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Research Paper

Assessment of Production Potentials And Challenges Of Horticultural Crops In East Siang District Of Arunachal Pradesh

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Abstract
This research paper presents a comprehensive assessment of the production potentials and challenges faced in horticultural crop cultivation in East Siang District of Arunachal Pradesh. The study examines the geographical, climatic, and socio-economic factors that influence horticultural production in this Himalayan region. East Siang District, characterised by its diverse agro-climatic zones ranging from sub-tropical to temperate conditions, offers significant potential for cultivating a wide variety of horticultural crops, including fruits, vegetables, spices, and plantation crops. The research identifies key production potentials such as favourable climatic conditions, diverse topography, rich biodiversity, and traditional farming knowledge. However, several challenges, including inadequate infrastructure, limited market access, lack of technical knowledge, insufficient post-harvest management facilities, and vulnerability to climate change impacts, constrain the sector's growth. The study employs both primary and secondary data collection methods, including field surveys, farmer interviews, and analysis of agricultural statistics. Findings reveal that while traditional crops like oranges, ginger, and local vegetables dominate production, there is substantial untapped potential for expanding cultivation of high-value crops such as kiwi, passion fruit, and organic vegetables. The paper concludes with strategic recommendations for enhancing horticultural production through improved infrastructure development, capacity building programmes, market linkage initiatives, and climate-resilient farming practices. This research contributes to understanding the horticultural landscape of Northeast India and provides actionable insights for policymakers, agricultural extension officers, and farming communities.

Keywords: *Horticulture, East Siang, Arunachal Pradesh, Production potential, Agricultural challenges, Northeast India, Hill agriculture*

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I. INTRODUCTION

Horticulture plays a pivotal role in the agricultural economy of India, contributing significantly to nutritional security, employment generation, and rural income enhancement (Ministry of Agriculture and Farmers Welfare, 2024). The northeastern region of India, particularly the state of Arunachal Pradesh, possesses immense potential for horticultural development due to its diverse agro-climatic conditions, ranging from tropical to alpine zones (Mailappa, Hazarika, & Geetarani, 2021).

Arunachal Pradesh has rich reservoirs of genetic variability and diversity of different crops, i.e., various kinds of fruits, different vegetables, spices, ornamental plants and also medicinal and aromatic plants. The diversity of horticultural crops of this region has mainly been managed by local farmers, often women. Considerable diversity exists among the regional horticultural species, including variation in plant type, morphological and physiological characteristics, reactions to diseases and pests, adaptability and distribution. Apart from the nutritional value, many regional horticultural crops are used for medicinal purposes and as an income-generating source in the rural areas (Mishra et al, 2020).

East Siang District, situated in the eastern part of Arunachal Pradesh, exemplifies this potential with its varied topography, favourable climate, and rich biodiversity that supports the cultivation of numerous horticultural crops.

East Siang District covers an area of approximately 3,603 square kilometres and is characterised by undulating terrain with altitudes ranging from 150 meters to over 4,000 meters above sea level (Directorate of Horticulture, Arunachal Pradesh, 2024). The district experiences a sub-tropical to temperate climate with annual rainfall varying between 2,000 and 3,500 mm, creating conducive conditions for diverse horticultural activities. The primary rivers, including the Siang River and its tributaries, provide essential water resources for irrigation, though their utilisation remains limited due to topographical constraints.

The East Siang district is mostly populated by the Adi tribe, which comprise of a large number of tribal groups and can be divided into various subgroups such as the Minyongs, Padams, Shimongs, Milangs, Pasis, Karkos, Ashings, Pangis, Tangmas and Boris. The Adis belong to the Mongoloid racial stock and are good-looking, sturdy and vigorous. According to Griession's linguistic classification, the languages spoken in East Siang District are put together under the North-Assam group of the Tibeto-Burmese group. There are various theories regarding the original home of the Adis; however, it seems probable that they came to their present habitat from the north, i.e., Tibet. The River Siang had a major role in determining the route of migration of most of the Adi clans. However, the exact location of their original home in Tibet or beyond that is still to be ascertained. Agriculture, including horticulture, engages approximately 70% of the district's population, making it the backbone of the local economy (Kumar, 2024). Traditional farming systems, characterised by jhum cultivation and terrace farming, have been practised for generations, demonstrating indigenous knowledge of sustainable land use practices adapted to hill ecosystems (Modi, 2025).

