

Impact assessment of ICAR FUSICONT using economic surplus model

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Abstract

India is the largest banana producer in the world, with a production of 36.61 million tons and Grand Naine is the leading variety cultivated. However, Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (Foc TR4), poses a significant challenge to this industry. The disease in India was first reported during 2017 in Uttar Pradesh further the disease has spread to other banana growing states like Bihar, Karnataka jeopardizing both commercial and subsistence farming. In this paper, we evaluate the impact of ICAR FUSICONT a bio-pesticide for managing Fusarium wilt on yield and economics in two cultivars viz., Grand Naine and Elakki. We used economic surplus method assuming closed economy model to assess the returns to research investment. The performance of ICAR FUSICONT led to significant improvements in yield and net returns. ICAR FUSICONT technology has been adopted in an area spanning 8,550 hectares. In Elakki banana, the yield increased by 8.25 t/ha in Karnataka, while the incremental yield was about 16.5 t/ha in Grand Naine variety in UP and Bihar. The farmers who adopted the technology witnessed a twofold increase in the net returns while the returns per rupee of expenditure increased from 1.30-1.34 to 1.78-1.85. Stepwise dummy variable regression indicated a substantial increase in net returns with adopting FUSICONT technology (Rs. 2,36,824 per ha). The total producer's surplus generated by the technology was Rs. 210 crores and Rs. 94 crores for consumers, leading to a total economic surplus of Rs. 304 crores. In the era of increased threat caused by Foc TR4, the widespread adoption of the technology must ensure sustainability in banana cultivation and protect the producers' livelihood.

Key words: ICAR FUSICONT, impact, economic surplus, sustainable banana farming, Fusarium wilt (Foc TR4)

Introduction

India occupies the most significant banana production in the Globe, with an annual production of 36.61 million tonnes from 0.994 million hectares (FAO, 2023). Cavendish represents around 90% of export production globally (Ploetz, 2005). The Cavendish cultivar, Grand Naine variety, dominates the Indian banana industry with 70% of total production and 57% of the total area (Singh, 2009). Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (Foc TR4) is one of the most devastating plant diseases worldwide, posing a threat to the banana industry in India and other parts of the world.

Fusarium wilt, caused by FoC TR4, is one of the most severe threats to banana crops, affecting banana production across the globe (Ploetz and Pegg, 2000; Cook *et al.*, 2015; Dita *et al.*, 2018). This disease ranks among the top six plant diseases globally, wreaking havoc similar to wheat rust and potato blight (Thangavelu and Uma, 2018). The strain was first identified in Southeast Asia in the early 1990s (Ploetz, 2006). The Foc TR4 has caused significant crop loss of Cavendish varieties in countries like Taiwan, Malaysia, Indonesia, China and the Philippines (Molina *et al.*, 2009). Its presence in India was confirmed in 2017 in the Ayodhya district of Uttar Pradesh (Damodaran *et al.*, 2018). Since then, the disease has spread to several states, including Bihar, Karnataka, and beyond, menacing India's banana industry, where the Grand Naine cultivar is grown essentially particularly

in Uttar Pradesh and Bihar. The Foc TR4 is also noticed to infest other varieties such as Elakki, Malbhog, and Karpooravalli.

The pathogen's virulence and polycyclic characteristics render it exceedingly difficult to manage through conventional biological methods, resistance breeding, or chemical remedies (Damodaran *et al.*, 2020). Scheerer *et al.* (2018) predicted that 17% of the present banana-growing areas could be lost within the next two decades, indicating the possibility of significant losses. Cook *et al.* (2015) anticipate substantial losses in Australia, regardless of the sluggish spread rate.

In India, where Cavendish cultivars are predominant, the disease threatens commercial production and subsistence farming, further exacerbating the obstacles presented by other pests, diseases, and nematodes that impede banana productivity. The global vulnerability of bananas to Foc TR4 threatens the stability of a crop that supports millions of livelihoods and is critical for food security in tropical and subtropical regions.

India's position as the foremost banana producer intensifies the earnestness to address Foc TR4. Effective solutions, such as innovative bio-pesticides, *in vitro* immunization, or resistant cultivars, are critical to upkeep this vital crop from Fusarium wilt disease that has transformed worldwide banana production. Without intervention, the economic and agricultural toll could be catastrophic.

