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Performance evaluation and economic analysis of *Bhut Jolokia* (*Capsicum chinense*) and tomato (*Solanum lycopersicum* L.) under polyhouse cultivation in NICRA-Adopted villages of Lakhimpur district, Assam

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Abstract
Vegetable cultivation in Assam, Northeast India faces significant climatic challenges including high temperatures, humidity, heavy rainfall, strong winds and frequent pest and disease outbreaks. A key constraint is the prolonged rainfall from April to October which delays planting and restricts early or off-season production. Consequently, harvests often coincide with peak market periods, leading to oversupply and reduced prices.To address this, protected cultivation using structures like polyhouses offers a promising solution by creating controlled growing environments. Under the National Innovations on Climate Resilient Agriculture (NICRA) project, five low-cost polyhouses (each 100 m²) were established in NICRA-adopted villages of Lakhimpur district to assess their effectiveness. Results showed a significant yield improvement under polyhouse conditions. *Bhut jolokia* produced 3.23 kg/m², compared to 1.16 kg/m² in open fields. Tomato yield increased to 7.068 kg/m² under polyhouses versus 1.92 kg/m² in open cultivation. Economic analysis further showed that *bhut jolokia* generated an average gross income of Rs. 1, 53,905 and an average net profit of Rs.109961.11, with a high benefit-cost ratio (BCR) of 5.15. Tomato cultivation earned Rs. 22627.89 in gross income and Rs. 5529.16 in net profit with a BCR of 1.56.

Keywords: Protected cultivation, low- cost polyhouse, bhut jolokia, tomato

Introduction
The availability of agricultural land is steadily declining, while the demand for food continues to rise due to population growth. This calls for the adoption of more intensive and efficient farming practices. Crop productivity is determined not only by genetics but also by the surrounding microclimate, which can significantly influence plant growth and yield. Traditionally, vegetable production is concentrated in the winter months, leaving the rest of the year underutilized (Chakraborty *et al*., 2014; Frantz, 2011) [1, 4].

In the Northeast region of India, particularly Assam, vegetable cultivation faces several climatic constraints such as high temperatures, humidity, heavy rainfall, strong winds and a high incidence of pests and diseases**.** One of the major limitations to vegetable productivity in Assam is the excessive rainfall from April to October which delays planting and prevents farmers from engaging in early or off-season production. As a result, vegetables often enter the market during the peak harvest period, leading to oversupply and low market prices. To realize better profits, farmers need to shift their production schedule either before or after the peak season to take advantage of higher prices.

One of the most viable solutions to this challenge is protected cultivation, which allows farmers to grow vegetables outside the regular season by shielding crops from extreme weather conditions such as heavy rains or low temperatures (Saikia *et al*., 2023) [5]. Protected cultivation is a technique where the microenvironment around the plant is either partially or fully controlled according to its growth requirements, thus improving yield, quality and resource use efficiency (Chakraborty and Sethi, 2015) [2].

Various types of protected structures such as greenhouses and polyhouses can be customized based on local climatic conditions to create favorable growing environments. Given the dual issues of price crashes during peak production and inability to cultivate during the rainy season, the cultivation of vegetables in protected structures presents a promising alternative. The use of low-cost polyhouses, in particular, has proven effective for the year-round cultivation of high-value crops, helping farmers make better use of limited land and resources (Saikia *et al*., 2023) [5].

A low-cost polyhouse is a simple structure typically covered with transparent polyethylene, which traps solar radiation and maintains a warm, humid environment. This helps extend the growing season, protect crops from adverse weather and improve the overall productivity of vegetables, flowers and other high-value crops. Such structures are especially effective for raising healthy, disease-free seedlings and cultivating off-season crops which can later be transplanted to open fields for early harvest.

During the regular growing season, crops like tomatoes, *bhut jolokia* (King chilli), capsicum and cucumbers often flood the market, causing price drops. On the other hand, extreme weather during the off-season makes it difficult to grow these crops in open fields. Low-cost polyhouse technology addresses this problem by enabling farmers to grow vegetables off-season, thereby avoiding market gluts and fetching better prices.