Despite these favourable conditions and traditional expertise, horticultural production in East Siang District faces numerous challenges that limit its potential. Infrastructure deficits, including poor road connectivity, inadequate storage facilities, and limited access to markets, significantly hamper the growth of commercial horticulture (Sati, 2004). Additionally, farmers often lack access to quality planting materials, modern cultivation techniques, and pest and disease management knowledge. Climate change impacts, manifesting as irregular rainfall patterns, increased pest incidence, and extreme weather events, further exacerbate production challenges (Bhati, Kumari, & Kumar, 2018; Singh et al, 2024).

This research paper aims to comprehensively assess the production potentials and challenges of horticultural crops in East Siang District. By examining geographical, climatic, socio-economic, and technological factors, this study seeks to provide evidence-based insights for developing effective strategies to enhance horticultural production and improve farmer livelihoods. The findings of this research will contribute to the broader understanding of hill horticulture in Northeast India and inform policy interventions aimed at sustainable agricultural development in the region.

II. LITERATURE REVIEW

Horticulture has emerged as a vital sector for agricultural diversification and income enhancement in India. According to the National Horticulture Board (2023), India ranks second globally in fruits and vegetables production, with the horticultural sector contributing approximately 33% to the agricultural Gross Domestic Product while utilising only 10% of the cultivated area. The northeastern region, blessed with diverse agro-climatic zones, has been recognised as having tremendous potential for horticultural development, particularly for temperate and sub-tropical fruits, spices, and flowers.

In Arunachal Pradesh, the practice of horticulture has been in existence for a long back but basically for self-consumption. As there is potential and a suitable climate for the promotion and cultivation of various horticulture crops in Arunachal Pradesh, the State government of Arunachal Pradesh has been promoting horticulture crops (Melo & das, 2022).

Several studies have documented the horticultural potential of Arunachal Pradesh. Research conducted by the Indian Council of Agricultural Research emphasises that the state's varied altitude and climate support the cultivation of tropical fruits in lower elevations, temperate fruits in mid-hills, and high-value crops like kiwi and apple in higher altitudes (Chadha, 2020). The unique biodiversity of the region offers opportunities for cultivating indigenous and exotic horticultural crops, many of which have high nutritional value and market demand (Boi, Sood, & Raj, 2024).

Studies on hill agriculture in the Himalayan region highlight both opportunities and constraints. The undulating terrain, while providing diverse microclimatic niches suitable for various crops, simultaneously poses challenges for mechanisation, irrigation, and transportation (Kumar & Singh, 2019). Research by agricultural universities in the northeast indicates that traditional farming systems, including shifting cultivation and terrace farming, have evolved as adaptive strategies to hill ecosystems but require modernisation to improve productivity and sustainability (Kumar, 2024).

Infrastructure deficits emerge as a recurring theme in literature on northeastern horticulture. Studies emphasise that inadequate road connectivity increases transportation costs and post-harvest losses, making it

difficult for farmers to access remunerative markets (Janakiram & Sanikommu, 2016). The lack of cold storage facilities, pack houses, and processing units results in significant wastage of perishable horticultural produce. Research also indicates that limited access to quality planting materials, modern inputs, and technical guidance constrains productivity improvements.

Climate change impacts on hill agriculture have gained increasing attention in recent literature. Studies document changing rainfall patterns, increased frequency of extreme weather events, and shifting pest and disease dynamics as major concerns for horticultural production in the Himalayan region (Bhati, Kumari, & Kumar, 2018). Research suggests that building climate resilience through diversification, improved water management, and adoption of climate-smart practices is essential for sustainable horticultural development.

Market linkage and value chain development have been identified as critical factors for horticultural growth. Literature emphasises that smallholder farmers in remote areas often lack bargaining power and receive unfair prices due to the presence of intermediaries (Hassan, Bhattacharjee, & Wani, 2021). Studies advocate for farmer-producer organisations, direct marketing initiatives, and contract farming arrangements as mechanisms to improve market access and ensure fair prices. Additionally, value addition through processing and branding of regional speciality products is recognised as a strategy for enhancing farm income.

The role of government schemes and institutional support in horticultural development has been extensively documented. Programmes such as the Mission for Integrated Development of Horticulture, Rashtriya Krishi Vikas Yojana, and various state-level initiatives provide financial assistance, technical support, and infrastructure development for the sector (Ministry of Agriculture and Farmers Welfare, 2024). However, studies indicate that implementation challenges, including limited awareness, bureaucratic delays, and inadequate monitoring, often reduce the effectiveness of these programmes in remote areas.

