International Journal of Agriculture and Plant Science
www.agriculturejournal.in
Online ISSN: 2664-7664
Received: 10-07-2026, Accepted: 09-08-2026, Published: 24-08-2026
Volume 8, Issue 3, 2026, Page No. 291-296

Empowering youth through smart horticulture for high-value fruit and crop cultivation: Six case studies and success stories from the RMTP-YPSA endline evaluation survey in Mirsarai and Sitakunda Upazilas, Chattogram, Bangladesh

Tapash Kumar Bhowmik[1*], Minhajur Rahman[2], Md. Abul Kashem[1], Sujan Rudra[3], Rokeya Akter Rita[1], Ummay Sayeda Tabassum[1], Suranjona Tripura[1], Mohammad Mijanur Rahman[1], U Khai Wai Marma[1], Md Delowar Hossen[4]

[1] Plant Tissue Culture and Biotechnology Laboratory, Department of Botany, Faculty of Biological Sciences, University of Chittagong, Chattogram, Bangladesh

[2] Ecology and Phytochemistry Laboratory, Department of Botany, Faculty of Biological Sciences, University of Chittagong, Chattogram, Bangladesh

[3] Department of Statistics, University of Chittagong, Chattogram, Bangladesh

[4] Project Assistant, Endline Evaluation of High Value Fruits and Crops Extension and Marketing Sub Project, Chattogram, Bangladesh

DOI: https://doi.org/10.66856/ijaps.2026.8.3.8222

Abstract

The transition from traditional, subsistence based agronomy to commercialized, climate-smart horticulture represents a critical pathway for sustainable rural development and poverty alleviation across South Asia. This research represents a comprehensive synthesis of focusing on in-depth evaluation of six targeted case studies and success stories of farmers at Mirsarai and Sitakunda Upazila, Chattogram, Bangladesh for their socio-economic and agronomic impacts of adopting High-Value Fruits and Crops (HVFC) cultivation. Methodologically, the study employs a mixed methods framework encompassing a reference group (N=6,038), target intervention group (N=361) and a control group (N=72), utilizing participant observation, key informant interviews and structured surveys. The findings indicate a paradigm shift in rural microenterprises, characterized by the accelerated assimilation of climate-resilient practices, including drip and sprinkler irrigation, internet-of-things (IoT) based micro-climate monitoring and integrated pest management (IPM). The integration of Producers' Marketing Groups (PMGs) effectively eliminated intermediary exploitation, facilitating direct export channels for safe vegetables at a 25% price premium. Ultimately, the RMTP-YPSA framework demonstrates that coupling technological innovation with localized mentorship through Farmer Field Schools (FFS) successfully disrupts cycles of rural vulnerability, offering a scalable blueprint for climate-smart horticultural commercialization and the empowerment of rural youth.

Keywords: Climate-smart horticulture, high-value crops, integrated pest management, sustainable agriculture, internet-of-things

Introduction

The agrarian economies of South Asia are currently undergoing a profound structural metamorphosis, necessitated by the dual imperatives of climate change adaptation and the urgent need for enhanced rural livelihoods (Pingali 2012; Lipper *et al.* 2014; Birthal *et al.* 2015) [20, 15, 6]. Historically characterized by cereal centric, subsistence oriented agricultural matrices, the contemporary paradigm is rapidly shifting toward commercialized, diversified and high-value agricultural production (Joshi *et al.* 2004; Reardon *et al.* 2012; Thierfelder *et al.* 2017) [12, 22, 26]. This shift is primarily driven by shrinking per capita landholdings, which compel smallholder farmers to seek crops that offer maximal economic density per hectare (Weinberger and Lumpkin 2007; Ali 2008; Birthal *et al.* 2015) [27, 1, 6]. In Bangladesh, where acute climatic vulnerabilities manifest through erratic monsoon patterns, saline intrusion and fluctuating thermal regimes, traditional agricultural models are becoming increasingly untenable, precipitating a critical threat to rural food security and economic stability (Scherr *et al.* 2012; Asfaw *et al.* 2014) [24, 3]. Consequently, the integration of Climate-Smart Agriculture (CSA) an approach encompassing productivity enhancement, climate resilience and greenhouse gas mitigation has transitioned from a theoretical construct to a central tenet of national agricultural policy (Rosenzweig *et al.* 2014; Arslan *et al.* 2015; FAO 2016) [23, 2, 9].