ICAR-FUSICONT is a bio-pesticide technology developed by the Indian Council of Agricultural Research (ICAR) to combat Panama Wilt disease, specifically the Tropical Race 4 (TR4) strain caused by *Fusarium oxysporum* f.sp. *cubense*. ICAR-FUSICONT formulated using a novel strain of *Trichoderma reesei* (CSR T-3), has proven highly effective in suppressing the pathogen. Further, this biocontrol agent has been proven to have a good effect on fruit yield and weight (Damodaran *et al.*, 2020). Collective action by the community in adopting the ICAR-FUSICONT was found effective in controlling the banana Fusarium wilt (Foc TR-4) in epidemic areas of Uttar Pradesh and Bihar (Damodaran *et al.*, 2019).

Evaluating the technology's performance and assessing its impact is essential to gauge its long-term sustainability, economic feasibility, and effectiveness. The current study was formulated to evaluate the impact of ICAR-FUSICONT's adoption on the disease's control and subsequent effect on yield and economics of banana cultivation. Understanding the performance and impact of the technology provides valuable insights for all the stakeholders in scaling up the use of technology and contributes to the sustainable banana industry.

Methods and materials

The economic surplus method was used for the study and it is commonly employed to assess the impact of technological change due to its minimal data requirements and less restrictive assumptions (Alston *et al.*, 1998). This approach offered a straightforward, flexible framework for determining research value by comparing scenarios with and without the technological intervention. It was based on key economic concepts such as supply, demand, and equilibrium. In this model, "supply" reflected the production costs of producers, while "demand" represented the consumption values of consumers. The interaction of these forces resulted in an equilibrium price and quantity. Economic welfare, as measured by this method, depended not only on the equilibrium price and quantity—often directly observable in the market—but also on the production costs of producers and the consumption values of consumers, which had to be inferred from their behaviors.

For this analysis, a static model of a closed economy was employed. This assumption suggested that the adoption of cost-reducing or yield-enhancing technologies led to an increase in the supply of a commodity, thereby affecting both the market equilibrium and overall social welfare.

Theoretical framework: The model is based on the Marshallian theory of economic surplus that stems from shifts over time in the supply and demand curves. Fig. 1 illustrates changes in economic surplus due to the adoption of improved technology (ICAR FUSICONT) in the case of a small, closed economy (Alston *et al.*, 1998; BIRTHAL *et al.*, 2012). Adopting yield-increasing technology shifts the supply curve for okra downward from S_0 to S_1 , while the demand curve is assumed to remain constant. The original market equilibrium a (P_0, Q_0) is shifted by the effect of technological change to b (P_1, Q_1).

Consumers gain because they are able to consume a greater amount (Q_1) at a lower price (P_1). The area P_0abP_1 represents the consumer surplus. Although, producers are receiving a lower price for their produce, they are able to sell more. Thus, the producers'

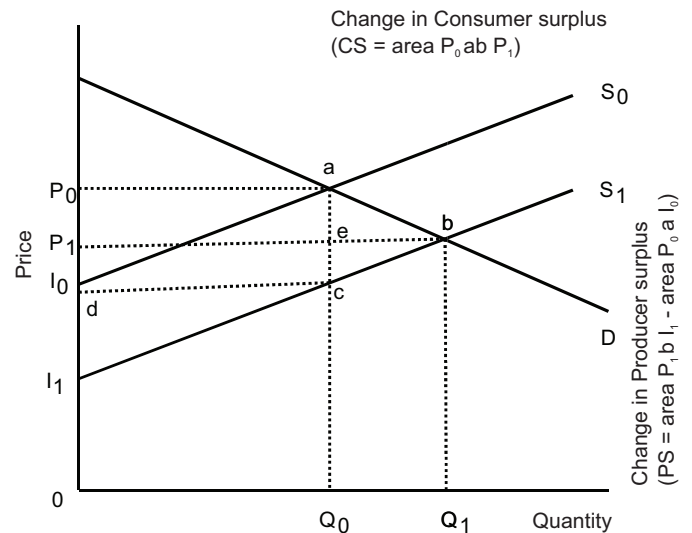


Fig. 1. Changes in economic surplus due to an adoption of ICAR-FUSICONT technology. Change in Consumer surplus ($\Delta CS = \text{area } P_0abP_1$). Change in Producer surplus ($\Delta PS = \text{area } P_1bI_1I_0 - \text{area } P_0aI_0$) surplus is defined as the area $P_1bI_1I_0 - \text{area } P_0aI_0$.