Organic horticulture has emerged as a promising avenue for the northeastern region, given its minimal chemical input usage and growing market demand for organic produce. Avasthe & Patel (2024) highlight that the region's traditional farming practices align well with organic certification requirements, providing opportunities for premium pricing and market differentiation. The authors emphasise that with appropriate support for certification, quality assurance, and market linkages, organic horticulture could become a major income source for hill farmers.

III. RESEARCH OBJECTIVES

The primary objectives of this research are:

i. To assess the current status of horticultural crop production in East Siang District
ii. To identify the production potentials for various horticultural crops based on agro-climatic suitability
iii. To analyse the major challenges and constraints faced by farmers in horticultural production
iv. To examine the existing support systems and infrastructure for horticulture development
v. To recommend strategic interventions for enhancing horticultural production and farmer income

IV. STUDY AREA AND METHODOLOGY

4.1 Study Area

East Siang District is located in the eastern part of Arunachal Pradesh, situated between 27°11' and 29°21' North latitude and 94°11' to 95°25' East longitude. The district headquarters is located at Pasighat, which serves as the administrative and commercial centre. The district is bounded by Dibang Valley District to the north, Upper Siang District to the northwest, West Siang District to the west, and the state of Assam to the south (Directorate of Horticulture, Arunachal Pradesh, 2024).

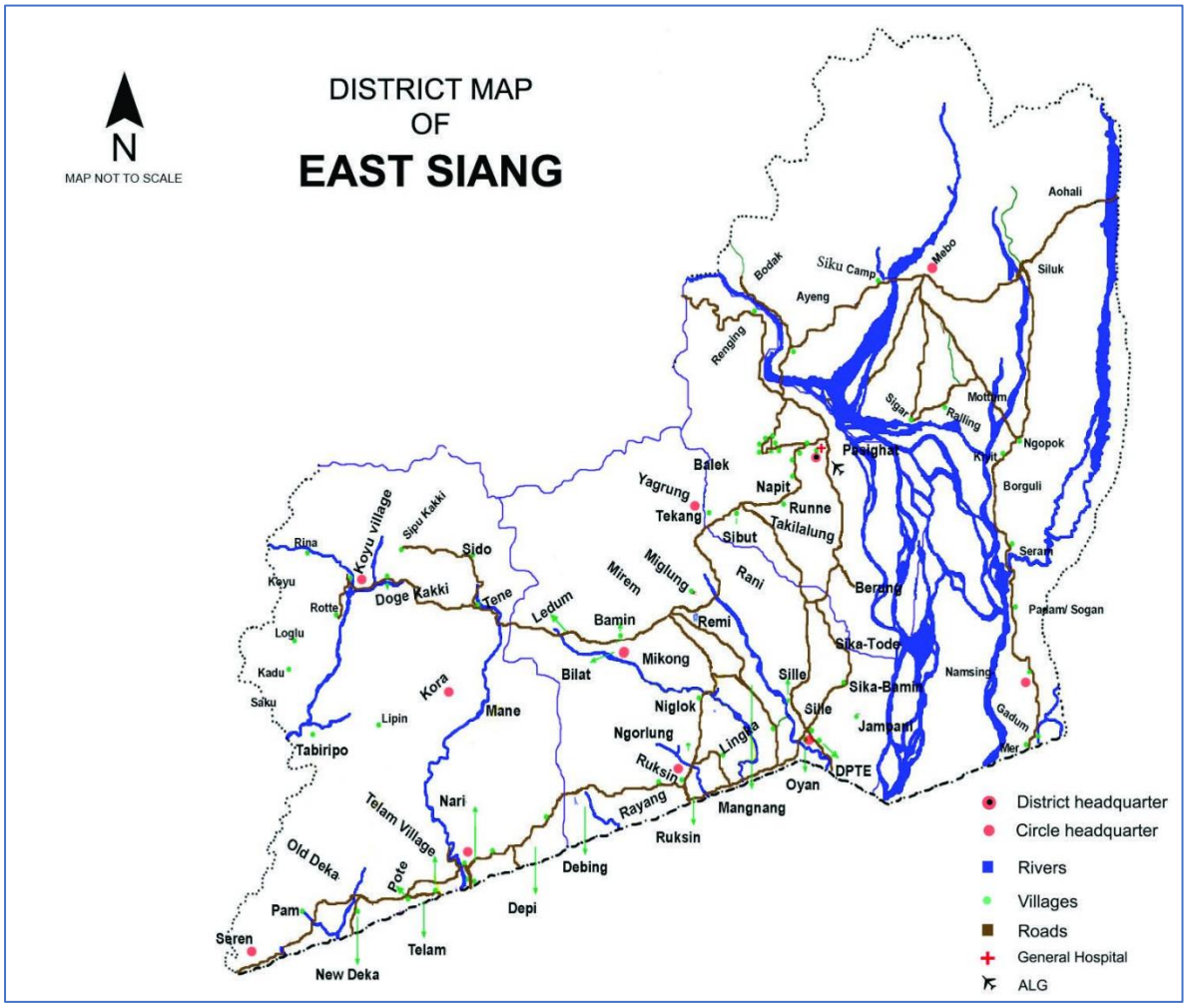

Figure 1: The Map of East Siang District (Study Area).

