2550	1800	3.40
Piglets	28000	15400	2.22
Vegetables	4100	2700	2.92
Fruits	5500	3700	3.05
Rice	1800	800	1.80
Total	59450	37400	2.70

GR, Gross Return; NR, Net Return; B:C, Benefit-Cost Ratio.

Constraints faced by farmers in pond based IFS

While the pond based IFS model holds great promise for sustainable agriculture in northeast India, its adoption faces several challenges due to lack of awareness, limited access to resources, inadequate infrastructure, cultural barriers, climate change, etc. The constraints are categorized into three main areas: Production constraints, Marketing constraints, and Financial constraints.

The Production constraints are challenges related to the actual farming process and resource availability. A significant portion of farmers (86.66%) face delays or lack of timely access to necessary farming inputs, which hampers production. Similarly, many farmers accounting to 86.66% struggle with the rising costs of labour, which can affect profitability and productivity. Another major constraint is lack of technical knowledge regarding pond based IFS (80%) among the farmers, limiting their ability to optimize the system followed by the high cost of inputs (70.00%) and insufficient power supply (63.33%).

Marketing constraints refer to challenges related to the sale and pricing of farm products. Low remunerative price for the product is being faced by the high percentage of farmers (86.66%) followed by the price fluctuations (86.33%). High transportation costs are another significant issue being faced by the 80% of the farmers. 73.33% of farmers report a lack of demand for their products, meaning they struggle to find buyers or sell their produce at profitable prices. The lack of proper storage facilities for perishable items result in higher risks of spoilage and waste, further affecting the income of the farmers.

Financial challenges such as lengthy procedure of loan sanctions hinders the ability of the farmers to finance their operations. Significant proportion of farmers (73.33%) faces difficulties in accessing subsidies or credit. On the other hand, for those who manage to access credit, high interest rates are a major issue increasing the overall financial burden.

Table 2. Constraints faced by the farmers in adoption of pond based IFS (N=30)

Sl. No.	Particulars	Response	
		Frequency	(%)
Production constraints			
1	Non-availability of inputs in time	26	86.66
2	High wage rates	26	86.66
3	High cost of inputs	21	70.00
4	Insufficient power supply	19	63.33
5	Lack of technical knowledge regarding IFS	24	80.00
Marketing Constraints			
1	Low remunerative price for the product	26	86.66
2	Price fluctuations	25	86.33
3	High transportation costs	24	80.00
4	Inadequate demand for outputs in market	22	73.33
5	No storage facilities for perishable farm produce	16	60.00
Financial constraints			
1	Length procedure of loan sanctions	26	86.66
2	Non availability of subsidies and credit	22	73.33
3	High interest rate	19	63.33

SUMMARY

The Integrated Farming System (IFS) model offers a viable solution for addressing the agricultural challenges faced by farmers in northeast India. By integrating various agricultural enterprises, IFS enhances resource use efficiency, promotes sustainability, and improves farm income. Pond based IFS has proven to be a viable and sustainable agricultural model for northeast India, where it effectively integrates fish farming with crop cultivation, livestock, and agroforestry. This approach not only helps improve farm productivity and resource use efficiency but also supports the livelihoods of smallholder farmers by providing diversified income sources. Given the region's unique agro-climatic conditions and the importance of fish and livestock in local diets, pond-based IFS offers significant benefits in terms of soil fertility enhancement, climate resilience, and economic stability. However, its adoption faces challenges such as limited access to technical knowledge, financial constraints, and infrastructural limitations. To fully realize its potential, there is a need for increased awareness, better access to resources, and support from government policies and programmes. With right interventions, pond based IFS can contribute to sustainable agriculture, food security, and improved livelihoods in northeast India.

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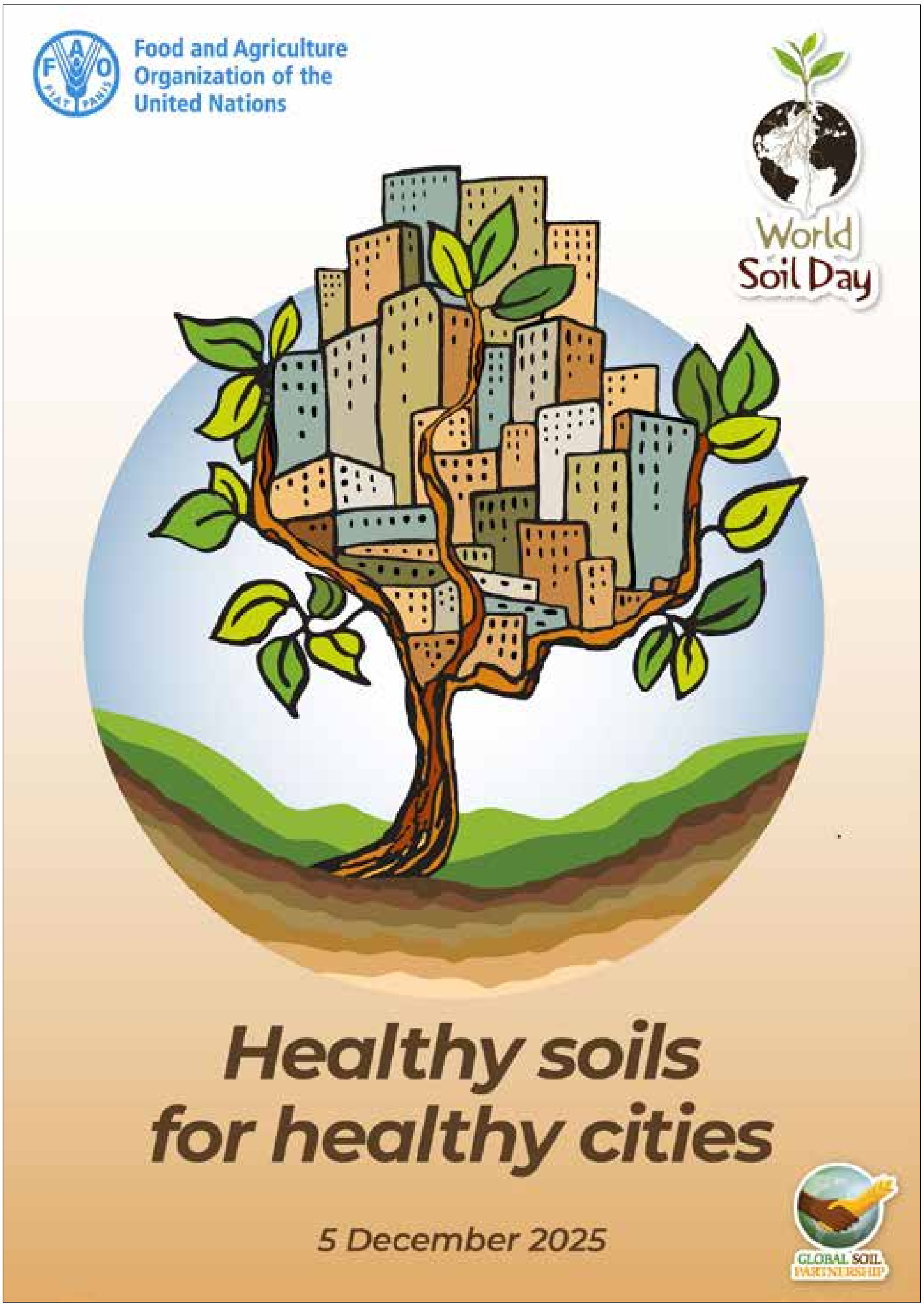

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Production techniques in natural farming

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Natural farming (NF) is an ecological farming approach which relies on environment friendly agricultural inputs and practices for improving soil health, agro-biodiversity, and self-sustaining production system. NF, an indigenous cow-based farming is based on the five components, viz. Beejamrit, Jivamrit, Acchadana, Whapasa and plant protection measures using cow dung and urine as the main ingredient in all its bio-formulations. Considering the nationwide promotional activities on NF, various comparative experimental trials were conducted in ICAR Research Complex for NEH Region, Umiam on NF with organic farming and integrated crop management practices for acidic soils of hill region. Three different case studies on NF field trials on different crops are presented here addressing its impact on soil, crop yield, and profitability in the region.

Keywords: Acid soil, Natural bio-formulations, Sustainable soil management, Traditional farming

NATURAL farming (NF) is a traditional and cow-based farming approach which encourage utilizing of natural locally available resources within the farm by cutting down the dependence on external inputs. It is a chemical free farming method rooted in Indian tradition enriched with modern understanding of ecology, resource recycling and on-farm resource optimization which protects the biodiversity and friendly with nature. It is considered as agro-ecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity. NF is considered as regenerative agriculture, by reassessing the agriculture system into sustainable management practices that has the ability to conserve soil nutrients, moisture and sequester carbon in the soil, with a prominent strategy to save the planet. The main purpose of this farming method is to practice the pre-green revolution system with a cost of production to almost zero.

The principal ingredient of NF is "indigenous cow dung and cow urine" and all the formulations are prepared by mixing dung and urine in different concentrations. NF is based on five pillars,viz.

- *Beejamrit* is usually formulated by combining fresh cow dung (200 g), cow urine (200 ml), lime (2 g), water (800 ml), and soil (8 g). It is mainly used for seed treatment at the rate of 25 L/kg of seed. Seeds of any crop are soaked in the *beejamrit* solution for about one hour, dried in shade, and then used for sowing. In the case of transplanted crops, seedlings should be dipped in the solution for 1–2 h before transplanting in the main field. Thus, seed treatment and root dipping with *beejamrit* offer multiple benefits, such as enhanced seed germination, better crop establishment, increased populations of beneficial rhizospheric micro-organisms, and suppression of soil- and seed-borne pathogens, thereby promoting healthy plant growth.
- *Jivamrit* is prepared by fermenting a mixture of

Components of natural farming

water (200 L), fresh cow dung (10 kg), cow urine (5–10 L), jaggery (2 kg), pulse flour (2 kg), and a handful of soil for 48 hours. The solution can be stored for up to 15 days without any loss of efficacy. In field crops, *jivamrit* is basically applied in soil with irrigation water and foliar feeding @200 L/acre at fortnightly intervals, but in fruit trees, the solution is applied directly to individual plants. The major functions of *Jivamrit* are providing essential plant nutrients, improving earthworm and microbial activities for nutrient cycling, and preventing different plant diseases.

- *Acchadana* (Mulching) is covering the soil surface or the area around plant roots with either live vegetation or crop residues to conserve soil moisture, maintain soil temperature, reduce runoff and prevent soil loss and suppression of weed growth.
- *Whapasa* is the combination of air and water vapour (50% each) for improving total porosity in the soil particles. It moderates the micro-climate and provides soil moisture to the plant roots, and microbes for better nutrient recycling. Further, it significantly reduces the net irrigation requirement by forming soil aeration with air and water molecules in the soil.
- **Plant protection**

Agniastra: Pour 200 L of cow urine into a container and mix in 2 kg of neem leaf paste, 500 g of tobacco powder, 500 g of green chili paste, 250 g of garlic paste, and 200 g of turmeric powder. Stir the mixture in a clockwise direction, cover it with a lid, and boil until foam appears. After boiling, remove it from the heat and place the vessel in a shaded area, away from direct sunlight, to cool and ferment for up to 48 h stirring the contents twice daily. After 48 h filter with a thin muslin cloth and store it. It can be stored for 3 months. Insecticidal and effective against the pests like leaf roller, stem borer, fruit borer, pod borer. It is used as a foliar spray at 2% concentration, applied at the rate of 200 L/acre. For spraying, 6–8 L of agniastra is diluted in 200 L of water. The dilution ratio may be adjusted depending on the intensity of pest infestation.

- 100 L of water 3 L of *agniastra*
- 15 Lof water 500 L of *agniastra*
- 10 Lof water 300 L of *agniastra*

Neemastra: Fill a drum with 200 L of water and add 10 L of cow urine, followed by 2 kg of local cow dung. Then mix in either 10 kg of finely ground neem leaf paste or 10 kg of neem seed pulp. Then stir it clockwise with a long stick and cover it with a gunny bag. Store the mixture in a shaded place, ensuring it is protected from sunlight and rain. Stir it in a clockwise direction twice daily, in the morning and evening. The solution will be ready for use after 48 h and may be stored for use up to 6 months but it should not be diluted with water. Strain the prepared solution through a muslin cloth and apply it directly to crops as a foliar spray at 3% concentration. It is effective against sucking pests such as jassids, aphids, whiteflies, small caterpillars, and mealybugs.

Preparation of natural farming bio-formulations

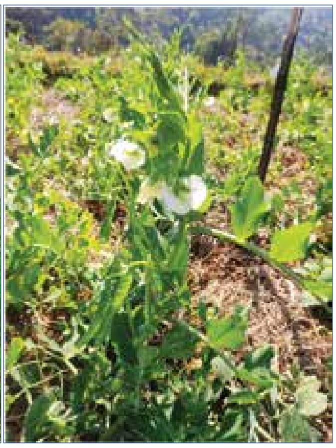
Brahmastra: Pour 20 L of cow urine into a vessel and add 2 kg each of neem leaf paste, karanj leaf paste, custard apple leaf paste, castor leaf paste, and datura leaf paste. Heat the mixture on a low flame until it begins to foam and slightly overflows once or twice. Stir in clockwise direction, then cover the vessel with a lid and keep on boiling it. Once the second foam appears, stop boiling and let the mixture cool for 48 h allowing the alkaloids from the leaves to infuse into the urine. After 48 h, strain the solution through a muslin cloth and store it in earthen pots or plastic drums kept in the shade. The preparation can be preserved for up to six months. It is used to control the sucking pests, viz. pod borer, fruit borer, etc. and caterpillar. For application, use it as a foliar spray at 3% concentration by diluting 6–8 L of *Brahmastra* in 200 L of water and spraying it on standing crops. This ratio may be changed depending upon the severity of pest attack as follows:

- 100 L of water + 3 L of *Brahmastra*
- 15 L of water + 500 ml of *Brahmastra*
- 10 L of water + 300 ml of *Brahmastra*

Practice of natural farming in acidic hill soils

Since traditional farming has been practiced by the farming communities for ages in North Eastern Hill (NEH) Region, therefore practicing zero budget natural farming (ZBNF) in this region provide wide scope for the small and marginal farmers. At present, the ICAR Research Complex for NEH region, various agricultural state departments and agricultural universities have recently initiated different projects and studies related to natural farming. Most of them have not come out with conclusive information for recommendation. Area and production survey is also not yet carried out for natural farming in northeast, India. From 2023, majority of the campaigns and capacity building programmes have been started by various organizations to sensitized the farmers on NF. Under the project "Outscaling

Finger millet + Cowpea



Field pea

Crops under natural farming

of Natural Farming through KVKs" many trainings, demonstrations and awareness programmes have been given to the farmers regarding the benefits and adoption of natural farming. Recently, Indian Council of agricultural Research (ICAR) launched a B.Sc. (Hons) Natural Farming as part of degree programme in Agricultural colleges in various parts of India. The main focus is to highlight the utilization and practices of indigenous knowledge in agreement with agro-ecological principles. ICAR has also initiated a research study on the assessment of NF on different crops.

Evaluation and validation of natural farming practices

Case study I: Considering the nationwide promotional activities on NF, a field trial was also conducted on NF at experimental field of ICAR-Research Complex for NEH Region, Umiam, Meghalaya to analyse the effect of nutrient management practices of natural farming comparing with organic farming (OF) practices in different crops. The treatments of NF and OF are: T_1- Traditional/farmers' practice (organic-FYM); T_2- Natural farming; T_3- Packages of practices (POP) organic (FYM+ Biofertilizer (specific to crop+Lime); T_4- NF+Lime; and T_5- NF+Vermiwash/Compost wash (foliar spray).

Table 1. Effect of different nutrient management practices of NF compared with OF on soil and crop yield

Treatment	Millet + Cowpea (soil data)				Field Pea (soil data)				Yield (t/ha)		
	pH	SOC (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	pH	SOC (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	Millet (t/ha)	Cowpea (t/ha)	Pea (t/ha)
Initial	4.45 -5.31	1.10 -1.39	125.4 -263.4	17.8 -26.3	4.90-5.56	1.18-1.35	213.3-263.4	29.4-36.2	-	-	-
T_1	5.07	1.35	263.4	31.4	5.52	2.08	468.0	70.1	1.88	3.69	1.52
T_2	5.56	1.21	225.8	36.2	5.30	1.36	306.0	20.0	1.58	5.43	2.22
T_3	4.97	1.18	213.3	29.4	5.25	1.64	369.0	26.5	1.44	5.41	1.61
T_4	5.00	1.32	250.9	35.8	5.21	1.50	337.5	22.7	1.64	5.98	2.67
T_5	4.90	1.35	263.4	33.8	5.23	1.44	324.0	25.0	1.97	5.84	1.83

These experiments were conducted in the existing terrace land of ICAR Research Complex for NEH Region. The soils are acidic in nature with pH range of 4.45–5.31 and SOC of 1.10–1.39% before starting of the experiment. The post-harvest soil analysis of millet *(Eleusine coracana)* and cowpea *(Vigna unguiculata)* showed that soil pH in T_2 was observed highest with higher available P comparing to the other treatments. Millet yield was highest (1.97 t/ha) in T_5 and cowpea in T_4 (5.98 t/ha) and T_5 (5.84 t/ha) treatments. During 2^{nd} year, field pea *(Pisum sativum)* crop was raised as second crop to analyse the effect of NF nutrient management comparing to organic farming practices.The results showed that pH ranged from 5.21–5.52, and SOC 1.36–2.08%. The yield was observed highest in T_4 (2.67 t/ha) followed by T_2 (2.22 t/ha) treatment.

Case study II: A field experiment on natural farming, organic and Integrated Crop Management (ICM) practices was established in 2021–22 to evaluate the impact on turmeric yield, and profitability. The experiment was laid out in a randomized block design with three replications. The treatment consists of T_1: Control, T_2: Complete natural farming, T_3: All India-organic farming package, T_4: Integrated Crop Management (50 % organic and 50% sources with *Neemastra, Dashparni* ark, *Brahmastra,* Neem seed kernel extract and T_5: Integrated Crop Management (50 % organic + 50% inorganic with need-based pesticides). The results showed that the significantly highest yield of turmeric was reported in the AI-NPOF package (21970 kg/ha), which was 5.09 to 56.7% higher than the remaining treatments. While the natural farming plot registered a turmeric yield of 11600 kg/ha but it was 20.2% higher than the control plots. Further, the minimum cost of cultivation was incurred in control plots (₹ 53468/ha) followed by natural farming (₹ 60397/ha) but maximum in AI-NPOF package

Pictorial view of experiment on natural farming at the ICAR Research Complex for NEH, Umiam, Meghalaya

(₹ 53468/ha) followed by ICM practices. Though, the cost of cultivation was higher in the AI-NPOF package, it registered a maximum net return (₹ 60397/ha), which was 55.0%, 58.8%, and 21.0% higher than natural farming, control and ICM practices, respectively.

Table 2. Impact of natural farming, organic and ICM practices on turmeric yield and economics

Treatments	Cost of cultivation (₹/ha)	Yield of Turmeric (kg/ha)	Net returns (₹/ha)
T_1: Control	53468	9500	65231
T_2: Complete Natural Farming (*Beejamrit* + *Ghanjeevamrit* + *Jeevamrit;* Crop residue mulching; Intercropping; and *Whapasa*)	60397	11600	71365
T_3: AI-NPOF package	75529	21970	158610
T_4: Integrated Crop Management (50 % organic and 50% sources with *Neemastra*, *Dashparni ark*, *Brahmastra*, Neem seed kernel extract	84094	20850	125300
T_5: Integrated Crop Management (50 % organic+50% inorganic with need-based pesticides)	73899	20180	116760

Case study III-Natural farming based-agro-pastoral (FSW-4) and agri-horti-silvi-pastoral (FSW-5) farming system models: The experiment on natural farming for sustainable system productivity in the mid-hills of acid soils was initiated on July 2023. The study aimed to assess the long-term effect of natural farming on system productivity, economic viability and soil health. Two existing micro-watershed farming system models (FSW-4 and FSW-5) that were established in 1983 were taken in the study, wherein ~70 % of the land is assigned to natural farming practices and 30% to conventional practices. Further to align with the mandate of natural farming, slight modifications in the crops and cropping system were made before the sowing of different crops. As per the guidelines of NITI Aayog, the desi cow breed 'Lakmi' (Assam) is reared for the preparations of various formulations and concoctions. Further, all other principles of natural farming, and management practices were followed as per the plan of the experiment. The results revealed that the natural farming practice produced a greater seed yield of mustard i.e. 706.0, 590.6 and 442.6 kg per unit area in lower, middle and upper, respectively which was 16.5%, 18.3% and 44.3% higher than the control plots. Further, the pod yield of peas was also higher under natural farming (4.63 t/ha) than the control (1.68 t/ha). However, the crop yield of maize, black gram, and tomato showed a lower value in natural farming practices as compared to control treatments. Additionally, the baseline soil samples were taken to assess the yearly and long-term impact of natural farming on the soil properties.

Table 3. Baseline description of the different soil properties under natural farming

Terraces	Depth	SOC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	pH
Lower	0–15 cm	1.71	282.24	27.17	241.36	5.25
	15–30 cm	1.01	172.48	12.83	169.68	5.15
Middle	0–15 cm	1.50	297.92	26.98	240.24	5.19
	15–30 cm	1.24	227.36	10.76	132.72	5.10
Upper	0–15 cm	1.21	261.33	21.01	188.91	5.15
	15–30 cm	0.98	188.16	9.81	133.65	5.03

SUMMARY

In north eastern India, indigenous farming practices like natural, organic, and bio-dynamic farming have been widely practiced for centuries. The suitable agro-climatic conditions, vast bio-diversity, and low use of synthetic chemicals make the region apposite to adopt natural farming (NF) practices. The NF practices integrate an ecological principle, resource recycling, and biodiversity conservation to create a regenerative system thereby reducing dependence on external inputs. The studies conducted at ICAR-Research Complex for NEH Region,

Agro-pastoral–based system (FW-4) | Concoctions preparation | Agri-horti-silvi-pastoral system (FSW-5)

View of natural farming based IFS models

Meghalaya showed an improved yield of millet under NF with vermi wash applications (1.97 t/ha). Further, it also had more stable soil organic carbon (SOC), and nitrogen (N) levels than the other practices. Similarly, the NF practices enhanced the rhizome yield of turmeric by 20.2%; and incurred the minimum production costs as compared to control, and other treatments, respectively. Moreover in terms of crop yield, mustard, and pea crops exhibited a positive response, while maize and tomato crops showed a negative response to NF practices. Nevertheless to harness the long-term benefits of NF practices, emphasis must be given on access to different NF bio-formulations, skill development programmes, premium prices or incentives to farmers, and infrastructure development in the NE region.

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Buckwheat cultivation potentially

enhance cropping intensity and income security of low input hill agro-ecologies under climate change

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Standardisation and intensification of diversified climate resilient farming systems having crops with increased climate stress resilience for more adaptability under fragile hill agro-ecologies of low population states of Eastern Himalaya Region (EHR) is need of the hour. Buckwheat, one of the forgotten and underutilised crop with year round cultivation prospects harbouring inherent stress adaptive mechanisms to overcome prevailing low moisture stress cum low pH soil induced low nutrient environments of hill slopes, is emerging as one of ideal crop for increasing cropping intensity and food security of hill inhabitants of EHR. Development and promotion of scientific cultivation practices with adoption of proper time of sowing between October to mid-December at mid-hills of Ribhoi district, April-May months in East Khasi hills, Garo hills and Jaintia hills of Meghalaya is paramount for achieving economic yield to the tune of 1.5–1.80 t/ha wherever the crop is suitable to cultivate anytime of the year for higher green biomass (1.26–3.84 t/ha). Enhanced low moisture stress tolerance ability and pronounced rhizosphere acidification with exudation of low molecular weight organic acids like oxalic acid by cultivated buckwheat cultivars under low phosphorus (P) conditions of acid soil has increased solubilisation of fixed forms of P vis a vis for enriching the soil with desirable root microbiome make the crop more productive under marginal hill environments of EHR. Some cultivars, viz. IC377275, IC26591, IC14890, IC37288 and Himpriya shown promising yields of 1.89 t/ha, 1.71 t/ha, 1.63 t/ha, 1.55 t/ha, 1.53 t/ha, respectively with adoption of scientific cultivation packages in hill slopes. Holistic understanding of interactive effects of acid soil and moisture deficit stress and strengthening of further crop improvement of robust crops like buckwheat could aid in enhancing food security and cropping intensity in EHR.

