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## INTEGRATING HIGH-VALUE HORTICULTURAL CROPS INTO TRADITIONAL FIELD CROP SYSTEMS: OPPORTUNITIES, CONSTRAINTS, AND ECONOMIC RETURNS

L. Geetarani Devi<sup>1</sup>, Ashwini Choudhary<sup>2</sup>, Pooja Patel<sup>3</sup>, Ujjwal Singh<sup>4</sup>, Sibani Das<sup>4</sup>, Chandan Tiwari<sup>5</sup>, Priyanka Solanki<sup>6</sup> and Pritam Roy<sup>7\*</sup>

<sup>1</sup>Department of Agricultural Economics, College of Agriculture, Central Agricultural University, Imphal, Manipur, India

<sup>2</sup>Department of Agricultural Economics, Mandan Bharti Agriculture College, Agwanpur, Saharsa, BAU, Sabour, Bhagalpur, Bihar, India

<sup>3</sup>Department of Floriculture and Landscape, Mahatma Gandhi Udyanikee Evam Vanikee Viswavidyalaya, Sankra, Patan, Durg, Chhattisgarh, India

<sup>4</sup>Department of Horticulture, School of Agricultural Sciences, Nagaland University, Medziphema Campus, Nagaland - 797106, India

<sup>5</sup>Department of Horticulture, Bindeshwari P.G. College, Ambedkar Nagar, Dr. Rammanohar Lohia Avadh University, Ayodhya, Uttar Pradesh, India

<sup>6</sup>Department of Social Science, College of Horticulture and Forestry, Jhalawar, Agriculture University, Kota, Rajasthan, India

<sup>7</sup>Division of Dairy Economics, Statistics and Management, ICAR-National Dairy Research Institute, Karnal, Haryana- 132001, India

\*Corresponding author Email: [proy60988@gmail.com](mailto:proy60988@gmail.com)

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### ABSTRACT

The integration of high-value horticultural crops into traditional field crop systems represents a transformative approach to modern agriculture, particularly in developing economies like India. This review examines the multifaceted opportunities, practical constraints, and economic implications of such integration. Evidence from field research and farm-level studies demonstrates that strategic diversification can enhance farm productivity, stabilize household income, and improve resource utilization efficiency. Future research should advance understanding of crop combination optimization for diverse agroecological contexts, develop horticultural integration models adapted to specific farming systems (rice-based, maize-based, cotton-based), and evaluate long-term sustainability of integrated systems under climate variability. Farmer-centered research emphasizing farmer experimentation and participatory technology development will likely yield more context-appropriate knowledge than researcher-driven approaches alone. However, successful implementation depends on careful crop selection, adequate infrastructure, extension support, and market linkages. This paper synthesizes current knowledge on intercropping systems, crop rotation strategies, and economic performance metrics, providing a foundation for evidence-based policy recommendations and farmer adoption pathways.

**Keywords :** Sustainable agriculture, Crop diversification, Field crop, Modern agriculture, Economic returns.

### Introduction

Agricultural systems worldwide face mounting pressure to enhance productivity while maintaining ecological sustainability and farmer profitability. Traditional field crop systems dominated by cereals,

pulses, and oilseeds have historically provided food security but often constrain income growth for smallholder farmers. The introduction of high-value horticultural crops (vegetables, fruits, spices, and medicinal plants) into these systems offers substantial promise for agricultural diversification. The Indian

agricultural context provides a compelling case for studying this integration. With horticultural production requiring only marginal land increases to generate significant income improvements, the sector has attracted policy attention at national and state levels. A recent analysis suggests that a mere 1% shift in cultivated area from non-horticultural crops to horticultural crops can meaningfully raise agricultural productivity per unit land. This potential has spurred government initiatives including the Pradhan Mantri Fasal Bima Yojana, Pradhan Mantri Kisan Samridhi Yojana, and cluster development programmes targeting horticultural value chains (Khanam *et al.*, 2018). Yet translating policy intent into farmer reality requires understanding both the genuine opportunities and realistic constraints. This review addresses three core questions: What are the principal advantages of integrating horticultural crops into field systems? What practical barriers limit widespread adoption? And what returns can be farming households realistically expect? By examining intercropping models, temporal crop rotations, and economic performance across diverse agro-climatic regions, this paper provides actionable insights for agricultural practitioners, researchers, and policymakers.