The topography of East Siang is characterised by hills, valleys, and river systems. The elevation varies dramatically across the district, with valley areas at approximately 150 meters above sea level rising to mountain peaks exceeding 4,000 meters. This altitudinal variation creates distinct agro-climatic zones, each suitable for different types of horticultural crops. The lower valleys support tropical and sub-tropical crops, mid-hills are ideal for temperate fruits and vegetables, while higher elevations can accommodate cold-climate speciality crops (Kumar & Singh, 2019).

The climate of East Siang District is influenced by monsoon patterns and altitude. The district receives abundant rainfall, averaging 2,500 to 3,000 mm annually, with most precipitation occurring during the monsoon season from May to September. Temperatures vary with altitude, with valley areas experiencing hot and humid conditions during summer (maximum 35-38°C) and cool winters (minimum 8-10°C), while higher elevations remain cool throughout the year with occasional frost and snowfall in extreme altitudes.

The soil types in East Siang are predominantly acidic, ranging from sandy loam to clay loam with varying degrees of organic matter content. River valleys have alluvial soils with good fertility, while hill slopes typically have shallow, less fertile soils prone to erosion. Soil pH generally ranges from 4.5 to 6.5, which influences crop selection and requires appropriate soil management practices, including liming and organic matter application (Kumar, 2024).

4.2 Research Methodology

This research employed a mixed-methods approach, combining quantitative and qualitative data collection and analysis techniques. The study utilised both primary and secondary data sources to ensure comprehensive coverage of the research objectives.

4.2.1 Data Collection

Primary data was collected through structured household surveys, focus group discussions, and key informant interviews. A sample of 250 horticultural farmers was selected using multi-stage random sampling from five

administrative circles of East Siang District. The sample included farmers engaged in the cultivation of fruits, vegetables, spices, and plantation crops, representing different landholding sizes and production systems.

Household surveys were conducted using pre-tested questionnaires covering aspects such as cropping patterns, production practices, input usage, yields, marketing channels, constraints faced, and support services received. Focus group discussions with farmer groups provided insights into community-level challenges, traditional knowledge systems, and collective action initiatives. Key informant interviews were conducted with agricultural extension officers, horticulture department officials, input dealers, and traders to understand institutional perspectives and market dynamics.

Secondary data was obtained from various government departments, including the Directorate of Horticulture, Arunachal Pradesh; the District Agriculture Office; the National Horticulture Board; and statistical abstracts of the various departments. Published research papers, reports, and documents related to horticulture in the northeastern region were reviewed to contextualise findings and compare with other studies.

4.2.2 Data Analysis

Quantitative data from surveys were analysed using descriptive statistics, such as means, frequencies, and percentages, to characterise the sample and production parameters. Production potential was assessed by analysing crop suitability based on agro-climatic conditions, existing production levels, and yield gaps compared to recommended practices.

Qualitative data from focus group discussions and key informant interviews were transcribed, coded, and analysed thematically. Constraint analysis was performed by ranking various challenges based on farmer perceptions using appropriate scoring methods. The findings from quantitative and qualitative analyses were triangulated to develop comprehensive insights into production potentials and challenges.

V. RESULTS AND DISCUSSION

5.1 Current Status of Horticultural Production

The survey results indicate that horticultural activities in East Siang District are dominated by a mix of traditional and introduced crop species. Oranges (*Citrus sinensis*) remain the most widely cultivated fruit crop, found in approximately 68% of surveyed households, primarily in mid-altitude areas ranging from 300 to 800 meters above sea level. The area under orange cultivation is estimated at around 3,200 hectares across the district, with average yields of 8-10 tons per hectare, which is considerably below the potential yield of 15-20 tons per hectare achievable with improved management practices (Chadha, 2020).

Ginger (*Zingiber officinale*) is the predominant spice crop, cultivated by 72% of respondents, particularly in areas with good drainage and moderate temperatures. The district produces approximately 4,500 tons of ginger annually from about 600 hectares. Local varieties are preferred for their pungency and flavour, though productivity averaging 6-7 tons per hectare remains below the achievable potential of 12-15 tons per hectare with high-yielding varieties and improved cultivation techniques (National Horticulture Board, 2023).