Keywords: Fragile hills, Low pH, Low moisture stress, Rhizospheric acidification,Yield

EASTERN Himalaya Region (EHR) of India is distinctly characterized by diverse edapho-climatic conditions, rich bio-diversity and unavoidable geographical constraints. Majority of farming in this region is considered asprimarily rainfed and current cropping intensity being low (≈ 120%) indicating huge scope for developing resilient cropping systems with higher productivity. Around 85% of total rainfall (240-250 cm per annum) is received during *kharif* months. During second season, crop lands/fallows after rice and maize cultivation remain uncultivated. For increasing cropping intensity, there is need of developing stress adaptable crops with higher yield under moderate to severe water scarcity and low pH soils that prevail in hill slopes. Low nutrient conditions also frequently occur owing to unprecedented erosion of top soil and predominance of traditional cultivation of exhaustive crops like turmeric and non-adoption of scientific package of practices are challenges for enhancing food and livelihood security in the region.

Buckwheat (*Fagopyrum esculentum* Moench), one of the lesser known gluten free short duration pseudo-cereal having multipurpose utility is found suitable for sustainable cultivation under marginal and degraded

Buckwheat crop at blooming stage with full canopy

lands of mountain ecosystem. Round and hollow knotted stem, commonly visible tinged with red and greenness bears heart shaped leaves with reticulate venation and dimorphic flowers arranged in compound raceme inflorescence. The flowers of different type of colours from white or light green to pink or red and the seeds are triangular in shape which is actually called as 'achene' having dark brown and tough rind. This form of seed is considered as a fruit rather than a grain with a exclusion from Gramineae or Poaceae even with similarity of grains. The husk of seed is ideally used as filling for pillows or mattresses, sometimes as cushioning in packaging and as prime item for heating, etc. Buckwheat is necessarily cross pollinated through bees, hoverflies, butterflies, wasps, and ants which is highly essential for improved seed production due to its self-incompatible and distylous flowers that exists in two forms: pin (long pistil, short stamens) and thrum (short pistil, long stamens). Even though pollination happens through wind, insect activity is crucial for maximizing seed yield which offers scope for quality honey production. However flowers of buckwheat act as good source of nectar for honey owing to their long flowering period.

It is a versatile pseudo-cereal with its gluten-free nutty flavour for myriad nutritional benefits and culinary purposes ideally for both sweet and savory dishes, viz. pancakes, crepes, gluten-free baked goods, as well as whole groats for porridges, salads, soba noodles and even in preparation of alcoholic drinks. Many efforts were also made to promote it for tea, sprouts, bio-greens and tender shoots are used as leafy vegetable which offers a unique sustainable and healthy alternative to traditional grains. The flowers and green leaves are also used for extraction of rutin which generally used in medicine and green leaves are used good fodder for cattle and hill goats. Because of its fast growing ability, it can escape weed competition. Sprouts of buckwheat could act as a fresh salad, vegetable and various other purposes like natural vegetable juice source. The products of buckwheat are used in regular diets of some tribes of Arunachal Pradesh as other staples like rice could not be properly cultivated due to prevailing low temperatures. In India, it is cultivated in states of high altitude regions, viz. Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, West Bengal, Meghalaya, Assam, Manipur, and Nagaland and in some stretches of southern states like Nilgiris and Palani hills of Tamil Nadu.

Nutritive value

Grains of buckwheat majorly contains quality protein (≈11–13%) that are rich in lysine and tryptophan, antioxidant like flavonoids, viz. rutin and quercetin, unique source of vitamins, nutri-elements like zinc and Fe, polyphenols and digestive fibre because of which this crop is considered as promising crop in the region especially with scientificorganic mode of cultivation. It emerged as good food for keeping heart health by lowering cholesterol, blood pressure, blood sugar (with low glycemic index) and promotes healthy digestion with improved gut health. Slowly digested starch of its groats is valuable for diabetics because it aid in flattening of glyceamic response curve with prolonged endurance and extended duration of satiety. Increased content of the rutin in their foliage have more relevance for increased fragility of capillaries which is associated with hypertension/ haemorrhage/purpura and bleeding from kidney.

Types of buckwheat

There are two species such as Common buckwheat *(F. esculentum* Moench*)* and Tartary buckwheat *(F. tataricum* Gaertn*)*. Achenes of F. *tartaricum* are grooved with acute angles while achenes of *F. esculentum* are not grooved without such sharp acute angles. Former buckwheat has bigger grains with smooth husks growing well at lower altitudes while the later has tougher husks and suitable to grow at high altitudes. Tartary buckwheat has more levels of rutin and other bioactive compounds and harbour substantial adaptability to cooler and low moisture environments than common buckwheat.

Agro-climatic suitability of buckwheat for hill slopes of NEH region

Even though buckwheat could be able to grow in different type of soil, it is more favourably suited to sandy loam, loam and silt loams of hill slopes with proper drainage. It increasingly grows better in acid soils with reduced soil moisture. As it is low temperature loving plant and preferably grow well under moderate to low moisture conditions of the soil, crop like buckwheat suits well to grow under rice and maize based fallows where the productivity of other crop like pulses is challenging. During the low moisture stress or low nutrient stress condition, buckwheat crop has a mechanism to adopt with extensive root growth and other physiological adaptations.

It is often preferred to grow as rapid crop of contingency under vagaries of climate change. In Ri-bhoi district of Meghalaya, winter months like sowing in October/ November/December is preferred because the crop could produce yield upto 9.7 q/ha and 11.0 q/ha with shorter duration even with adverse conditions like low moisture and unexpected frost damages. In addition, it is known for nonchemical weed suppression as it grows faster and also its shade the weeds or out competes weeds for increased nutrient and water uptake with denser crop stands.

Table 1. Vegetative growth and yields of local buckwheat (var. Gossigaon local) in Meghalaya

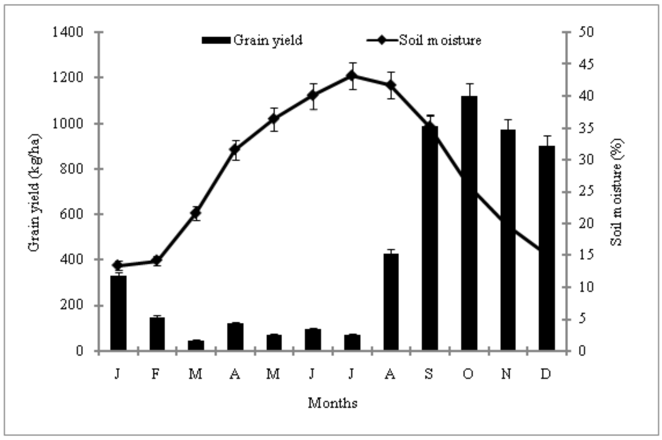
Sowing time	Plant height (cm)	Duration (days)	Grain yield (q/ha)	Straw yield (q/ha)
October	87.8	132	9.73	10.2
November	54.6	143	11.0	10.1

It nicely fit into low input agriculture of hill slopes or jhum cultivated areas of eastern Himalaya with fewer incidences of disease and pests and with less external inputs like nutrient manures and irrigation for the successful cultivation. Small and marginal farmers of this region practicing *jhum* cultivation (in ≈1.38 mha) could effectively cultivate this crop with substantial stress tolerance. Low soil moisture conditions of hill slopes like 12.0–15.0% was more preferred over excess moisture (18.0–28.0%). Apart from remunerative crop yields with low inputs, it is more helpful in preventing soil erosion and restoration of soil fertility across hill slopes. Appropriate technology transfer with needful policy interventions for adequate value addition and marketing might help in popularising this crop in eastern Himalayan conditions.

The results of one experiment conducted in our institute farm showed that lowest yield observed in the months of May (0.123 t/ha) and April sowing (0.132 t/ha) owing to incidence of high intensity rainfall. As low temperature and low humidity prevails during *rabi*, planting in October to December months results in more economical yields (0.973 to 1.1 t/ha) with increased harvest index. The water content in the soil was higher (44.0%) in July and lower in the months of January (14.5%) and February (15.1%).

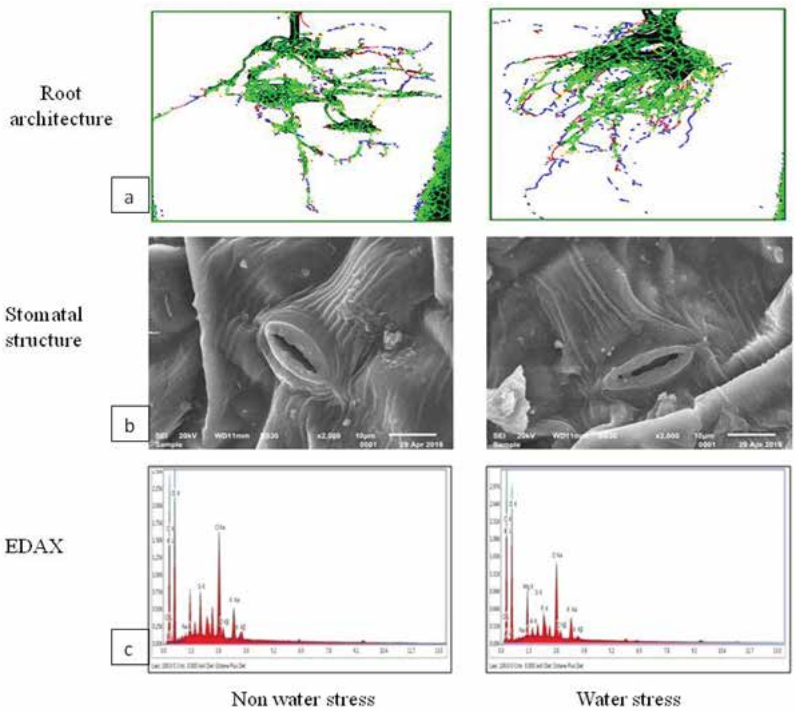
Buckwheat is robust moisture stress tolerant crop of EHR

During winter months, buckwheat cultivation undergone varied levels of water deficit and imminent low pH induced edaphic impacts on its crop physiology. Usually water deficits over lesser time, plants produce more biomass per unit of water consumed by lowering loss of water rate; whereas under longer moisture deficit, the conductivity of stomata is lowered with corresponding changes in root growth, pore structure and cuticle deposition. Root architecture and stomatal characteristics with leaf cuticle features significantly altered under water deficits (10–15% soil moisture) of hill slopes. Since the root system is slowly explored as key source for water deficit stress tolerance and adaptation, fibrous roots with a deeper taproot distributed in the upper surface of soil significantly help in soil binding and check erosion during the rainy season.



Trends of buckwheat grain yield with associated changes in soil moisture

The leaf contents particularly chl b and carotenes could able to scavenge free radicals to reduce oxidative stress and thereby confer tolerance to water deficit conditions with minimal effects on leaf photosynthetic machinery. Modulation of carbon metabolic machinery under varying radiation levels of slopy terrains is pivotal for robust crop such as buckwheat. Under water deficit, the pore dimensions slightly reduced or shown partial closure (at lower side) but in water sufficient conditions pore remains open. Pore dimensions and extent of distribution on the epidermis could reasonably alter photosynthetic parameters. Changes in wax deposits could overcome free escape of vapours of moist liquid through living surfaces of canopy and accordingly vary



Root architecture, stomatal structure and EDAX (Energy dispersive x-ray analysis) of high yielding buckwheat under water stress and non-water stress conditions the nutrient uptake and accumulation in leaves under water deficit and water sufficient circumstances.

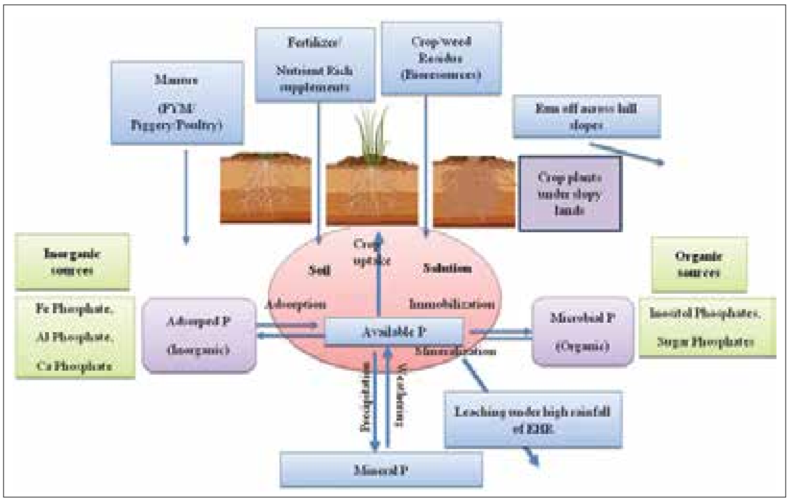
Enhanced phosphorus uptake in low pH status of hill slopes

Phosphate availability in low pH of hill slopes is important limitation for higher productivity as active phosphate ions binds to other elements such as Fe and Al in addition to low mobility of ions making available phosphate levels lower than the plant requirement. Even though higher doses of P rich manures incorporated into the soil, phosphate ions get precipitated to form inorganic and organic complexes. This means that almost all plant P uptake comes from the soluble soil Pi pool, suggesting that Po must first be converted to the Pi forms for plant uptake. In addition to white lupin, buckwheat (BW) has been classified as P uptake efficient. Even when total soil P may be high, >80% still exists in forms that are unavailable to plants, with inorganic phosphorus (Pi) in most top soils between 25% and 75% and organic P (Po) within the same range. Various mechanisms involved in efficient P uptake by plants such as lupins and robust crops like as *Fagopyrum* under low phosphate levels along with adequate variability in rhizopsheric level modulation including exudation of low molecular weight organic acids such as oxalic acids secreted to dissociate fixed forms of phosphate complexes in concomitance with favourble physiological traits.

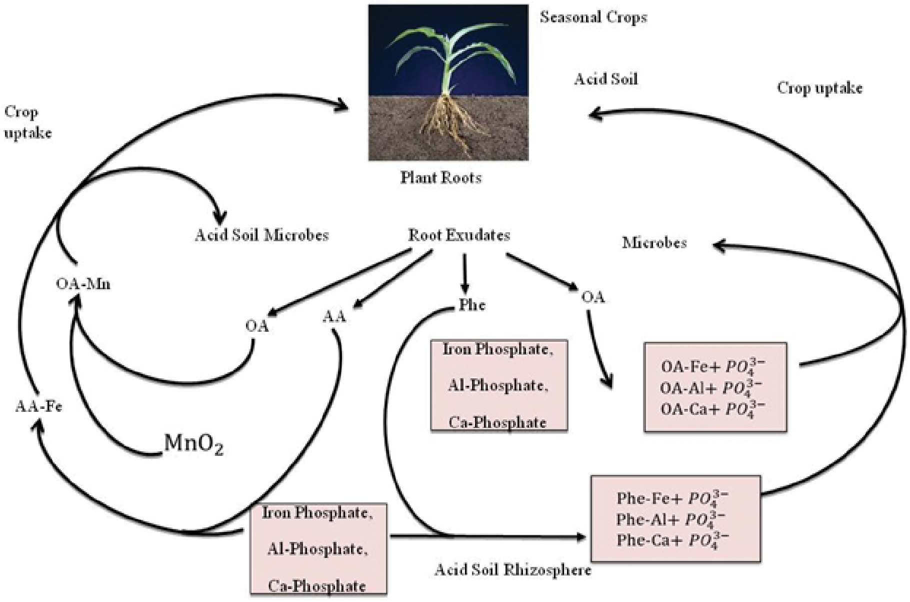
In the study conducted by Jasper and David (2011), it was shown that buckwheat can significantly solubilize phosphorus (P) from sparingly soluble soil P to subsequent crops. Calcium-bound P contributed the most P (72% of inorganic pool) to the available fraction, and P uptake by buckwheat (40 kg/ha) was significantly greater than wheat (16 kg/ha) from the inorganic pools, whereas wheat uptake was significantly greater from the organic pool. Following harvest, more P was found in available P pools after buckwheat suggesting potential solubilisation of P to subsequent crops compared with wheat. Buckwheat is often called a P scavenger because it can take up soil P more efficiently than other plants. In its growing stage, the roots of buckwheat exude substances that help to solubilise P that may otherwise be unavailable to plants. The roots of buckwheat were also found to have a high storage capacity for inorganic P. As a result, when buckwheat plants are incorporated in the soil, they decay quickly, making phosphorus and other nutrients available to the succeeding crop.

The ability of buckwheat roots to acquire phosphorus (P) was characterized by morphological features, and chemical changes in the rhizosphere. Root exudates of low-P plants have lower pH values than exudates of high-P plants and increased the solubility of $FePO_4$ and MnO_2 to a greater extent. Enhanced hydrolysis of glucose-6-phosphate by exudates from low-P plants was due to an increased "soluble" acid phosphatase activity. And root surface phosphatase activity was also slightly enhanced with P deficiency. In the rhizosphere soil of buckwheat, some depletion of organic P forms was also observed. The mechanisms conferring P efficiency have to be associated with either the acquisition of P nutrient from the environment or the movement and distribution within the plant, or the utilization in metabolism. Efficient acquisition of P under insufficient supply like acid soils of HER may be due to a higher ability to explore the soil by a more extensive root system (with rapid development, higher root to shoot ratio, finer and longer roots and root hairs), or a greater ability to absorb P from a dilute solution (i.e. an efficient uptake mechanism). Exudation of reducing, chelating, and/or acidifying substances by the roots, resulting in solubilization of soil P, may also be of importance.

As buckwheat known for P solubilisation, some studies were conducted to confer its potential in intercropping systems. Intercropping of buckwheat can improve the productivity of cropping systems due to increased soil nutrient availability and plant nutrient use efficiency. A 2-year field experiment was conducted to determine the effects of different intercropping ratios and fertilizer types on nitrogen (N) and phosphorus (P) concentrations and yields of fenugreek and buckwheat at the research farm of Shahrekord University, Iran (Aliyeh *et al*. 2018). The treatments consisted of sole cropping of fenugreek (F), buckwheat (B) and three intercropping ratios (F:B = 1:2, 1:1 and 2:1) under three fertilizer types: chemical fertilizer (CF), integrated fertilizer (IF) and broiler litter (BL). At flowering and at harvest, intercropping increased total above-ground dry matter, total seed yield, N and P concentrations (plant) and uptake. The applied N use efficiency (ANUE) and applied N recovery efficiency (ANRE) in the intercropped plots were also higher as compared to the sole cropping. The intercropping ratio of F:B (2:1) was the most suitable for improving the tested nutrient variables. The IF and BL showed significant benefits as compared to CF, total seed yield, NC and PC in the plant, as well as N and P uptake in sole and intercrops. For ANUE and ANRE, CF proved to be more effective.



Fate of added phosphorus in acid soil: P fixed either through adsorption, immobilization and precipitation



Effects of root exudate components on nutrient availability and uptake by plants and rhizosphere microbes. OA; organic acids; AA, amino acids including phytosiderophores; Phe, phenolic compounds.

Therefore 2:1 fenugreek–buckwheat intercropped system with the application of IF and BL can successfully be implemented for improving productivity, N and P contents of fenugreek and buckwheat as well as the nutrient land equivalent ratio (compared with sole cropping with CF) under semi arid growing conditions of Iran.

SUMMARY

Specialised stress adaptive mechanisms apparent in buckwheat up-regulated under stressful environments of hill slopes of EHR designate the crop as more suitable for cultivation in the region for higher grain productivity during winter months (mid-September to October) but found better for producing higher green biomass during all through the year. Root morphological traits, photo-protective pigments and stomatal modifications were emanated as beneficial stress rescue mechanisms in buckwheat to overcome inimical moisture stress and soil acidity conditions of hill slopes of EHR under changing climate. In view of its increased resilience and sustained productivity under marginal hill environments, it was found remunerative and potential stress tolerant crop for increased cropping intensity and food security with prevailing low input agriculture in the region.

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Poultry farming for livelihood and nutritional security in northeast India

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Poultry farming is rapidly expanding in India, playing a crucial role in the national economy and food security. India ranks fifth in chicken meat and second in egg production globally, with both commercial and backyard poultry systems playing vital roles. In the northeastern region, which holds over 69 million poultry, backyard farming predominates, supporting rural livelihoods, nutritional security, and women's empowerment. The region's varied agro-climatic conditions, availability of local breeds, and reliance on traditional agricultural practices offer both unique opportunities and challenges. Different range of poultry farming systems from traditional backyard to commercial intensive practices coexist, with newer initiatives like improved backyard poultry farming with Low Input Technology (LIT) birds and native chicken like Kadaknath farming are becoming popular. Notwithstanding the sector's potential, there are challenges like disease outbreaks, high feed cost, insufficient infrastructure, market restrictions, lack of adequate government assistance, etc. Tackling these challenges with focused strategies like region specific breed improvement or developments, provisioning financial support, imparting training and capacity building along with improved market connections can unleash the potential of poultry farming in the region. Through strategic interventions, policy backing, and community involvement, the sector has the capacity to evolve into a fundamental element of rural economic advancement and nutritional security within the region.

Keywords: Capacity building, Market restrictions, Rural economic advancement

POULTRY has emerged as one of the most rapidly growing segments in the Indian agricultural sector, with an annual growth rate exceeding 6 percent. The total poultry population of India is 851.81 million, producing about 4.99 MMT of chicken meat (5^{th} largest in the world) and 138.38 billion eggs (2^{nd} position in the world) contributing ₹2.3 lakh crores to the national economy during 2022–23. The poultry industry in India can be mainly divided into two main sub-sectors: A well-structured commercial sector and unorganized rural or traditional backyard sector. During 2022–23, backyard poultry contributed around 37.22% of the total poultry population with a production of 20.2 billion eggs, which was 14.6% of the total production. Rest of the eggs and major proportion of chicken meat came from the commercial poultry sector. Due to increasing urbanization, and changing dietary habits, the per capita consumption of poultry and poultry products has been steadily rising. The sector is largely driven by private investments and integrates modern technology in breeding, feeding, and disease management. The sector is providing direct and indirect employment to over 6 million people, including farmers, traders, feed manufacturers, veterinarians, and transporters.

The total poultry population of the north eastern region of India is 69.22 million which accounts for 8.13% of country's total poultry. 94% of the total poultry accounts for the indigenous or native birds which are located mostly in the rural areas in the region. The poultry sector in the region is largely dominated by backyard and small-scale intensive poultry farming due to traditional farming practices and land constraints. Although the backyard poultry farming has low productivity, it still plays an important role in the food and nutritional security of rural people living in fragile ecosystems of the region. Village or backyard poultry production can effectively be promoted in rural areas, as large-scale commercial poultry operations remain predominantly located in urban and semi-urban areas. The backyard poultry farming has proven to be a significant mechanism for reducing rural poverty, eliminating malnutrition, and generating meaningful employment opportunities in rural households.

Poultry raised in backyards is seen as a practical way to empower women, combat poverty, and provide food and nutrition security for rural poor people. Assam is the north eastern state with the highest population of poultry, followed by Manipur, Meghalaya, Tripura, Nagaland, Mizoram, Arunachal Pradesh, and Sikkim, according to the 20th Livestock Census. Chicken is reared in all the states, while ducks, swan, and goose are predominantly found in Assam, Manipur and Tripura. Many improved chicken varieties, including Vanaraja, Gramapriya, Giriraja, Srinidhi, Kalinga brown, Rainbow Rooster, and Kuroiler, are introduced and mostly raised in low input systems in the region.