## Conceptual Framework and Terminology

### Defining Horticultural Integration

Horticultural integration into field crop systems encompasses multiple approaches. The most common involve intercropping the simultaneous cultivation of two or more crops on the same plot and crop rotation the sequential cultivation of different crops over successive growing seasons. These practices differ fundamentally in their spatial and temporal dimensions yet share the objective of enhanced land productivity and farm income diversification. Intercropping represents spatial diversification, wherein crops with complementary growth patterns, rooting depths, and nutrient requirements occupy the same field during overlapping periods. Traditional examples include millet-legume mixtures in rainfed regions and maize-cowpea systems in semi-arid environments (Ahmed *et al.*, 2024). Horticultural intercropping introduces vegetables, fruit saplings, or medicinal plants as intercrops beneath or beside field crops, maximizing resource use and revenue generation. Crop rotation, by contrast, involves temporal diversification wherein different crops occupy the field in successive seasons. This approach has been employed for centuries to manage soil fertility, interrupt pest and disease cycles, and maintain long-term productivity (Moreira *et al.*, 2024). Modern interpretations integrate high-value horticultural crops into rotation sequences, allowing

farmers to capture premiums from specialized markets while managing agronomic risks.

### Conceptual Underpinnings

The theoretical basis for horticultural integration rests on several ecological and economic principles. First, complementarity of resource use permits multiple crops to extract and utilize inputs (light, water, nutrients) more efficiently than monocultures. Where crops occupy different ecological niches whether through rooting depth, growth duration, or light requirements combined productivity can exceed the sum of individual crops grown separately (Vats, 2025). Second, diversification provides economic risk reduction. Farmers depending on single commodities face market price volatility and production risks from pests and weather. Horticultural diversification creates multiple income streams with potentially uncorrelated price movements and distinct seasonal peaks, thereby stabilizing household cash flow and consumption patterns (Ankush, 2024). Third, agronomic benefits emerge through reduced pest pressure, improved soil structure, and enhanced biological activity. Mixed crops confuse insect pests that rely on host plant cues, while legume intercrops fix atmospheric nitrogen, reducing fertilizer dependence. Diverse crop residues improve soil organic matter accumulation and microbial diversity (Yadav *et al.*, 2024).

### Opportunities in Horticultural Integration

#### Productivity and Yield Advantages

Empirical evidence from India's National Initiative on Climate Resilient Agriculture (NICRA) programme demonstrates substantial yield improvements through appropriate intercropping. Across demonstration sites spanning diverse agroecological zones, intercropping configurations generated yield advantages ranging from 10.5% to 85.2% relative to monocropped systems (Kumar *et al.*, 2025). These gains represent the combined productivity of component crops expressed through the Land Equivalent Ratio (LER) a metric comparing intercrop land requirements to monocrop requirements for equivalent productivity. The mechanisms underlying these improvements vary by crop combination. Maize-cowpea intercropping generates two complementary harvests: grain from maize and pulse from cowpea because cowpea benefits from maize structural support and nitrogen fixation, total system output (grain+pulse+fodder) often exceeds monoculture returns. Studies specifically examining horticulture field crop combinations found that vegetable intercrops grown beneath fruit tree canopies produced marketable yield despite partial shading,

provided shallow rooted species were selected and sowing timing was optimized (Obasi, 2023). The yield advantage mechanism often reflects capture of spatially heterogeneous growing space. Tall field crops (cotton, maize, sorghum) create microclimates favorable for short-duration vegetables, spices, and medicinal plants. Strategic selection ensures minimal competitive interaction during critical crop growth stages. Research from agricultural universities in India's central and northern regions consistently documents yield improvements for base crops when appropriately selected intercrops are integrated, challenging the historical perception that diversification inevitably reduces primary crop output.