Vegetable cultivation, primarily for household consumption with limited marketable surplus, is practised by nearly all surveyed farmers. Common vegetables include local varieties of leafy greens, beans, cucurbits, and tomatoes. Production is largely seasonal and rain-fed, with limited adoption of protected cultivation or off-season production technologies. The total area under vegetables is estimated at 1,800 hectares with high diversity but low individual crop volumes.

Banana cultivation has gained popularity in recent years, particularly in the valley and foothill areas with assured irrigation. Approximately 45% of farmers grow bananas, mainly local varieties alongside introduced cultivars like Jahaji and Malbhog. The crop provides year-round income and contributes to household nutrition. However, production is constrained by pest and disease problems, particularly Panama wilt and Sigatoka leaf spot.

Emerging crops showing increasing farmer interest include passion fruit, kiwi, and pineapple. Passion fruit (*Passiflora edulis*) has been successfully introduced in mid-altitude areas, with 28% of farmers experimenting with small plantations. Kiwi (*Actinidia deliciosa*) cultivation is being promoted in higher elevations with favourable results in pilot projects, though scale remains limited. Pineapple (*Ananas comosus*) is cultivated in scattered pockets, primarily in warmer, well-drained slopes.

5.2 Production Potentials

Analysis of agro-climatic conditions, existing production systems, and successful case studies reveals substantial untapped potential for horticultural expansion in East Siang District. The diverse altitudinal and climatic zones enable the cultivation of a wide range of crops that can cater to different market segments and ensure year-round production and income (Kumar & Singh, 2019).

5.2.1 Fruit Crops

Citrus fruits, particularly oranges and mandarins, represent the most significant production potential given the favourable soil and climate conditions in mid-altitude zones. With improved orchard management practices,

including regular pruning, integrated pest management, and balanced nutrition, existing orchards could increase yields by 50-80% (Chadha, 2020). Expansion of citrus cultivation to suitable but currently underutilised areas could potentially double the current production area.

Kiwi fruit presents exceptional potential for higher altitude areas (1,200-2,000 meters). The crop commands premium prices in domestic and international markets, with limited production areas in India providing a competitive advantage. Pilot projects have demonstrated successful cultivation with yields of 15-20 tons per hectare (Directorate of Horticulture, Arunachal Pradesh, 2024). An estimated 500-800 hectares of suitable land could be brought under kiwi cultivation, potentially generating substantial income for farmers in higher elevation villages.

Passion fruit, well-adapted to the district's climate and requiring minimal inputs, offers quick returns (fruiting within 12-18 months) and year-round production. The crop has a growing demand for juice processing and fresh consumption. Conservative estimates suggest potential for expanding cultivation to 300-400 hectares, which could produce 3,000-4,000 tons annually, supporting establishment of small-scale processing units.

Other fruit crops with significant potential include pineapple in warm, well-drained slopes; papaya for homestead cultivation and commercial production in valley areas; and indigenous fruits such as local plums, peaches, and berries that could be developed for niche markets and value-added products.

5.2.2 Vegetable Crops

Off-season vegetable production represents a major opportunity given the district's altitude and climate advantages. During summer months when plains areas experience extreme heat, East Siang's mid and high altitude zones can produce temperate vegetables, including cabbage, cauliflower, peas, and beans that command premium prices in urban markets of Assam and other northeastern states (Kumar & Singh, 2019).

Protected cultivation using low-cost polyhouses and shade nets could extend production seasons and improve quality and yields. Pilot projects with protected cultivation have shown 2-3 times higher productivity compared to open field cultivation, along with better pest and disease control. An estimated potential exists for establishing 200-300 units of protected cultivation structures across the district.

Organic vegetable production presents another promising avenue, leveraging the district's minimal use of synthetic chemicals and growing consumer demand for chemical-free produce (Avasthe & Patel, 2024). With appropriate certification and marketing support, organic vegetables from East Siang could access premium market segments in metropolitan cities, potentially commanding a 30-50% price premium over conventional produce.

5.2.3 Spice Crops

Ginger production has enormous potential for expansion both in area and productivity. The traditional varieties are highly valued for their quality, and with improved agronomic practices and disease management, yields could be enhanced significantly (National Horticulture Board, 2023). Value addition through processing into dried ginger, ginger powder, ginger oil, and other products could substantially increase farmer incomes. An estimated 1,000-1,500 additional hectares could potentially be brought under ginger cultivation.