Importance of poultry farming in northeast India

Poultry farming plays a crucial role in the socio-economic development of northeast India. With its diverse agro-climatic conditions, rich biodiversity, and availability of indigenous poultry breeds or varieties, the region has significant potential for poultry production. It serves as an essential livelihood resource for rural communities, delivering both income and nutritional security. The key aspects of the poultry farming in northeast India have been highlighted below:

Source of livelihood and rural employment: Poultry farming provides direct employment to thousands of farmers, especially small and marginal landholders in rural areas in the region. It is a major income generating activity for tribal communities, self-help groups (SHGs), and women entrepreneurs. Moreover, the low capital investment with quick returns makes it an affordable business opportunity for unemployed youth. Therefore, many individuals and cooperatives are venturing into poultry farming, leading to business growth and rural development.

Enhancing nutritional security: Poultry meat and eggs provide abundant high-quality protein, vitamins (B12, D), and essential minerals (iron, zinc), which are vital in addressing malnutrition and protein deficiency, especially in children and pregnant women. Furthermore, eggs and chicken meat are cost-effective compared to other animal protein options, making them a key dietary element for low-income households. The improved backyard poultry contributed significantly to the food and nutritional security of tribal farmers in mountainous regions of northeast India.

Low investment and high returns: Poultry farming requires minimal land and can be started with a small flock in a backyard system. Fast growth rate of broiler chicken ensures quick income generation in just 5–6 weeks of rearing. Layer farming offers a steady income through the production of eggs. Profitability can be increased with value-added products like processed meat and organic eggs.

Support for women empowerment and self-help groups (SHGs): It is largely managed by women in rural areas, making it an important tool for women's empowerment. In rural areas of low and middle-income countries, it is primarily women who manage and own backyard poultry operations (FAO and IFAD 2022). Enhancing women's empowerment through backyard poultry farming can play a crucial role in alleviating poverty, boosting food security, and promoting gender equality. Many government and NGO-led SHGs are involved in backyard poultry farming, generating economic independence for women. Women's engagement in poultry farming plays a significant role in improving nutrition, education, and the general welfare of households.

Utilization of locally available resources: The native breeds of poultry like Miri and Daothigir in Assam, Chittagong in Meghalaya and Tripura, Kaunayen in Manipur are found in the north eastern region. Apart from these, improved chicken varieties like Vanaraja, Gramapriya, Srinidhi, Kalinga Brown, Kamrupa, Kuroiler, Rainbow Roster, etc. are suitable and popular in the regions which are well-adapted to the climate with minimal healthcare. Using local grains and kitchen waste as feed in backyard farming helps lessen dependence on expensive commercial feeds. Poultry manure serves as a valuable organic fertilizer, enhancing soil fertility and benefiting small-scale farmers engaged in agriculture.

Entrepreneurship and small-scale enterprises promotion: The region is witnessing a rise in small and medium-scale poultry farming, which is aiding the growth of local entrepreneurship. There are business prospects in hatcheries, feed manufacturing, poultry processing, and egg distribution. The demand for poultry meat and eggs remains consistent in urban and semi-urban markets, guaranteeing continuous revenue generation.

Climate resilience and adaptability: Poultry farming is less vulnerable to climate risks compared to crop farming, which is often affected by floods and erratic weather in northeast India. The north eastern area have climatic advantage for poultry farming, thereby minimizing the necessity for costly temperature regulation systems. Indigenous and crossbred poultry varieties such as Vanaraja and Gramapriya, are well-suited to local conditions. Indigenous poultry breeds are naturally adapted to the local climate, requiring only minimal healthcare assistance. Small-scale backyard farming can continue even during adverse weather conditions, ensuring food and income security.

Contribution to the regional economy: Poultry farming contributes significantly to the agriculture and livestock sector of northeast India. It helps in reducing dependency on poultry imports from other states, leading to self-sufficiency in egg and meat production. It also generates revenue for local traders, feed manufacturers, and veterinary service providers.

Poultry farming systems in northeast India

The majority of the farmers in the region are practicing traditional poultry farming systems which is basically a backyard poultry production. However, commercial poultry farming has been expanding in recent years in the region. Backyard poultry production can be classified into several systems, such as small-scale extensive scavenging, scavenging, semi-intensive, and small-scale intensive (FAO 2014). The backyard poultry production system in India has been classified into traditional backyard system (<20 birds with little or no input), semi-intensive farming (50–200 birds under semi-scavenging conditions), small-scale intensive farming (200 or more birds with improved birds under a high-input system), and native chicken farming (indigenous birds with a run area and complete ration). The type of backyard poultry production system is based on the availability of poultry germplasm, marketing avenues, availability of natural food base resources, food habits of the population, etc. Generally, the following different poultry farming systems are found in the region.

Traditional backyard system: Traditional backyard poultry farming is an age-old practice prevalent in rural and tribal villages of the region with few numbers of native birds either chicken or ducks (less than 20) with nominal or no inputs. In this system, birds are not confined and can scavenge for feed over a wide open area in and around home. The fertile eggs are hatched to provide replacements and the birds feed by scavenging or are provided with kitchen wastes, and crop by-products. The number of birds may go up to 50 birds in this system, provided there are enough scavenging areas and supplementary feeding. The surplus males are used for self-consumption or sold at about 3–4 months of age for meat purposes and the females are retained for egg production.

Semi-intensive system: The birds are reared under semi-scavenging conditions i.e. a limited free-range area for scavenging during day time with supplementation of 30–40% of feed requirements. In the semi-intensive system of backyard poultry farming, flock size should be 50–200 or more. Supplementary feed is offered generally in the evening hours based on the availability of the natural food base in the specific area and season. This type of system can be practiced in orchards and gardens with a poultry house as night shelter or shade during sunny days. The surplus males are sold at about 3–4 months of age and females are retained for egg production.

Small-scale intensive system: It comprises more than 200 to a few thousands of birds, which are reared by providing all the inputs till they attain about 1.5 kg of body weight. This kind of farming is usually practiced for meat purpose using fast-growing breeds like Vanaraja, Krishibro, Srinidhi, Kuroiler, and Rainbow Rooster and also for small scale broiler and layer farming. The low cost poultry house is constructed using locally available materials like wood, bamboo, thatches, etc. and materials like saw dust, wood shaving, paddy husk, etc. are used as bedding materials.

Commercial intensive system: In this system, birds are fully confined in houses under deep litter or battery systems. These systems are followed by the medium or large scale commercial layer or broiler farms under optimum housing, feeding and proper healthcare with high input and high output. Under commercial intensive farming system, the capital expenditure is higher and the production is also higher.

Native chicken farming: Backyard poultry with indigenous/native chicken for meat purposes is the recently adopted business model, which has huge scope and potential in the coming years. Demand for meat and eggs from the native chicken breeds are increasing considerably both in urban and rural areas. The native chickens are slow growers and poor egg producer with intermittent brooding phases. However, they are ideal mothers and good sitters, excellent foragers, hardy, and naturally tolerant to common diseases. The birds are reared up to 3–5 months under intensive farming with a run area and complete ration. The birds fetch a premium price based on the season and the quality of meat e.g. Kadaknath, the most popular native chicken in recent times.

Challenges and strategies of poultry farming in northeast India

Despite the immense potential of poultry farming in northeast India, several challenges hinder its growth and sustainability. These challenges include disease outbreaks, high feed costs, poor infrastructure, and market-related issues. Addressing these obstacles is crucial for improving poultry productivity, farmer income, and the overall poultry sector in the region.

Disease outbreaks and poor veterinary care: Common poultry diseases like *Avian influenza* (Bird Flu), Newcastle disease, Fowl pox, and Salmonellosis frequently affect poultry populations, causing high mortality rates. The veterinary services in rural areas of the region is limited due to lack of trained veterinarians, proper vaccination programmes, and diagnostic facilities. Moreover, small-scale farmers face losses due to high mortality in backyard poultry birds because of lack of awareness about disease prevention, biosecurity, and vaccination.

Strategies:

- Establishing more veterinary clinics in rural areas.
- Government-supported vaccination and disease surveillance programmes.
- Training farmers on biosecurity and hygiene practices.

High cost and shortage of poultry feed: Feed costs make up 60–70% of production expenses in commercial poultry farming. Maize and soybean serve as the primary ingredients for poultry feed; however, they are either costly or insufficiently available in the region. Therefore, poultry feed is often sourced from other states outside the region which creates a supply bottleneck and increasing transportation costs and overall expenses for farmers.

Strategies:

- Encouraging local production of maize and soybean to reduce dependency on external markets.
- Government subsidies on poultry feed to support small-scale farmers.
- Establishing more poultry feed processing units in northeast India.

Poor market linkages and low profit margins: Due to lack of organized poultry market linkages in the region, the farmers rely on middlemen who take a significant share of profits. The small farmers often sell their products at lower prices due to the absence of direct wholesale and retail market linkages. Moreover, mismatches of seasonal demand and supply lead to price fluctuations which affect the income stability of the farmers. The non existence of structured poultry cooperatives weakens the negotiating power of farmers.

Strategies:

- Developing poultry cooperatives to help farmers get better prices.
- Government support for direct farmer-to-market linkages through e-commerce and wholesale markets.
- Strengthening local poultry processing industries to add value to products.

Lack of proper infrastructure and technology: Many small-scale farmers use traditional shelters that do not provide proper ventilation, temperature control, or predator protection. Majority of farmers of the region lack knowledge of modern poultry farming techniques like disease control, and improved breed management. Poor electricity supply also affects incubators, brooding systems, and storage of poultry products in the region.

Strategies:

- Providing affordable and improved poultry housing models.
- Organizing farmer training programmes on modern poultry farming techniques.
- Investing in solar-powered poultry equipment and storage facilities.

Climate and environmental challenges: The challenging terrain and climate conditions in some north eastern states affect poultry production, especially in remote areas where transportation of feed and other inputs is difficult. In Assam, Meghalaya, and other north eastern states, high humidity, heavy rainfall, and flooding adversely impact poultry health and the quality of feed. Seasonal variations leading to heat and cold stress additionally impede poultry development, egg yield, and overall farm efficiency. Poultry waste disposal is often unregulated in the region, leading to water and soil pollution.

Strategies:

- Promoting climate-resilient poultry farming practices.
- Encouraging controlled-environment poultry housing systems.
- Using poultry manure for organic farming to manage waste sustainably.

Poor availability of improved breeds: Due to poor availability of quality chicks of improved breeds or varieties, the farmers rear the local birds which are poor egg and meat producers compared to commercial breeds although hardy and disease-resistant with broodiness characters. Therefore, poultry farmers of the region struggle to access high-yield broilers and layers while depending on hatcheries from other states. Moreover, research on local breeds of the region is still in its early stages.

Strategies:

- Strengthening local hatcheries and breed improvement programmes.
- Promoting cross-breeding programmes to improve indigenous poultry productivity.
- Encouraging conservation of disease-resistant local breeds while enhancing productivity.

Financial limitations and insufficient credit availability: The majority of poultry farmers in the area are small-scale and marginal producers. Therefore, establishing a modern commercial poultry farm requires a significant financial commitment to housing, equipment, and feed. Many rural poultry farmers lack access to institutional credit, relying on high-interest loans from informal lenders due to limited bank loans available for small and marginal farmers. Moreover, poultry farmers rarely have insurance, making them vulnerable to losses due to disease outbreaks or natural disasters.

Strategies:

- Government-supported microfinance and low-interest loans for poultry producers.
- Promoting banks and financial institutions to offer accessible credit options.
- Establishing poultry insurance plans to shield farmers from unexpected financial setbacks.

Competition from poultry imports: The poultry eggs and broilers originating from states like West Bengal and Andhra Pradesh are prevalent in the northeast Indian markets, which diminishes the demand for locally produced poultry.

Strategies:

- Promoting branding and certification of local poultry products (e.g. organic, free-range).
- Implementing government policies to encourage local poultry consumption.
- Strengthening local poultry farming industries to meet market demand.

Lack of government support and policy implementation: Many government poultry development schemes initiatives take time to reach farmers due to bureaucratic delays. Moreover due to insufficient extension services, farmers of the region are not aware about available subsidies, training, and support programmes.

Strategies:

- Enhancing government poultry assistance programmes to facilitate easier access for farmers.
- Expanding awareness initiatives regarding the financial and technical support that is available.
- Fortifying veterinary and poultry extension services.

SUMMARY

Poultry farming in northeast India has immense potential to enhance rural livelihood and nutritional security. Nonetheless, obstacles such as disease outbreaks, elevated feed expenses, inadequate infrastructure, and restricted market access impede its development. Addressing these issues requires a multi-pronged approach, including government intervention, technological advancements, improved breeds, financial support, and better market linkages. By tackling these challenges and improving productivity, the poultry industry can greatly enhance the economic and nutritional well-being of the population in the region.

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Containerised nursery systems: An efficient technique for the production of quality planting material in Khasi Mandarin

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Khasi Mandarin is a valuable commercial fruit of the NEH region, India. The fruits are of premium quality and have a distinctive taste and flavour due to the ideal agro-ecological conditions in the area. The demand for citrus fruits is rising, offering great potential for future expansion. However, the productivity of this crop is only half the national average (10.36 t/ha). The lack of certified citrus quality planting materials (CQPM) can be a major constraint hindering the expansion of area and the commercial production of Khasi Mandarin. Furthermore, poor-quality propagules are vulnerable to many pathogens, which can be transmitted both through grafting and vectors. It is crucial to adopt containerised nursery systems (CNS), efficient methods of propagation and nursery management, pathogen detection and elimination, and an effective regulatory framework through the accreditation and certification of stocks. Furthermore, the shortage of CQPM can be addressed by doubling the windows of operations, i.e. during January-February through budding and July-August via wedge grafting. Therefore, strictly adopting a protocol and efficiency techniques may assist in producing the highest horticulturally superior and pathogen-free plants as the most strategic means for the success of the citriculture industry in the region.

Keywords: Certified citrus quality planting materials, Pathogen-free plants, Regulatory framework

KHASI mandarin *(Citrus reticulata* Blanco*)* is an ecotype of mandarin fruit and represents the most significant commercial crop in the NEH region, India. The fruits of this crop is of premium quality due to suitable agro-ecological conditions, and thus, a Geographical Indication (GI) tag was granted in 2014. The fruits of Khasi Mandarin have been exported from the region to the Middle East and neighbouring countries since 2022. However, the productivity of this fruit crop is relatively low (5.91 t/ha) vis-a-vis the average productivity in the country (10.36 t/ha). Unproductive citrus orchards can have an array of underlying causes, especially systemic viruses, virus-like diseases, and systemic bacteria. It is a fact that, in addition to good orchard management practices, the availability of reliable and good quality propagules is among the various technical factors responsible for higher crop performance, both in yield and quality. Quality planting materials are a vital part of any citrus production system to minimise the spread of threatening pathogens, enhance adaptability, and ensure sustainability with better crop performance. Therefore, the success of the citrus sector in the region critically depends on implementing a citrus certification programme for the production of certified citrus quality planting materials (CQPM). Certified CQPM is a healthy planting material with the highest yield and quality attributes for distribution to growers. Certified CQPM can only be obtained by establishing a strong certification system at the regional and/or national level through the adoption of the following main components of the certification programme.

Component 1: Identification and production of plus plants

The certification of CQPM begins with the identification and production of plus plants, which involve the following two steps:

Step I-Selection of a plus plant: The first step is selecting a candidate plant (plus plant), which can be achieved through the following three practices: domestic selection, new varieties (or clones), and exotic elite materials. Khasi mandarins are native to the region and available locally. Therefore, candidate plants of Khasi mandarin can be selected by a survey of the elite genotypes, followed by intensive testing using robust diagnostic criteria in the certification programme. In the event of introduction of any exotic citrus species, whether as scions or rootstocks, the material must undergo a quarantine programme. The detection of any potential infection with an identified or unidentified virus or virus-like pathogens can be performed using high-throughput sequencing and then confirmed through standard molecular and serological tests.

There are two main criteria for selecting candidate plants. The primary criterion is selection based on horticultural excellence (A+), such as high yield and good quality. The second essential step is the pathogenicity test or viral indexing to obtain pathogen-free (B+) plants.

Step II-Testing of a plus plant: The selected candidate plants may adopt one of the two approaches, either Plan A or Plan B, depending on the presence or absence of viruses. In plan A (candidate plants A+ and B+), the candidate plants with horticultural superiority traits (A+) and freedom from diseases (B+) must be assigned a unique identification number. Such plants shall be relocated and maintained in the foundation block. Plan B (candidate plants A+ and B-) is implemented when the candidate plants have all the horticultural superiority traits (A+) but are found (+ve) with virus pathogens (B-). Such candidate plants (A+ and B-) must be reconstituted in a pot culture under controlled laboratory conditions. The representative plus plants (potted plants) should be carefully subjected to any of the following virus (pathogen) elimination techniques to produce candidate plants (A+ and B+).The following are the techniques for pathogen elimination:

- **Heat treatment (thermotherapy):** When using heat chambers for potted plants or tissues, thermotherapy protocols should be carefully followed to partly or entirely inactivate many viruses with minimal or no damage to the host tissues, for obtaining virus-free shoot tips.
- **Chemical treatment:** The use of therapeutic chemicals like virazole and vidarabine (antimetabolites) to eliminate viruses from infected plants in culture media.
- **Meristem tip culture:** The culture of a small, incision, pathogen-free apical dome under aseptic conditions can produce 'clean nucleus stock.'
- **Micrografting:** Grafting meristematic tissues onto a virus-free rootstock (seedling) *in vitro* can eradicate the virus.

Other *in vitro* methods for regenerating plant resistance to disease include somatic cell hybridisation, gene transformation, and somaclonal variation. The five key graft-transmissible infections that the candidate plants must be screened for are: i) Citrus greening disease (Huanglongbin), ii) Citrus tristeza virus (CTV), iii) Indian Citrus ringspot virus (ICRSV), iv) Citrus mosaic badnavirus (CMBV), and v) citrus exocortis viroid (CEVd). The candidate plants (A+ and B+) will be maintained in the foundation block following standard procedures after the elimination of pathogens.

Component 2: Development and maintenance of elite plants

Block 1-Provisional nucleus foundation plant stock: Planting materials identified as pathogen-free are regarded as clean, pathogen-tested, certified nucleus material and must be maintained in the provisional nucleus foundation plant stock (Block 1). In this section, stocks will be verified for genetic purity and identification of genotype or cultivar using molecular tools. Non-true-to-type planting materials will be discarded, while genetically true-to-type ones will be sent to the Certified Clean Foundation Plant Stock (Block 2).

Block 2-Certified clean foundation plant stock: The elite stocks of true-to-type obtained from Block 1 are classified as certified clean foundation plant stock (Block 2). This block maintains a small number of plants, usually 5 to 10 per variety. The nucleus planting materials under this block are maintained at a 2 m x 2 m spacing in an insect-free environment to prevent contamination by pathogens and insects, adhering to strict biosecurity protocols. Key diseases transmitted by vectors and clonally transmissible should be periodically tested for and tracked in the block. The stock of plants in this block should be maintained at the institutional level.

Block 3-Certified clean budwood increase stock: A scion or budwood obtained from Block 2 shall be cultivated and maintained in the certified clean budwood increase block, also referred to as the certified clean registered nursery plant stock. This block serves as a source of bud wood and scion sticks for further propagation. The establishment of this block in the field facilitates the scaling up of the multiplication and distribution of CQPM to farmers. In such cases, the fields should be located in an isolated area where the risk of infection is minimal or nonexistent. If facilities are available, growing in a container under fully controlled environmental conditions is the ideal choice. The number of plants maintained within this block can be about 50 or more, depending on requirements and facility availability.

Component 3: Multiplication and distribution of elite planting materials

Block 4-Rootstock nursery block: In this block, seedlings of the recommended rootstocks are grown in a Containerised Nursery System (CNS), preferably under controlled conditions to avoid any vector-transmissible diseases. The concept of CNS is very significant, especially in regions with a high occurrence of soil-borne pathogens. Typically, once soil-borne pathogens like *Phytophthora* are present in field nurseries, eradicating them proves to be very challenging. To address this issue, the concept of CNS was introduced. Facilities required for CNS include a 50% shade net house for congenial growing conditions, UV-stabilised transparent polythene for solarisation, sterilised plastic trays for sowing seeds, UV-stabilised black polybags (100 μ) for transplanting seedlings, fumigation facilities for items such as potting materials, and a separate set of nursery equipment.

- **Media preparation:** The media mixture of virgin fertile soil, FYM, and sand (1:1:1 v/v) can be sterilised by steam. In the primary nursery, the sterile mixture is utilised to fill the plastic trays for sowing seeds. The same sterile mixtures are utilised in the secondary nursery.

- **Primary Nursery:** Rootstock seedlings are grown in a sterilised plastic tray (60 cm x 40 cm x 12 cm). Sterilised mixtures are filled in a tray and set on a solid platform at least 1.5–2.0 feet above the ground to reduce soil-borne contamination. The nursery floor is layered with 2.0–4.0 inches of stone dust and boulders to prevent soil-borne pathogens from splashing, and it is regularly treated with a mixture of copper and lime through spraying or dusting. Fully ripened fruits of the recommended rootstocks (Rough lemon and Rangpur lime) are harvested from the rootstock mother block. The extracted seeds are carefully washed and surface sterilised. A prophylactic treatment of seeds was applied with Ridomil MZ 72 and Bavistin before sowing in plastic trays.

  The treated seeds are sown at a depth of 1.0–1.5 cm, spaced 2.5–3.0 cm apart in a row and 5.0–7.0 cm between rows, under a 50% shade net house. Seed sown during November-December takes about 35–60 days for germination after sowing,with 85–90% seed germination in Rough lemon and Rangpur lime.

- **Secondary nursery:** Seedlings at 4–6 leaf stage and attaining the desired height are ready for transplanting to a secondary nursery. Only nucellar seedlings (based on visual observations), i.e. true-to-type, are identified as rootstock seedlings. The identified seedlings are carefully uprooted to avoid root damage during transplanting into polybags, followed by gentle irrigation. The stunted, thin, hook-necked, bent or twisted seedlings can be discarded. Monitoring is done regularly to avoid contamination from *Phytophthora* and other soil-borne diseases.

Block 5-Multiplication of elite planting materials: In this block, budding and grafting are performed on a recommended rootstock.

- **Collection of scions/budwood:** The scion sticks and/or budwood can be collected from block 3. The buds originate from a shoot of an adequately mature current-year and non-bearing growth. The selected shoots contained a longitudinal white streak on the bark with swollen buds and were non-sprouting but ready to burst following grafting.
- **Multiplication techniques:** Khasi mandarin is generally propagated once a year, during January-February, by T-budding. Considering the high demand for quality planting materials, there is a need for a second window of propagation operations. The ICAR RC NEH Region, Umiam, has developed a wedge grafting for propagation during July-August. Furthermore, this technique can be carried out in six month old rootstocks, vis-a-vis one year old rootstocks in T-budding.

Table 1. Protocol for vegetative propagation of Khasimandarin

Particulars	Wedge grafting	T-budding
Type of rootstock	Vigorous	Vigorous
Sowing of rootstock seeds in the primary nursery	Plastic tray: 60 cm x 40 cm x 12 cm)	Plastic tray: 60 cm x 40 cm x 12 cm)
Timing of seed sowing	November to December	November to December
Transplantation procedures in the secondary nursery.	Polythene bag (LDPE)	Polythene bag (LDPE)
Size of a polyethene bag	30 cm x 15 cm	30 cm x 15 cm
Rootstock age	6–7 months	11–12 months
Rootstock diameter	4–6 mm	6.0 – 10 mm
Age of the scion shoot	3–4 months	5 – 6 months
Length of the scion	8–10 cm	---
Length of the vertical cut on the rootstock.	1.5–2.0 cm	---
Length of the slanting cut on both sides at the lower end of the scion.	1.5–2.0 cm	---
Length of the bud wood	---	2.0–2.5 cm
Length of the cut on the rootstock for inserting the bud at the T-point.	---	2.0–2.5 cm
Grafting or budding height	12–15 cm above the soil surface	20–22 cm above the soil surface
Timing of grafting/budding	July-August	January-February

- **Care and maintenance of budded/grafted plants:** Frequent light irrigation with automatic sprinklers and misters can be applied to propagated plants. In addition to the regular recommended fertiliser mixture, spraying of urea twice a month can improve the growth of nursery plants. Regularly remove any side suckers below the bud union. The multiplication of CQPM can be carried out at a government farm or through intermediaries such as registered private nurseries and other propagation and distribution agencies.