### **Economic Returns and Income Enhancement**

The economic dimension offers particularly compelling motivation for farmer adoption. Studies from diverse farming systems demonstrate income multiplicative effects through horticultural integration. One documented case involved coconut + black pepper + pineapple intercropping, generating net returns of approximately INR 45,600 per hectare (roughly USD 600) substantially exceeding pure coconut production returns (Weinberger *et al.*, 2007). Income enhancement operates through multiple channels. First, horticultural crops command market premiums reflecting higher quality, dietary value, and market demand than cereals and pulses. Vegetables typically fetch 3-5 times the per-unit-weight price of cereals. Spices (turmeric, coriander, red chillies) and medicinal plants carry substantial premiums when quality standards are met. Second, temporal diversification spreads household income across growing seasons, reducing seasonal cash stress that characterizes single-season field cropping. Where horticultural crops (vegetables, fruits) mature on shorter cycles than field crops, farmers can capture multiple market opportunities within a single year, accelerating capital turnover. Third, integration reduces input costs for farmers who can source seeds, saplings, and materials from on-farm production or local suppliers rather than commercial channels. The maize-cowpea intercrop example illustrates this principle: cowpea inputs beyond seed were negligible, yet market returns for cowpea were substantial, generating benefit-cost ratios of 1.3-4.2 depending on regional context (Bagchi *et al.*, 2024).

### **Resource Efficiency and Environmental Benefits**

Integration of horticultural crops improves three critical resource dimensions i.e. water, nutrients, and land. Water use efficiency improves through complementary extraction patterns. Short-duration intercrops occupy early season when moisture

availability peaks, while field crops develop root systems deeper into soil profiles. This sequential exploitation of soil moisture reserves reduces overall irrigation requirements and improves rainfed productivity. In semi-arid regions where water constitutes the primary productivity constraint, this benefit substantially enhances agricultural viability. Nutrient efficiency gains emerge from legume incorporation into rotation or intercrop sequences. Legumes establish mutualistic relationships with Rhizobium bacteria, converting atmospheric nitrogen into plant-available forms. A cereal-legume intercrop system thereby achieves nitrogen sustainability without chemical inputs, addressing both cost and environmental concerns. Research documented 20-30% reductions in nitrogen fertilizer requirements through legume integration without yield penalties, with benefits accruing across subsequent seasons through nitrogen residues (Walia *et al.*, 2025). Soil and environmental benefits extend beyond nutrients. Diverse crop residues improve soil organic matter accumulation and enhance microbial community complexity. Mixed cropping systems support greater arthropod diversity both pest species and beneficial predators creating more balanced natural enemy populations that suppress insect herbivores without insecticide dependence. These ecosystem services provide immediate economic value through reduced input requirements and represent long-term capital investment in soil health and productivity.

### **Constraints and Challenges**

#### **Technical and Agronomic Constraints**

Despite documented opportunities, numerous practical barriers limit horticultural integration adoption. Crop selection constitutes the primary technical challenge. Successful intercropping demands deep understanding of crop phenology, morphology, and growth requirements. Incompatible crop combinations fail to capture productivity gains and may generate competitive stress exceeding monoculture productivity. For instance, vegetables grown beneath fruit canopies may suffer excessive shading if tree pruning is inadequate or if shade-intolerant species are selected. While research identifies profitable combinations, farmer knowledge about these nuances remains uneven, particularly among smallholders with limited extension contact. Temporal coordination presents another technical hurdle. Horticultural crops require precise sowing timing to ensure maturity synchronization with field crop cycles. Early-sown vegetables may complete harvest before field crop canopy closure, maximizing light interception, whereas late sowing subjects

vegetables to excessive shading. Geographic variation in rainfall onset, temperature regimes, and soil conditions means that blanket recommendations rarely succeed across diverse contexts. Farmers must adapt general principles to local conditions through experimentation a process entailing production risk that many risk-averse smallholders cannot absorb without support.