Under the NICRA project, five low-cost polyhouses (each of 100 m²) were established in NICRA-adopted villages in Lakhimpur district, Assam to demonstrate the potential of protected cultivation. These polyhouses serve a dual purpose-enabling the cultivation of high-value off-season vegetables and facilitating the early raising of vegetable seedlings, particularly for rabi crops. This is especially beneficial in areas like Lakhimpur, where heavy rainfall until mid-October delays the sowing of key vegetable crops such as cole crops, brinjal, chilli, and tomato.

By shielding crops from excessive rainfall and making better use of residual soil moisture, these polyhouses help ensure timely crop establishment and improve production efficiency. The cultivation of off-season high-value vegetables in protected structures offers farmers a sustainable pathway to enhance income, optimize land use, and build resilience against climate variability.Keeping this in view, a study was undertaken from 2018-2024 in five NICRA adopted villages with the following objectives:

1. To evaluate the yield performance of *bhut jolokia* and tomato under polyhouse conditions.
2. To analyze the economics and benefit-cost ratio of both crops in a protected environment.

Materials and Methods

The NICRA (National Innovation on Climate Resilient Agriculture) project was implemented across a cluster of five villages- Chamua, Nogaya, Borbali, Borkhet, and 1 no.Jakaipelua in Lakhimpur district, Assam. The project aimed to address various agricultural challenges arising from weather variability, soil degradation, and water stress. These villages are located in the North Bank Plain zone of Assam, with an altitude ranging between 83 to 90 meters.

The total cultivated area across these villages is 287 hectares all of which is rainfed. The dominant soil type in the region is *inceptisols*, with textures ranging from sandy loam to silty clay loam. Soil pH varies between 4.65 and 6.38 and organic matter content ranges from 0.34% to 3.03%. The region experiences a mean annual rainfall of 1987 mm, with the majority of rainfall occurring during the Kharif season (June–September), which accounts for 1958 mm. During the Rabi season (October–February), only 397 mm of rainfall is recorded.

The region faces a major drought challenge, especially during the rabi season and the high rainfall intensity during the kharif season, combined with periodic soil moisture stress in winter, severely impacts agricultural productivity.

From 2018 to 2024, an experiment was conducted in these five NICRA-adopted villages with the objective of improving agricultural resilience. Five farmers were selected from each village to conduct experiments with two high-value crops: *bhut jolokia* (*Capsicum chinense*) and tomato (*Solanum lycopersicum* L.).

Bhut jolokia, also known as King Chilli, is a high-value chilli variety indigenous to Northeast India, particularly Assam. It is known for its extreme pungency and market demand, both locally and internationally. However, in open-field conditions, its cultivation is highly sensitive to excessive rainfall, temperature fluctuations and disease incidence, all of which limit productivity. The adoption of low-cost polyhouse structures has shown promising results in improving its yield and economic returns.

Tomato (*Solanum lycopersicum* L.) is a high-value crop that responds well to protected cultivation. Under low-cost polyhouse conditions, yields are generally higher compared to open field cultivation due to the controlled microclimate that minimizes abiotic and biotic stresses.

The experiment followed a Randomized Block Design (RBD) with five replications for each crop. A control plot was also maintained during the study period where *bhut jolokia* and tomato were cultivated in open field condition and the results obtained were compared with those under polyhouse cultivation.

The yield data (kg/m²) for both crops under polyhouse conditions and open field conditions was recorded from 2018 to 2024. The average yield data from the entire period was calculated and analyzed using the RBD design. In addition, an economic analysis was conducted including a detailed study of the benefit-cost ratio for both crops to assess the financial feasibility and potential for scaling up polyhouse-based cultivation in the region.

