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Research Article

Performance and challenges of a woman-led bio-input enterprise: A case study of agricultural technology commercialization in plantation crops

Kuppusamy Ponnusamy*, M Ajith, Sona Saji

ICAR-Central Plantation Crops Research Institute, Kasaragod-671124, Keralam

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*Corresponding author: K Ponnusamy, E-mail: ponnusamyk@hotmail.com

Abstract

Commercialization of publicly funded agricultural technologies can support rural entrepreneurship and sustainable plantation agriculture. This case study documents the commercialization of ICAR–Central Plantation Crops Research Institute (CPCRI) microbial and organic-input technologies by Sree Krishna Agrofert, a woman-led agro-input enterprise established in Kasaragod district, Keralam. A descriptive single-case study was conducted using structured interviews, direct observations, enterprise records and production and marketing data verified during field visits in 2026. The enterprise uses locally available agro-industrial residues, including fish waste, poultry manure, coir pith, neem cake and cow dung, in a diversified portfolio of organic nutrient formulations and *Trichoderma*-based microbial bio-inputs. In 2025, annual returns were Rs.20.00 lakh against operating expenditure of Rs.16.40 lakh, giving an operating surplus of Rs.3.60 lakh, equivalent to 18.0% of annual returns. Annual sales increased from Rs.8.00 lakh in 2021–22 to Rs.20.00 lakh in 2024–25, while the customer base increased from 42 to 156. While the share of sales from Keralam declined from 92% to 70%, it increased from 8% to 22% in Karnataka during the same period. The enterprise generated seven direct employment opportunities, including five for women. The case highlights the role of technology licensing, technical mentoring, quality assurance, demonstrations and market facilitation in supporting commercialization, while also identifying market awareness, seasonal demand, working-capital requirements and gender-related barriers as continuing challenges. The findings support structured incubation and post-licensing support for women-led, decentralized bio-input enterprises in plantation agriculture.

Keywords: Bio-input commercialization, ICAR–CPCRI, *Trichoderma*, Women entrepreneurship, Technology transfer

Introduction

Agricultural production systems undergo multiple challenges due to declining soil health, dependence on synthetic fertilizers, climate variability, degradation of natural resources and increasing demand for environmentally sustainable production systems (Altieri, 1995). These challenges are particularly relevant to plantation crop ecosystems, where long production cycles require sustained soil biological activity, nutrient recycling and biological management. Sustainable nutrient management and resource recycling have therefore become important components of resilient agricultural systems (Baligar *et al.,* 2001; FAO, 2018).

Microbial and organic agricultural inputs are increasingly used as components of integrated crop management because they can contribute to nutrient availability, soil biological activity and suppression of soil-borne pathogens (Singh *et al.,* 2011). *Trichoderma* species are widely studied as microbial biocontrol agents because of their interactions with plant roots and their capacity to suppress several plant pathogens (Harman *et al.,* 2004; Vinale *et al.,* 2008; Woo *et al.,* 2014). Their application has also been reported in plantation crops including coconut, cocoa and arecanut (Chakrabarty & Sarma, 2017; Neeraja *et al.,* 2025). Residues such as coir pith, fish waste, poultry manure and oil cakes can therefore be treated as biological resources that support nutrient recycling and value addition.

ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), Kasaragod has developed technologies related to microbial inputs, organic inputs, value addition and plantation crop management. Through its Agri-Business Incubation Centre (ABIC) and Institute Technology Management Unit (ITMU), the institute facilitates technology licensing, entrepreneurship development, incubation and technology transfer to farmers, start-ups and MSMEs. Documenting enterprise-level outcomes following technology transfer can provide practical evidence for strengthening agricultural innovation systems (Ponnusamy *et al.,* 2025).

Women-led enterprises usually face constraints related to finance, technology, markets and institutional networks, while successful enterprises can provide useful models for inclusive agricultural innovation (Ponnusamy & Padaria, 2021). Against this background, the present case study examines the commercialization pathway of ICAR–CPCRI technologies adopted by Sree Krishna Agrofert, with emphasis on enterprise performance, market expansion, environmental practices, employment generation and commercialization challenges.

Materials and methods

Study area and case boundaries

The investigation was carried out at Sree Krishna Agrofert, a women-led agro-input enterprise located in Kasaragod district, Keralam, India. The enterprise was established in 2021 with the objective of producing eco-friendly organic inputs and microbial formulations

using locally available agro-industrial residues. The case boundary covered enterprise development from establishment in 2021 through the 2024–25 marketing year, with field verification undertaken in 2026. The enterprise adopted CPCRI-developed microbial/input technologies through formal technology transfer and also obtained fish-waste fertilizer know-how from ICAR–Central Institute of Fisheries Technology (ICAR–CIFT), Kochi.