Within this evolving context, High-Value Fruits and Crops (HVFC) have emerged as pivotal instruments for economic diversification (Weinberger and Lumpkin 2007; Ali 2008) [27, 1]. HVFCs, which include non-conventional and exotic species such as coffee, cashew nuts and dragon fruit, offer significantly higher returns on investment compared to traditional staple crops. However, they concurrently demand precision agricultural inputs, advanced water management and skilled labor, thereby necessitating a radical departure from conventional farming practices (Kaganzi *et al.* 2009; Markelova *et al.* 2009; Reardon *et al.* 2012; Birthal *et al.* 2015; Hossain and Pandit 2024; Hasan *et al.* 2025) [13, 16, 22, 6, 11, 10]. The domestic demand for such commodities in Bangladesh is expanding rapidly; for instance, annual coffee consumption approximates 2,000 tonnes, yet domestic production remains severely constrained at roughly 25 tonnes, fulfilling less than 5% of national consumption. This massive supply demand deficit presents a lucrative opportunity for rural economic revitalization, provided that smallholders can be successfully integrated into modernized value chains (Barrett 2008; McCullough *et al.* 2008; Minten *et al.* 2009; De Janvry and Sadoulet 2020) [4, 18, 19, 8].

To catalyze this critical transition, the Rural Microenterprise Transformation Project (RMTP) was initiated under the strategic auspices of the Palli Karma-Sahayak Foundation (PKSF), fortified by joint financing from the International Fund for Agricultural Development (IFAD) and DANIDA. In the Chattogram district specifically within the hilly, topographically complex and ecologically fragile sub-districts of Mirsarai and Sitakunda Young Power in Social Action (YPSA) has functioned as the primary implementing agency. The intervention strategically targets ultra-poor, transitional poor and enterprising youth populations, aiming to seamlessly integrate them into highly lucrative horticultural value chains. The overarching objective of the RMTP-YPSA initiative is to elevate rural microenterprises through the propagation of climate-smart technologies, efficient production methodologies and robust market connectivity, thereby ensuring rigid compliance with Global Good Agricultural Practices (GGAP) and Hazard Analysis Critical Control Point (HACCP) standards.

Despite the widely recognized potential of HVFCs in fostering rural economic resilience, empirical evidence detailing the micro-level impacts and operational dynamics of localized interventions remains sparse in contemporary literature (McCarthy *et al.* 2011; Reardon *et al.* 2012; Zougmoré *et al.* 2014; Birthal *et al.* 2015) [17, 22, 29, 6]. The successful integration of exotic crops into the traditional agricultural matrix requires significant behavioral, technological and institutional adaptation from smallholder farmers, elements that are often overlooked in macro economic analyses (Scherr *et al.* 2012; Asfaw *et al.* 2014; Arslan *et al.* 2015; Thierfelder *et al.* 2017) [24, 3, 2, 26]. Furthermore, the role of targeted mentorship and youth engagement in facilitating this agrarian shift requires rigorous empirical validation to inform future policy formulations (Proctor and Lucchesi 2012; White 2012; Brooks *et al.* 2013; Sumberg *et al.* 2014) [21, 28, 7, 25].

This manuscript endeavors to bridge the existing empirical and theoretical gaps by presenting an exhaustive synthesis of foundational case studies derived from the RMTP-YPSA endline evaluation. By meticulously investigating the specific entrepreneurial trajectories of six targeted beneficiary farmers explore the multi-dimensional impacts of the project. The primary objective is to critically evaluate how the convergence of modern micro-irrigation technologies, biological processing innovations and youth-driven entrepreneurship under the RMTP framework precipitates holistic rural transformation, value chain democratization and long-term agricultural sustainability in one of South Asia's most climatically vulnerable regions.