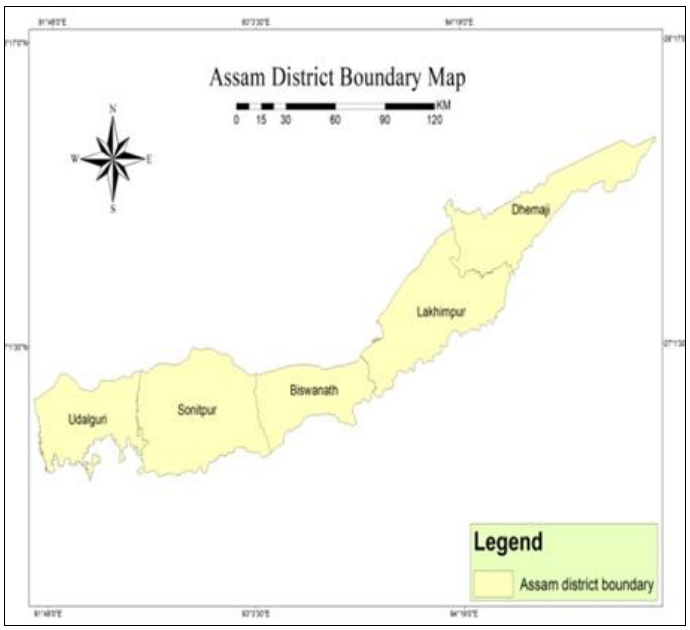

Fig 1: Map of North Bank Plain Zone of Assam

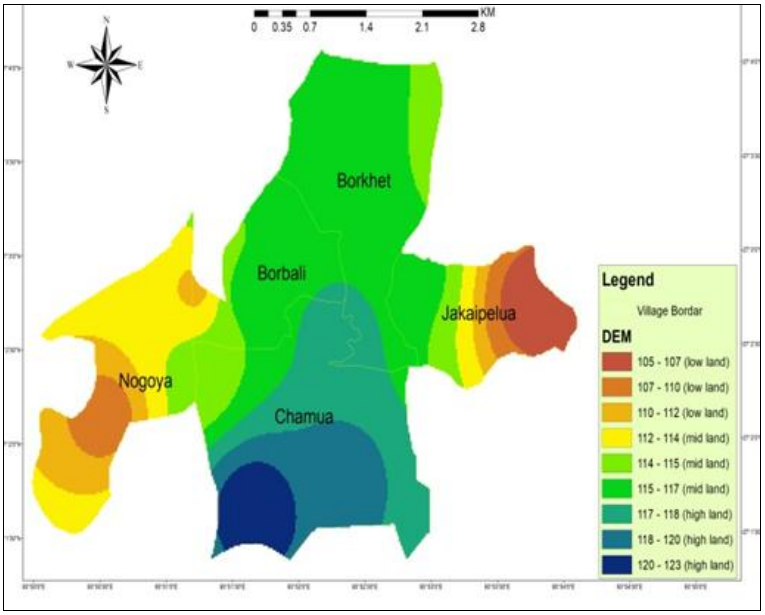

Fig 2: DEM of study area (100 ha)