Block 6-Distribution block: The certified CQPM, whether multiplied by the government or recognised private nurseries, can be distributed through an authorised agency. The label "Certified Planting Materials" must be applied to all certified cleaned plant batches produced through CQPM. Each label, as "Certified Planting Materials", should include a unique barcode or QR code that provides details about the mother stock, genetic purity, and quality testing attributes. This certification can be carried out by a certified or recognised nursery following guidelines issued by a certified agency.

Traceability records

The accredited nursery should record and maintain the pedigree of the chain of custody for certified CQPM at every stage. This includes the certified mother stocks, maintenance, multiplication, and continuing until distribution or sale to growers.

Monitoring and registration

The "Certified Clean Foundation Plant Stocks" must be subjected to periodic testing for serious vector- and clonally-transmitted infections. Registration and certification of the Clean Foundation Block and Multiplication Stock should be compulsory to guarantee pathogen-free planting materials. An intensive approach is necessary to prevent viral infections via vectors and to maintain a clean, infection-free environment for the foundation blocks and budwood increase/multiplication stock. Any plants that test positive should be eliminated to stop the spread of infections.

Plant protection measures

The most prevalent disease in citrus nurseries is damping off. The pathogens, especially *Phytophthora*, pose a threat and can occur at any stage of plant growth in nurseries through contaminated water, soil, nursery staff, and tools. Regular monitoring and control strategies include excluding, removing the source of infection, avoiding conducive conditions for disease development, and preventing entry. The most common insect pests in citrus nurseries are leaf miner (regular spray of Dimethoate @1 ml/L), leaf-eating caterpillar (Imidacloprid @0.3 ml/L), aphids (Quinalphos @1 ml/L), and mites (3 g/L wettable sulphur or 1.5 ml Dicofol). The alternate spray of neem oil (1%) with any insecticides demonstrated greater effectiveness.

SUMMARY

It is essential to establish standard procedures for producing quality planting materials with the highest horticultural quality and free from pathogens. Furthermore, propagation and nursery efficiency techniques, including two windows of operation each year, i.e. January-February by budding and July-August by wedge grafting using containerised nursery systems, will help to increase the production of CQPM. The traceability records and monitoring of the accredited nursery need to be updated to maintain the reliability and genuineness of the nursery.

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Protecting pig resources from African swine fever

in north eastern India

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African Swine Fever (ASF) is a highly contagious and lethal viral disease affecting domestic pigs and wild boars. First detected in India in 2020, ASF quickly spread across the north eastern states, severely impacting pig populations and rural economies. North eastern India, culturally and economically dependent on pig farming, is particularly vulnerable due to its predominantly small-scale, backyard-based farming systems, rich indigenous breeds, and structural inadequacies. The region suffers from uneven veterinary infrastructure and limited organized trade systems, hindering effective disease management. ASF outbreaks in Assam, Arunachal Pradesh, Mizoram, and Manipur have disproportionately impacted tribal pig farmers, especially smallholders, due to inadequate biosecurity, sub-optimal outbreak response, including compensation. Informal pig trade and poor carcass disposal practices further amplify disease risks, with potential spillover into wildlife populations, threatening local biodiversity, including endangered species like pygmy hogs. Given the absence of reliable vaccine for the diseases, comprehensive, multi-sectoral prevention strategies are critical, emphasizing farm-level biosecurity, strengthened veterinary surveillance, regulated pig trade, fair compensation, and robust public awareness. Addressing deep-rooted systemic and ecological challenges through tailored, science-based policies and sustainable veterinary frameworks will ensure ASF control, protecting pig farming as an essential socio-economic and cultural pillar in north eastern India.

Keywords: Effective disease management, Pig farming, Public awareness,Veterinary surveillance

AFRICAN Swine Fever (ASF) is a lethal and highly contagious transboundary viral disease affecting domestic pigs and wild boars (*Sus scrofa*), caused by the African Swine Fever Virus (ASFV)—a large DNA virus and the only known member of Asfarviridae family. ASFV is unique since it is the only DNA arbovirus, capable of being transmitted by soft ticks (*Ornithodoros* spp.) in some ecological settings, although tick-borne transmission has not been confirmed in India. The disease results in nearly 100% mortality in affected pigs and currently has no vaccine or specific treatment. First confirmed in India in 2020, with outbreaks initially reported in Assam and Arunachal Pradesh, ASF has since spread rapidly across north eastern India, devastating pig populations and causing serious disruptions to rural livelihoods and the regional economy.

Pig farming plays a vital role in the socio-economic fabric of north eastern India. It is deeply integrated into the region's culture, nutrition, and livelihoods, particularly among tribal and marginal communities. The predominance of backyard pig farming makes the region especially vulnerable to ASF outbreaks, leading to devastating losses in livestock, income, and food security. Given the complexity of pig production systems and transboundary nature of ASF, region-specific, multi-sectoral strategies are urgently required. These must include farmers, veterinarians, wildlife authorities, policy makers, and food regulators.

Pig resources and pig farming in north eastern India

The pig resource base in north eastern India is robust yet vulnerable. It has rich indigenous diversity and is important economically and culturally. However, structural weaknesses must be addressed to protect it sustainably from threats like ASF. North eastern India holds a unique position in the country's pig farming

(a)

(b)

Varying types of pig rearing facilities employed by the farmers (a) Cemented flooring and walls, (b) Minimally resourced wooden plank walls and brick floor

sector due to its high population of pigs, strong pork demand, and cultural integration of pig rearing. According to the Basic Animal Husbandry Statistics (BAHS) 2024 (Department of Animal Husbandry and Dairying 2024), the region accounts for a significant proportion of India's total pig population, with Assam leading at over 2.1 million pigs, followed by Meghalaya (706,364), Nagaland (404,695), and Mizoram (292,465). While Assam, Meghalaya, and Mizoram showed population growth from 2012 to 2019, states like Arunachal Pradesh, Tripura, and Manipur recorded substantial declines, possibly due to systemic farming challenges.

Pig farming in this region is primarily backyard-based, practiced by smallholder and tribal households. These low-input systems rely on local feed resources and minimal infrastructure and are vital to livelihoods, food security, and rural economies. Backyard pig farming contributes significantly to household income, dietary protein, and even social status in many communities. While medium and large commercial farms are gradually emerging, especially near urban markets, traditional systems still dominate.

The region is rich in indigenous pig breeds, including Doom (Assam), Niang Megha (Meghalaya), Zovawk (Mizoram), Tenyi Vo (Nagaland), and Manipur Black. These breeds are prized for their adaptability to local conditions and disease resilience. However, crossbreeding with exotic breeds such as Large White Yorkshire and Hampshire is becoming common in semi-commercial systems to improve productivity. Balancing breed improvement with the conservation of genetic diversity remains a key policy consideration particularly with respect to disease resistance.

Despite the region's pig-farming potential, several non-disease-related challenges persist. According to BAHS 2024, veterinary infrastructure is uneven. For instance, while Assam has 431 veterinary hospitals and 767 dispensaries, states like Nagaland, Mizoram, and Sikkim have considerably fewer institutions related to their pig populations (Department of Animal Husbandry and Dairying 2024). Moreover, access to organized markets, veterinary services, and modern slaughter facilities is limited, restricting the growth of the formal pork value chain. These gaps significantly hamper timely detection and effective containment of ASF outbreaks, exacerbating the region's vulnerability.

ASF threat and its impact on pig farming and trade

ASF is not transmissible to humans, but it is devastating to pigs, with case fatality rates often reaching 100% in acute cases. Transmission occurs through direct contact with infected animals, indirect spread via contaminated feed, fomites (tools, clothing, vehicles), and infected pork products in which virus can remain viable for months. Clinically, ASF presents as high fever, loss of appetite, skin discolouration, incoordination, diarrhea, and sudden death. Chronic forms exist but are less common and may act as hidden sources of viral persistence. Crucially, there is no effective vaccine or treatment, making strict biosecurity and early detection the pillars of disease control (WOAH 2024).

Since its first detection in India in 2020, ASF has emerged as a major disruptor of pig farming in north eastern India. The region, where pig farming is firmly embedded in local traditions and economically vital, has suffered disproportionate losses due to the rapid spread and poor controllability of the disease.

Official data from 2020–2023 paints a stark picture. Assam, with the country's largest pig population, reported over 42,000 pig deaths due to ASF during this period, including a peak of 38,971 deaths in 2022 alone. Arunachal Pradesh recorded more than 7,700 pigs death in 2022, while Mizoram reported a sharp surge in both deaths (12,044 pigs) and culling (10,756 pigs) in the same year. Manipur showed significant impact in 2023, with 4,319 pigs dead and 1,681 culled. These numbers are likely underestimated due to limited surveillance coverage in backyard settings.

The disease's impact has been most devastating for smallholder and tribal farmers, who dominate pig production in the region. Backyard pig farms often lack adequate biosecurity, and infected carcasses may not be promptly removed, contributing to further spread. In many cases, ASF led to the complete loss of pig herds,


(a) Clinical signs of ASF


(b) Lesions of ASF

leading to economic hardship. Compensation, pegged at ₹ 3,000 per pig, may have only partially covered losses, as it often fails to reflect the market value of breeding stock, adult pigs, or secondary losses from disrupted trade.

ASF has also crippled trade and disrupted the pork value chain. Movement restrictions, both formal and informal, have affected interstate and local pig transport. Markets have experienced panic selling and price crashes, undermining confidence among producers and traders alike. The risk of disease spillover into wild boar populations and national parks further complicates management, threatening biodiversity and reintroducing the virus to domestic settings through vulnerable farm-forest boundaries.

Besides market disruptions, ASF also exposed critical gaps in veterinary surveillance, emergency response, and disease reporting. Varying pace of culling in different states and outbreak notification methods suggest a need for stronger institutional preparedness and coordination across states. Without significant policy and infrastructural interventions, the long-term viability of pig farming in the northeast remains at risk.

ASF prevention: Multi-stakeholder measures

While the above measures address immediate concerns, deeper systemic and ecological challenges continue to hinder long-term control efforts. In the absence of an effective vaccine or treatment, the only viable strategy against African Swine Fever (ASF) is the prevention of its introduction and spread. For north eastern India, where pig farming is largely unorganized and community-based, ASF control requires a multi-tiered, locally tailored approach. This includes practical measures for farmers, strengthened veterinary infrastructure, regulated trade mechanisms, and policy support that acknowledges the unique challenges of backyard pig systems.

At the farm level, emphasis must be on improving basic biosecurity, particularly in traditional backyard farms that dominate the pig production landscape in the region. These systems, though economically significant, are often characterised by poor infrastructure, open housing, and informal sourcing of animals. Here, biosecurity begins with simple but critical practices i.e. isolating new pigs before introducing them into existing herds, preventing access of wild animals and dogs to pig enclosures, and ensuring the immediate removal


(a)


(b)

African swine fever: (a), Lesions; (b), Disposal of carcass and safe disposal of carcasses. The traditional practice of swill feeding, especially using kitchen waste or pork scraps, should be discouraged, unless heat treated. ASF virus (ASFV) has a unique persistence profile marked by high virulence and high environmental resilience, meaning it can survive for prolonged periods in carcasses and contaminated feed, even under adverse conditions. Disinfecting sties, transport vehicles, and tools using approved agents such as sodium hydroxide, formalin, or chlorine is vital to reduce viral persistence. Equally important is the avoidance of purchasing pigs from unknown or unverified sources, which may serve as undetected carriers of ASFV.

These measures, however, will only be effective if they are complemented by strong veterinary surveillance and diagnostic systems. Early detection is key to containment, and this demands field-level engagement, especially in remote and pig-dense districts. Veterinary field assistants and mobile veterinary units (MVUs) must be deployed to monitor animal health and respond to farmer reports. The region's diagnostic laboratories must be strengthened with molecular and serological capabilities to confirm ASF cases quickly and reliably. Surveillance should not be limited to domestic pigs. Monitoring of wild boars, especially near forest fringes and protected areas, is essential to understand the potential spillover or maintenance of ASFV in wildlife populations. The detection of genotype II ASFV in wild boars in Assam's Manas and Nameri National Parks, which were genetically similar to strains isolated from domestic pigs, underscores the urgency of such efforts.

Regulating pig movement and trade present other challenges. Much of the pig trade in north eastern India occurs through informal channels, with limited oversight and traceability. This significantly raises the risk of disease spread across regions. Practical solutions include the enforcement of health certification for pigs in transit, establishing free disinfection and quarantine facilities at market points, and temporary market closures in outbreak zones. At the same time, pig movement restrictions should be based on real-time risk assessments and should avoid unnecessary disruptions to unaffected communities. Traders and transporters must be made aware of ASF symptoms and reporting protocols and encouraged to follow them through incentivised compliance and accessible veterinary support.

At the policy level, governments must act decisively to provide an enabling environment for ASF control. Besides the available National Action Plan on ASF (Department of Animal Husbandry and Dairying 2020), customized state-level contingency plans should clearly define outbreak response mechanisms, including surveillance zones, movement controls, humane culling procedures, and disposal protocols. Importantly, compensation packages must be fair and timely, with provision of revision based on market scenario.

Beyond reactive measures, long-term solutions must include the promotion of compartmentalization-especially in semi-commercial and large farms, which involves implementing standardised biosecurity and management practices that allow pig establishments to continue operations during regional outbreaks. Although originally designed for commercial systems, this concept could be adapted, at least in part, to cooperative or cluster-based backyard farming systems with shared veterinary oversight. Furthermore, border control measures should be revisited.

Effective ASF control also demands broad-based public engagement. Awareness campaigns must go beyond urban centers and reach tribal and rural communities in vernacular languages. These campaigns should clearly communicate that ASF is not a human health risk but poses a serious threat to livelihoods and food security. Community-level biosecurity networks, perhaps through existing self-help groups or village councils can serve as first responders in disease detection and containment.

Critical systemic and ecological challenges

What makes ASF particularly dangerous is not just its virological properties, but the context in which it spreads. In north eastern India, a majority of pig farmers operate in informal, resource-constrained settings with little to no access to veterinary guidance or regulated markets. These systems, while firmly embedded in local traditions and are economically significant, often involve pigs of varying age and health status reared in close quarters with minimal biosecurity. Carcasses of ASF-infected pigs are frequently left exposed or disposed improperly, creating conditions for environmental contamination and potential spillover into nearby wildlife habitats.

This overlap between domestic pig farms and wildlife-rich landscapes further complicates control efforts. The recent detection of ASFV in wild boars from Manas and Nameri National Parks in Assam underscores the growing threat of a wildlife-livestock transmission cycle. Such spillovers not only risk reintroducing the virus into domestic herds but also endanger India's biodiversity, including threatened species like the pygmy hog. Managing this interface will require not just fencing or buffer zones, but also close coordination between veterinary, wildlife, and forest departments.

The informal nature of pig trade adds another layer of complexity and movement across village, district, and even state borders. In the absence of traceability systems and health certification, the movement of pigs especially from unknown sources remains a major risk factor. Many smallholder farmers and traders lack awareness of ASF symptoms or reporting procedures. Addressing these gaps calls for targeted, multilingual awareness campaigns, farmer training, and institutional mechanisms that are locally grounded but scientifically sound.

Policy efforts must go beyond reactive culling and compensation. While compensation is necessary, it is often inadequate to match the full extent of economic loss. Strategic investments are needed in veterinary infrastructure, mobile veterinary units, diagnostic laboratories, and frontline personnel. At the same time, regulatory frameworks must evolve to support risk-based trade restrictions, state-level surveillance protocols, and inter-agency coordination for effective outbreak response.

One promising approach is the adaptation of compartmentalization concept; currently applied in commercial systemsfor clusters of smallholder farms. This could allow disease-free pockets to maintain operations and trade even during regional outbreaks, provided they follow uniform biosecurity standards and are supported by state veterinary systems.

SUMMARY

African Swine Fever (ASF) has emerged as one of the most formidable threats to pig farming in north eastern India. While the disease itself is non-zoonotic and poses no direct risk to human health; its impact on rural livelihoods, animal health systems, and regional economies has been deeply destabilizing. The outbreaks since 2020, particularly in Assam, Arunachal Pradesh, and Mizoram, have laid bare the structural systemic weaknesses that underlie India's pig production systems, most notably in smallholder and backyard farming settings.

In sum, effectively managing in north eastern India demands a layered approach that integrates community participation, veterinary preparedness, and inter-departmental coordination. A one-size-fits-all model will not work in a region defined by its diverse landscapes, farming practices, and cultural traditions. Instead, region-specific strategies, anchored in scientific evidence, responsive governance, and public trust, must be adopted. These should include locally adapted biosecurity measures, tailored compensation frameworks, and integrated disease surveillance systems. With the right policy, vision and sustained investment, ASF can be controlled, enabling pig farming to endure as a resilient and vital source of livelihood and food security across the region.

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Wallago attu (Freshwater shark) culture in pond: Prospects for farming in Manipur

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Wallago attu *(locally known as Sareng) is a highly valued culinary delicacy in Manipur, northeast India. In view of its cultural and economic relevance, this study focused on developing culture techniques and seed production protocols to support farming of this vulnerable species. Broodstock were raised in ponds (0.2–0.5 ha) at Laphupat Tera, Imphal, using wild-caught juveniles. To promote maturation, the brooders were fed with live carps and tilapia spawn and fry, achieving maturity within just over a year. Induced breeding of selected broodfish (average 5080 g for females and 1024 g for males) was successfully conducted using a synthetic hormone combination (sGnRH analogue + Domperidone) at dosages of 0.8 ml/kg for females and 0.4 ml/kg for males, which triggered spawning within 6–8 h. Fertilized eggs (1.8 ± 0.2 mm) hatched within 18–24 h at 26.2–26.8°C. Nursery rearing of the cannibalistic larvae, were fed with live zooplankton and carp spawn, resulted in fry attaining lengths of 3.8–5.42 cm and weights of 2.0–2.8 g within 15 days, with 65–70% survival. Grow-out trials in ponds (0.02–0.75 ha) showed that stocking 20-day-old fingerlings (100–120 mm) at 2000–3000/ha, with regular size segregation and feeding of live fish, allowed marketable harvest within 5 months. The findings highlight that periodic segregation of fry and fingerlings is essential to reduce cannibalism and ensure successful culture of this commercially important species, contributing to both aquaculture development and conservation.*

Keywords: Cannibalism, Commercial farming, Induced breeding, Synthetic hormone, Sareng

WALLAGO *attu* is a large freshwater catfish found in rivers, reservoirs and connected watersheds across the Indian subcontinent, including India, Pakistan, Bangladesh, Nepal, Burma, Sri Lanka, Thailand, Vietnam, Kampuchea and Indonesia. This bony fish is commonly known as freshwater shark, belonging to the family Siluridae, grows to about 2 m, weighing over 45 kg,with a calculated lifespan of about 10 years. Its rapid growth, majestically elongated and silvery body and highly nutritious flesh encourage investigation into its aquaculture potential. The present decline in yield from wild fisheries lists *W. attu* as an endangered species. It was assessed for the IUCN Red List of Threatened Species in 2019 and listed as Vulnerable under criterion A2d. Increased consumer demand is stimulating the development of intensive aquaculture for this species in Asian countries. Methods for induced spawning and successful hatching of eggs were successfully performed by various, however, a major constraint in successfully rearing *W. attu* larvae is the high mortality rate due to intense cannibalism during early life stages. Known as “Sareng” in Manipuri, *Wallago attu* is a highly preferred and royal delicacy. In Manipur, a grand feast is generally considered incomplete without Sareng. However, capturing Sareng in Manipur have virtually ceased and the population of this species has been drastically reduced. Consequently, a huge quantity of frozen Sareng is imported from other states. Very recently, the Chief Minister of Manipur declared the revival of Sareng in the state, the need of the hour. In this regard, the ICAR Research Complex for NEH Region, Manipur Centre, has worked closely with dedicated fish farmers to develop culture and seed production technologies of Sareng.

Wallago attu is a bottom feeder with nocturnal habits, feeding at night and exhibiting highly carnivorous behavior. In the wild, it feeds on fish such as *Channa* species, *Parambassis* species, other small fishes and


Brood fish selection for breeding


Injecting hormone


Examining of eggs

prawns. The feeding frequency in the adult stage is higher in all months except July and August. It has an enormous mouth and a deep fissure extends far behind its eyes. Jaw teeth are arranged in broad rows with two small patches of vomerine teeth. *Wallago attu* generally breeds in its natural habitat during the rainy season. Seeds are available from June to August in the rivers and tributaries of the Barak River at Jiribam and can be collected from breeding grounds.

Brood stock development

Wild *Wallago attu* specimens weighing 45.2±1.2 g were procured from the Borobekara River (24°37′57.1″N; 93°05′57.4″E) in 2022. They were stocked @2000/ha in a pond at Lafupat Tera, Imphal West district, Manipur (24°30′17.3″N; 93°52′30.7″E) on June 3, 2022. The fish were fed with spawn of common carp, Tilapia, *Labeogonius*, etc. @10–15 lakh every 10 days, followed by 10–15 lakh fries of carps and tilapia every 15–25 days.

Brood stock pond

The broodstock rearing unit is an essential component for the successful captive breeding of any fish species. The ideal pond size for rearing *W. attu* is between 0.2 and 0.5 ha with a water depth of 1.0–1.5 m. The adult fish prefer to eat live fish or aquatic organisms. Proper feeding is required for optimal growth and to maintain a healthy fish population, especially for brood fish. The fish were fed with live fish at 1.2–2% of their body weight per day. Live fish, including tilapia, grass carp, common carp and silver carp fingerlings, were added to the pond to ensure a steady food source. *W. attu* matured in 1+ years. Water quality was maintained at pH 7.0–7.5, dissolved oxygen 5.0–8.2 ppm and total alkalinity 72.5–89.2 ppm.

Selection of brooders

It usually breeds in June-August in the valley of Manipur. Efforts towards the induced breeding has been made by the ICAR Research Complex for NEH Region, Manipur Centre, Imphal. The fish were observed to be fully mature during the first half of July 2024, showing distinct secondary sexual characteristics in males and females. Ripe males and females can be easily distinguished: The male has an elongated and pointed genital papilla near the anus, while female has a spherical, tubular-shaped reddish vent. A swollen abdomen in the female indicates readiness to spawn. The maturity of the female can be examined by gently inserting a soft, flexible catheter into the vent.

Induced breeding

Synthetic hormones such as Ovatide, Ovaprim or Wova-FH can be used for induce breeding of *Wallago attu*. A fully mature pair comprising two males (average body weight 1024 g) and one female (5080 g) was selected from the rearing pond for induced breeding. The brood fish were acclimatized in a circular tank (10′ diameter, 1.2 m water depth) for 10 prior to hormonal injection. An injection of salmon gonadotropin-releasing hormone (sGnRH) analogue (20 mg) and Domperidone (10 mg) in propylene glycol IP was administered at 0.8 ml/kg body weight for the female and 0.4 ml for the males in the evening.

The injected fish were released into a circular spawning tank (10′ diameter, 1.2 m water depth) with a water flow rate of 2.5 L/sec. Spawning was observed 6–8 h after hormone injection at a water temperature of 26.5°C. Fertilized eggs were slightly yellowish-green, spherical, demersal and sticky while unfertilized eggs were paler and opaque.

Hatching operation

Fertilized eggs were transferred to a series of hatching trays. Water was dripped over the hatching trays from an overhead tank through a perforated PVC pipe. The fertilized eggs hatched 18–24 h post-fertilization at temperatures of 26.2–26.8°C. The freshly hatched larvae were slender, straight and transparent, gradually tapering towards the tail and measured 4.5 mm long and weighed 1.5 mg. They do not take exogenous food for about 12–24 h at 26°C. The yolk sac is fully absorbed on the 2nd day after hatching, by which time the hatchlings grow to 7.5–9.0 mm long. The spawn can be kept in the incubation unit until the yolk sac is absorbed and then shifted to separate tanks for nursery rearing.