Research design

A descriptive single-case study design was used, following the case-study approach described by Yin (2018). The unit of analysis was the enterprise and its commercialization process. The case was selected because it provided an opportunity to examine the translation of publicly developed agricultural technologies into a functioning woman-led startup under real-world market conditions. The analysis was descriptive rather than experimental and was intended to document technology adoption, enterprise development, economic performance, market expansion, environmental practices, employment and institutional support.

Data collection and triangulation

Primary information was collected during field visits through the following sources:

- Structured interview with the entrepreneur
- Direct observation of production facilities
- Verification of enterprise records, including employee and attendance records, purchase and sales registers, stock and accounts records, customer records, vouchers and GST records
- Interaction with technical personnel
- Observation of laboratory and quality-control facilities

Information was compiled on enterprise history, technology acquisition, product portfolio, production capacity, investment, expenditure and returns, employment, sales, customer base, market channels, geographical expansion, waste utilization, quality assurance, storage and commercialization constraints. Information from interviews was cross-checked, where possible, against enterprise records and field observations to improve internal consistency.

Technology commercialization process

The enterprise acquired CPCRI-developed microbial/input technologies through a formal technology licensing mechanism. Technology transfer included licensing, technical training, process standardization and continued scientific support from institute scientists. Additional fish-waste fertilizer know-how was obtained from ICAR-CIFT, Kochi. The study therefore treats commercialization as a process involving technology transfer, adaptation, quality assurance and market development rather than licensing alone.

Regulatory and terminology clarification

The study distinguishes microbial bio-inputs from the regulatory category of biofertilizers. In accordance the term "biofertilizer" is not used generically for all *Trichoderma* formulations. *Trichoderma*-containing products are therefore described here as microbial bio-inputs or biocontrol formulations, as appropriate, while organic nutrient products are described separately.

Analytical framework

The enterprise was evaluated using four complementary dimensions: economic performance, market performance, environmental/resource-recycling practices and social performance.

Economic performance

Economic performance was assessed using 2025 operating expenditure, annual returns, operating surplus, initial investment and reported profit information. Because complete audited cost accounts, depreciation, taxes and owner remuneration were not available in the case records, the derived measure is reported as operating surplus (returns minus reported operating expenditure) rather than audited net profit.

Market performance

Market performance was assessed using annual sales, customer numbers and geographical sales shares for 2021–22 to 2024–25. Changes in sales and customer base were quantified as absolute and percentage changes, and compound annual growth rates (CAGR) were calculated over the three-year interval.

Environmental performance

Environmental performance was assessed qualitatively from observed use of agro-industrial residues, recycling practices, production of organic/microbial inputs and reported waste-management practices. No life-cycle assessment, greenhouse-gas inventory or direct nutrient-loss measurements were available; therefore, environmental outcomes are presented as observed practices and potential contributions rather than quantified environmental impacts.

Social performance

Social performance was assessed from direct employment, women's participation, technology dissemination, demonstration activities and reported livelihood linkages associated with raw-material supply, transport and dealer networks.

Data analysis

Descriptive statistics were used because the study represents one enterprise rather than a multi-enterprise sample. Frequencies, percentages, absolute changes, operating surplus and growth rates were calculated from enterprise records. Sales CAGR and customer CAGR were calculated for the 2021–22 to 2024–25 interval.

Qualitative information from interviews and observations was organized thematically around technology adoption, market development, quality assurance, institutional support and commercialization constraints.

Results and discussion

Enterprise establishment and commercialization pathway

Sree Krishna Agrofert was established in 2021 in Kasaragod district as a woman-led enterprise producing organic nutrient formulations and microbial bio-inputs. The enterprise adopted CPCRI-developed technologies through formal technology transfer and subsequently diversified its portfolio with fish-waste fertilizer know-how obtained from ICAR-CIFT. The entrepreneur identified scientific credibility, technical training, process standardization and continued guidance as important enabling factors.

Technology commercialization therefore extended beyond licensing to include training, standard operating procedures, quality assurance, troubleshooting and market-facing demonstrations. The case illustrates how continued interaction between a research organization and an entrepreneur can reduce operational uncertainty during early commercialization, consistent with innovation-system perspectives (Bozeman, 2000; Klerkx *et al.,* 2012).

Production system and technological innovation

The enterprise uses locally available residues including fish waste, neem cake, poultry manure, bone meal, press mud, cow dung and coir pith in its product portfolio. These materials are processed into organic nutrient products and microbial bio-inputs, thereby linking waste utilization with agricultural value addition. The microbial component includes the strain reported in the enterprise records as *Trichoderma harzianum CPTD28.*

For microbial formulations, colony-forming unit (CFU) count was identified as an important quality parameter. The entrepreneur reported that dealer-awareness activities were needed because some market participants initially associated product quality with physical characteristics such as granule size rather than microbial quality. This finding emphasizes the extension and market-development role of technical communication and quality assurance in bio-input commercialization.