### **Infrastructure and Input Supply Challenges**

Physical infrastructure constitutes a formidable practical constraint. Horticultural crops demand superior irrigation control compared to cereals and pulses. Vegetable production typically requires 20-25 irrigations during growing seasons, with precise scheduling according to crop phenology and soil moisture status. In regions with deficient irrigation infrastructure, inadequate electricity supply for pump operation, or unreliable water availability, horticultural integration remains technically infeasible regardless of economic returns. Seed and planting material supply chains often lack consistency in quality, authenticity, and availability. While open-pollinated field crop seeds are widely available through established government and private channels, improved vegetable varieties, fruit saplings, and medicinal plant seeds require more specialized distribution networks. Smallholder farmers in remote areas frequently face prohibitive travel costs to procure quality seeds from distant markets, creating adoption barriers independent of economic viability. Input availability extends beyond seeds to fertilizers, crop protection products, and tools. Horticultural crops frequently require specialty fertilizers balanced for high-value crops (NPK ratios distinct from field crops) and pest management products targeting specific vegetable pests. Where local dealers stock only field crop inputs, farmers incur additional search and transaction costs acquiring horticultural inputs.

### **Knowledge and Capacity Constraints**

Extension service capacity constitutes a critical limiting factor. Effective horticultural integration demands farmer knowledge spanning crop selection, agronomic management, pest identification, and post-harvest handling a substantially broader knowledge portfolio than field crop monoculture. Government extension systems in most Indian states face severe human resource constraints, with agent-farmer ratios often exceeding recommended standards by 5-10 fold. Consequently, reaching smallholders with intensive, specialized knowledge proves logistically challenging. Farmer experience and prior practice represent additional knowledge constraints. Many smallholders lack firsthand exposure to horticultural crops,

particularly in regions where agriculture historically centered on cereals and pulses. Risk perception regarding unfamiliar crops even when supported by research evidence of profitability limits adoption. Farmers naturally exhibit preference for crops with which they have experience and established marketing relationships.

### **Economic and Market Related Constraints**

Market access challenges substantially constrain horticultural integration's economic benefits. High-value crops generate premiums only when reaching markets in condition and time windows meeting quality specifications. Post-harvest losses estimated at 20-40% for Indian vegetables despite substantial quality improvements reflect inadequate cold chain infrastructure, limited processing facilities, and market information asymmetries. Where farmers cannot reliably reach buyers or must accept price penalties for quality degradation, realized returns fall substantially below research projections. Price volatility particularly affects horticultural markets. Vegetable prices exhibit substantial fluctuations driven by seasonal supply surges, limited storage capacity, and high perishability. Sudden market saturations during harvest seasons can reduce prices 50-70% relative to off-season levels, eroding profitability. Farmers lacking market information, contractual buyer relationships, or value addition capabilities face elevated price risk. Labor availability and costs introduce additional economic constraints. Horticultural crops are substantially more labor-intensive than field crops. Vegetable harvesting, grading, and packaging require 15-30 labor days per hectare compared to 5-10 days for cereals. Where rural labor markets have tightened due to urban migration and rural nonfarm employment growth, agricultural labor becomes scarce and expensive. The resulting labor cost increases compress horticultural profit margins unless yields or prices compensate.

### **Scale and Farm Size Considerations**

Farm size fundamentally mediates integration success. Recent research examining French farm data revealed that crop diversification benefits differ markedly across farm size categories (Rosenberg *et al.*, 2025). Small farms (< 30 hectares' economic size) demonstrate positive income effects from diversification, while larger farms face income challenges despite potential efficiency improvements. This pattern reflects per-hectare overhead and transaction cost considerations: small farmers benefit from risk reduction and market premium capture; large farmers face information and market transaction costs that proportionally outweigh diversification benefits. In

India's context with median farm holdings around 1-1.5 hectares, horticultural integration often requires spatial or temporal concentration rather than broad-based diversification. Intensive vegetable production on small plot areas may generate acceptable income, whereas dilute intercropping across larger areas faces labor and management constraints that reduce profitability.

### **Economic Returns: Evidence and Analysis**

#### **Comparative Profitability Assessment**

Field-level research across Indian agroecological zones provides concrete economic data. A comprehensive assessment examined horticultural integration profitability across legume-based diversified systems. Findings indicated that rice-legume diversified systems integrating horticultural components generated economic returns substantially exceeding rice monoculture. Specifically, farms incorporating horticultural diversification documented 25-35% income increases relative to baseline monoculture practices (Baba, 2024). These returns reflect multiple sources. Direct horticultural production contributions typically constitute 40-50% of total additional income, with remaining increments deriving from field crop productivity maintenance (yielding equivalent cereal production) plus reduced input costs through legume nitrogen fixation and crop protection benefits. The systems thereby generated both higher total output and lower per-unit production costs a favorable economic combination.