Nursery rearing of *Wallago attu*

The early larval stages are the most critical and vulnerable in the life cycle of *Wallago attu*. Once the yolk sac is fully absorbed on the 2nd day after hatching, it is referred to as a post-larva. The post-larva starts feeding on exogenous food. The young fish begin

Wallago attu nursery

Wallago attu fry harvest for segregation

12 days old *W. attu*

feeding on minute zooplankton such as *Moina*, *Daphnia* and copepods. *Wallago attu* seed is generally classified into three categories: Spawn, fry and fingerling stages. For nurseries, small ponds of 0.02–0.10 hectare with a water depth of 1.0–1.2 m are ideal, while fry production can take place in larger areas up to 0.25 ha. The ideal stocking density in a nursery pond is 10–12 lakhs/ha. In nurseries, spawn is stocked after acclimation to the new environment, ideally in the morning or evening. At stocking, the water depth should be below 40 cm and can be increased after 4–5 days. A low initial water depth is beneficial for *W. attu* spawn. Plantain leaves can be placed on the water surface to protect the juvenile fish from predators like birds and intense sunlight. *W. attu* fries exhibit cannibalistic and highly predatory tendencies. Therefore, a plentiful food supply in the nursery is crucial.

Small fish, such as the spawn of carp, tilapia, and silver barb, are provided as feed. *Wallago attu* fry grows at an incredibly fast rate in the first 10–15 days under these conditions. Every seven to eight days, the fish are sorted and separated into groups of comparable size to avoid cannibalism. The fish reach a length of 3.8–5.42 cm and a weight of 2.0–2.8 g in 15 days, with a survival rate of 65–70%.

Water quality of nursery pond

They prefer naturally occurring plankton, which is promoted by pond fertilization. After removing unwanted predatory and weed fish, nursery ponds are limed according to soil pH. The ponds are then fertilized with chemical fertilizers and organic manures such as raw cow dung, chicken droppings or both. The most successful combination is 200 kg of poultry droppings, 750 kg of semi dry cow dung, 3–5 kg of urea and 2–3 kg of single superphosphate. A high manure dose should be avoided just before stocking. To improve water quality, Green AQ (Green Biotech Ecosolution) was also applied at 4 L/ha.

Wallago attu farming

Varying production levels have been achieved using packages of practices developed by the ICAR Research Complex for NEH Region, Manipur Centre, in collaboration with two progressive farmers. *Wallago attu* was cultivated in ponds ranging from 0.02–0.75 ha in area and 1.5–2.0 m in depth across different locations in the Manipur valley. The management techniques for *W. attu* culture can be broadly categorized into pre-stocking, stocking and post-stocking activities, involving biological and environmental modifications.

Ponds are cleaned, treated with lime, filled with fresh water, manured as needed and stocked with fish spawn prior to stocking *Wallago attu*. Fingerlings over 100 mm in size are recommended for stocking in grow-out culture ponds. *W. attu* is a cannibalistic bottom feeder that primarily preys on smaller fish. However, the urge to prey on other fish or engage in cannibalism is reduced when the stomach is full. Suitable, nourishing feed is required for complete growth and good survival rates in captivity. Effective feed management and stocking of equal-sized fish can mitigate cannibalism during the rearing phase. Fingerlings (100–120 mm or 20 days old) may be stocked at densities of 2000 per hectare for non-segregated rearing and 3000 per hectare for segregated rearing. Periodic segregation is advised for higher

20 days old fingerling

A harvest of *Wallago attu* seed for sale

Wallago attu seed harvest at S. Rohendro's Farm stocking densities. Depending on the availability of fish seed, *W. attu* stocked in June, July and August can be harvested after 5 months of rearing, based on consumer demand.

SUMMARY

The study demonstrated that *Wallago attu* (Sareng), a culturally and economically significant fish in Manipur, which can be successfully bred and farmed under controlled conditions. The results highlighted the feasibility of captive broodstock development, induced breeding and seed production, which together provide a strong foundation for large-scale aquaculture of this vulnerable species. Despite challenges such as cannibalism during the early life stages, appropriate management practices such as regular size segregation, proper feeding and careful nursery and grow-out rearing proved effective in ensuring survival and growth. The successful outcomes not only open avenues for commercial farming but also contribute to the conservation and revival of this species in Manipur. It is recommended that wider adoption of these protocols by farmers, supported through training and extension works will enhance local production, reduce dependence on imports and help to safeguard the long-term sustainability of *W. attu* in its native waters.

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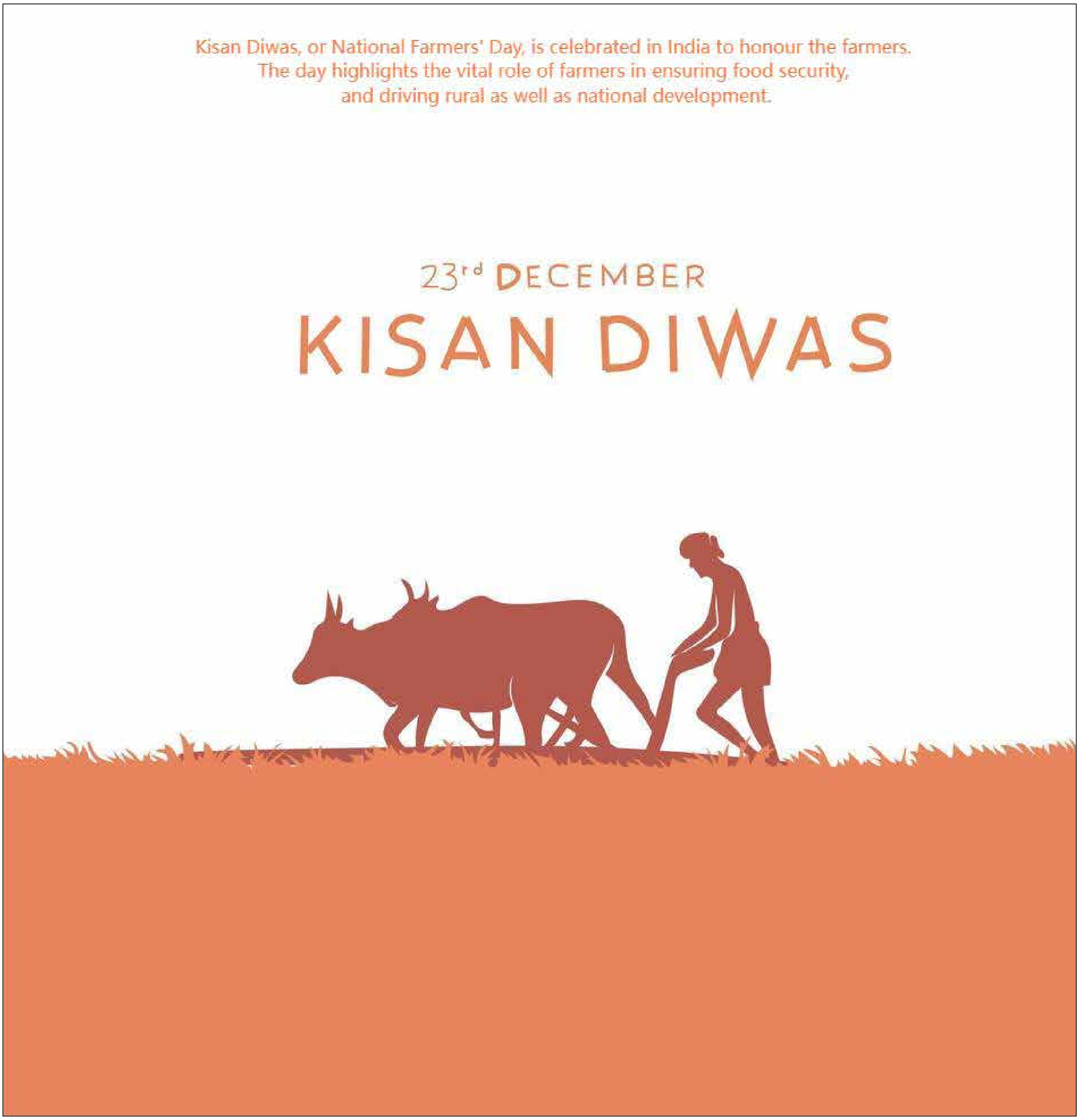

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Quality cashew production techniques in Garo hills, Meghalaya

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Despite the high economic potential of cashew as a valuable trade commodity, its widespread low yields remain a major challenge, requiring urgent and effective solutions. Despite numerous research initiatives aimed at enhancing cashew production and productivity, the crop has yet to realize its maximum potential. Adopting improved production practices could lead to higher crop yields, increased foreign exchange earnings, better livelihoods for growers, and enhanced consumer health through more nutritious products. It would also drive industrial growth through the production of processed nuts and elevate overall output across the production value chain. This article focuses on the improved production techniques of cashew for quality production and productivity in Garo Hills, Meghalaya.

Keywords: Consumer health, Foreign exchange earnings, Processed nuts

CASHEW (*Anacardium occidentale* L.) commonly known as 'gold mine of wasteland' and'poor man`s crop, rich mans food. Cashew nuts are a rich source of nutrients, containing approximately 21% protein, 47% fat, 22% carbohydrates, 0.45% phosphorus, 0.05% calcium, and 5 mg of iron per 100 grams. The lipids in cashew kernels are particularly high in unsaturated fatty acids, including oleic acid (73.7%), linoleic acid (7.67%), and stearic acid (11.2%). Cashew kernels are considered cholesterol-free, largely due to their high content of mono-unsaturated fatty acids, particularly oleic acid, which is known to help lower blood cholesterol levels. Thiamine, niacin, and vitamin E are among the few vitamins found in cashew kernels. This crop has its origin in Brazil and it was brought to India by the adventurous Portuguese travelers when they came sailing down the Indian coasts in the 16th century to control soil erosion on the coasts. Cashew has adapted well to Indian agro-climatic conditions and is now widely cultivated along the coastal regions on the east coast in Andhra Pradesh, Odisha, Tamil Nadu, and West Bengal, and on the west coast in Maharashtra, Goa, Karnataka, and Kerala. It is believed that cashew was introduced to the north eastern states particularly Meghalaya, parts of Assam, Mizoram, and Tripura during the 1950s as part of efforts to reclaim land previously used for shifting cultivation. Cashew has become one of the most popular commercial horticultural crops globally. Its consumption continues to grow worldwide and is expected to maintain a positive trend. Beyond its economic value, cashew industry in India supports livelihoods of over 1.5 million people, primarily women, working in both farms and processing units located in rural areas. This highlights the crucial role of cashew sector in promoting social and economic security in rural India.

Area and production

Though cashew was introduced as a soil binding crop, it has now proved to be a high-income generating crop in degraded and marginal land. In the year 2022–23, cashew cultivation in Meghalaya covered an area of 10,616 hectares, yielding a total production of 18,363 metric tonnes.

Table 1. Status of cashew in Meghalaya (2022–23)

District	Area (ha)	Production (MT)	Productivity (kg/ha)
East Garo Hills	235.0	294.0	1251.0
North Garo Hills	129.0	145.0	1124.0
West Garo Hills	4013.0	7578.0	1888.0
South West Garo Hills	1663.0	3233.0	1944.0

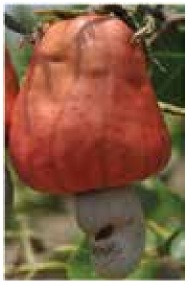
South Garo Hills	4576.0	7113.0	1554.0
Total	10616.0	18363.0	1552.2

Source:https://megagriculture.gov.in/PUBLIC/dwd_docs/ApprovedSLCSR2022_23.pdf

Cashew varieties suitable for Meghalaya

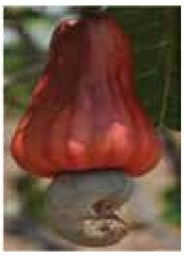
Cashew varieties are broadly categorized into three flowering types based on their blooming period viz. early varieties (Flower during December–January), mid-season varieties (Flower in February) and late varieties (Flower in March). Since cashew is typically harvested 60–70 days after fertilization, early and mid-season varieties are more suitable for the Garo Hills region of Meghalaya. These varieties help farmers avoid the early onset of rains, which can negatively affect both the yield and quality of the nuts.

VRI-3: This is an early-flowering cashew variety, blooming during December-January in the eastern regions of India. It features a compact canopy and an intensive flowering habit, with approximately 12.1% perfect flowers. This variety is highly responsive to pruning and is well-suited for high-density planting systems. Apple colour: Red, juice content: 72.8%, yield: 11.68 kg/tree, nut size: 7.2 g, kernel weight: 2.16 g, shelling percentage: 29.1%, kernel grade: w 210 export standard.

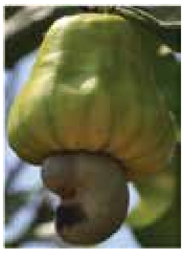


Vengurla-1: This early-flowering cashew variety blooms in December–January and features a compact canopy with a very intensive flowering habit. Apple colour: Yellow with 65.0% juice content, nut yield: 19 kg/tree, nut weight: 6.2 g, kernel weight: 1.39 g, shelling percentage: 31%, kernel grade: W 240.

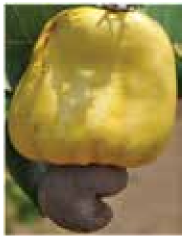
Vengurla–4: This mid-season cashew variety flowers in February. Branching habit: extensive, canopy type: open, bearing habit: cluster with a high sex ratio, apple colour : red with 76% juice content, nut yield: 17.2 kg/tree, nut weight: 7.7 g, kernel weight: 1.91 g, shelling percentage: 31%, kernel grade: w 210 (export grade).



BPP 8: This cashew variety is a mid-season hybrid, known for its compact canopy and intensive branching habit. Flowering season: February–April, apple colour: Yellow, juice content: 64%, nut yield: 14.5 kg/tree, nut weight: 8.2 g, kernel weight: 1.89 g, shelling percentage: 29%, kernel grade: w 210 (export grade).



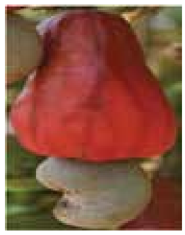
Bidhan Jhargram-2: Flowering Season: January–February, Canopy: Compact and erect, leaf colour: massive bottle-green, flowering density: intensive, with 12.8 inflorescences/m², fruit colour: Golden yellow, average apple weight: 63 g, juice content: 68.9%, nut weight: 9.2 g, kernel weight: 2.85 g, shelling percentage: 32%, kernel grade: w180 (export grade), average yield: Consistently over 11 kg/tree from 10 years onward.



Bidhan bonsai kaju: It is a very early variety. The variety is a highly pruning responsive which can be accommodated in high density, ultra-high density planting systems. It is a cluster bearer with average of 21.50 no. of nuts/tree and yield is 14.60 kg/tree. Apple colour: Red, apple weight: 34.5g with 71.3% juice content. Nut weight: 4.80 g, kernel weight: 1.5 g, shelling percentage: 33.06%, kernel grade: W320 (export grade).

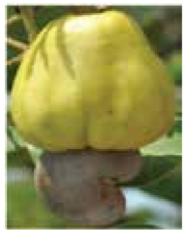
Jhargram-1: It is an early variety flowers in January-February. The tree exhibits a medium-compact canopy with a vigorous branching pattern. Apple colour: Yellow with 65.5% juice content, nut yield: 8.5 kg/tree, nut weight: 5 g, kernel weight: 1.5 g, shelling percentage: 30%, kernel grade: W 320.

Bhubaneswar-1: This variety is noted for its cluster-bearing habit, producing approximately 12 fruits per bunch. The flowering season lasts for around 70 days, from January to March. Nuts weight: 4.6 g, nut yield: 10.5 kg/tree, kernel weight: 1.47 g, shelling percentage: 32%, kernel grade: W 320.



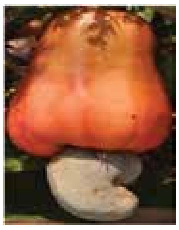
Balabhadra: This variety flowers early (December-February). Apple colour: yellow, apple weight: 56 g with 78.33% juice recovery. Nut weight: 7.4 g, nut yield: 10.0 kg/tree, shelling percentage: 33%.

Madakkathara-1: It has an intensive branching habit with compact canopy. Apple colour: yellow, apple weight: 56 g with 72% juice recovery. Nut weight: 6.2 g, yield: 13.8 kg/tree, kernel weight: 1.64 g, shelling percentage: 26.8%, kernel grade: W 280.



Poornima: Nut weight: 7.8 g, shelling percentage: 31%, kernel weight: 2.6 g, kernel grade: W 210, nut yield: 14.1 kg/tree, apple colour: Yellow weighing 77.96 g.

Ullal-3: This variety is recognized for its early flowering and high yield potential. Fruiting period: Short duration of 50–60 days, from January to February, branching type: Intensive, canopy type: open, apple colour: red, apple weight: 63 g, juice content: 66.1%, nut yield: 14.7 kg/tree, nut weight: 7 g, kernel weight: 2.1 g, shelling percentage: 30%, kernel grade: w210 (export grade).



NRCC selection-2: It exhibits a mid-season flowering habit in February, with a flowering duration of 74 days. Apple colour: pink, apple weight: 51 g, juice recovery: 76.0%, nut yield: 9 kg/tree, nut weight: 9.2g, shelling percentage: 28.6%, kernel grade: Export grade W 210.

Netra ganga: It is an extremely valuable variety that blooms early and bears fruit for a long time. It adapts well to ultra-density planting systems and responds well to thinning. Bearing habit: Cluster (10–20 nuts per panicle) and nut size: Jumbo (12–13 g), kernels weight: 3.5–5.0g, shelling percentage: 29.9%, kernel grade: W-130–150.

Chintamani–2: It is dense and has many branches. The blooming period occurs in December or January. Apple colour: Red purple, apple weight: 70g, juice content: 60%, yield: 12.4 kg/tree, nut weight: 7.9g, shelling percentage: 30%, kernel weight: 2.35 g, kernel grade: W 210.

Soils and climate

Cashew can be cultivated in various soil types, but it performs best in well-drained brown forest soils, red sandy loam, and light coastal soils that retain moisture well and are rich in organic matter. The ideal soil pH ranges between 5.5 and 7.5, and the water table should be deeper than 1800 mm. Soils with a pH above 8 are unsuitable for large-scale cashew farming. Cashew trees are adaptable to diverse environmental conditions and have become naturalized across vast tropical regions, with their geographic range extending between latitudes 27° N and 28° S. While optimal growth occurs at elevations below 700 m where temperatures consistently remain above 20°C, cashews can also be found growing at altitudes up to 1200 m.

Propagation

As a cross-pollinated crop, seedlings in cashew orchards exhibit variation in yield, nut size, apple colour, and several other traits. Therefore, vegetative propagation is practiced, since clonal progenies are genetically identical to the mother plant, producing more uniform yields and reaching fruiting earlier. Softwood grafting is considered the most effective vegetative propagation method and has been shown to greatly enhance cashew productivity.

Planting

Before planting, chosen site should be cleared of shrubs and other vegetation. Planting pits measuring 1m x 1m x 1m should be dug, spaced either 7.5 m × 7.5 m or 8 m × 8 m apart, allowing for approximately 175 or 156 trees per hectare, respectively. On sloped terrain, pits should be aligned along contour lines to minimize soil erosion. Each pit should be filled with a mix of topsoil, 10 kg of compost, 2 kg of poultry manure, and 200 g of rock phosphate. Grafted cashew seedlings are typically planted during June-July. When planting, ensure the graft union remains above the soil surface. After planting, apply light irrigation, making sure the pits are not waterlogged, especially during the rainy season.

Canopy management

Cashew canopy if not properly shaped and managed from the early stages of orchard development, can grow irregularly, become difficult to control, and lead to reduced yields. A modified leader system or open centre system may be followed for widely spaced plants. It is important to regularly remove sprouts that emerge from the rootstock at consistent intervals. The graft's growth should be encouraged by maintaining a single stem up to a height of 0.75–1 m, achieved by eliminating sprouts or suckers not only below the graft union (stock portion) but also above it. During the first two years of graft growth, it is advisable to remove flower panicles emerging later in the season. This facilitates proper vegetative growth, ensuring the attainment of the appropriate height with robust canopy development. Starting from the third year, plants can be allowed to flower and fruit. To achieve better fruiting, it is important to permit well-spaced branches (4–6) in all directions. Regular pruning, adjusted according to the plant's variety and growth vigor, is crucial for encouraging optimal fruit production.

Nutrient management

Annually, cashew trees take up a significant quantity of nutrients. A 30-year-old tree reportedly removes 2.8 kg N, 0.75 kg P_2O_5, and 1.265 kg K_2O. Nutrient management is very important to get early and high yields in new plantations and to get regular high yields in mature plantations. ICAR-Directorate of Cashew Research, Puttur recommended applying organic manure at 10 kg/tree along with in organic fertilizers i.e. NPK at 500 g + 125g + 125g/tree in two splits during June-July and September-October for optimizing the yield of cashew under normal density planting system. The foliar application of 0.25 % Urea + SOP + SSP each) + 0.25 % ($ZnSO_4$ + Borax + $CuSO_4$ each) + 0.01 % Ammo. molybdenum increased the cashew yield (3.50 kg/plants) significantly over control (2.15 kg/plant). Further, 2% foliar spray of 19:19:19 (complex nutrients available in the market) produced significantly greater fruit set and yield (kg/tree) over control.

Soil and moisture conservation

Cashew is often grown in poor soils, making proper soil management essential to improve nutrient levels. In case of lands owing to frequent exposure to weather conditions, particularly heavy rainfall, top soil is almost completely eroded and the subsoil with poor nutrient reserve is exposed in elevated areas. When the crop is planted in such soils, the yield per tree is generally poor. *In situ* soil and water conservation practices are therefore crucial for harvesting rainwater and ensuring its availability to cashew plants during critical growth stages. This can be achieved through appropriate agronomic measures such as crop spacing, intercropping, and mulching, as well as by enhancing moisture retention using mechanical methods like trenching, bunding, terracing, basin construction, micro-catchments, or contour furrows, with trenching being the most effective. Methods like modified crescent bunds and use of coconut husks have proven effective in reducing annual runoff, soil and nutrient loss, while also improving average soil moisture, plant growth, cashew yield, and overall profitability showing a 40% increase in net profit compared to untreated areas. With proper soil and water conservation, the soil loss can be minimized; runoff water from post-monsoon and pre-monsoon rainfall can be harvested and made available to the plant during the critical period.

Irrigation

Cashew with an extensive root system is generally rain-fed and not irrigated. However, during the initial stages, especially in sandy soils, light irrigation may be provided for better growth and development. Irrigation should be applied only after flowering, starting one or two weeks post-flowering, depending on the specific characteristics of the variety. Therefore, in areas with irrigation facilities, providing water to cashew crops can enhance yield and profitability. It's crucial to note that cashew can not tolerate waterstagnation, flooding, orimpeded drainage, necessitating proper drainage wherever there is a risk of water stagnation.

Intercropping

Inter-cropping has gained popularity with the systemic development of large-scale orchards. It is commonly practiced during the initial years when there is enough space between the cashew rows, aiming to generate income before the cashew trees become productive, control weed growth, minimize nutrient loss, and make efficient use of sunlight and soil resources. Intercropping with vegetable crops such as yardlong bean, okra, cowpea, turmeric, ginger or short-stature fruit crops such as pineapple during early years can provide subsidiary income to growers. Among fruit crops, pineapple has proven to be the most suitable for intercropping or mixed cultivation with cashew plantations during the first seven years. Cultivating tuber crops in the spaces between 15-year-old cashew trees, without disrupting their root systems, provides cashew growers with an extra source of income such as ₹ 84,440/ha (Greater yam) followed by lesser yam (Rs. 66,440) and ₹ 65,350 from elephant foot yam.