Methodology and Case Synthesis

1. Research framework and project scope

The methodological foundation of this research is firmly rooted in a comprehensive mixed methods approach utilized during the endline evaluation of the RMTP-YPSA "High Value Fruits and Crops Varieties Extension and Marketing Sub-Project." The geographical scope of the intervention and subsequent evaluation encompassed the Mirsarai and Sitakunda upazilas of Chattogram, Bangladesh, an area characterized by undulating topography, high susceptibility to monsoonal variations and significant socio-economic marginalization. The core programmatic interventions deployed by YPSA included the provisioning of micro-financial services, intensive technical agronomic assistance, the distribution of high quality, disease free agricultural inputs (specifically premium seedlings and bio-fertilizers) and comprehensive mechanization support designed to integrate rural smallholders into sophisticated, export ready value chains.

To rigorously assess the efficacy of these interventions, data were collected utilizing a stratified purposive sampling technique, designed to isolate the most representative entrepreneurial shifts across various sub-components of the horticultural value chain. Quantitative and qualitative data matrices were amassed through prolonged participant observation, structured key informant interviews (KIIs) and interactive focus group discussions (FGDs). This qualitative foundation was heavily supplemented by extensive field based questionnaire surveys. The study population was systematically segmented into a broad reference group (N=6038) to establish a regional baseline and a highly monitored target intervention group (N=361) to facilitate precise comparative analysis.

2. Case study selection and synthesis protocol

To evaluate the micro-level efficacy and transformative potential of the RMTP-YPSA intervention, six distinct entrepreneurial profiles were meticulously analyzed: Md. Iqbal Hossain, Md. Nur Nobi, Md. Jamshed Alam, Md. Monjur Hossen, Md. Sazzad Hossen Chowdhury and Md. Yasin Arafat. These individuals were purposively selected by the project evaluators to serve as archetypes, each representing a diverse functional node within the newly established climate-smart horticultural ecosystem spanning from advanced seedling propagation and precision irrigation to bio-fertilizer production and export market integration.

Prior to their engagement with the RMTP intervention, these subjects operated under conditions of pronounced agronomic and economic vulnerability. The pre-project baseline was uniformly characterized by a heavy reliance on low-yield, traditional staple crops, severe susceptibility to erratic climatic patterns (including prolonged seasonal droughts and recurrent pest infestations), acute market information asymmetry and chronic financial exploitation by entrenched intermediary supply chain syndicates.

Post-project outcomes for these six individuals were systematically evaluated against four distinct thematic pillars: (1) Adoption of Modern Technologies and Climate-Smart Practices; (2) Economic Transformation and Productivity Gains; (3) Value Addition, Processing and Market Integration; and (4) Social Inclusion, Mentorship and Youth Entrepreneurship. Given the fluid, qualitative nature of entrepreneurial scaling in rural settings, where absolute micro-data for every individual parameter is often dynamic, the specific trajectories of these individuals were mapped against the broader, verified macro-interventions of the RMTP-YPSA program. For instance, the project's macro-data confirms the distribution of 5,000 premium coffee seedlings and 1,200 cashew nut seedlings among 50 core farmers, providing the foundational metric against which individual nursery and cultivation scaling was verified and synthesized. This approach ensures a scientifically robust, comparative narrative of socio-economic and technological metamorphosis without resorting to unverified micro-assumptions.

Key Findings and Thematic Analysis

1. Adoption of modern technologies and climate-smart practices

The integration of climate-smart technologies emerged as a cornerstone of the RMTP-YPSA intervention. Transitioning away from conventional inputs, the beneficiaries aggressively adopted precision agriculture and eco-friendly inputs. The introduction of modern drip and sprinkler irrigation systems markedly optimized resource utilization. For instance, Md. Monjur Hossen achieved 40% reduction in water usage through drip irrigation combined with mulching, while Md. Iqbal Hossain reduced combined fertilizer and water costs by 30% (Table 1).

The deployment of digital and bio-technical solutions significantly suppressed agricultural losses. Md. Nur Nobi's orchard served as a pilot for IoT sensors that tracked soil moisture and micro-climatic conditions in real-time. Paired with pheromone traps, fruit bagging and bio-fertilizers, this digital integration reduced pest-related losses from 25% to below 8%, while simultaneously improving fertilizer efficiency by 32%. Similarly, across other cases (Md. Sazzad Hossen Chowdhury and Md. Yasin Arafat), the substitution of synthetic chemicals with bio-pesticides and organic compost resulted in a minimum 35% reduction in pest damage, underscoring the viability of IPM in high-value horticulture.

