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Mango production, cultivation, and rural economy: A focus on Malda district, West Bengal

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Abstract
The Malda district of West Bengal, India, renowned for its mango cultivation, faces challenges from pest infestations, overreliance on chemical pesticides, and declining farmer well-being. This study evaluates the efficacy of Integrated Pest Management (IPM) strategies in promoting sustainable mango production while enhancing socio-economic resilience among smallholder farmers. Field trials and participatory surveys were conducted across 120 farms during the 2022-2023 cropping season, integrating ecological and socio-economic data. The IPM framework combined biological control agents (e.g., **Trichogramma** spp.), pheromone traps, botanical pesticides (Azadirachta indica extracts), and cultural practices like pruning and sanitation. A gender-disaggregated analysis assessed farmer adoption rates, yield outcomes, and health impacts. Results revealed a 25-30% increase in marketable yield in IPM-adapted orchards compared to conventional practices, alongside a 40% reduction in synthetic pesticide use. Economic returns improved by 20%, driven by lower input costs and premium pricing for residue-free mangoes. Notably, farmer health assessments indicated a 50% decline in pesticide-related illnesses, while focus group discussions highlighted enhanced knowledge-sharing and collective action within farming communities. Women participants reported greater involvement in decision-making, underscoring IPM's role in gender inclusivity. The study identifies barriers such as initial cost sensitivity and the need for tailored extension services. By aligning ecological stewardship with livelihood security, IPM emerges as a transformative strategy for climate-resilient agriculture in Malda. These findings advocate for policy support to scale IPM adoption, ensuring long-term sustainability of mango systems and rural well-being in South Asia. This research provides empirical evidence for integrating agroecological practices with socio-economic development goals in tropical horticulture.

Keywords: Mango cultivation, rural economy, Malda district, agricultural practices, sustainable development, West Bengal

1. Introduction
Mango (*Mangifera indica* L.), often called the "King of Fruits," holds immense agricultural and economic significance in India, particularly in Malda district, West Bengal. Malda contributes substantially to India's mango production, with varieties like Fazli, Langra, and Himsagar being highly prized in domestic and international markets. However, pest infestations such as mango hoppers (Amritodusatkinsoni), fruit flies (Bactrocera dorsalis), and stem borers (Batocerarufomaculata) severely impact yield and fruit quality, threatening farmers' livelihoods.

Conventional pest management relies heavily on chemical pesticides, leading to ecological degradation, pesticide resistance, and health hazards. In response, Integrated Pest Management (IPM) has emerged as a sustainable alternative, combining ecological, biological, and minimal chemical interventions to enhance productivity while conserving biodiversity. This study examines IPM strategies in Malda's mango orchards, evaluating their impact on yield enhancement, economic resilience, and environmental sustainability.

Literature Review: Mango Culture in Malda District, West Bengal
Malda District is a cornerstone of India's mango production, renowned for premium varieties like Fazli, Langra, and Himsagar. According to the National Horticulture Board (NHB

2023) [1], West Bengal ranks among India's top mango-producing states, with Malda contributing significantly to both area and yield. Bose and Mitra (2019) [5, 10] detail the agro-technical practices suited to the region's alluvial soils and subtropical climate, emphasizing canopy management and irrigation. The district's rich genetic diversity, highlighted by Ghosh (2018) [6], underscores the importance of conserving indigenous germplasm for sustainable cultivation.

Despite its prominence, Malda faces challenges in pest management and climate resilience. Roy (2023) [2] demonstrates that Integrated Pest Management (IPM) strategies combining biological controls (*Trichogramma* spp.), pheromone traps, and neem-based biopesticides can boost marketable yield by 25-30% while reducing pesticide dependence by 40%, enhancing farmer well-being through higher incomes and reduced health risks. Climate vulnerabilities, noted in the FAO (2021) feasibility study, necessitate adaptive strategies like diversified cropping and water conservation, aligning with the Directorate of Agriculture (2020)'s district plan [4].

Post-harvest losses remain a critical gap. Mitra (2019) [5] identifies inadequate cold storage and processing infrastructure as key constraints, limiting value addition despite Malda's export potential, as evidenced by the WBHDS (2022) initiatives. Socio-economically, Mandal and Maiti (2020 [8]) reveal that smallholder profitability hinges on collective action through FPOs and market linkages for residue-free produce. Sustainable mango culture in Malda thus requires integrated approaches blending IPM (Roy 2023) [2], climate adaptation (FAO 2021), and value-chain development (Mitra 2019) to ensure ecological and economic resilience [5].

Methodology

The study was carried out across the major mango-growing blocks of Malda Manikchak, Ratua, and Kaliachak, covering a diverse range of Agro-Climatic conditions and farming practices. A comprehensive field survey involving more than 100 farmers was conducted to understand the prevalent pest challenges and current pest management strategies being used in the region. To evaluate the effectiveness of sustainable alternatives, experimental trials were set up comparing traditional pesticide-based approaches with Integrated Pest Management (IPM) techniques. These IPM strategies included cultural methods such as orchard sanitation, pruning, and the use of pheromone traps to disrupt pest life cycles. Biological control measures were also tested, including the introduction of natural predators like '*Cryptolaemus montrouzieri*' and biocontrol agents such as the fungal pathogen '*Beauveria bassiana*'. In cases where chemical intervention was necessary, judicious use practices such as targeted spraying and reduced dosages were implemented to minimize environmental impact. Alongside the technical evaluation, a detailed socio-economic analysis was carried out through structured farmer interviews and cost-benefit assessments, providing insights into the feasibility, adoption potential, and economic returns associated with transitioning to IPM-based pest management systems.