After care

Staking the young plant with strong stick is necessary because when the plant grows to a height of 0.75 to 1 m with single stem, the graft is likely to lodge due to wind blow. Cashew plantations must be maintained free of weeds through manual, mechanical, or chemical methods. Mulching the tree basins with organic materials or residues helps control weed growth, deters soil-dwelling insects and disease-causing pathogens, reduces surface evaporation in the summer, and helps regulate soil temperature. Black/silver colour polythene mulch was helpful to conserve soil moisture and to repel sucking insects due to reflections of sun rays by the mulch sheet. The mulching of coir-pith (7.5 cm thickness) has reduced weed growth to the extent of 73.2 per cent in propagation plot followed by 46.00 and 45.16 per cent in top worked trees and nursery plot, respectively.

Pest and disease management

Tea mosquito bug (TMB): It is a major pest of cashew that causes significant damage in many regions worldwide. Of the four species that attack cashew, *Helopeltis antonii* is the most prevalent. Both nymphs and adults feed by sucking sap from leaves and flower clusters. This feeding results in leaf deformation and angular lesions, especially along the veins, which can cause leaves to fall off. During the flowering stage, it leads to inflorescence blight. When the bugs feed on the stalks of young shoots, they create elongated green lesions, sometimes accompanied by gum exudation. Severe damage causes shoot dieback due to the combined effect of bug saliva and fungi entering through the feeding wounds. This stimulates the growth of numerous side buds, producing a dense cluster of growth known as 'witches broom.' In heavy infestations, the trees may appear scorched as if burnt by fire. Bug feeding on developing apples and nuts causes brown sunken spots. The growth of trees is seriously retarded and fruit formation of attacking flowering shoots is reduced. The water based emulsions of pongamia oil (3%) resulted in high mortality of TMB up to 7 days after application, followed by neem oil (3%). Additionally, neem seed extract caused TMB mortality, but at levels below 50%. Likewise, seed extracts of *Annona reticulata* and *A. squamosa* induced less than 50% mortality of TMB.

Cashew stem and root borer: The Cashew Stem and Root Borer (CSRB), *Plocaederus ferrugineus* L., is a major pest attacking cashew trees. Its small larvae bore into fresh tissue, feeding on the phloem and xylem of the trunk and roots, creating irregular tunnels. This extensive tunneling damages the vascular tissues, disrupts the movement of plant sap, and ultimately causes the death of the tree. To manage CSRB, the most effective treatment was applying 250g of *M. anisopliae* spawn per tree combined with 500g of neem cake, resulting in the lowest infestation rate of 7.40%. This was followed by the application of 250g of *B. bassiana* spawn per tree along with 500g of neem cake, which reduced infestation to 11.11%.

Gummosis: The disease is caused by the fungus, *Ceratocystis* species. It is identified by the oozing of a reddish-brown liquid from the main stem and branches, which eventually darkens to black. Longitudinal cracks develop in the infected areas, releasing gum. The inner tissues of the affected parts appear reddish-brown and contain small cavities filled with this reddish fluid. To manage the disease, remove the infected sections by chiseling them out and treat the exposed area by applying Bordeaux paste or wiping it with a copper oxychloride suspension.

Harvesting and yield

Cashew plants start bearing 3 years after planting, however, it is advisable to take the crop from the fourth year onward to encourage proper vegetative growth. Harvesting commences from February and continues till May depending on the varieties. Harvesting is usually carried out manually by picking up the nuts from the ground, which is highly labour-intensive. Alternatively, it is done by using a small basket or sack attached to a ring at the end of a long stick. The highest quality nuts are obtained when freshly fallen fruits are harvested. The area beneath the trees should be kept free of weeds and cleared regularly to ease nut collection.The average yield is about 10–15 kg/tree of raw nut and 80–100 kg/tree of cashew apple from the 10^{th} year onward with proper management practices being followed.

Post-harvest management

After harvesting, cashew apple and nut should be separated using a nylon thread or sharp knife. The nuts should be air dried on concrete floors, drying mats or tarpaulins under shade for 3–4 days. While drying, the nuts should be turn frequently to ensure uniform drying. Well-dried nuts produce a rattling sound when turned on the drying floor. Dried nuts should be kept in gunny bags, safeguarded from rodents, and placed on a platform raised above the ground, ensuring there is space around all sides of the storage area. Properly dried raw nuts with a moisture content of 8–9% can be stored for up to one year without losing quality. Similarly cashew apple should be cleaned and kept for preparation of cashew apple products. Cashew apples can be maintained for 4–6 days by dipping with 1% mustard oil, 3 weeks by dipping with 0.25% citric acid and 500 ppm SO2, 4–5 weeks at 0–1.5°C and relative humidity 85–90% and 4–5 months with deep freezing.

SUMMARY

Lately, cashew cultivation has gained more attention across India because of the numerous benefits the crop offers. It was introduced to India as a soil binding crop but has now proved to be a high-income generating crop in degraded and marginal land. Its climate resilience provides an additional advantage compared to other perennial crops. Reliable markets and processing infrastructure in India have given farmers greater confidence. Currently, there is a strong demand for cashew both in domestic and international markets. Considering the growing demands, it is imperative to enhance the production of cashew by increasing productivity through adoption of scientific management practices, development of new plantation and replanting of old senile and uneconomical cashew gardens with high yielding varieties.

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Farm mechanization in northeast Indian hill agriculture

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Limited farm mechanization in the hill agriculture of northeast India resulted into low farm power availability (0.37–0.69 kW/ha). Steep hill slopes, fragmented land holding, poor infrastructure and limited connectivity hinders the technology dissemination process, resulting poor farm productivity. Affordable community centric farm mechanization efforts are essential to reduce labour cost, efficient input application, water conservation and post-harvest management of farmers' produce. High initial investment also bars the widespread adaptation of modern farm mechanization technologies. Establishment of community specific need based custom hiring centres, skill and technical expertise development among the rural youths with public financial support from public institutions became one of the most effective options to expand the future prospect of farm mechanization across northeast India.

Keywords: Custom hiring centre, Farmer income, Portable light weight machineries, Post-harvest, Skill development

DIVERSIFIED traditional subsistent farming systems with limited capacity for agricultural mechanization have epitomized the foundation of the local economy and daily rural livelihood of the native population of the northeast Indian hills. Complex accessible terrain features (lack of arable lands), limited infrastructure availability, and low adaptation rate of modern agricultural technologies have still added paramount difficulties to the region's struggle to shift from 'food deficit' to 'food surplus' status. In courtesy of rising food demand for nourishing the ever-increasing regional population and rapid urbanization trend in present days, the traditional agricultural production system needs to be evolved. Mechanization contributes to the diversification of Indian agriculture, shifting from traditional practices to the cultivation of commercial crops. The traditional crop production system of the northeast Indian hills relied heavily on human and animal labour and has significantly decreased over the years, traversing the rising scope of advanced farm mechanization suitable for hill agriculture. Farm mechanization enhances farming operations, decreases labour-intensive time-consuming tasks, reduces drudgery, boosts output, and raises farmers' profit. Nevertheless, the present status of agricultural farm mechanization in India is approximately 40–45%, compared to 95% in the United States and 75% in Brazil, indicating that India continues to lag far behind the developed nations in farm mechanization.

The Government of India (GoI) facilitates agricultural mechanization, viz. tractors, power tillers, combine harvesters, irrigation pumps, plant protection devices, threshers, improved implements, and hand tools, etc. through Sub-Mission on Agricultural Mechanization (SMAM) initiative. In the Indian context, Punjab and Haryana have the highest Farm Power Availability (FPA) of 6 KW/ha and 5.50 KW/ha, respectively, indicating highest adoption rate of farm mechanization against the least mechanized northeast Indian states. In contrast with the relatively higher farm power availability (kW/ha) in Tripura plains, steep undulated hills, rough terrain, limited communication service, and expensive transportation costs often contribute to the low mechanization status of India's north eastern hill region. Furthermore, the small, localized, and scattered farm holding increases difficulties in implementing and adapting readily available large-scale automation options across the other mainland Indian states.

Table 1. Farm power availability and electrification status (rural and urban) in different northeast Indianstates

Sl. No	States	Farm power availability (kW/ha)
2.	Arunachal Pradesh	0.57
3.	Meghalaya	0.37
4.	Manipur	0.65
5.	Mizoram	0.68
6.	Nagaland	0.62
7.	Sikkim	0.69
8.	Tripura	1.63

Source: FICCI and PwC 2019, WAPCOS Limited 2020

Mechanization and availability of agricultural power, including mechanical, electric, and human and animal power, are closely associated. The proportional positive association between electricity availability and farm mechanization signifies an enormous opportunity for future expansion of small-scale, lightweight, and adaptable gear towards a potential increase in farm power availability, efficient farm labour management, meeting the location-specific farmer's demand, and associated skill development, particularly among the unskilled rural youths, in the highly electrified (100% rural and urban electrification; Ministry of Power 2022) north eastern hill states of India.

Unique challenges in mechanizing hill agriculture

Since the late 1960s, Green revolution banked on the critical role of promoting farm mechanization in India, helping to boost agricultural productivity through the adoption of high-yield varieties, irrigation facilities, and machine-based farming. In contrast, hill agriculture provides a number of unique problems that restrict the adoption and efficiency of technological automation. As compared to the highly mechanized lowlands where large-scale machinery can be easily deployed the harsh topography and socioeconomic conditions of hill areas make mechanization challenging. Mechanization is necessary to improve work efficiency, attending sustainability, and boost up agricultural production system through managing several labour-intensive seasonal farm operations likely, weeding, seedbed preparation, etc. in the high rainfall receiving summer/ rainy seasons, and conjunctive use of water during the winter months across the northeast Indian states. The accounted challenges for farm mechanization in north east Indian hills include:

- ***Steep slopes and difficult terrain:*** Conventional tractors and heavy mechanical machines are difficult for sloping fields because they might tip over, and the steep inclines make it difficult to operate huge motorized equipment efficiently.
- ***Small and scatter farm lands:*** The majority of hill farmers hold small terraced fragmented land, limiting the utilization of large-scale farming machines, mostly designed for flat lands. This demands the research needs to design location-specific small-scale farm machinery.
- ***High initial investment and limited financial access:*** Specialized machinery for hill agriculture, such as small horsepower (hp) power tillers and lightweight machinery, is costly. Furthermore, farmers sometimes lack access to loans or government subsidies to fund automated alternatives. Low farm profitability further discourages high investment in farm mechanization in hill agriculture.
- ***Limited infrastructure, regulatory network and road connectivity:*** Poor road connectivity, and inadequate regulatory framework in the hilly areas, makes transportation of farm machinery challenging. Moreover, the absence of adequate storage, maintenance and repair facilities further hinders the scope of farm mechanization in hill farming.
- ***Environmental risks:*** The use of heavy machinery often accelerates soil erosion or facilitates soil compaction from the use of heavy machinery in high-altitude locations having variable weather, making automated farming difficult. Heavy rains, landslides, and frequent climatic fluctuations exacerbate agricultural mechanization attempts.
- ***Limited community awareness,technically efficient and periodic availability of skill labour force:*** Limited sensitization on community-level usage of farm machinery, low skill, scarce availability of efficient labour force, and deformed extension services often discouraged the expansion of cultivatable land area and extensive adaptation of farm mechanization among the tribal farming communities of northeast India.

Farm mechanization in the hill agriculture system of northeast Indian hills

Despite increased mechanization, traditional farm implements remain popular in northeast India's hill regions due to their adaptation to the terrain and ease of use. These tools, which are predominantly powered by human or animal, are required for a variety of agricultural tasks, including land preparation, sowing, weeding, harvesting, and post-harvest processing. Modern small and lightweight farm machinery made expressly for hill agriculture contributes to overcoming the obstacles in hill farming systems by providing multipurpose options. These devices not only increase efficiency but also promote sustainable agriculture practices by reducing soil degradation and optimizing input utilization in hill agriculture.

The use of farm machinery appears critical for increasing agricultural output, lowering labour intensity, and boosting sustainability in hill regions. Because of the undulating topography, tiny and scattered landholdings, and unpredictable weather circumstances, traditional large-scale agricultural machinery is frequently unsuited for hilly terrains. Instead, lightweight, compact, and adaptable technology suited to steep slopes and tiny terraces is required. Mechanization in hill agriculture improves field preparation, weed management, irrigation, harvesting, and post-harvest processing, resulting in greater efficiency and profitability for the farmers inhabiting the northeast Indian hills. However, the scope of extensive heavy farm mechanization in *Jhum* (shifting cultivation) fields of the northeast Indian hill region is limited to check soil erosion and ecological sustainability. Hence, small-scale hand-operated tools remain the most promising option in Jhum farming. However, the potential community-based farm mechanization options in low-lying paddy-based agriculture system remain economically profitable options for the farmers in the Lusei hills of Mizoram, Manipur, and Naga hills of the Patkai range, through a reduction in labour engagement for diverse farm operations, easing manoeuvrability and engaging versatile works. In Sikkim Himalaya, traditional organic agricultural practices are no longer sufficient to supply the demand for grains, pulses, and oilseeds. Being India's first organic state, farming is mainly carried out on terraced slopes, with very low farm power availability. The energy needed for agricultural operations increases as the slope percentage of the land increases. Therefore, mass-scale adaptation of improved crop cultivation methods and productivity enhancement through extensive need-based mechanization are at the topmost priority under the steep hill slopes and narrow terraces of northeast Indian hills. Our farm mechanization policy should aim to reduce the dependency on draught animals and human labour and promote community adaptation to mechanized hill farming. Some of the key benefits of farm mechanization in hill farming systems of northeast Indian states are summarized below:

- ***Managing labour-intensive tasks:*** In traditional crop cultivation, diverse farm operations, viz. ploughing, sowing, intercultural, harvesting-threshing, etc. require ample human labour engagement, boosting the rural economy. However, higher daily wages (₹500/day) often reduce farmers' profitability in northeast Indian hills. The extent of labour engagement and ploughing time requirement often depends on weed density and other field conditions in hill agriculture of northeast Indian hills. In Sikkim, controlling weeds is one of the most difficult issues in organic farming due to the state-imposed ban on conventional herbicides. Replacing traditional ploughing methods with a small power weeder can dramatically reduce labour needs, boosting weed management efficiency, soil aeration, and crop health. Lightweight models (35–40 kg), with continuous running hours (2.5–3.0 h) and adjustable handles are suitable for terrace


a


b


c


d

(a) Field demonstration of light weight power weeder (b) Use of chaff cutter in livestock farming (c) HDPE pipe lining for storage (d) Foliar spray of sea weed extract through manually operated sprayers in hill agriculture at Dzongu, North Sikkim farming and can be easily transported from one terrace to another by 2–3 persons. Ploughing operation in 1-acre terraced land traditionally requires one pair of bulls and 3–4 labour engagements involving 7–8 hof continuous engagement with other recurrent expenses. In contrast, farm mechanization engaging mini power weeder led to a considerable reduction in labour intensity (>60%), time (~80%), and cost expenses (50%). However, ploughing of agricultural hilly lands with undulating topography (without terracing) accelerates soil erosion. Mechanical hand weeding becomes extremely labour intensive and time-consuming. Furthermore, mechanical weeders assist farmers in keeping weed-free fields and orchards with less manual labour; thereby enhancing productivity and sustainability in organic farming in Sikkim Himalaya.

- ***Precise application of agricultural inputs:*** Traditional land preparation techniques involving basal application of compost, manure, and biofertilizers are more labour-intensive, costly, and time-consuming in northeast India's mountainous regions. Traditional farmyard manure (FYM) and compost applications followed by fertilizers are spread manually over the fields engaging 4–5 labours/day in 1 acre of land area. Moreover, transporting bulky organic manure in up hills are labour intensive and facilitate uneven distribution, decreased soil fertility, and lower input use efficiency in hill agriculture. In hilly states like Himachal Pradesh, Uttarakhand, and Arunachal Pradesh, soluble fertilizers, synthetic pesticides, and herbicides are often applied using a knapsack sprayer which increases the risk for farmers due to prolonged exposure to chemicals. Farm mechanization using power sprayers and automated pesticide applicators facilitates uniform coverage, and reduce wastage and associated health risks. In organic states like Sikkim where chemical pesticides are not used, application of seaweed extract, neem-based, cow urine formulations, and microbial solutions are widely used for pest control. The application of bio-pesticides using power sprayers has brought significant benefits, resulting in higher soil fertility and better crops.
- ***Increased productivity and income:*** Mechanization increases cropping intensity, and crop diversification, and minimizes post-harvest losses in organic farming resulting in better farm incomes. The use of chaff cutters significantly reduces daily labour requirements in terms of work hours from one hour to 10–15 minutes for the preparation of 50 kg of livestock feed in a commercial animal-rearing venture in Sikkim Himalaya.
- ***Water conservation and efficient irrigation:*** The intensification of the winter water scarcity problem depends on the extent of adaptation for efficient water management techniques at both micro and mini-watershed levels. Motorized water pumping system may be useful to lift water from perennial streams in the low-lying river banks, while HDPE pipe-lining carrying gravity flow water from perennial streams and springs to the surrounding catchment areas of a watershed for optimization of seasonal water usage using sprinklers and drip irrigation systems in up-hill crop fields. In Sikkim, HDPE pipe lining for diversion-based irrigation systems from the perennial steam became an effective water management option in both micro and mini-spring sheds.
- ***Post-harvest processing through custom hiring centres:*** Higher cost involvement still hinders the extensive mechanization in the post-harvest processing and management sector of northeast Indian hills. The advantages of diversified farm products get nullified by the non-availability of post-harvest management, packaging, and storage facilities for the majority of perishable agricultural produce. Therefore, the relative contribution from north eastern hill agriculture to the local market economy is maintained; but reduces the competitiveness for the local farm products to an export-based free-global market economy.

Establishing village-level community-based custom hiring centres (CHCs) offers access to mechanical technologies for post-harvest processing and packaging towards reducing post-harvest losses and increasing the marketability of local farm produce through efficient market chain development. Small and marginal farmers inhabiting distant locations of remote tribal villages, lacking their financial means to invest in need-based equipment facilities, might get access to the community-based CHCs, as an alternative to effectively process their farm produce. Cluster-based CHCs established in the northeastern hill states under the Tribal sub Plan (TSP) projects of ICAR-NEH provided ample opportunities to the hill farmers in the mechanization for post-harvest processing, value additions, and marketing.

Technological innovations are still lagging in several sectors of post-harvest processing. In particular, the large cardamom is frequently grown on steep slopes without terracing in Sikkim; now rapidly expanding acreage in Nagaland and Arunachal Pradesh. However, post-harvest processing remained still challenging. The farmers compromise the quality of capsules processed through traditional bhattis that require less fuel. The enormous fuel consumption and time involved in processing large cardamom capsules using modified bhattis limits the large-scale adaptation among the tribal farmers of northeast India despite retaining good quality and preventing discoloration of final products. Eco-friendly biodegradable areca nut leaf plate making has substantiated future potential in agro-waste recycling and rural women empowerment, towards sustainable economic development across the lower Assam belts (including Mizo hills) of northeast India. Despite these benefits, the use of automation in the agriculture sector still confronts problems such as high prices, a shortage of tailored machinery, and limited farmers' knowledge. Government incentives, training, and location-specific

Combustion drying of large cardamom in (a) Traditional and (b) Improved bhattis at Dzongu, north Sikkim

Operational training on farm mechanization for the tribal Lepcha farmers at North Eastern Region Farm Machinery Training and Testing Institute in Bishwanath Charali, Assam

research are needed for widespread adaptation in hill agriculture. Community-based adaptation of hill-specific farm technology can assist in bridging the gap and encourage sustainable mechanized automated farming, even using drone technology.

Capacity building, skill and entrepreneurship development

The sustainability of farm mechanization and custom hiring centers (CHCs) requires supportive skill development programmes. The institutional support (ICAR, SAUs, etc.) on farm mechanization should be coupled with periodic technical training for capacity building and skill development of rural tribal youths. The North Eastern Region Farm Machinery Training and Testing Institute was established in Bishwanath Charali, Assam to develop competent skill-oriented human resources to facilitate farm mechanization in the northeast India. Unemployed educated rural youths should be trained for future widespread agri-entrepreneurship development.

Future prospects

The future prospect of expanding farm mechanization in hill agriculture is primarily dependent on planned interventions from public institutions that solve current mechanization issues in hill agriculture towards increasing productivity, sustainability, and economic feasibility of farm production. Several essential aspects must be targeted to guarantee that mechanization is widely adopted for NEH region in this direction:

Government subsidies and financial support:

- Increased government support and incentives for small and marginal farmers looking to buy or rent small farm machineries through community sharing dynamics.
- Existing initiatives, such as the Sub-Mission on Agricultural Mechanization (SMAM), would be expanded to incorporate additional hilly region-specific interventions.
- Low-interest loans and financial incentives are offered to stimulate investment in farm gear.

Research and development for hill-specific machinery:

- The creation of small, lightweight, and multi-functional farm machinery designed for hilly terrains.
- Portable post-harvest machineries on underutilized location specific crops of NEH region may develop as innovation priority, viz. buckwheat, perilla, jobstear, millets, etc.
- Introduction of solar and battery-powered farm equipment to minimize reliance on fuel and make automation more cost-effective.
- Collaboration between research institutes, universities, and the corporate sector to develop technologies suitable for modest landholdings.

Expansion of custom hiring centres (CHCs):

- Establishment of more CHCs in all areas to provide mechanized tools, machinery for post harvesting, packaging and values addition. Also providing real-time technical assistance when needed.

Training and skill development programmes:

- Large-scale training programmes to teach farmers about the use, maintenance, and advantages of agricultural machinery and entrepreneurship development.
- Women's and youth capacity-building initiatives to enhance involvement in mechanized agriculture

and entrepreneurship.

- Collaboration with agricultural colleges, KVKs, and ICAR institutions to provide skill-building workshops on mechanization in hilly areas.

Strengthening market links and agro-processing units:

- Cooperative models and farmer producer organizations (FPOs) are being developed to enable communal investment in farm machinery and post-harvest processing units.
- Establishing agro-processing hubs in hill regions to produce value-added goods such as processed spices, dried fruits, and organic food grains.
- Policy actions to improve rural road infrastructure and logistics so that market ready product can reach quickly to the retail outlets with cheaper transportation cost.

SUMMARY

Extensive farm mechanization in hill agriculture remained indispensible to increase the productive capacity and efficiency of hill farming systems in northeast Indian hills. Funding support from public sector institutions on the technical innovations and field scale adaptation of portable lightweight handy machineries for profitable crop cultivation and post harvesting processing became essential to increase crop productivity, farming efficiency and farmers income towards better sustainable daily livelihood of the habitants in northeast India. Community sensitization and participation in capacity building programmes aiming technical expertise development on farm machineries and establishment of farmers' need based custom hiring centres on rental basis, will encourage precision farming across the remote difficult terrains of northeast India in the forthcoming future.