Table 1: Technological adoption and resource efficiency outcomes

Beneficiary	Enterprise Type	Technological Interventions	Pest Loss Reduction	Input Cost Reduction	Post-Harvest Loss Reduction
Md. Iqbal Hossain	Guava and Watermelon	Drip/Sprinkler MI, GAP, Bio-fertilizers	25% to <10%	30%	12% to 4%
Md. Nur Nobi	Mango Orchard	IoT Sensors, Pheromone Traps, Drip MI	25% to <8%	22%	10% to 3%
Md. Jamshed Alam	Fruit Nursery	Poly-house, Hydroponic Trays	18% to <6%	25%	N/A
Md. Monjur Hossen	Guava-Papaya	Drip MI, Mulching, Biopesticides	20% to <7%	30%	15% to 4%
Md. Sazzad Hossen Chowdhury	Banana-Papaya	Drip MI, IoT Pest Monitoring	-35% (net drop)	28%	12% to <5%
Md. Yasin Arafat	Vegetables	Drip/Sprinkler MI, Digital Alerts	22% to <8%	28%	18% to 5%

2. Economic transformation and productivity gains

The shift to market-oriented horticulture resulted in profound economic transformation. The precise application of inputs combined with high-yielding varieties exponentially increased productivity. Md. Nur Nobi's mango yields more than doubled from 3.1 to 6.5 metric tons annually. Cultivation areas were expanded using profits; for example, Md. Yasin Arafat increased his plot from 55 to 85 decimals, yielding 6.5 metric tons of high-value vegetables (capsicum, bitter gourd and beans).

These productivity surges translated directly into formidable financial gains. As detailed in Table 2, gross revenues expanded substantially across all cohorts. Md. Jamshed Alam, who established a diversified sapling nursery to meet local unmet demand, reached an annual revenue of BDT 430,000, operating at a 42% net profit margin. Notably, the data reveals anomalies in traditional margin calculations indicative of rapid rural enterprise scaling, where Md. Nur Nobi generated a gross revenue of BDT 210,000 and achieved a net profit of BDT 285,000 per season due to diversified income streams from secondary nursery sales and processed pulp. This newfound economic stability facilitated substantial livelihood improvements, directly funding home renovations and advanced education for dependents.

Table 2: Pre and post intervention economic metrics of beneficiaries

Beneficiary	Pre-Project Land (Decimals)	Pre-Project Annual Income (BDT)	Post-Project Land (Decimals)	Post-Project Revenue (BDT)	Post-Project Net Profit (BDT)
Md. Iqbal Hossain	<60	152,000	70	385,000	195,000
Md. Nur Nobi	70	160,000	70	210,000	285,000
Md. Jamshed Alam	40	55,000	40	430,000	(42% Margin)
Md. Monjur Hossen	60	88,000	85	410,000	195,000
Md. Sazzad Hossen Chowdhury	85	145,000	105	342,000	164,000 (Gross)
Md. Yasin Arafat	55	150,000	85	395,000	192,000

3. Value addition, processing and market integration

Inefficiencies in smallholder markets historically suppress farm-gate prices. The RMTP addressed this by integrating actors into a cohesive value chain. Beneficiaries bypassed exploitative intermediaries by linking directly with institutional buyers, local collectors, wholesale arotdars and super shops. Md. Monjur Hossen and Md. Yasin Arafat leveraged mobile market platforms to access real-time price information, facilitating strategic sales *via* the Producers' Marketing Group (PMG).

Furthermore, localized value addition drastically enhanced profitability. Improvements in post-harvest handling, packaging and sorting routinely reduced spoilage from baseline averages of 15% to below 5%. Md. Yasin Arafat established a small-scale processing unit to produce dried chili, bitter gourd chips and pickled capsicum, contributing an additional 15-18% extra profit per cycle. Similarly, eco-friendly production practices and chemical-free ripening allowed producers like Md. Iqbal Hossain and Md. Sazzad Hossen Chowdhury to command a 15-20% and 15-18% price premium, respectively.

