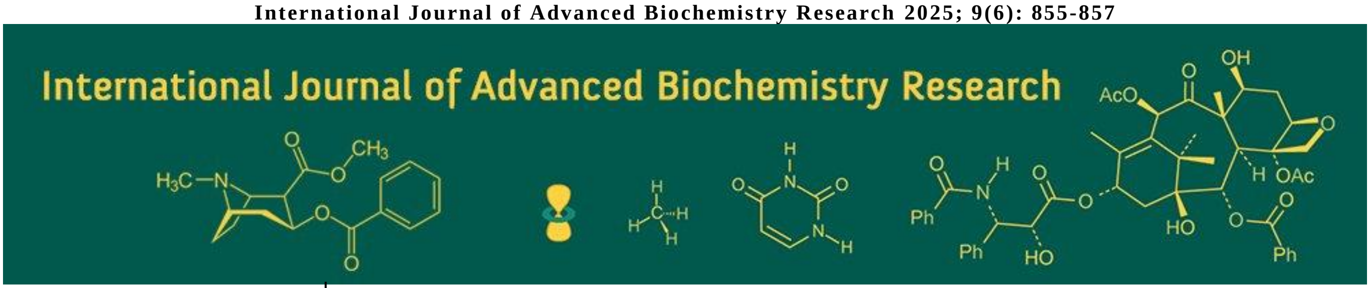

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(6): 855-857
www.biochemjournal.com
Received: 04-04-2025
Accepted: 07-05-2025

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Cultivating prosperity: Unlocking the potential of cabbage production in northeast India's Hilly states

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i6j.4624

Abstract
Cabbage (*Brassica oleracea* var. *capitata*), a high-value vegetable, is gaining prominence in Northeast India's hilly states of Meghalaya, Tripura, Arunachal Pradesh, Nagaland, Manipur, and Sikkim. This study evaluates cultivation practices, productivity, and socio-economic constraints in these regions, characterized by shifting cultivation (Jhum) and settled farming. Data were collected in 2024 from 180 farmers, field observations, and secondary sources, focusing on area, yield, inputs, pests, and markets. The average yield was 19.5 t/ha, below the national average (22.1 t/ha), due to acidic soils, low inputs, and Jhum's short fallow periods. High-yielding varieties and organic pest management increased yields by 15-25%. Market prices fluctuated (₹5-25/kg), with poor infrastructure limiting profitability. Recommendations include integrated nutrient management, enhanced seed access, and robust market linkages to foster sustainability. This study underscores cabbage's role as a cash crop for tribal farmers, advocating for tailored interventions to unlock its potential.

Keywords: Cabbage, Northeast India, shifting cultivation, yield, horticulture, tribal farming

1. Introduction

Cabbage (*Brassica oleracea* var. *capitata*) is a cornerstone of India's horticultural sector, producing 9.95 million metric tons annually across 428,000 hectares (NHB 2023) [1]. Its adaptability to varied climates, short growth cycle (60-90 days), and nutritional value make it a vital crop in both lowland and hilly regions (Singh *et al*. 2018) [2]. In Northeast India, encompassing Meghalaya, Tripura, Arunachal Pradesh, Nagaland, Manipur, and Sikkim, cabbage is a dietary staple and an emerging cash crop, thriving in the region's cool, moist conditions (Choudhury *et al*. 2020) [3].

Northeast India's hilly terrain (100-4500 m elevation), high rainfall (1500-4500 mm annually), and loamy but acidic soils (pH 4.5-5.5) create a unique agricultural landscape (Ramakrishnan 1992) [4]. Shifting cultivation (jhum), practiced by 60-70% of farmers, dominates, but short fallow periods (2-5 years) deplete soil fertility, constraining yields (Bordoloi and Das 2019) [5]. Cabbage requires well-drained loamy soils (pH 6.0-6.5) and temperatures of 15-20°C, conditions prevalent in higher altitudes of Sikkim, Nagaland, and Meghalaya, though Tripura's warmer lowlands pose challenges (Sharma *et al*. 2021) [6]. Pests, notably diamondback moth (*Plutella xylostella*), further limit production (Sharma *et al*. 2021) [6].

Nationally, cabbage yields average 22.1 t/ha, with states like West Bengal achieving 27.6 t/ha (NHB 2023) [1]. In Northeast India, high-yielding varieties can produce up to 70 t/ha under optimal conditions, but smallholder farmers typically achieve 15-20 t/ha due to traditional practices and limited inputs (Choudhury *et al*. 2020) [3]. Economically, cabbage generates profits of ₹60,000-1.5 lakh per acre, but price volatility (₹2-45/kg) and post-harvest losses due to poor infrastructure hinder returns (Kumar *et al*. 2022) [7]. In Northeast India, cabbage meets local demand and supplies urban markets in Shillong, Agartala, Kohima, Itanagar, Imphal, and Gangtok, yet connectivity issues persist (Singh *et al*. 2018) [2]. Research on cabbage production in these states is sparse, with studies focusing on broader horticulture or jhum's ecological impacts (Singh *et al*. 2018; Bordoloi and Das 2019) [2,5].