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Dragon fruit cultivation:

A potential crop for north eastern hill region

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In India, dragon fruit has been named as Kamalam and though there are many varieties, the commonly cultivated dragon fruit species are, Hylocereus polyrhizu *(Red skin and red flesh),* Hylocereus costaricensis *(red skin and purple flesh), and* Hylocereus undatus *(red skin white flesh) and* Hylocereus megalanthus *(yellow skin white flesh). Red fleshed varieties are mostly preferred in India namely, Moroccan Red, Jumbo Red and Vietnam Red, etc. Rooted stem cuttings (15–25 cm) collected from the mother plants are used as planting material. Planting spacing is 2m × 2m or 3m × 3m (plant to plant and row to row). Concrete poles or even angle iron poles fitted with a tyre on the top are used for supporting the growing plants. Bearing plants are fertilized @11 Kg FYM + 12 Kg vermicompost and 143 g urea + 138 g MOP + 52 g SSP per plant at three months interval for maintaining the tree growth and fruiting. Hand pollination at 7.30–8.30 pm in the night is critical for better fruit set as the flowers arepin type heterostyly in nature. Yield varies from 25–35 kg/pole and around 62.0–85 t/ha.*

Keywords: *Hylocereus polyrhizu*, Jumbo red, Moroccan red, Vietnam red

IN India, dragon fruit has been named as Kamalam by the Chief Minister of Gujarat, Shri Vijay Rupani in 2021 resembling the fruit colour and shape as lotus. Scientific name of Kamalam fruit is *Hylocereus* spp. and family Cactaceae. It is also called as pitaya fruit, pitahaya fruit, strawberry pear, etc. in different countries. Centre of origin of this fruit is southern Mexico as well as in central and south American parts. However, southeast Asian countries became the leading producer of this fruit over the years. This fruit was first introduced by the European Missionaries during 19th century in this part of the world. At present countries namely, Vietnam, China, Mexico, Colombia, Nicaragua, Ecuador, Thailand, Malaysia, Indonesia, Australia and United States are the major dragon fruit producing countries. In India, this fruit was introduced in late 90s and presently Gujarat, Karnataka and Maharashtra are leading producer in the country. However, almost all the Indian states have introduced this fruit and initiated its cultivation including sub-tropical zone of Himachal Pradesh and Jammu and Kashmir, even in Rajasthan. Among the north eastern Indian states, commercial cultivation has been started in Tripura, Mizoram and Nagaland. This fruit may be considered as super fruit because of its richness in minerals, vitamins and antioxidants content. On the basis of 100g fresh fruit weight, it contains 80–85% water, 4.5–7.5 g total sugars, 4–10 mg vitamin C, 0.2–0.3 mg acidity in the form of lactic acid, 14–18^{0}B TSS, 2.5–3.0% dietary fiber, 10–13 g carbohydrate, 1.0–1.2 g protein, 270–400 mg potassium, 27.0–39.0 mg magnesium, 0.7–1.0 mg iron and 18 mg calcium and 19.0–36.0 mg phosphorus, 59 IU of vitamin A, 0.1 mg riboflavin, 150 µg vitamin E, 0.04 mg Vitamin B1 (Thiamine), 0.16 mg Vitamin B3 (Niacin). Pink flesh fruits have higher phenolics and flavonoids content (40–60 mg GAE and 20–40 mg CE, respectively), whereas, white fleshed fruits contains 15–20 mg GAE and 10–20mg CE, respectively. It provides 60–66 kcal calories of energy. This fruit is an immune booster, digestion helper and minimizes risk of diabetes, heart ailment, and cancer. The plant may be described as fast-growing cactus type climber having flashy and succulent green branches which are actually stems with wavy ribbed margins and small spines along the edges of the stem. There is a suppressed bud at each point of the spines spaced (areola) from which flower bud arises. This plant is grouped under perennial semi epiphytic or xerophytic.

Three major countries namely Vietnam, China and Indonesia contribute more than 90% of dragon fruit production of the world. Vietnam produced 1.4 million tonnes of dragon fruit over an area of 55,000 ha with productivity of 22–35 t/ha. Around 80% dragon fruit produced in Vietnam is exported to China. Area in India is around 14.51 thousand ha under Kamalam with production of around 53.72 thousand MT. Considering the vast potential of this fruit, it has been planned to expand area under dragon fruit to 50,000 ha from present area. This fruit has a very high domestic as well as inter-nation market demand. China, Europe and America are the major importing markets for the dragon fruits produced in Asia. India has also started to export it to mainly Qatar, Maldives and Saudi Arabia. Vietnam, China and Ecuador are leading exporter of dragon fruit.

Climate

Suitable under tropical and sub-tropical, high humid to dry areas. Optimum temperature range is 6–20^{0}C in winter and 25–40^{0}C in summer. Rainfall in the range of 500 mm (Baramati, Maharashtra)–2500 mm (Tripura). It cannot be cultivated in low land with waterlogged conditions. Dragon fruit plants are very much delicate and sensitive to sub-zero and freezing temperature causes freezing injury and has been reported to be not suitable for temperate zone. Whereas, very high temperature above 400^{0}C for longer period or cloudy sky with high humidity and continuously heavy rain is also detrimental for plant growth and flowering and fruit growth.

Soil

All types of soils, but loose, well fertile, rich in organic matter, sandy to loam soil is good. The ideal soil pH ranges 5.0 –7.0. Water stagnation around the collar region will cause rooting of the fleshy stem exposing the mid rib vein.

Planting materials

Production of quality planting material is very much important for dragon fruit to avoid spread of diseases like anthracnose and bacterial spot, and insects like mealy bug and aphids. Due care should be taken in selecting the nurseries for supply of the plants as there is huge demand for the plants in different states. Mother plants should be maintained properly under better fertilization and insect-disease management protocol. Stems of 20–30 cm from one year old growth are collected and planted in poly bags containing rooting medium of soil:sand:FYM/vermicompost (3:1:1) or soilless medium such as cocopeat. Rooting media is treated with fungicides such as carbendazim + mancozeband/or *Trichoderma* formulations to avoid soil borne diseases. Cuttings may be collected from June to October and nursery is raised in poly house or net house

Propagation of dragon fruit by stem cuttings

protecting from direct rain and sun radiation. Plants are ready for planting in the field after 5–8 months. Plants may be sold @₹ 50–60/plant and apart from earning form the fruits, any nurseryman or gardener can earn huge money by selling quality planting materials only considering the high demand. Planting time is July to August. Grafting on seedlings has been found to be successful, but growth of the grafted plants just after grafting was not satisfactory, in comparison to rooted cutting. Rooted plants may be wrapped in moss grass or newspapers properly in bundles to prevent desiccation and packed in corrugated fiber boxes (CFB) for long distance transportation.

Varieties

Species specific varieties: Varieties are designated on the basis of skin and flesh colour and these traits of the fruits are species specific. Different species are, *Hylocereus polyrhizus*, Skin and flesh of this species is red; *Hylocereus costaricensis*, Fruit skin is red and flesh is attractive purple; *Hylocereus undatus*, Fruit skin is red while flesh is white; and *Hylocereus megalanthus*, is yellow skinned fruit with white flesh. Fruits with red skin and red or purple flesh are mostly liked by the consumer. However, fruit with red skin and white flesh are also in high demand in China.

On the basis of skin and flesh colour:

- **Red varieties:** This group has pink skin with dark red flesh. Varieties that fall under this type are Costa rican sunset, Bloody mary, Red jaina, Zamorano, Alice red, Moroccan red, Jumbo red, Vietnam red and Natural mystic.
- **Pink varieties:** Have pink-red flesh with red skin. Varieties like Delight, Dark star, Purple haze, Makisupa, Cosmic charlie, Townsend and American beauty come in this type.
- **White varieties:** Fruits are pink skinned and white fleshed. Varieties are David bowie, LA woman, Delight, Alice and Neitzel.

Dragon Fruit Plantation under Mulching and drip irrigation system

- **Yellow varieties:** Yellow skinned fruits with white flesh. Varieties are *Pitaya megalanthus* and Israeli yellow, Colombia yellow and Golden dragon.

Planting system

Spacing: Spacing for dragon fruit in the main field depends on the planting system. Spacing may be 2 m × 2 m or 3 m × 3 m for square planting system. In another improvised wire trellis system, plant to plant spacing may be 1–1.5 m and row to row of 1.5–2 m.

Support poles and planting: Dargon fruit plant is climbing in nature and cannot stand on its own. Therefore, there is requirement of strong support system. Traditionally, poles are made of concerts with 3 numbers of 8–10 mm rods at the center. Specification of poles is, 6–7.0 feet height and 4–6 inches diameter. Base of the pole inserted 1 ft. into the soil and fixed by pouring concrete cement mix. A bike tyre is placed on the top of the pole supported with prefixed 2–3 ft. long iron rods. Cost per pole may be around ₹500–600. Generally, four plants are planted per pole from four directions at a distance of 30 cm from the base of the pole. However, two plants may be planted considering the ease of canopy management. Angle iron poles may also be used and T-bar made of angle iron rods are fixed at 1–1.5 m spacing and 2–3 galvanized wires are placed on the top of the T bar along the row. Single plants are trained on these T bars and growing branches hangs on both the sides.

Fertilizer management

Integrated nutrient management (INM) is very much important considering the nature of plant growth and 4–5 flushed of flowering from May to September. Tap root is absent and adventitious and shallow roots requires better nutrient supply around the top soil. Dragon fruit plants are heavy feeder and fertilizer along with organic manure should be applied in split doses at various growth stages. Organic management with sufficient quality of FYM, vermicompost, biofertilizers, rock phosphates, bone meals and oil cakes has also been adopted by many farmers in India. However, a standardized INM schedule comprises bioagents such as VAM formulation (50g/plant) and *Azotobacter formulation* @50 g/plant, which is applied at the time of planting in the pit along with FYM and vermicompost.

Table 1. Schedule of fertilizer application in dragon fruit

Growth stage of plants for fertilizer application	Fertilizer dose/plant	
	Urea + SSP + MOP (g/plant)	Vermicom post + FYM (Kg/ plant)
One month after planting	13+12.5+5	1+1
Six month after planting (g/ plant)	26+25+10	2 +3
12 month after planting	40+38+15	3+4
15 month after planting	52+50+20	4+5
18 month after planting (Before flowering)	65+63+24	5+6
21 after planting (Fruit Development)	78+75+27	6+7
24 month after planting	92.0+88+32	7+8
27 months after planting	105+100+37	8+9
30 month after planting	117+113+42	9+10
33 months after planting	130+125+47	10+11
36 month after planting	143+138+52	11+12
After 36 months i.e. in the 3rd year of planting, all the plants attain full bearing potential and starts bearing. Considering the synchronization of vegetative and reproductive growth, manures and fertilisers are applied in several split doses at specified growth stages as mentioned below: This schedule is followed in the successive years.		
1st split dose: In last week of May (Just after the first flush of fruiting)	143+138+52	12 kg + 12 kg
2nd split dose: In last week of July (Just after the end of 2nd fruiting cycle)	143+138+52	12 kg + 12 kg
3rd split dose: In last week of September (Just after the 3rd flush of the fruiting)	143+138+52	12 kg + 12 kg
4th spilt dose: In the month of November (to encourage the vegetative growth and healthy fruiting bud initiation)	143+138+52	12 kg + 12 kg
5th spilt dose: In the month of February for better flowering of 1st flush of fruiting in the second year	143+138+52	12 kg + 12 kg

Intercropping

It is always advisable to utilize the interspaces by growing short duration low height annual crops in the initial year before the start of fruiting stage. Suitable crops are French bean, green peas, spinach, leafy coriander, onion and marigold in winter season; and cowpeas, amaranthus and any other location specific crops fulfilling the intercropping criteria.

Irrigation management

Soil water conservation by mulching is very useful for better plant growth and fruit quality. Resource conservation technology is beneficial by adopting mulching and micro irrigation. Mulching with organic materials such as paddy straw or biomass which will improve the soil fertility after decomposition. Black polyethylene (30–40 micron) or weed mat mulching along the row with provision of ease of fertilizer application at the basin is generally good for conserving soil moisture, soil temperature and enhance microbial activities. Drip irrigation with four drippers at each four plants with discharge rate of 6–8 L/h is good. Crassulacean acid metabolism (CAM) mode of photosynthesis restricts water loss via transpiration during the heat of the day. However, irrigation during dry spell @1.5–2.0 L water/ day through drip system is essential for better plant growth and fruit production or at the interval of 15–20 days depending upon the mulching type and season.

Foliar application

N: P:K (19:19:19) @2 g/L 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). Commercial growth promoters and organic formulations can be also applied as per the prescribed recommendations.

Pollination

Pollination management is very much essential for this fruit as flower opens at 7–9 pm in the night i.e. dragon fruit flowering is nocturnal. Moreover, flowers are hermaphrodite but heterostyly (distyle) in nature with androecium part (filaments along with anthers i.e. male parts) remains at the base of the flower and gynoecium part (style) over grows and come out of the flower. As a result, pollens of the same flower do not reach the stigma surface. Only bats are reported to act as pollinator in the night. Therefore, to ensure better pollination, hand pollination is done for higher fruit set. Pollens may be collected separately and are placed on the stigma surface by fine brash. In the next day pollinated flowers remain closed and gradually fruit set occurs and fruit development starts. Appropriate time for pollinations 7–9 pm in the night.

Fruit bearing

Fruiting takes place in 3–4 flushes from June to October. Fruit shape is oblong to oval, unripe fruits are deep green which turns into reddish pink in case of red skinned varieties. Fruits mature in 35–40 days after flowering and right harvest stage of fruit is when fruit skin including bracts turned full red. Fruit attains around 300–400 g weight on an average and TSS approx. 13–14^{0}B. Being non-climacteric in nature, fruits will not ripe significantly after being harvested. Shelf life varies from 7–20 days (approx.).

Harvesting

Fruits mature in 1–1½ months after fruit set. Fruits are harvested when skin starts to turn green to red/rosy pink. Yield varies from 25–35 kg/pole and around 62.0–85 t/ha. Market price of fresh fruit: ₹ 200–300/kg.

Table 2. Cost of cultivation on hectare basis with pole spacing of 2 m x 2 m

Head	Numbers or Unit	Rate (₹/ Unit)	Amount (₹)
Field preparation and pit digging	1 ha	50000	50000.00
Concrete pole	2500	500	1250000.00
Plants	10000 @4 plants/pole	50	500000.00
Tyre	2500	100	250000.00
Fertilizer and manures, irrigation, mulching, etc./year	10000 plants	30	300000.00
Cultural operations weeding, intercropping, foliar sprays, etc./year	10000 plants	20	200000.00
Total			2550000.00

Diseases and insect-pests

Initially dragon fruit plants were thought to be free from major diseases and insects. But recently, incidence of few diseases have been reported which are threatening the plantations in north eastern India. Anthracnose (*Colletotrichum spp*.) is one of the major diseases which infect the stem as well as fruits. Incidence may vary from 10–60% in the plantations resulting into drying of plants. Stem canker caused by *Neoscytalidium dimidiatum* has been reported in India. Preventive measures are important to protect the plants from such diseases by avoiding heavy stem cutting. Spray of appropriate fungicides should be done. Cactus virus X (CVX) have also been reported on dragon fruit plants with symptoms of numerous small, dull yellowish spots on the stem, drying of stem tissues, stunted, malformed and mottled growth of fruits. Whenever stems are pruned, secateurs should be well sterilized with spirit or alcohol. Cut end should be treated with Copper based fungicide paste. Diseases like stem rot (*Xanthomonas campestris*) and brown spots on fruits (*Dothiorella spp*.) also occur in dragon fruit plants. Bacterial spots may also be noticed in some plants. The insects namely mealy bugs, aphids, mites, fruit fly and termite have been found damaging the plants and fruit.

SUMMARY

Dragon fruit has been found an economical, high value fruit crops for the north eastern India. The farmers can get a higher yield and income by the adoption of the good agricultural practices.

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Lakadong turmeric: Package of practice
for organic production, challenges and opportunities

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Turmeric is an important indigenous spice of India, grown widely in different parts of the country. The crop is having huge potential for improving the livelihood security of the farmers through production, processing and value addition. North eastern India being a hot spot of biodiversity, a wider genetic variability has been observed in local landraces of the turmeric for different agro-morphological and quality traits. Amongst them, "Lakadong", a local geographical indication (GI) tag genotype from West Jaintia Hills, Meghalaya, has been found superior for curcumin content of over > 7.0%. There is also wide variability in curcumin content within the genotypes of Lakadong grown in the niche area and to get better prices, there is a need for the selection and multiplication of the planting materials of curcumin-rich genotypes. Moreover, the high-yielding (20–25 t/ha), curcumin-rich (6.6%) genotype Megha Turmeric-1 developed through clonal selection from the Lakadong should be promoted to other parts of the region. Productivity of the crop can also be enhanced by the adoption of a developed organic package of practices. Further, the use of newly developed machinery such as manually operated washer, slicer and hybrid drier can increase the efficiency of the post-harvest operation and farmers can get a better price by improving the quality of the produce.

Keywords: Curcumin, Lakadong, Meghalaya, Organic production,Turmeric

GOLDEN spice turmeric (*Curcuma longa* L.) is an important, widely grown native rhizomatous crop of the Zingiberaceae family. India is the world's leading producer, importer, and consumer of turmeric. In India, it is cultivated in an area of 3.24 lakh hectares and produces 11.61 lakh metric tonnes, which accounts for over 80% of global turmeric production. India is also the major exporter of turmeric, with over a 62% share of world trade in turmeric and earned a foreign exchange of 207.45 million USD through the export of 1.534 lakh tonnes of turmeric and turmeric products in the year 2022–23. The prime export markets for Indian turmeric are Bangladesh, UAE, USA and Malaysia (Ministry of Commerce and Industry 2023). The major turmeric-producing states are Maharashtra, Telangana, Karnataka and Tamil Nadu.

Since ancient times, turmeric has been used to treat inflammatory conditions of various organs, for liver and digestive tract problems, and for wound healing. Curcumin is the key compound responsible for the colour and medicinal properties of turmeric. Curcumin is an orange-yellow dye practically insoluble in water and is synthesised in plants from phenylalanine. It is the main molecule of curcuminoids; the curcuminoids comprise curcumin (77%) as well as include bisdemethoxycurcumin (BDMC) (17%) and demethoxycurcumin (DMC) (6%). Due to the medicinal properties of curcumin and traditional uses in food and cosmetic products, there has been a significant increase in the demand for turmeric by culinary, pharmaceutical and cosmetic industries over the years in national as well as international markets. Due to growing health consciousness, people around the world prefer organically grown products for daily consumption.

Turmeric is one of the leading commercial crops of north eastern India, and it is grown in an area of 0.34 lakh hectares with a production of 1.13 lakh metric tonnes and which accounts for 14.30% and 9.7% of the country's turmeric area and production, respectively (National Horticulture Board 2022). Amongst the north eastern states, Assam, Mizoram and Meghalaya are the leading states in turmeric production. Due to diverse climatic conditions, there is a wide variability in the local landraces of turmeric grown in the region and amongst

Crop of turmeric genotype Lakadong at farmers' field

Harvested rhizome of turmeric genotype Lakadong

them the popular landraces are Maran, Bhola, Jorhat Local (Assam); Reiek Local (Mizoram); and Lakadong, Laskein and Ladaw (Meghalaya). Landrace Lakadong is a native genotype to the Lakadong village in the Laskein block of the west Jantia Hill district of Meghalaya. It is traditionally known as Shynrai or Chyrmit Lakadong in Pnar (Jaintia Hills). Due to its richness in curcumin content, the variety has been given Geographical Indication tag in 2024 by the Geographical Indications Registry in Chennai.

The cultivation of the Lakadong turmeric is concentrated in the Nongbah and Shangpung belts of the west Jantia Hills. The crop covers an area of about 2.98 thousand hectares in the state with a share of 7.73% in the NER during 2020. The production accounted for 18.61 thousand tonnes with a productivity of 6.25 t/ha. A district-wise comparison of area and production for 2019–20 shows that west Jantia Hills has the major acreage with a magnitude of 1.69 thousand hectares, which accounted for 56.84% of the total turmeric area in Meghalaya. West Garo Hills and Ribhoi districts had more than 150 hectares and the remaining districts had less than 150 hectares under the crop. Similarly, the production follows the same pattern. The west Jantia Hills (10.69 thousand tonnes) were the highest producer of turmeric, which accounted for 57.42% of the total state production. It is followed by west Garo Hills (2.47 thousand tonnes) and Ribhoi (1.46 thousand tonnes). Fascinatingly, Ribhoi district showcased the highest productivity (8.02 t/ha) not only at the state level but also at the national level. However, the west Jantia Hills, a significant region for the production of Lakadong turmeric, witnessed productivity of 6.31 t/ha in 2021.To promote turmeric production in the country, several initiatives have been taken by the Government of Meghalaya, such as launching of Lakadong Mission in the year 2018 and recently, establishment of a separate board for turmeric from the Spices Board in the year 2025 by the Government of India with headquarter at Nizamabad (Telangana).

Growth, yield and quality attributes of Lakadong turmeric

As per the distinctiveness, uniformity and stability (DUS) guidelines of the Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi, the characteristics of Lakadong turmeric are presented in the Table 1. Lakadong turmeric has been found to be medium in crop maturity and rich in curcumin contents (7.0–7.8%).

Table 1. DUS characteristics of the Lakadong turmeric

Sl. No.	Characteristics	Value
A. Plant Characteristics		
1	Plant height (cm)	102.80
2	Leaf length (cm)	49.88
3	Leaf width (cm)	13.46
4	Petiole length (cm)	24.10
5	Leaf margin	Plain
6	Leaf disposition	$<45^0$
7	Leaf venation	Close
8	No of leaves/stem	6–8
9	Stem diameter (cm)	2.30
10	No of tillers/plant	2.33
B. Rhizome characteristics		
11	Rhizome length	Medium
12	Rhizome internode	Distant
13	Rhizome habit	Intermediate
14	Rhizome shape	Straight
15	Rhizome inner core colour	Orange
16	Yield/plant (g)	220.0–390.0
17	Yield (q/ha)	15.0
C. Quality traits		
18	Dry matter (%)	18.5–21.8
19	Curcumin (%)	7.0–7.8

Comparative performance of turmeric genotypes under organic production

To assess the comparative performance of the turmeric genotypes under the organic package of practices, six genotypes, including two local landraces of Lakadong, were evaluated during 2020–22. Amongst the genotypes, the maximum yield was observed in Megha Turmeric-1 (22.5 t/ha), followed by Narendra Haldi-1(20.9 t/ha) and Rajendra Sonia (19.4 t/ha). However, the lowest yield was recorded from the genotype Lakadong-RiBhoi (15.38 t/ha). Further, the dry matter content was maximum in genotype Pragati (21.30%), followed by Lakadong-Jowai (19.68%). Lakadong-Jowai (a collection from west Jaintia Hills) was found superior for the dry matter as well as curcumin content.

Table 2. Comparative performance of turmeric genotypes under mid-hills of Meghalaya

Genotypes	Plant height (cm)	Leaf length (cm)	No. of tillers /plant	No of leaves / plant	Stem dia. (cm)	Petiole length (cm)	Yield (t/ha)	Dry matter (%)	Curcumin content (%)
Megha Turmeric-1	105.60	54.87	3.67	8.67	2.57	21.40	22.50	19.31	6.67
Rajendra Sonia	96.67	54.60	2.67	8.33	2.12	19.90	19.62	18.06	5.70
Narendra Haldi-1	105.50	47.27	3.00	10.67	2.24	19.43	20.95	19.58	5.72
ISSR-Pragati	109.63	53.40	4.00	9.00	2.11	16.87	17.13	21.30	4.95
Lakadong -RiBhoi	107.80	49.60	4.00	6.67	2.20	18.70	15.38	19.65	6.88
Lakadong-Jowai	103.73	51.20	3.00	7.00	2.27	16.70	16.67	20.19	7.23
Mean	104.82	51.82	3.39	8.39	2.25	18.83	18.66	19.68	6.19
CV (%)	2.15	1.52	7.60	11.17	1.45	3.56	8.36	2.92	3.22
CD at 5%	3.16	0.68	0.48	0.75	0.25	1.90	2.30	0.77	0.56

Package of practices for organic production

Climate and soil: Turmeric can be grown in diverse tropical conditions from sea level to 1500 m above sea level, at a temperature range of 20–35ºC with an annual rainfall of 1500 mm or more, under rainfed or irrigated conditions. It thrives best in well-drained sandy or clay loam soils with a pH range of 4.5–7.5 with good organic status. The yield and quality of turmeric are highly affected by the weather parameters. GI genotypes, Lakadong of turmeric, are found to be superior in their curcumin content (>7.0%) when they are grown in the niche area (West Jantia Hill) of the Meghalaya where the climate is mild-warm and humid during the growing period (March-December) and soil acidic in nature (pH ≈ 4.8). However, when it is grown in other areas, the curcumin content is affected significantly. Moreover, the improved cultivar Megha Turmeric-1, developed through clonal selection from Lakadong, has been found stable across the location under the multi-location testing trials of the AICRP on Spices.

Planting time: Turmeric is mostly grown in the Jhum field after clearing of the forest (February-March), land preparation (raised beds) after getting the first shower of the season (March-April).

Spacing: The turmeric is grown on the raised beds and the optimum spacing between the beds is kept at 45.0 cm and between plant to plant and row to row at a 30 cm x 30 cm spacing.