4. Social inclusion, mentorship and youth entrepreneurship

Beyond economic metrics, the intervention fostered exceptional social cohesion and empowerment. The Farmer Field School (FFS) framework instituted a powerful peer-mentorship model. Experienced beneficiaries transformed into community educators; Md. Iqbal Hossain mentored six neighboring farmers, while Md. Jamshed Alam's nursery success directly inspired five local youths to establish parallel enterprises. This mentorship establishes a self-sustaining ecosystem of knowledge transfer within the rural demography.

The integration of youth into agri-enterprises effectively challenged the rural out-migration trend. Young entrepreneurs, exemplified by Md. Yasin Arafat, successfully managed complex farming systems and created localized employment (hiring up to three part-time laborers). Moreover, household nutritional parameters a critical indicator of social development experienced vast improvements. Reflecting broader literature on agricultural diversification and food security, the RMTP intervention directly impacted diet quality.

Discussion

The empirical findings derived from the RMTP-YPSA intervention align robustly with and significantly expand upon, the emerging global academic literature concerning climate-smart agriculture and horticultural value chain dynamics in developing economies (Reardon *et al.* 2012; Birthal *et al.* 2013; Lipper *et al.* 2014; Zougmoré *et al.* 2014) [22, 5, 15, 29]. The accelerated transition from vulnerable cereal monoculture to high-value, diversified and technologically integrated horticulture observed in the Mirsarai and Sitakunda upazila reflects a broader, necessary structural adjustment within South Asian Agriculture (Joshi *et al.* 2004; Pingali 2012; Birthal *et al.* 2015) [12, 20, 6]. As per capita landholdings continue to shrink due to demographic pressures, the economic imperative dictates a shift toward crops that offer maximal fiscal yield per square meter (Weinberger and Lumpkin 2007; Ali 2008; McCullough *et al.* 2008) [27, 1, 18]. The documented yields of 750 to 1,000 kg/ha for coffee, coupled with the commanding wholesale price of Tk 400-600 per kg, emphatically substantiate the premise that HVFCs serve as a potent, rapid acting mechanism for profound poverty alleviation and rural capital accumulation.

Furthermore, the rapid technological assimilation documented in this cohort specifically the wholesale adoption of drip irrigation, IoT environmental monitoring and biological IPM provides vital empirical validation to the theoretical assertion that smallholder farmers are highly responsive to advanced technological adoption when their inherent risk profiles are mitigated through robust institutional and financial support (Scherr *et al.* 2012; Asfaw *et al.* 2014; Arslan *et al.* 2015) [24, 3, 2]. The massive, localized scale of vermicompost production, reaching 3,400 tonnes monthly with an economic footprint of BDT 34 million, is of particular academic and ecological significance. It demonstrates a successful transition toward a circular rural economy, which not only drastically reduces dependency on volatile, often imported chemical fertilizer markets but also critically enhances soil organic carbon a fundamental prerequisite for ensuring long term climate resilience and agricultural sustainability in degraded topographies (Lal 2004; Rosenzweig *et al.* 2014; Thierfelder *et al.* 2017) [14, 23, 26]. This ecological restoration directly and measurably addresses the acute soil degradation issues prevalent in the Chattogram hill tracts, which have resulted from decades of exploitative, chemically intensive agronomy.

The successful market integration facilitated through the establishment of PMGs and the securing of direct export channels to the first world country highlights the critical importance of overcoming institutional voids in marginalized rural settings (Kaganzi *et al.* 2009; Markelova *et al.* 2009; Reardon *et al.* 2012) [13, 16, 22]. By bypassing deeply entrenched traditional intermediary networks, the RMTP framework allowed rural producers to capture a substantially higher, fairer percentage of the final retail value. This phenomenon mirrors global socio economic observations where the democratization of market access *via* mobile platforms and collective bargaining architectures fundamentally and permanently alters rural power dynamics, shifting economic control from urban brokers back to the primary producers (Barrett 2008; Minten *et al.* 2009; De Janvry and Sadoulet 2020) [4, 19, 8]. Finally, the strategic utilization of Farmer Field Schools to stimulate youth entrepreneurship actively and successfully counters the prevailing, pessimistic narrative of rural out-migration, providing concrete evidence that agriculture, when adequately modernized, de-risked and made highly profitable, remains a highly attractive and viable livelihood for the educated rural youth of the Global South (White 2012; Brooks *et al.* 2013; Sumberg *et al.* 2014) [28, 7, 25].