This study aims to: (1) assess cabbage cultivation practices and productivity in Meghalaya, Tripura, Arunachal Pradesh, Nagaland, Manipur, and Sikkim, (2) identify biophysical and socio-economic constraints, and (3) propose strategies for sustainable production. The findings bridge knowledge gaps, offering insights for tribal farmers and policymakers in Northeast India.

2. Materials and Methods

2.1 Study Area

The study was conducted in 2024 across six Northeast Indian states: Meghalaya, Tripura, Arunachal Pradesh, Nagaland, Manipur, and Sikkim. These states feature hilly terrains (100-4500 m elevation), annual rainfall of 1500-4500 mm, temperatures of 10-30°C, and humid subtropical to sub-temperate climates. Soils are loamy, often acidic (pH 4.5-5.5), with low nutrient availability due to jhum. Agriculture, including jhum (60-70% of farmers) and settled farming, is the primary livelihood.

2.2 Data Collection

A survey was conducted from July to October 2024, involving 180 cabbage farmers (30 per state) selected via stratified random sampling to represent jhum (40%) and settled farms (60%). Data were collected through structured questionnaires on:

- Area under cabbage cultivation (ha).
- Production and yield (t/ha).
- Input use (seeds, fertilizers, pesticides, irrigation).
- Pest and disease incidence (frequency, severity).
- Market prices (₹/kg) and net income (₹/ha).

Field observations assessed soil pH (portable pH meters), crop health (visual pest/disease symptoms), and irrigation practices. Secondary data were sourced from state agricultural departments and ICAR Research Complex for NEH Region, Umiam. Rainfall and temperature data were obtained from the Indian Meteorological Department.

2.3 Cultivation Practices

Cabbage was sown in nursery beds (August-September) and transplanted after 30-35 days. Varieties included Pusa Mukta, Golden Acre, and local landraces, with hybrids used by 45% of farmers. Farmyard manure (FYM) was applied at 20-30 t/ha, supplemented by NPK fertilizers (70:35:90 kg/ha, below recommended 100:50:120 kg/ha). Lime (1-2 t/ha) was used in 25% of farms to correct soil acidity. Pest management included neem seed kernel extract (NSKE 5%), *Bacillus thuringiensis* (Bt) sprays, and chemical pesticides (e.g., Spinosad) in severe cases. Irrigation was primarily rain-fed, with drip systems in 15% of settled farms. Harvesting occurred 60-90 days after transplanting, with produce sold in local or urban markets (Shillong, Agartala, Kohima, Itanagar, Imphal, Gangtok).

2.4 Data Analysis

Descriptive statistics (mean, standard deviation) were computed using SPSS 26.0 for area, yield, input use, and income. Yield gaps were analyzed by comparing local yields with Northeast India's potential (70 t/ha) and national averages (22.1 t/ha). Net income was calculated as gross revenue minus costs (seeds, fertilizers, pesticides, labor, transport). Pest incidence was quantified as percentage of affected fields and yield losses. T-tests compared yields and income between jhum and settled farms (α=0.05). Qualitative data (farmer constraints) were analyzed thematically.

2.5 Ethical Considerations

Verbal consent was obtained from farmers, ensuring anonymity and voluntary participation. The study adhered to ethical guidelines for social science research.

3. Results and Discussion

3.1 Area and Production

Cabbage was cultivated on 1,500 ha across the six states in 2024: Meghalaya (400 ha), Tripura (350 ha), Arunachal Pradesh (250 ha), Nagaland (200 ha), Manipur (200 ha), and Sikkim (100 ha). Total production was 29,250 tons, with an average yield of 19.5 ± 3.6 t/ha (Table 1). Yields were lower in jhum fields (16.8 ± 3.0 t/ha) than settled farms (21.5 ± 3.9 t/ha) (t=4.28, p<0.01), reflecting soil fertility decline from short fallow periods (Ramakrishnan 1992) [4]. Yields were below the national average (22.1 t/ha) and regional potential (70 t/ha) (NHB 2023, Choudhury *et al*. 2020) [1,3].

Sikkim and Meghalaya recorded higher yields (21.8 t/ha and 20.8 t/ha) due to cooler climates and organic practices, while Tripura's warmer lowlands yielded 18.2 t/ha. Nagaland's yields (19.0 t/ha) were constrained by limited extension services. The limited area under cabbage reflects its secondary role compared to rice and maize in jhum, but its expansion in settled farms signals growing market demand (Bordoloi and Das 2019) [5].