Turmeric (*Curcuma longa*), currently cultivated in limited pockets, has excellent potential given suitable climatic conditions and market demand. Large cardamom, successfully grown in neighbouring districts, could be introduced in higher elevation areas with appropriate canopy cover. Black pepper as a companion crop in arecanut and orange orchards offers potential for additional income without requiring separate land allocation.

5.3 Major Challenges and Constraints

Despite significant production potential, horticultural development in East Siang District faces multiple challenges that constrain productivity and limit farmers' ability to capitalise on market opportunities. Based on farmer surveys and stakeholder consultations, the following constraints have been identified as critical barriers requiring urgent attention.

5.3.1 Infrastructure Deficits

Inadequate infrastructure emerges as the most severe constraint, identified by 89% of surveyed farmers. Poor road connectivity, particularly in remote villages, results in high transportation costs (30-40% of produce value) and limits market access (Janakiram & Sanikommu, 2016). During monsoon season, many villages remain cut off for extended periods, leading to distress sales at exploitative prices or complete loss of perishable produce.

The absence of cold storage facilities and pack houses results in post-harvest losses estimated at 25-30% for fruits and vegetables. Farmers lack facilities for grading, sorting, and packaging produce to meet market quality standards. This infrastructure gap not only causes economic losses but also discourages farmers from expanding production, as they cannot handle increased volumes without appropriate storage and handling facilities.

Irrigation infrastructure is minimal, with less than 15% of horticultural areas having assured irrigation. Most farmers depend entirely on rainfall, limiting their ability to grow water-intensive crops or ensure production

during dry spells. The hilly terrain makes irrigation development challenging and expensive, requiring innovative solutions like drip irrigation, sprinkler systems, and water harvesting structures.

5.3.2 Market Access and Price Realisation

Limited market linkages and dependence on intermediaries result in poor price realisation for farmers. Approximately 76% of farmers sell their produce to local traders or commission agents at the farm gate or nearby collection points, receiving prices 40-60% below retail market rates (SFAC, 2012). The lack of an organised marketing infrastructure and farmer collective action weakens bargaining power and exposes farmers to price exploitation.

Market information systems are inadequate, with only 23% of farmers having access to regular price information from terminal markets. This information asymmetry benefits traders while farmers remain unaware of actual market prices and demand trends. The absence of regulated markets in the district means farmers have limited options for fair price discovery and transparent transactions.

Value chain development remains nascent, with minimal processing, value addition, or branding of local horticultural products. The district lacks processing units that could absorb surplus production during peak harvest, create value-added products, and generate off-farm employment. Branded marketing of speciality products that could command premium prices has not been developed effectively.

5.3.3 Technical Knowledge and Extension Services

Inadequate technical knowledge about improved cultivation practices limits productivity. Survey findings indicate that 67% of farmers lack awareness about the recommended package of practices for horticultural crops, including proper spacing, pruning techniques, integrated pest management, and nutrient management. Traditional practices, while sustainable, often result in suboptimal yields (Kumar, 2024).

Extension services coverage is insufficient, with an average farmer-extension worker ratio of approximately 1:800, far exceeding manageable limits. Extension personnel face challenges in reaching remote villages due to poor connectivity and a lack of resources. The quality of extension services is further compromised by limited training opportunities for extension staff on emerging crops and technologies relevant to hill conditions.

Access to quality planting material is a major constraint identified by 71% of farmers. Certified nurseries are few and located far from farming areas, forcing farmers to rely on unverified sources or self-produced materials that may not ensure genetic purity, disease freedom, or true-to-type characteristics. This affects establishment success rates and long-term orchard productivity.

5.3.4 Pest and Disease Management

Pest and disease incidence pose serious threats to horticultural production. Citrus greening disease, fruit flies, and various fungal infections cause substantial yield losses. Approximately 58% of farmers reported moderate to severe pest and disease problems, but lack knowledge of effective integrated management strategies (Chadha, 2020). The warm and humid climate favours pest proliferation, while limited access to quality pesticides and bio-control agents constrains management options.

Indiscriminate use of pesticides by some farmers, driven by a lack of proper guidance, creates concerns about residue levels, environmental impacts, and the development of pest resistance. The district lacks adequate plant protection infrastructure, including pest surveillance systems, diagnostic laboratories, and spray equipment support that could enable timely and effective interventions.