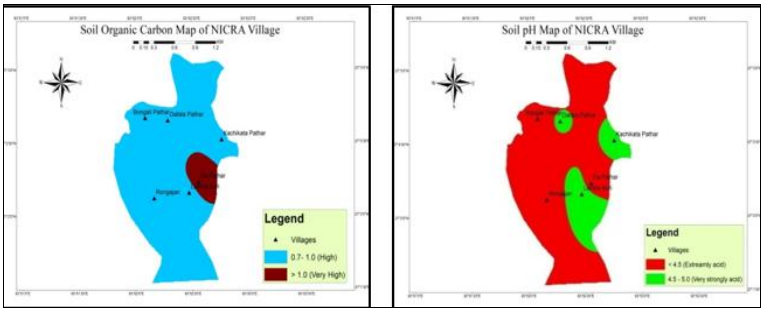

Fig 3: Soil organic carbon and pH of NICRA village

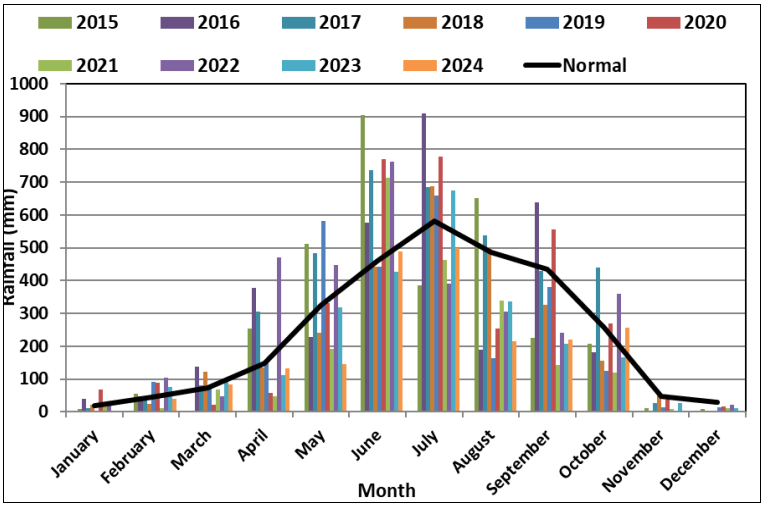

Fig 4: Rainfall (mm) of Lakhimpur district during 2015-2024

Results and Discussion

Under low-cost polyhouse cultivation, both *bhut jolokia* (King Chilli) and tomato have shown marked improvement in terms of growth, productivity and profitability compared to traditional open field farming. The production figures clearly demonstrate a substantial increase in crop output under protected cultivation. Specifically, *bhut jolokia* achieved an average yield of 3.23 kg/m² in the polyhouse which is more than the yield obtained under open field conditions (1.16 kg/m²). Similarly, tomato recorded an average yield of 7.068 kg/m² under the polyhouse setup, significantly higher than the 1.92 kg/m² achieved in open conditions (Table 1).

This increase in productivity is likely due to the controlled environment provided by the polyhouse, which protects crops from extreme weather conditions, pests and diseases while optimizing temperature, humidity, and soil moisture levels. These conditions are particularly beneficial for high-value crops like *bhut jolokia* and tomato, which are sensitive to climatic fluctuations and require precise growing conditions for optimal yield. These results are in conformity with Singh, 2014 [6] where it was found that production of vegetable crops under protected structure not only provides nutrient efficiency and high water

but it can easily increase production & productivity by 3-5 folds over outside/open field conditions for the crops under varied agro-climatic cultivation of the country.

Economic analysis further supports the advantages of polyhouse cultivation. *Bhut jolokia* under polyhouse conditions generated an average gross income of Rs. 1, 53,905 per production cycle with a net profit of Rs. 1, 09,961.11 after accounting for input and operational costs. In contrast, tomato cultivation under the same system yielded an average gross income of Rs. 22627.89 and a net income of Rs. 5529.16. The average benefit-cost ratio (BCR), a key indicator of profitability was found to be 5.15 for *bhut jolokia*. For tomato, the BCR was 1.56, although lower than that of *bhut jolokia*, still indicates a profitable venture under protected conditions (Table 2 & 3). Economic analysis of *Bhut jolokia* and Tomato under open field conditions records a substantially low average gross income of Rs 62691.67 and Rs 7026.5 respectively. The average net income of *Bhut jolokia* and Tomato under open field conditions was found to be Rs 33525 and Rs 1876.5 respectively. The average benefit cost ratios was also found to be significantly lower than those cultivated under low cost polyhouse, *i.e*. 2.26 and 1.33 for *Bhut jolokia* and Tomato respectively (Table 4 & 5).

These findings clearly demonstrate the potential of low-cost polyhouse technology to transform agricultural practices, particularly in regions where conventional farming is hindered by climatic or environmental challenges. The ability to grow crops in the off-season and under optimized conditions not only improves yield but also ensures better quality produce, reduced crop loss, and higher market prices especially for niche, high-demand crops like *bhut jolokia.*

Moreover, these results are consistent with the findings of Das *et al.* (2016) [3], who reported that tomato cultivation under low-cost polyhouse structures resulted in superior yield performance and higher benefit-cost ratios compared to open-field cultivation. This reinforces the conclusion that protected cultivation is a viable and sustainable approach to enhancing both productivity and profitability in modern horticulture, especially for small and marginal farmers seeking to maximize returns from limited land resources.

Table 1: Yield (kg/m^2/season) of *Bhut jolokia* (king chilli) and Tomato under poly house during 2018-24

Crop: Bhut jolokia	**Yield (kg/m^2)**						
	2018-19	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**2023-24**	**Mean**
Farmer1	3.17	3.89	1.35	3.25	3.67	3.55	3.14
Farmer 2	3.24	3.83	3.76	2.87	3.17	3.28	3.35
Farmer 3	2.65	3.63	2.48	3.25	4.12	3.15	3.21
Farmer 4	1.85	3.65	2.42	3.72	3.18	3.35	3.02
Farmer 5	4.33	3.53	2.74	3.67	2.96	3.49	3.45
Control (Open field)	0.69	0.82	1.54	1.70	0.90	1.31	1.16
CV							20.748
SE(d)							0.347
CD(5%)							0.718
Crop: Tomato	**Yield (kg/m^2)**						
	2018-19	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**2023-24**	**Mean**
Farmer1	7.75	4.57	7.78	6.36	8.16	7.58	7.03
Farmer 2	7.56	7.48	5.23	8.87	6.43	7.21	7.13
Farmer 3	8.74	7.67	5.63	7.23	6.75	9.21	7.53
Farmer 4	8.95	7.53	6.32	5.78	7.84	8.43	7.47
Farmer 5	4.43	8.58	4.58	7.41	6.69	5.42	6.18
Control (Open field)	1.82	2.53	1.36	1.23	1.87	2.71	1.92
CV							20.023
SE(d)							0.718
CD (5%)							1.488