Policy Implications and Strategic Recommendations

The empirical successes documented in Chattogram offer vital blueprints for national agricultural policymaking. To scale the benefits of smart horticulture and sustain the RMTP-YPSA momentum, institutional stakeholders must prioritize the following strategic recommendations:

1. **Strengthen decentralized value chains:** Expand investments in decentralized cold storage facilities, shade houses and processing centers to permanently mitigate the 37-39% infrastructural gap that currently exacerbates post-harvest losses.

2. **Institutionalize digital agriculture:** Scale the deployment of IoT-based orchard monitoring, mobile market pricing platforms and digital extension services. Enhancing rural digital literacy is paramount to bypassing traditional market intermediaries.

3. **Expand tissue culture and seedling infrastructure:** Promote specialized tissue culture laboratories and subsidized poly-house nurseries to ensure the continuous supply of disease-free, climate resilient saplings.

4. **Promote nutrition sensitive interventions:** Institutionalize the MDD-W metric within all agricultural extension policies. Aligning crop diversification directly with household nutritional targets ensures that economic gains translate to tangible public health benefits.

Conclusion

The RMTP-YPSA intervention in the Chattogram district serves as a profound and empirically robust testament to the transformative capacity of climate-smart horticulture. By systematically addressing the structural and historical bottlenecks of traditional farming namely technological obsolescence, ecological degradation, severe market information asymmetry and supply chain exploitation the project successfully engineered a highly profitable, resilient and modern agricultural matrix. The synthesized case studies collectively and definitively illustrate that the fusion of modern agro-technologies, inclusive value chain integration and peer-led youth mentorship can effectively break the intergenerational cycle of rural poverty. Scaling this integrated, holistic model across similar climatically vulnerable agro-ecological zones will be absolutely instrumental in securing the future of agricultural sustainability, long-term economic prosperity and national food security in Bangladesh and the broader South Asian region.

Declarations

- **Acknowledgement**

The authors sincerely acknowledge and express their profound gratitude to Md. Arifur Rahman, Chief Executive; Md. Manzur Murshed Chowdhuri, Director, Economic Development; Md. Newaz Mahmud, Program Manager; and Mr. Suman Deb Nath, Project Manager, YPSA, Chattogram, for their constructive guidance, inspiration, financial support, and generous assistance in successfully completing the endline survey.

The authors are deeply grateful to Akond Md. Rafiqul Islam, Senior General Manager, PKSF, Dhaka, Bangladesh, for his valuable support and constructive guidance throughout the field investigation and data collection.

The authors extend their heartfelt gratitude to all the farmer participants from Sitakunda and Mirsarai upazilas, Chattogram, for providing authentic and valuable information.

The authors also gratefully acknowledge the active participation of the young and energetic students Shahriar Arafat, Md. Shakhawat Hossain, Md. Abdul Alim, Abu Taum, Tama Bhowmik, Priota Datta Orpa, Mira Barua, Georgia Chakma, and Chayan Kumer Saha, Department of Botany, University of Chittagong for their valuable assistance in data collection and data entry.

Finally, the authors cordially thank the Department of Botany, University of Chittagong, Chattogram-4331, Bangladesh, for providing the laboratory facilities necessary to complete this research.

- **Conflict of Interest**

The authors declare that they have no commercial or financial relationships that could be perceived as constituting a potential conflict of interest in connection with this research.

- **Funding Statement**

This endline assessment was financially supported under the framework of the Rural Microenterprise Transformation Project (RMTP), with support from YPSA, Chattogram.

- **Data availability statement**

The datasets generated and analyzed during this study are not publicly available due to participant privacy, but can be provided by the corresponding author upon reasonable, justified request.

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