Seed rate: About 20–25 q healthy disease-free rhizomes (4–5 cm in length and 25–30 g in weight) are sufficient for one hectare of land.

Seed treatment: To prevent the crops from soil-borne diseases, the seed rhizomes should be treated with *Pseudomonas fluorescens*10 g/kg and *Trichoderma viride* @5 g/kg seed.

Manuring: Turmeric is a long-duration and nutrient-exhaustive crop, which requires a heavy dosage of nutrients to maintain the soil fertility with a higher yield. The application of organic manures in agriculture greatly enhances turmeric yield, quality, and soil health.

Table 3. Per hectare doses of manure and fertilizers and their schedules for organic production of turmeric

Schedule	Neem cake	Rock phosphate	Ash/Sulphate of Potash	Organic manure
Basal	2 tonnes	250 kg	-	Cow dung/ FYM: 20 tonnes
After 45 days	-	-	Ash: 0.5 1 tonnes	Vermicompost: 2 tonnes
After 90 days	-	-	Sulphate of potash: 100 kg	Vermicompost: 2 tonnes

Weeding: The weeds are managed by manual weeding and earthing-up. The 8–12 weeks after planting (WAP) are the critical period of weed competition, therefore, weeding should be done thrice, at 60, 90 and 120 days after planting. Mulching of green leaves @12–15 t/ha right after planting has been found to be an effective way to control weeds. Mulching can also be done with paddy straw and green or dry available weed biomass. For better results, the mulching may be repeated @7.5 t/ha at 40 and 90 days after planting. For proper aeration and development of the rhizomes, the manures should be applied at 45 and 90 days after each weeding and earthing up. The application of cow dung slurry above the mulch enhances the activity of beneficial microbes and nutrient availability.

Irrigation: Turmeric is grown as a rainfed crop in the region. The region falls under a high rainfall area and proper drainage is essential for better yield and protection from diseases.

Mixed farming/crop rotation: As a mixed crop, turmeric can be grown or rotated with chillies, brinjal, okra, colocasia, sweet potato, maize, ragi, French bean, cowpea, etc. enabling the effective nutrient build-up as well as management of the pest or disease. When growing turmeric in a mixed cropping system, it is imperative that all of the crops be produced using organic practices. The crop is partially shade-loving, and it can be grown with cucurbits (bottle gourd/pumpkin) under vertical farming. It also can be grown in intercropping with the plantation crop arecanut.

Plant protection measures

Insect-pest: Shoot borer (*Conogethes punctiferalis* Guenee) is a major pest of turmeric. The crop is damaged by the larvae, which eat the developing shoot after boring into the pseudostem, which causes the shoots to dry out and turn yellow. The presence of pores in the pseudostem through which frass is extruded and withering are the peculiar symptoms of the shoot borer infestation. Spraying Neemgold 0.5% or Neemoil 0.5% or Spinosad 0.5 ml/L water during July-October (at 15-day intervals) is effective against the shoot borer. The shoot borer in ginger and turmeric can also be managed by the use of biopesticides, such as soil application of entomopathogenic nematodes *Heterorhabditis indica* at 5–10 kg/ha in FYM (75–100 kg FYM) or spraying of entomopathogenic fungi *Beauveria bassiana* @2–5 ml/L water or entomopathogenic bacteria *Bacillus thuringiensis* products such as Dipel 0.3% at 15 days intervals during July to October. The light traps attract the adult moths. The use of 3–4 traps/ha has been found effective in managing the pest population by trapping and killing.

Rhizome scale (*Aspidiella hartii* Cockerell) is another important pest of the turmeric, attacking rhizomes, and affecting the yield and quality of the rhizomes by sap-sucking by the adults. In case of severe infestation, the rhizome and buds become shrivelled, and eventually the entire rhizome dries. It can be managed by the use of pest-free seed rhizomes, following crop rotation, and treatment of the rhizomes with hot water (50°C) for 10 minutes before planting.

The root knot and cyst nematodes also damage the crop of turmeric, and they can be managed by the drenching of liquid formulation (@1.0 ml/L water) of *Pochonia chlamydosporia*, a fungal species known for its ability to parasitize the plant-parasitic nematodes, especially root-knot and cyst nematodes.

Diseases:

Rhizome rot: The rhizome rot disease of turmeric is a complex disease and it is caused by soil borne pathogen (*Pythium spp., Fusarium spp., Rhizoctonia spp.*). The disease of rhizome rot can be controlled by selection of healthy rhizomes, treating the seeds, soil solarisation, and applying biocontrol agents like *Trichoderma* or *Pseudomonas* that have multiplied in appropriate carrier media like cocopeat, well-rotted FYM, or neem cake at the time of sowing and at regular intervals.

Foliar disease: Leaf spot (*Colletotrichum capsici*) and Leaf blotch (*Taphrina maculans*) are the two most important foliar diseases of turmeric. The disease appears during the month of August-September due to congenial weather (high temperature and humidity) for the pathogen. Lakadong turmeric has been found to be tolerant of diseases like leaf spots as well as leaf blotches. Spraying of copper oxychloride 0.25% immediately after the appearance of symptoms and at 15-day intervals is effective in controlling the disease.

Harvesting: The crop is ready for harvesting 7 to 9 months after planting, depending on the cultivar. The early, mid- and late-maturity cultivars mature in 7–8, 8–9 and >9 months after planting, respectively. Lakadong is a mid-maturity genotype, and it takes about 8–9 months to mature. The crop should be harvested when leaves are yellowing and gradually drying up.

Yield: The yield of the turmeric depends on the cultivars, and management practices. The average yield of Lakadong turmeric is 12–15 t/ha, while the improved cultivar Megha Turmeric-1 has 20–25 t/ha.

Storage of seed rhizomes: After harvest, the disease-free bold rhizomes are selected, cleaned, and treated with 1% bordeaux mixture for 20 minutes and further stored in pits of convenient size after shade drying. Dry grass/paddy straw should be kept at the bottom and top of the stored rhizome in the pit and sealed by plastering with mud. The rhizomes are taken out 20–25 days before planting.

Challenges and opportunities in organic production

Despite the premium quality of the Lakadong turmeric, as well as huge demand in the domestic as well as international markets, farmers are not getting the premium prices of their produce due to many factors.

- ***Lack of quality planting materials:*** There is wide genetic variability in the quality of the Lakadong turmeric grown in the region. Hence, there is a need for the selection and large-scale production of the quality planting materials of the Lakadong genotypes found superior for the curcumin content in the niche area (Jaintia Hills, Meghalaya). Lakadong being unstable in quality when it is grown in other parts of the region, the stable genotype Megha Turmeric-1 should be promoted as it is also rich in curcumin (6.8%) and higher (20–25 t/ha) in yield. It can be strengthened by participatory production through cluster farming with the help of SHGs/FPO, etc.
- ***Poor cultivation practices:*** Comparatively, the productivity of the crops in the region is very low due to poor agricultural practices, no uses of the inputs like manure and fertilisers, weed management, etc. Hence, there is a need for increasing awareness amongst farmers about good agricultural practices, especially for organic production.

- ***Non-availability of essential inputs:*** There is also a lack of availability of quality inputs, such as bio-fertilisers, bio-pesticides, etc. for the organic production in the growing pockets of turmeric.
- ***Organic certification:*** In Meghalaya, turmeric is produced organically and there is no well-set-up mechanism for the certification of organic products. Despite huge market demand, farmers are not getting the higher prices of organically grown turmeric. Hence, there is a need for the development of a mechanism for the certification of the product.
- ***Price fluctuations:*** Due to the absence of a regulated market,the price of turmeric varied from ₹40–70/kg. Most of the produce is sold by the farmers to the village traders. Farmers can get better prices through the establishment of a regulated markets and their linkage.
- ***High transportation cost:*** Although Lakadong is rich in curcumin content, the farmers of the Meghalaya are getting the average low market price (₹ 179.47/kg) as compared to the higher market price of ₹ 267.0/kg for the GI turmeric Waigaon (Curcumin: >6%) in Maharashtra. This is mainly due to the involvement of the higher transportation costs in the Lakadong turmeric exported from the Meghalaya.
- ***Lack of processing and value addition:*** Based on a household survey (2017–20), only 0.75% of the turmeric is used for local consumption, 20.27% is used for seed purposes and, after the field loss (0.91%), the remaining 78.06% is used for the selling in the markets. Due to poor processing and value addition, most of the turmeric produce is sold as dry flakes (67.28%), fresh rhizomes (29.03%), and only 3.69% as powder. Hence, there is huge scope for the development of the infrastructure for the processing and value addition of turmeric.
- ***Lack of mechanisation:*** Most of the cultural operations as well as post-harvest operations are practised manually, which increases the cost of production with lower efficiency. The ICAR-NEH, Umiam developed improved farm machinery such as manually operated turmeric washer, slicer and hybrid driers that can be promoted to improve the efficiency of post-harvest operation.
- ***Absence of a quality testing facility:*** Due to the lack of a quality testing facility in the growing pockets, farmers and traders are facing a major challenge in getting the premium prices based on export quality. Therefore, the establishment of the quality testing laboratory is very important to realise the premium price by the farmers as well as traders.

SUMMARY

The GI tag variety "Lakadong" turmeric can be a boon for the growers of the Jaintia Hills of Meghalaya through the use of quality planting materials, adoption of good agricultural practices, especially for organic production, use of farm machinery for post-harvest operations, processing and value addition in the growing pockets through cluster approaches involving SHGs, and proper market linkage. Further, the farmers of the other parts of the region can benefit from the adoption of the high-yielding, curcumin-rich stable variety, Megha Turmeric-1.

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Role of farmer producer organization
in agriculture

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Farmer Producer Organizations (FPOs) play a crucial role in empowering small and marginal farmers by facilitating collective access to markets, financial resources, and technology. This study explores the concept, objectives, types, and current status of FPOs in India, with a specific focus on the North Eastern Region (NER). Government initiatives, including financial and policy support, have contributed to the expansion of FPOs, however several challenges persist, such as inadequate infrastructure, limited financial resources, and weak market linkages. This study highlights the impact of FPOs in improving farmers' incomes, promoting sustainable agricultural practices, and enhancing rural livelihoods. Key strategies for strengthening FPOs include improved financial assistance, infrastructure development, market integration, and capacity-building initiatives. These findings suggest that a collaborative approach involving government agencies, financial institutions, and private stakeholders is essential for ensuring the long-term sustainability of FPOs and fostering economic resilience among farmers.

Keywords: Agricultural cooperatives, Economic resilience, Farmer producer organization, Marginal farmers, Market linkage

A Producer Organisation (PO) is a legally recognized entity formed by primary producers, including farmers, milk producers, fishermen, weavers, rural artisans, and craftsmen. These organizations can adopt different legal structures such as producer companies, cooperative societies, and other frameworks designed to ensure equitable profit-sharing among members. In specific cases, institutions of primary producers can also become members of these organizations.

A Farmer Producer Organization (FPO) is a specialized type of PO exclusively comprising farmers. The Small Farmers' Agribusiness Consortium (SFAC) plays a pivotal role in promoting FPOs across India. Broadly, Producer Organizations (POs) can cater to a diverse range of goods, including agricultural products, non-farm items, and handicrafts.

Concept of FPO

The concept of Farmer FPOs was to enable farmers to collectively register as a company under the Indian Companies Act. The Department of Agriculture and Cooperation, under the Ministry of Agriculture, Government of India, has entrusted Small Farmers' Agribusiness Consortium (SFAC) with the responsibility of facilitating FPO formation in coordination with state governments. The fundamental objectives of FPOs is to enhance farmers' competitiveness and enable them to leverage market opportunities more effectively. The key activities of FPOs include: 1) Provision of agricultural inputs such as seeds, fertilizers, and machinery, 2) Establishing market linkages, 3) Conducting training and capacity-building programmes, and 4) Offering financial and technical support.

Type of farmer producer organization

Producer Organizations (POs) serve the interests of producers by strengthening their ability to overcome production and marketing challenges. They can be formed around specific commodities (e.g. Maharashtra State Grapes Grower Association), activities like water management (e.g. Pani Panchayats), cooperatives (e.g. NDDB milk cooperatives), or producer companies (e.g. VANILCO). Farmer organizations take various forms, including interest groups, cooperatives, self-help groups, and federations, all bound by common interests, membership rules, and shared responsibilities.

Chamala (1990) classified them into two types: i) Community-based, resource-oriented organizations and ii) Commodity-based, market-oriented organizations.

Need for farmers producer organizations

Approximately 86% of Indian farmers belong to the small and marginal category, with an average landholding of less than 1.1 ha (Ministry of Agriculture and Farmers' Welfare 2021). These farmers, including landless ones, encounter multiple challenges such as: 1) Limited access to technology, quality seeds, fertilizers, and pesticides, 2) Insufficient financial resources, and 3) Difficulty in marketing agricultural produce due to low bargaining power.

FPOs help small, marginal, and landless farmers overcome these issues by promoting collective decision-making and resource-sharing, leading to improved technology adoption, enhanced market access, and better financial security.

Objectives of FPOs

The objectives of FPOs as per the Ministry of Agriculture and Farmers' Welfare, are as follows:

- Formation of 10,000 new FPOs to establish a sustainable agrarian support system.
- Enhancing productivity through efficient resource utilization and market expansion.
- Providing financial and technical support to new FPOs for up to five years.
- Building entrepreneurial capacity to ensure the long-term sustainability of FPOs.

Global status of FPOs

Worldwide, FPOs play a crucial role in improving smallholder farmers' access to markets, technology, and financial services. The global landscape of FPOs presents two broad models:

- ***Developed economies:*** Well-established cooperative models with strong financial backing, advanced infrastructure, and extensive market integration.
- ***Developing economies:*** Emerging FPO networks facing challenges such as financial literacy gaps, inadequate infrastructure, and weak institutional support.

Key trends in global FPO development

- Digital transformation, enabling farmers to access e-commerce, online banking, and precision farming.
- Emphasis on sustainability, focusing on organic farming and climate-resilient agricultural practices.
- Increased governmental and institutional support, ensuring FPO sustainability through policy reforms and financial aid.

Current status of FPOs in India

FPOs primarily consist of farmer collectives, with approximately 70–80% of their members being small or marginal farmers. Currently, India has around 7,000 FPOs (including FPCs), established over the past 8–10 years through various initiatives by the Indian government, state governments, NABARD, and SFAC. Of these, about 4,800 FPOs are registered as Farmer Producer Companies (FPCs) under NABARD and SFAC, while the rest operate as cooperatives or societies. Karnataka, Maharashtra, Madhya Pradesh, Telangana, and Uttar Pradesh together account for 40% of all registered FPOs, while Odisha, Tamil Nadu, West Bengal, Andhra Pradesh, Bihar, Gujarat, Rajasthan, and Jharkhand make up another 40%. Studies indicate that around 60% of registered FPOs have approximately 500 farmer shareholders, while 10–15% have over 1,000 members. Nearly half of the FPOs have an authorized capital of about ₹1 lakh.

Table 1. State-wise number of FPOs registered through respective agencies

No.	State/UTs	Number of FPOs registered by respective agencies			
		Small Farmers' Agri-Business Consortium (SFAC)	NABARD	FPOs registered by IAs under CSS for the formation and Promotion of 10,000 FPOs	Total
1	Andaman andNicobar	0	3	0	3
2	Andhra Pradesh	16	295	88	399
3	Arunachal Pradesh	6	10	12	28
4	Assam	18	72	95	185
5	Bihar	38	217	101	356
6	Chhattisgarh	26	57	61	144
7	Delhi	4	1	0	5
8	Goa	2	2	1	5
9	Gujarat	25	190	140	355
10	Haryana	23	85	93	201
11	Himachal Pradesh	8	99	67	174
12	Jammu and Kashmir	2	23	64	89
13	Jharkhand	10	150	96	256
14	Karnataka	125	287	166	578
15	Kerala	0	134	36	170
16	Ladakh	0	0	3	3
17	Madhya Pradesh	149	254	147	550
18	Maharashtra	105	291	173	569
19	Manipur	8	12	16	36
20	Meghalaya	3	12	10	25

21	Mizoram	1	19	14	34
22	Nagaland	2	5	16	23
23	Odisha	41	241	165	447
24	Punjab	7	93	22	122
25	Puducherry	0	0	2	2
26	Rajasthan	50	166	135	351
27	Sikkim	30	8	2	40
28	Tamil Nadu	13	264	133	410
29	Telangana	26	335	99	460
30	Tripura	7	1	23	31
31	Uttarakhand	7	90	57	154
32	Uttar Pradesh	57	183	210	450
33	West Bengal	89	305	10	404
Total	All States andUTs	898	3904	2257	7059

Source: Press Information Bureau 2022

FPOs in north eastern region of India

FPOs in the North Eastern Region (NER) have emerged as a significant model for agricultural empowerment. Government schemes like Rashtriya Krishi Vikas Yojana and Formation and Promotion of Farmer Producer Organizations Scheme provide essential support for FPO development. FPOs in the NER play a crucial role in empowering small and marginal farmers by improving access to markets, financial resources, and technology. However, the region faces unique challenges that hinder the growth and sustainability of FPOs (Advancing North East 2025).

The north eastern region (Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura) has a total of 402 registered FPOs, with 348 registered as Farmer Producer Companies (FPCs) with the Ministry of Corporate Affairs. Assam has the highest number of FPOs among the northeastern states.

State-wise status of FPOs in north eastern region of India

Assam: The highest number of FPOs in the NER region. Many are involved in tea, horticulture, and organic farming.

Arunachal Pradesh: Growing interest of FPOs, mainly in organic crops like large cardamom.

Manipur: FPOs focus on paddy, fishery, and handloom-based products.

Meghalaya: Several FPOs, especially in spices (ginger, turmeric, black pepper), dairy, and horticulture.

Mizoram: Agro-based FPOs involved in broom grass, fruits, and organic farming.

Nagaland: FPOs working on Naga chilli, bamboo, and livestock.

Sikkim: The organic farming hub of India, with FPOs playing a key role in marketing organic products.

Tripura: Focus on rubber, pineapple, and fisheries.

Government initiatives for FPOs in the north eastern region

Central government schemes:

- Formation and Promotion of 10,000 FPOs: This central sector scheme aims to set up and strengthen 10,000 FPOs by 2023–24, with support extended till 2027–28.
- NABARD's FPO Support Programme provides financial and technical assistance.
- Small Farmers Agribusiness Consortium (SFAC) helps in market linkages, financial grants, and business development.
- Rashtriya Krishi Vikas Yojana (RKVY) focuses on value chain development.
- Operation Greens supports FPOs in developing value chains for tomato, onion, and potato.
- Pradhan Mantri Formalization of Micro Food Processing Enterprises (PMFME) encourages processing and branding for FPOs.

State-Specific initiatives:

- **Meghalaya:** Has Mission Organic Meghalaya, supporting FPOs involved in organic farming.
- **Nagaland:** Runs a dedicated FPO Promotion Programme under the state's Agri and Allied Sector.
- **Sikkim:** Recognized as the first 100% organic state, Sikkim promotes FPOs for organic production and marketing.
- **Tripura:** Supports FPOs involved in rubber-based industries and horticulture.
- **Assam:** Assam Agribusiness and Rural Transformation Project (APART) works on FPO strengthening.

Key challenges faced by FPOs in north eastern region of India

Financial and institutional challenges:

- **Low paid-up capital:** Many FPOs lack sufficient funds, making them ineligible for government grants.
- **Limited credit access:** Banks are hesitant to lend to FPOs due to weak business models.

Market linkage issues:

- **Poor infrastructure:** Lack of storage, processing, and transport facilities increases post-harvest losses.
- **Limited market access:** FPOs struggle to connect with national and international buyers.

Organizational and operational challenges:

- **Weak business planning:** Many FPOs lack expertise in financial management and business strategy.
- **Limited participation:** Farmers often lack awareness and trust in FPOs.

Geographic and logistic issues:

- **Difficult terrain:** Hilly and remote areas increase logistics costs.
- **Lack of connectivity:** Transporting goods to markets is costly and time-consuming.

Impact of FPOs in the north eastern region

- ***Better price realization:*** Farmers in FPOs get 15–30% higher prices compared to individual selling.
- ***Market expansion:*** FPOs have started linking with online platforms like e-NAM.
- ***Women empowerment:*** Women-led FPOs are growing, especially in Manipur and Meghalaya.
- ***Organic farming promotion:*** States like Sikkim and Meghalaya have benefited from organic FPO models.
- ***Value addition and processing:*** Some FPOs are moving towards processing ginger, turmeric, and tea.

Strategies for strengthening FPOs in north eastern region

Enhance financial support:

- Provide higher equity grants for Northeast-based FPOs.
- Set up dedicated credit schemes for FPOs in hilly regions.

Strengthen market linkages:

- Connect FPOs with e-commerce platforms for direct sales.
- Promote contract farming with corporate buyers.

Develop infrastructure:

- Invest in cold storage, processing centers, and transportation facilities.
- Encourage public-private partnerships (PPP) for agri-logistics.

Capacity building:

- Conduct training on business planning and governance.
- Create a state-level support body for FPO handholding.

Leverage technology:

- Use digital platforms for market intelligence and farm advisory.
- Explore block chain for traceability of organic products.

SUMMARY

FPOs have the potential to revolutionize Indian agriculture, especially for smallholder farmers in north eastern region of India. By addressing challenges such as limited market access, infrastructure gaps, and financial literacy, FPOs can enhance rural livelihoods and strengthen the agrarian economy. For north eastern region of India, well suited policies, skill development initiatives, and region-specific interventions are crucial for unlocking the full potential of FPOs. Government support, financial inclusion, and modern technological integration can transform FPOs into sustainable economic drivers. A collaborative approach involving government agencies, financial institutions, and private sector stakeholders will ensure the long-term success of FPOs, fostering resilience and self-sufficiency among farmers in the region.

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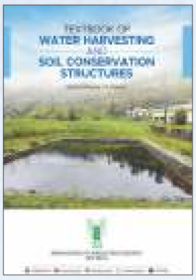

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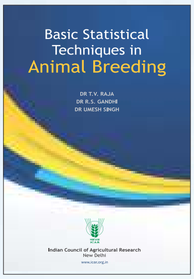

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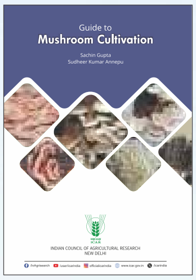

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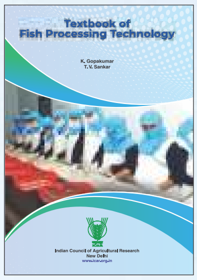

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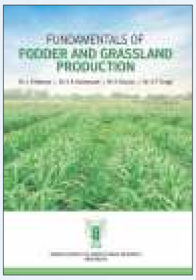

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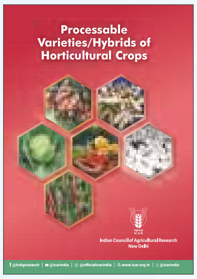

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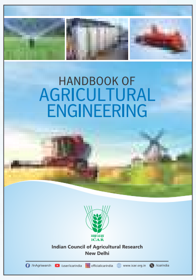

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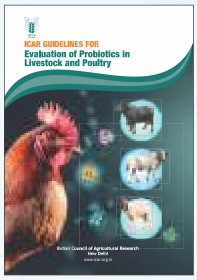

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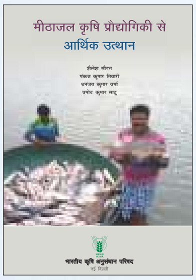

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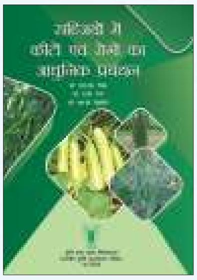

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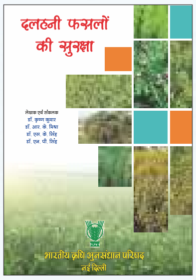

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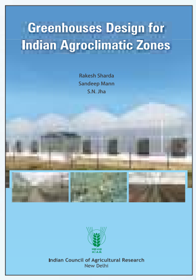

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