5.3.5 Climate Change Impacts

Climate variability and extreme weather events are increasingly affecting horticultural production. Farmers report changes in rainfall patterns with delayed monsoon onset, longer dry spells interspersed with intense rainfall, and increased frequency of hailstorms and strong winds (Singh et al, 2024). These changes disrupt traditional planting schedules, increase crop stress, and cause physical damage to plants and fruits.

Temperature fluctuations affect flowering, fruit setting, and development, particularly for temperate fruits that require specific chilling hours. Changes in pest and disease dynamics, with some pests expanding their range to higher altitudes previously unsuitable for them, create new management challenges. Limited climate information services and a lack of crop insurance coverage exacerbate farmer vulnerability to climate-related production risks.

5.3.6 Socio-Economic Constraints

Small and fragmented landholdings limit economies of scale and the adoption of capital-intensive technologies. The average horticultural holding size is approximately 0.8 hectares, often divided into multiple scattered plots across different elevation zones. This fragmentation increases management complexity and transportation costs while reducing productivity potential.

Limited access to institutional credit forces farmers to depend on informal sources at high interest rates or constrains their ability to invest in orchard development, inputs, and equipment. Only 31% of surveyed farmers had accessed formal credit for horticulture, with lengthy procedures, documentation requirements, and lack of awareness about schemes cited as major barriers.

Labour availability, particularly during peak periods of planting, harvesting, and weeding, is increasingly challenging due to rural-urban migration and the shift to non-farm employment. Approximately 54% of farmers reported difficulty in securing adequate labour, leading to delayed operations that affect productivity. Labour costs have also increased significantly, reducing the profitability of labour-intensive horticultural enterprises.

VI. STRATEGIC RECOMMENDATIONS

Based on the assessment of production potentials and challenges, the following strategic interventions are recommended to enhance horticultural production and improve farmer livelihoods in East Siang District. These recommendations require coordinated action by government departments, financial institutions, research organisations, and farmer communities.

6.1 Infrastructure Development

Prioritise development of rural roads connecting major production areas to markets, with particular focus on all-weather roads that remain functional during the monsoon season (Janakiram & Sanikommu, 2016). Establish collection centres at strategic locations equipped with basic facilities for sorting, grading, and temporary storage. Develop cold chain infrastructure, including cold storage facilities, refrigerated transportation, and pack houses at the circuit or district level through public-private partnership models.

Promote irrigation development through community-based water harvesting structures, drip and sprinkler irrigation systems, and spring-fed gravity flow systems suitable for hill conditions. Provide subsidies and technical support for on-farm water conservation structures and micro-irrigation installations. Establish demonstration sites showcasing efficient irrigation technologies adapted to local topography.

6.2 Market Linkage and Value Chain Development

Promote formation and strengthening of Farmer-Producer Organisations to enable collective marketing, bulk procurement of inputs, and enhanced bargaining power (Hassan, Bhattacharjee, & Wani, 2021). Facilitate direct linkages between FPOs and retail chains, hotels, institutional buyers, and export agencies, eliminating intermediary layers. Establish a regulated agricultural market in the district to ensure transparent price discovery and fair trading practices.

Develop market information systems using mobile technology to disseminate real-time price information, market demand, and quality requirements to farmers. Support the establishment of small-scale processing units for value addition, including fruit pulping, juice extraction, drying, and preservation. Promote the development of regional brands for speciality products like organic ginger, passion fruit, and traditional citrus varieties to access premium market segments.

6.3 Capacity Building and Extension Services

Strengthen extension service delivery through increased staff deployment, regular training programmes, and provision of necessary resources for field visits. Establish Farmer Field Schools and demonstration plots showcasing improved technologies for major crops. Develop a location-specific package of practices for different agro-climatic zones, incorporating both scientific knowledge and traditional wisdom (Kumar, 2024).

Promote farmer-to-farmer learning through exposure visits to successful horticultural regions and progressive farmers within and outside the state. Utilise digital extension tools including video tutorials in local languages, mobile apps for pest identification and management advice, and SMS-based advisory services. Engage youth in agriculture through specialised training programmes and incentives for horticultural entrepreneurship.

6.4 Quality Planting Material and Input Supply

Establish certified nurseries at different locations to ensure availability of quality planting material for fruits, vegetables, and spices (Chadha, 2020). Strengthen existing nurseries with infrastructure, technical expertise, and mother plant banks. Promote private sector participation in nursery development through appropriate incentives and quality certification mechanisms. Ensure availability of quality seeds, bio-fertilisers, and bio-pesticides through reliable distribution networks.