Mathematically, the change in consumer surplus, producer surplus and total surplus can be represented as:

$$\Delta CS = P_0Q_0Z(1+0.5Z\eta)$$

$$\Delta PS = P_0Q_0(K-Z)(1+0.5Z\eta)$$

$$\Delta TS = \Delta CS + \Delta PS = P_0Q_0K(1+0.5Z\eta)$$

Where,

K is the vertical shift of supply function expressed as a proportion of the initial price, η is the absolute value of the elasticity of demand

$Z = K\epsilon / (\epsilon + \eta)$ is the reduction in price, relative to its initial (*i.e.*, pre-research) value, due to the supply shift. ϵ is the elasticity of supply.

Estimation of benefits from improved technology

$$\text{Benefits} = K * P * Q * (1+0.5Z\eta)$$

P is commodity price, Q is production, η is price elasticity of demand and ϵ is price elasticity of supply.

K is supply shift due to improved technology

Z is change in price due to improved technology

$K = \text{Net cost change} * \text{Probability of success in research} * \text{adoption rate} * \text{depreciation rate of technology}$

$$Z = K * \epsilon / (\epsilon + \eta)$$

Net cost change = Reduction in marginal cost – Reduction in unit cost

Reduction in marginal cost = Change in yield / ϵ

Reduction in unit cost = Change in cost of inputs per acre / (1+change in yield)

Data: The information used in this paper was obtained through field surveys, published sources and literature reviewing. Information on cost of production, crop yield, output prices and other relevant variables was collected through a field survey involving about 135 farmers of Karnataka, Uttar Pradesh and Bihar.

Results and discussion

Farm-level effects of ICAR FUSICONT on yield and income of the banana growers: A comparison of cost, yield and returns of Elakki banana in Karnataka and Grand Naine in Uttar Pradesh and Bihar for both control farmers and farmers who adopted ICAR FUSICONT is presented in Table 1.

The results highlight the potential increment in yield and returns

Table 1. Economics of banana Elakki and Grand Naine banana cultivation (Rs. per ha)

Sl. No.	Particulars	Elaichi Banana (Karnataka)		Grand Naine (UP and Bihar)	
		Control	Treated	Control	Treated
1	Variable cost components				
	Human Labour	78200	78650	69400	71150
	Machine Labour	17082	16167	13228	14115
	Planting Material	28678	30151	46296	50926
	Pit Digging & planting	11300	11300	15432	15432
	FYM	31044	31115	17780	22225
	Fertilizer	38646	39434	37950	38540
	PPC	75900	85800	65260	68950
	Irrigation cost	45625	45625	42583	42583
	Interest on working capital @7%	22062	22886	20475	21594
	Total Variable cost	348536	361128	328405	345516
2	Fixed cost components				
	Land revenue	100	100	100	100
	Rental value of land	74803	74803	71120	71120
	Interest on fixed capital @12%	8988	8988	8546	8546
	Total Fixed cost	83891	83891	79766	79766
3	Total cost	432428	445019	408171	425282
4	Yield (tonn)	19.25	27.5	38.5	55
5	Price per ton	30000	30000	13750	13750
6	Gross returns	577500	825000	529375	756250
7	Net returns	145072	379981	121204	330968
8	Returns per rupee of expenditure	1.34	1.85	1.30	1.78

in both varieties for treated farmers. Their shares of the cost of labour (machine and human), irrigation, manures, and fertilizers did not vary much across different varieties and groups. The plant protection cost (PPC) was increased by 13% for treated farmers of Elakki and in the case of Grand Naine, there was an increment of 5%. Nonetheless, there was a marginal increase in the total cost of cultivation for the farmers who adopted the technology (Rs. 12591 per ha for the Elakki banana and Rs. 17,111 per ha for the Grand Naine banana). However, the incremental yield and economic gains outweighed the increase in cost. The treated farmers realized an additional yield of 8.25 tons per ha in Elakki banana and 16.5 tons per ha in Grand Naine.