The enterprise manufactures seven major product categories (Table 1), including liquid plant-growth formulations, Trichoderma-enriched organic products, talc-based microbial formulations, coir-pith cake formulations and urea-free coir-pith compost. The portfolio serves plantation crops, vegetables, spices and horticultural crops (Figure 1).

Economic performance and quantified indicators

For 2025, reported operating expenditure was Rs.16.40 lakh and annual returns were Rs.20.00 lakh, giving a derived operating surplus of Rs.3.60 lakh. The operating surplus represented 18.0% of annual returns and 21.95% of operating expenditure. The enterprise also reported an initial investment of approximately Rs.40 lakh (Table 2). These calculations provide transparent indicators from the available records; they should not be interpreted as audited net profit because depreciation, taxes, owner remuneration and other accounting adjustments were not separately documented.

The earlier reported figure of a 40–50% "net profit margin" could not be reconciled with the reported 2025 expenditure and returns and is therefore not used as a derived performance indicator. Verification of detailed

Table 1: The products of Sree Krishna Agrofert

S. No.	Product category	Source of technology	Approx. annual capacity	Sales/market reach	Brief description
1	Haritha Plant Growth Booster	ICAR–CPCRI	10,000 litres/year (liquid & bulk)	Regular sales in Keralam and Karnataka	Fish-waste-based organic plant-growth formulation used in vegetables, paddy and horticultural crops.
2	Haritha Plant Growth Booster (Trichoderma-enriched)	ICAR–CPCRI	50,000 litres/year	Growing demand among organic and progressive farmers	Plant-growth formulation enriched with *Trichoderma* for microbial disease-management applications and root-zone support.
3	Haritha Orgarich (Organic Fertilizer)	Own technology	500 tonnes/year	High repeat demand in local markets	Organic fertilizer made from a mixture of seven materials and marketed for plantation crops, vegetables and field crops.
4	Haritha Orgarich (Trichoderma-enriched)	ICAR–CPCRI	300 tonnes/year	Niche but expanding market	Organic nutrient product enriched with *Trichoderma* for combined nutrient and biological-input use.
5	Haritha Trichoderma Talc	ICAR–CPCRI	2,000 kg/year	Dealer-based sales across Keralam	Talc-based *Trichoderma* formulation used for biological management of soil-borne fungal diseases.
6	Haritha Trichoderma Coir Pith Cake	ICAR–CPCRI	5,00,000 pieces/ year	Seasonal demand (pre-monsoon)	Coir-pith cake formulation enriched with *Trichoderma* and marketed for biological management in coconut.
7	Urea-free Coir Pith Compost	ICAR–CPCRI	~5 tonnes/year	Organic farmers and nurseries	Coir-pith compost used as an organic soil-conditioning/basal input.

audited accounts would be required before a formal net-profit margin is reported. The available evidence indicates three practical contributors to enterprise performance: use of locally available organic residues, diversification across several product categories and continued institutional support for technology transfer, standardization and market development. Because the case has no comparison enterprise, these are interpreted as observed enabling factors rather than statistically isolated determinants.

Market expansion and commercialization strategy

The enterprise showed measurable geographical diversification. While share of sales declined from 92% in 2021–22 to 70% in Keralam during 2024–25, it increased from 8% to 22% in Karnataka and other states increased from 0% to 8% (Table 3). Market expansion was supported by dealer networks, agricultural exhibitions, trade fairs and technical demonstrations. The entrepreneur reported that the visibility and scientific credibility associated with ICAR–CPCRI helped establish market confidence, particularly during the early phase of commercialization.



Figure 1: Products of Sree-Krishna Agrofert

Table 2: Enterprise economic indicators based on reported 2025 records

S. No.	Economic indicator	Value
1	Operating expenditure, 2025	Rs. 16,40,000
2	Annual returns, 2025	Rs. 20,00,000
3	Derived operating surplus	Rs. 3,60,000
4	Operating surplus as % of returns	18.0%
5	Initial investment (reported)	~Rs. 40,00,000

Annual sales increased from Rs.8.00 lakh in 2021–22 to Rs.20.00 lakh in 2024–25, representing a 150% increase and a calculated CAGR of 35.7%. The customer base increased from 42 to 156, representing a 271.4% increase and a CAGR of 54.9% (Table 3). These descriptive indicators show substantial growth over the observation period, while the single-case design does not permit attribution of the growth to any single intervention.