#### **Risk-Return Trade-offs**

Recent economic analyses document nuanced risk-return relationships in diversified systems. An examination of maize-based diversified cropping systems under different management approaches revealed that diversification consistently reduced yield variability across seasons while modestly reducing average yields (Nayak *et al.*, 2025). This risk reduction proves economically valuable under conditions of price uncertainty and natural variability. Farmers facing high income uncertainty demonstrate willingness to accept moderate yield reductions in exchange for increased income stability a preference reflected in insurance uptake and credit behavior. The economic value of risk reduction can be quantified using agricultural risk management frameworks. Where market prices exhibit coefficient of variation (CV) exceeding 25-30% (common for Indian vegetables), reduced production variability through diversification offers economic value roughly equivalent to 10-15% income premium compared to higher-variance monoculture. This implicit insurance value supplements direct

productivity and price premium benefits in diversified system economic calculations.

### **Scaling Considerations and Farm Size Effects**

As previously noted, economic returns scale nonlinearly with farm size. Detailed economic analysis comparing small (< 2 hectares) and large (> 10 hectares) farms revealed that horticultural integration returns per hectare decline substantially as farm size increases (Blanton and Feinman 2025). This pattern reflects fixed transaction costs: farmer time searching markets, negotiating prices, and managing logistics represents larger per-hectare overhead on larger farms. Consequently, small farm diversification frequently proves economically viable while large-farm diversification struggles economically despite potential sustainability benefits. This finding has profound policy implications. National objectives emphasizing agricultural diversification for sustainability must recognize that economic incentives naturally align with small farms. Large farms may require subsidy or regulatory instruments to achieve diversification, whereas policy supporting small farmer access to extension, credit, and market information generates self-sustaining economic motivation for horticultural integration.

### **Policy Frameworks and Support Mechanisms**

#### **Existing Government Initiatives**

The Indian government has recognized horticultural integration's potential through multiple policy mechanisms. The Cluster Development Programme promotes integrated, market-led development encompassing production, post-harvest handling, value addition, branding, and marketing. This systems approach addresses the comprehensive constraints discussed previously rather than focusing narrowly on production technology (Yojana, 2016). The Pradhan Mantri Fasal Bima Yojana (agricultural crop insurance scheme) extends to many horticultural crops, reducing production risk through premium subsidies. Kisan Credit Cards extend credit at favorable rates for agricultural inputs including horticultural production. State governments operate seed production systems generating certified seeds for vegetables, enhancing quality input supply. Agricultural universities operate demonstration plots showcasing horticultural integration models adapted to regional agroecology.

#### **Gaps and Needs**

Despite these initiatives, substantial gaps persist. Extension service capacity remains insufficient for intensive horticultural knowledge transfer. Credit

availability, while improving, remains constrained for resource-poor smallholders lacking land titles or collateral. Cold chain infrastructure concentrates in major urban-serving corridors, leaving many production regions inaccessible to quality preservation systems. Farmer producer organization capacity remains variable, with many organizations struggling with financial sustainability and member engagement. Effective policy would address these gaps through: (a) extension service augmentation with specialists in horticultural crop management; (b) targeted credit schemes with subsidized interest rates for horticultural integration, particularly for smallholders; (c) infrastructure investment in regional cold storage and processing facilities; (d) farmer producer organization capacity building; (e) market information dissemination systems enabling real-time price discovery; and (f) participatory demonstration programmes proving horticultural integration feasibility within community contexts.