Table 2: Economics of crops (Rs/100m^2/crop cycle) under low cost poly house during 2018-2024

Crops		**2018-19**			**2019-20**			**2020-21**	
	Gross income (Rs)	**Net income (Rs)**	**B:C**	**Gross income (Rs)**	**Net income (Rs)**	**B:C**	**Gross income (Rs)**	**Net income (Rs)**	**B:C**
Bhut jolokia	119475	89475	3.98	145125	118125	5.37	119083.33	84083.33	3.4
Tomato	19625	1625	1.09	19180	6180	1.47	18025	5025	1.38
Crops		**2021-22**			**2022-23**			**2023-24**	
Bhut jolokia	**Gross income (Rs)**	**Net income (Rs)**	**B:C**	**Gross income (Rs)**	**Net income (Rs)**	**B:C**	**Gross income (Rs)**	**Net income (Rs)**	**B:C**
Tomato	178446.67	158446.67	8.92	180000	142000	4.73	181300	141300	4.53
	23357.33	8857.33	1.61	25160	10160	1.67	30420	16420	2.17

Table 3: Average economics of crops (Rs/100 m^2/crop cycle) under low cost poly house during 2018-2024

Crops	**Gross Income (Rs)**	**Net Income (Rs)**	**B:C**
Bhut jolokia	153905	109961.11	5.15
Tomato	22627.89	5529.16	1.56

Table 4: Economics of crops (Rs/100m^2/crop cycle) under open field conditions during 2018-2024

Crops		2018-19			2019-20		2020-21		
	Gross income	**Net income**	**B:C**	**Gross income**	**Net income**	**B:C**	**Gross income**	**Net income**	**B:C**
Bhut jolokia	31050	11050	1.55	36900	11900	1.47	77000	49000	2.75
Tomato	5460	60	1.01	7590	2090	1.38	4760	760	1.19
		2021-22			**2022-23**		**2023-24**		
Crops	**Gross income**	**Net income**	**B:C**	**Gross income**	**Net income**	**B:C**	**Gross income**	**Net income**	**B:C**
Bhut jolokia	98600	76600	4.48	54000	14000	1.35	78600	38600	1.96
Tomato	4674	674	1.16	7480	2480	1.49	12195	5195	1.74

Table 5: Average economics of crops (Rs/100 m^2/crop cycle) under open field conditions during 2018-2024

Crops	Gross Income (Rs)	Net Income (Rs)	B:C
Bhut jolokia	62691.67	33525	2.26
Tomato	7026.5	1876.5	1.33

Fig 4: Cultivation of *bhut jolokia*

Fig 5: Cultivation of Tomato

Conclusion

In Assam, where vegetable cultivation is often hampered by erratic climatic conditions such as heavy rainfall, high humidity and pest infestations, the adoption of low-cost polyhouses presents a practical and effective solution. A polyhouse, essentially a protective structure made of transparent material allows farmers to control environmental factors such as temperature, humidity and light. When constructed using locally available and affordable materials like bamboo, these structures become even more accessible and economically viable for small and marginal farmers. Bamboo is abundantly available in Assam and widely used in traditional construction. It is lightweight, flexible and durable when properly treated, making it an ideal choice for the framework of low-cost polyhouses. Using bamboo instead of metal or PVC can reduce construction costs by up to 50% allowing more farmers to adopt protected cultivation without requiring heavy financial investment. Moreover, bamboo structures are environmentally sustainable and blend well with local farming practices.

Thus,building low-cost bamboo polyhouses in Assam is a sustainable and economically rewarding strategy for improving agricultural productivity and resilience. With careful design, proper crop selection and good management practices, polyhouses can help farmers overcome climatic challenges, stabilize incomes and contribute to food security in the region. This approach not only modernizes agriculture but also empowers smallholders by making advanced technologies more accessible and profitable.

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