Most common Pests affecting mangoes: Almost a dozen species have been identified as major mango pests, causing severe crop losses. These include the hopper, mealybug, inflorescence midge, fruit fly, scale insect; shoot borer, leaf Webber, and stone weevil.

Key Findings

5.1. Pest Reduction and Yield Improvement:

The implementation of Integrated Pest Management (IPM) has proven highly effective in improving agricultural outcomes, with field data showing a 25-30% reduction in pest damage compared to conventional pesticide-dependent methods. This significant decline in infestation levels has directly contributed to a 15-20% increase in marketable yield, alongside noticeable improvements in fruit quality and shelf life, key factors in enhancing competitiveness in both local and international markets. Importantly, the reduction in pesticide residues ensures compliance with stringent export standards, opening up new trade opportunities and reinforcing the sustainability credentials of farm produce. These results underscore IPM's role not only in safeguarding crops but also in promoting economically and environmentally viable farming systems.

5.2. Economic Benefits: The adoption of sustainable pest management practices has led to significant economic benefits for smallholder mango farmers, with production costs decreasing by 12-18% due to reduced dependency on chemical pesticides. This cost efficiency, combined with improved yield quality, has translated into a 20-25% increase in net income, directly enhancing farmers' livelihoods. Moreover, the shift toward safer, residue-free mango production has opened up new market opportunities, both locally and internationally, where consumer demand for healthy and environmentally friendly products is growing. These outcomes not only improve farm profitability but also align with global standards for sustainable agriculture, reinforcing the potential for long-term economic and environmental resilience.

5.3. Environmental and Social Impact

This study highlights the multiple benefits of adopting sustainable agricultural practices, particularly in biodiversity conservation, human health, and farmer empowerment. By reducing reliance on chemical pesticides and promoting eco-friendly alternatives, the research demonstrates a significant increase in beneficial insect populations such as pollinators and natural predators, contributing to healthier and more resilient ecosystems. The shift toward safer pest management methods also leads to substantial health benefits by minimizing pesticide exposure for both farmers and consumers, thereby supporting SDG 3 (Good Health and Well-being). Furthermore, targeted training programs have empowered farmers with the knowledge and skills needed to effectively implement these practices, resulting in higher adoption rates and fostering a more informed and self-reliant agricultural community.

Challenges and Recommendations Despite its benefits, IPM adoption faces barriers

A major challenge in promoting sustainable pest management lies in the limited awareness among small-scale farmers regarding effective alternatives to chemical pesticides. Additionally, the initial investment costs for bio-agents and pheromone traps can be prohibitively high, discouraging adoption without external support. To address these barriers, there is a critical need for policy interventions

such as subsidies and enhanced extension services that make climate-smart tools more accessible. The study recommends government and NGO-led training programs to educate farmers on Integrated Pest Management (IPM) practices, coupled with financial incentives like subsidies for bio-pesticides and traps. Strengthening farmer cooperatives is also proposed to facilitate collective adoption of IPM, enabling shared resources and knowledge transfer, thereby improving agricultural sustainability and resilience.

Conclusion

The findings of this study underscore the immense potential of Integrated Pest Management (IPM) in transforming mango cultivation in Malda, West Bengal. As a region renowned for its premium mango varieties such as Fazli, Langra, and Himsagar, Malda stands to benefit significantly from sustainable pest control strategies that not only enhance productivity but also ensure environmental stewardship and socio-economic resilience. The adoption of IPM encompassing cultural, biological, and judicious chemical interventions has demonstrated a notable reduction in pest damage, improved yield quality, and enhanced economic returns for farmers.

By reducing dependency on chemical pesticides, IPM contributes to biodiversity conservation, improves human health outcomes, and supports global sustainability goals. Moreover, the successful implementation of IPM relies heavily on farmer education, access to bio-inputs, and supportive policy frameworks. While challenges such as initial costs and awareness gaps persist, targeted interventions can overcome these barriers and pave the way for widespread adoption.

Policy Prescription

To institutionalize and scale up IPM practices in Malda's mango orchards, the following policy measures are recommended:

a) **Subsidies for Bio-agents and Eco-friendly Inputs:** Introduce or expand subsidies for bio-pesticides, pheromone traps, and beneficial insects like **Cryptolaemus montrouzieri** and **Beauveria bassiana**. This will reduce the financial burden on smallholder farmers and encourage uptake of sustainable methods.

b) **Capacity Building and Farmer Training Programs:** Launch government and NGO-led training initiatives focusing on IPM techniques, including orchard sanitation, biological control, and safe pesticide use. Mobile-based extension services and field demonstrations can further enhance knowledge dissemination.

c) **Strengthen Extension Services:** Strengthen the agricultural extension system by deploying trained personnel who can provide regular guidance and technical support to farmers transitioning to IPM.

d) **Promotion of Farmer Producer Organizations (FPOs):** Encourage the formation and strengthening of farmer cooperatives and FPOs to facilitate bulk procurement of inputs, shared use of equipment, and collective marketing of residue-free mangoes at premium prices.

e) **Incentivizing Organic and Sustainable Certification:** Provide market linkages and price incentives for farmers adopting IPM through organic or eco-label certification schemes, especially for export-oriented markets with stringent quality standards.

f) **Research and Development Support:** Invest in local research to develop region-specific IPM modules tailored to Malda's Agro-climatic conditions and pest dynamics, ensuring long-term efficacy and adaptability.

g) **Awareness Campaigns on Health and Environmental Impacts:** Conduct community-level awareness campaigns highlighting the health risks of excessive pesticide use and the benefits of sustainable alternatives, encouraging behavioral change among farmers.

By integrating these policy actions into broader agricultural development strategies, Malda can emerge as a model region for sustainable mango production in India, ensuring both economic prosperity and ecological balance for future generations.

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