Environmental sustainability and circular bioeconomy

The enterprise uses fish waste, coir pith, poultry manure and other biodegradable residues as raw materials for value-added agricultural inputs. This practice demonstrates resource recovery and circular nutrient management at the enterprise level. The evidence available for this case supports the presence of waste valorization practices, but it does not provide quantitative estimates of greenhouse-gas reduction, nutrient-loss reduction or life-cycle environmental performance.

Accordingly, environmental benefits are presented as observed practices and potential contributions rather than measured impacts. A future life-cycle assessment, including raw-material sourcing, processing energy, transport, product use and waste handling, would be required to quantify environmental gains.

Social impact and women entrepreneurship

The enterprise generated seven direct employment opportunities, including five for women. It also created indirect livelihood linkages through raw-material supply, transport and dealer networks. The entrepreneur reported that consistent product quality, scientific credibility and continued customer engagement helped overcome initial skepticism among dealers and intermediaries. The case also provides an extension-relevant example of how a research institution can support an entrepreneur beyond technology licensing through technical mentoring, demonstrations, quality assurance and market-development activities. However, the study did not quantify household-income effects or the wider livelihood impact of indirect employment.

Table 3: Year-wise sales performance, customer growth and geographical market spread of Sree Krishna Agrofert

S. No.	Year	Sales (Rs.)	Customers	Sales growth (%)	Customer growth (%)	Keralam (%)	Karnataka (%)	Other states (%)
1	2021–22	8,00,000	42	—	—	92	8	0
2	2022–23	11,50,000	68	43.8	61.9	85	12	3
3	2023–24	15,80,000	108	37.4	58.8	78	17	5
4	2024–25	20,00,000	156	26.6	44.4	70	22	8

Sales and customer growth are expressed as percentage changes relative to the preceding year. Geographical market spread represents the percentage distribution of sales across the respective regions

Table 4: Challenges and commercialization strategies identified from the case

Challenge observed	Evidence from the case	Strategy documented/suggested
Market awareness of microbial quality	Dealer/farmer perception may emphasize physical characteristics over CFU	Dealer education, demonstrations and clear quality specifications
Seasonal demand	Seasonal sales pattern reported, especially for coir-pith cake	Product diversification and expansion into additional markets
Working-capital requirement	Additional capital needed for production scaling	Financial linkages, phased expansion and improved market planning
Gender-related barriers	Reported social barriers in a male-dominated agro-input sector	Institutional mentoring, networks and visibility through credible public research linkages
Regulatory documentation	Product/strain approval and registration details require verification	Document current authorization, strain identity/ deposit and validity before commercial claims

Extension and institutional implications

The case indicates that technology licensing is more likely to translate into a functioning enterprise when accompanied by structured incubation, technical mentoring, quality assurance and market facilitation. For agricultural extension systems, practical support can include dealer and farmer awareness programmes on microbial quality, demonstrations at the point of adoption, documentation of product quality parameters and linkages with financial and market-support institutions. Public research organizations can strengthen commercialization by maintaining post-licensing advisory support and by facilitating credible platforms for product demonstration and market networking.

Challenges and strategies for scaling

The main challenges identified from the case were limited awareness of microbial quality among market intermediaries, seasonal demand, working-capital requirements for expansion and gender-related barriers in the agro-input sector. The course correction strategies included dealer education, product demonstrations, participation in agricultural exhibitions, continued technical support and stronger institutional linkages. Future opportunities include expansion into additional states, product diversification, digital marketing and participation in government-supported procurement programmes, subject to applicable regulatory requirements.

The case therefore suggests a practical commercialization pathway: (i) formal technology transfer and licensing; (ii) hands-on technical training and process standardization; (iii) quality assurance and documentation; (iv) demonstrations and dealer education; (v) market-network development; and (vi) continuing post-licensing mentoring. These elements directly address the constraints observed in the enterprise and provide a framework that can be examined in future multi-enterprise studies (Table 4).

Conclusion

This woman-led startup case demonstrates how publicly developed agricultural technologies can be translated into a functioning agro-input enterprise when technology transfer is combined with technical mentoring, process standardization, quality assurance and market facilitation. The enterprise reported returns of Rs.20.00 lakh in 2025 against operating expenditure of Rs.16.40 lakh, giving a derived operating surplus of Rs.3.60 lakh. While sales increased by 150%, the customer base rose by 271.4% between 2021–22 and 2024–25, market expanded beyond Keralam into Karnataka and other states. The enterprise engaged more women and incorporated several agro-industrial residues into its product portfolio. The principal challenges such as market awareness, seasonal demand, working capital and gender-related barriers were addressed through technical support, demonstrations, dealer education and institutional linkages.

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