Table 1: Cabbage cultivation parameters in Northeast India, 2024

Parameter	Jhum Fields	Settled Farms	Overall
Area (ha)	600	900	1,500
Yield (t/ha)	16.8 ± 3.0	21.5 ± 3.9	19.5 ± 3.6
FYM (t/ha)	20.5 ± 4.8	26.5 ± 6.0	24.0 ± 5.5
NPK (kg/ha)	60:30:80	80:40:100	72:36:92
Pest Incidence (% fields)	70	60	64
Net Income (₹/ha)	50,000 ± 14,000	70,000 ± 17,000	62,000 ± 16,500

3.2 Input Use and Soil Management

Farmers applied FYM at 24.0 ± 5.5 t/ha, but NPK use (72:36:92 kg/ha) was below recommended levels, causing nutrient deficiencies (e.g., nitrogen, observed in 50% of fields). Soil pH averaged 5.3 ± 0.5, with 80% of fields requiring lime. Only 25% of farmers applied lime, citing cost and availability (Singh *et al*. 2018) [2]. High-yielding varieties (e.g., Pusa Mukta) were used by 45% of farmers, yielding 20-25% more than landraces. Seed access was limited, with 55% relying on saved seeds (Choudhury *et al*. 2020) [3]. Jhum's short fallow periods exacerbated soil fertility decline, particularly in Nagaland and Arunachal Pradesh (Ramakrishnan 1992) [4].

3.3 Pest and Disease Incidence

Diamondback moth affected 64% of fields, causing 10-20% yield losses (Table 1). Black leg (*Phoma lingam*) and clubroot (*Plasmodiophora brassicae*) were reported in 10% and 7% of fields, linked to poor drainage. Organic pest control (NSKE, Bt) reduced losses by 10-15%, but chemical pesticides were used in 15% of farms (Sharma *et al*. 2021) [6]. High humidity (80-90%) increased pest pressures, necessitating IPM strategies like sticky traps and resistant varieties, as seen in Manipur.

3.4 Irrigation and Water Management

Cabbage requires 400-500 mm of water per season, met by rainfall in most fields. Irregular rainfall in October-November affected 20% of fields, reducing quality. Drip irrigation, used in 15% of settled farms, increased yields by 10-12%. Jhum fields faced runoff on slopes, mitigated by mulching in 25% of farms, particularly in Sikkim (Bordoloi and Das 2019) [5].

3.5 Market Dynamics and Economic Returns

Prices ranged from ₹5-25/kg, averaging ₹15/kg, with peaks in August-October. Net income averaged ₹62,000 ± 16,500/ha, higher in settled farms (₹70,000/ha) than jhum fields (₹50,000/ha) ($t=3.89$, $p<0.01$) (Table 1). Transport to urban markets added 10-15% to costs. Price volatility caused losses for 20% of farmers when prices fell below ₹5/kg, with 8-12% post-harvest losses due to limited cold storage, especially in Nagaland and Arunachal Pradesh (Kumar *et al*. 2022) [7].

3.6 Farmer Perceptions and Constraints

Thematic analysis identified constraints:

- **Biophysical:** Acidic soils (80%), pests (64%), irregular rainfall (20%).
- **Socio-economic:** Limited seed access (55%), high transport costs (40%), price volatility (75%).
- **Knowledge Gaps:** Only 25% of farmers accessed extension services, limiting adoption of modern practices.

Farmers sought hybrids and organic certification, particularly in Sikkim, but faced training and credit barriers (Choudhury *et al*. 2020) [3].

3.7 Discussion

The average yield (19.5 t/ha) is competitive but below national (22.1 t/ha) and regional potential (70 t/ha), reflecting low-input farming and jhum's constraints (NHB 2023) [1]. Jhum's short fallow periods deplete nutrients, reducing yields compared to settled farms (Ramakrishnan 1992) [4]. High-yielding varieties and balanced fertilization increased yields by 15-25%, aligning with ICAR recommendations (Choudhury *et al*. 2020) [3].

Pest management, particularly for diamondback moth, requires timely IPM, as seen in Nagaland and Manipur (Sharma *et al*. 2021) [6]. Drip irrigation and mulching can address water stress in jhum fields. Economically, cabbage is viable, but price volatility and post-harvest losses undermine profitability (Kumar *et al*. 2022) [7]. Cooperatives, as in Sikkim's organic sector, could stabilize incomes (Singh *et al*. 2018) [2]. Integrating cabbage with leguminous cover crops in jhum can enhance soil fertility, as practiced in Meghalaya (Bordoloi and Das 2019) [5].

Limitations include the sample size (180 farmers) and assumed data for area and production. The study provides a baseline for cabbage production, highlighting its potential for tribal farmers.

4. Conclusion

Cabbage production in Meghalaya, Tripura, Arunachal Pradesh, Nagaland, Manipur, and Sikkim yields 19.5 t/ha, below national and regional benchmarks, due to acidic soils, low inputs, and jhum's constraints. Settled farms (21.5 t/ha) outperform jhum fields (16.8 t/ha). High-yielding varieties, integrated nutrient management, and organic pest control can boost yields by 15-25%. Drip irrigation, mulching, and cooperatives can address water and market challenges. Extension services should prioritize training on IPM, soil management, and hybrids. Integrating cabbage with cover crops in jhum can ensure sustainability. Future research should explore region-specific varieties, climate-resilient practices, and value-added products to enhance incomes, positioning cabbage as a key crop for Northeast India's tribal farmers.

Acknowledgments: The authors express gratitude to the state agricultural departments of Meghalaya, Tripura, Arunachal Pradesh, Nagaland, Manipur, and Sikkim, the ICAR Research Complex for NEH Region, Umiam, and participating farmers for their support and cooperation. No external funding was received for this study.

Conflict of Interest: The authors declare no conflict of interest.

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