### Regional Case Studies and Farmer Experiences

Farmer experiences across India's agroecological zones illuminate both opportunities and realistic constraints. In the red soil regions of central India, turmeric intercropping with vegetables (onion, coriander, chillies) and redgram significantly enhanced farmer income. Turmeric served as primary crop, with vegetables providing diversification and income before turmeric harvest. This arrangement proved sustainable across multiple seasons, with farmers reporting 40-50% income increases relative to prior turmeric monoculture, with reduced fertilizer requirements through redgram nitrogen fixation (Singh *et al.*, 2025). In coastal regions, coconut-based systems integrated black pepper and pineapple, generating diversified outputs spanning spice and fruit markets. The spatial arrangement efficiently used palm orchard space while reducing replanting requirements. Economic returns from diversified systems exceeded coconut monoculture substantially, approaching INR 46,000 per hectare annually. In irrigated northern plains, vegetable intercropping beneath early-harvested fruit orchards captured off-season vegetable market premiums. Rapid vegetable growth and harvest completed before tree canopy fully expanded, avoiding competitive stress. These systems generated additional income streams with minimal yield penalty to primary fruit crops. These diverse examples demonstrate that horticultural integration success patterns exist across India's agroecological regions when crop combinations are carefully matched to local conditions. However, they also illustrate that universal prescriptions fail;

context-specific knowledge development remains essential.

### Discussion and Synthesis

The evidence reviewed in this paper establishes that horticultural integration into traditional field crop systems offers genuine productivity, economic, and sustainability benefits under appropriately configured circumstances. Yield advantages documented across NICRA demonstrations consistently exceeded 10%, with many systems demonstrating 40-50% productivity improvements when measured as total system output. Economic returns increased substantially, with case studies documenting income increases ranging 25-50% above monoculture baselines. Environmental benefits through reduced chemical inputs and improved soil health represent additional gains difficult to quantify monetarily but recognized as economically valuable through reduced input costs and increased productivity sustainability. The challenge is not whether horticultural integration works in principle the agronomic and economic evidence is clear but rather how to transition from demonstrated models to sustained farmer adoption at scale. The constraints identified are not biologically insurmountable but rather represent practical, institutional, and economic barriers that policy and support systems must address. Small farm size advantages for horticultural integration economics suggest policy should emphasize mechanisms supporting smallholder adoption. Conversely, sustainable large-farm diversification may require complementary policy instruments beyond market incentives. Extension system strengthening remains foundational, as knowledge gaps constitute critical constraints across all regions. Matching credit availability to horticultural cycles with longer terms than field crop credit adapts financial services to crop-specific characteristics. Cold chain infrastructure investment creates essential post-harvest value preservation capacity. Participatory, community-embedded demonstration programmes prove more effective than centralized extension in encouraging farmer adoption of unfamiliar practices. Farmer producer organizations when effectively capacitated and governed address market access challenges and reduce per-farmer transaction costs, making horticultural marketing economically viable for smallholders. These mechanisms work synergistically: demonstrations prove feasibility, extension provides knowledge, credit enables investment, and farmer organizations manage marketing. Targeting combinations of support mechanisms to farmer contexts proves more effective than single-intervention approaches.

## Conclusion

Integrating high-value horticultural crops into traditional field crop systems represents a viable pathway toward enhanced farm productivity, income growth, and agricultural sustainability. The agronomic evidence demonstrating yield and resource efficiency advantages is robust. Economic analyses documenting income increases of 25-50% validate the farmer incentive for adoption. Environmental benefits through reduced chemical inputs and improved long-term soil and ecosystem health provide societal value complementing farmer private returns. However, widespread adoption requires comprehensive support addressing knowledge gaps, infrastructure constraints, input supply reliability, market access challenges, and credit availability. Policy frameworks must recognize that benefits scale differently across farm sizes, with small farms naturally advantaged in horticultural diversification economics. Effective policy therefore targets support mechanisms toward smallholder populations while recognizing that large-farm diversification requires complementary policy beyond market incentives. Future research should advance understanding of crop combination optimization for diverse agroecological contexts, develop horticultural integration models adapted to specific farming systems (rice-based, maize-based, cotton-based), and evaluate long-term sustainability of integrated systems under climate variability. Farmer-centered research emphasizing farmer experimentation and participatory technology development will likely yield more context-appropriate knowledge than researcher-driven approaches alone. As global agriculture confronts mounting challenges from population growth, natural resource constraints, and climate change, horticultural diversification offers a practical, evidence-supported approach to building more productive, equitable, and sustainable agricultural systems. The opportunities are substantial, the constraints are surmountable with appropriate support, and the economic returns justify investment in overcoming adoption barriers. Realizing this potential remains primarily a challenge of institutional innovation, policy prioritization, and sustained commitment to supporting farmer-centered agricultural change.

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