6.5 Integrated Pest and Disease Management

Establish pest and disease surveillance systems with regular monitoring and early warning mechanisms. Promote integrated pest management practices combining cultural, biological, and need-based chemical control methods. Support production and distribution of bio-control agents and organic pesticides. Establish plant health

clinics and diagnostic laboratories to provide farmers with accurate pest identification and management recommendations.

6.6 Climate Resilience

Promote crop diversification and mixed cropping systems to spread climate risks and ensure year-round production (Singh et al, 2024). Develop and disseminate climate information services, including seasonal forecasts and weather-based advisories. Support the adoption of climate-smart practices, including mulching, rainwater harvesting, protected cultivation, and stress-tolerant varieties. Establish weather-based crop insurance schemes with simplified procedures and quick claim settlements to provide risk coverage.

6.7 Financial Support and Credit Access

Simplify credit procedures and increase credit flow for horticultural development, including longer repayment periods, considering the gestation period of perennial crops. Provide interest subsidies and credit guarantees to encourage lending to smallholder farmers. Promote innovative financial products, including leasing arrangements for equipment, value chain financing, and group-based lending through FPOs. Ensure effective implementation of existing government schemes and subsidies with transparent processes and timely fund disbursement (Ministry of Agriculture and Farmers Welfare, 2024).

6.8 Research and Development

Strengthen research on location-specific crop varieties, cultivation practices, and pest management solutions for hill conditions. Conduct participatory research involving farmers in technology development and validation. Focus research efforts on high-value crops suitable for local conditions, post-harvest management technologies, and value addition processes. Document and validate traditional knowledge and practices for integration with modern scientific approaches (Kumar & Singh, 2019).

VII. CONCLUSION

This comprehensive assessment reveals that East Siang District possesses substantial potential for horticultural development, supported by favourable agro-climatic conditions, diverse topography, and rich biodiversity. The district's varied elevation zones enable cultivation of a wide range of crops from tropical to temperate species, offering opportunities for diversification, market specialisation, and year-round production. Existing production systems, though primarily traditional, demonstrate farmer knowledge and adaptive capacity that provide strong foundations for sustainable intensification (Kumar, 2024).

However, realisation of this potential is constrained by multiple challenges spanning infrastructure deficits, market access limitations, technical knowledge gaps, pest and disease pressures, climate change impacts, and socio-economic barriers (Sati, 2004; Bhati, Kumari, & Kumar, 2018). These constraints are interrelated and mutually reinforcing, requiring comprehensive and coordinated interventions rather than isolated solutions. The severity of infrastructure challenges, particularly poor connectivity and the absence of post-harvest facilities, emerges as the most critical constraint requiring urgent attention from policymakers and development agencies.

The strategic recommendations outlined in this paper provide a roadmap for sustainable horticultural development in East Siang District. Implementation of these recommendations requires convergence of various government schemes and programmes, active participation of farmer organisations, private sector engagement in market linkages and value addition, and sustained support from research and extension systems. Special emphasis should be placed on developing infrastructure, strengthening farmer collectives, and building climate resilience to ensure long-term sustainability.

Success in horticultural development will require balancing commercial production objectives with environmental sustainability and social equity considerations. The unique ecological sensitivity of the Himalayan region demands that intensification strategies incorporate conservation principles, minimise external input dependence, and preserve indigenous knowledge systems. Organic and natural farming approaches aligned with consumer preferences for chemical-free produce offer pathways for sustainable growth that protect environmental integrity while improving farmer incomes (Avasthe & Patel, 2024).

Looking forward, horticultural development in East Siang District can catalyse broader rural transformation, generating employment, enhancing nutritional security, and contributing to poverty reduction. The sector's growth will create opportunities not only in primary production but also in allied activities, including input supply, transportation, processing, marketing, and services. Youth engagement in horticultural entrepreneurship, supported by appropriate skill development and financial incentives, can help stem rural-urban migration while bringing innovation and energy to the sector.

This research contributes to understanding the horticultural landscape of Northeast India and provides evidence-based insights for policy formulation and programme design. Further research should focus on developing location-specific technologies, understanding market dynamics and consumer preferences, assessing climate change adaptation strategies, and evaluating the effectiveness of different institutional and organisational

models for smallholder horticulture development. Continuous monitoring and adaptive management approaches will be essential to navigate uncertainties and ensure that interventions remain relevant and effective in changing contexts.

In conclusion, while challenges are significant, the opportunities for horticultural development in East Siang District are equally compelling. With appropriate policy support, adequate investment in infrastructure and human capital, effective institutional arrangements, and farmer-centric approaches, the district can emerge as a significant horticultural hub in Northeast India, contributing to regional food security, economic prosperity, and sustainable rural development.

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