On the other hand, the gross and net revenues were higher for technology adopters than those who used chemicals to control the disease. The net returns were higher by 162 percent over control in Elakki banana and 173 percent over control in Grand Naine banana cultivation. The gross return realized by treated farmers saw a significant rise to Rs. 825000 per ha against Rs. 577500 per ha in Elakki banana, while it was Rs. 756250 per ha against Rs. 529375 per ha in Grand Naine. The returns per rupee of expenditure for adopters were 1.85 and 1.78 in Elakki and Grand Naine banana, respectively, for treated farmers and it was 1.34 and 1.30 for control farmers. These statistics underscore the relative profitability of ICAR FUSICONT technology over other control measures to address the Panama wilt. Hence, switching to ICAR FUSICONT from other measures would generate additional net revenue of Rs. 234909 and Rs. 209764, respectively in Elakki and Grand Naine banana cultivation.

The details of the area under Fusarium wilt, the spread of the technology and yield benefits across Karnataka, Uttar Pradesh and Bihar are depicted in Table 2. The area under banana cultivation is more in Karnataka (1,13,730 ha) followed by UP (91,460 ha) and Bihar (42,670 ha). The Fusarium wilt across these states accounts for 12.71 % of their collective area under banana. In Karnataka, Fusarium wilt has spread across 13.63 % of its area. In Uttar Pradesh, it is 12.57% and in Bihar it is 10.55 %. The wilt was first detected in 2017 and has spread to 31,500 ha across these states in the span of six years. As per the information received from the license holders and sales data from CISH, the area under ICAR FUSICONT is more in Karnataka (6000 ha) followed by Uttar Pradesh (2000 ha) and Bihar (550 ha). This includes a noteworthy spread in Karnataka, where 38.71% of infested area is treated with the technology.

The yield of Elakki banana in Karnataka in control plots was 19.25 t ha⁻¹ while the yield of Grand Naine banana in Uttar Pradesh and Bihar was 37.2 t ha⁻¹ and 39.8 t ha⁻¹, respectively. Nevertheless, with the use of ICAR FUSICONT by treated farmers, the yield increased to 27.5 t ha⁻¹ in Elakki banana. The yield rose to 56 t ha⁻¹ and 54 t ha⁻¹ in Grand Naine in Uttar Pradesh and Bihar, respectively. The use of FUSICONT led to an increase in yield by 42.85 % in Karnataka (Elakki banana), 50.53 % in UP, and 35.67 % in Bihar, with an overall average yield improvement of 42.85 %. These results reflect the success of ICAR FUSICONT in combating the yield losses because of Panama wilt.

Table 2. Spread and yield benefits from the use of ICAR-FUSICONT

Particulars	Karnataka	U.P.	Bihar	Total
Area under banana (ha)	1,13,730	91,460	42,670	2,47,860
Area under Fusarium Wilt (ha)	15500	11500	4500	31500
Area under ICAR FUSICONT (ha)	6000	2000	550	8550
Yield in control plot (t/ha)	19.25	37.2	39.8	32.08
Yield in treated plot (t/ha)	27.5	56	54	45.83
Increase in yield (t/ha)	8.25	18.8	14.2	13.75

Table 3. Projected yield loss from Panama wilt and economic gain from adoption of ICAR FUSICONT

Particulars	Elaichi Banana (Karnataka)		Grand Naine (UP & Bihar)	
	Control	Treated	Control	Treated
Current Max. yield (t/ha)	21.5	29.5	42.0	58.5
Current Min. yield (t/ha)	16.0	24.0	32.0	48.5
Current Mean yield (t/ha)	19.3	27.5	38.5	55.0
Projected yield loss if disease spreads to 20% of total area (000 t)	188		443	
Projected yield loss if disease spreads to 30% of total area (000 t)	281		664	
Incremental net returns that can be gained if ICAR FUSICONT is adopted in total current diseased area (incremental net returns *current area under Fusarium wilt)	364.11		335.62	

The minimum yield obtained in control plots was 16 and 32 tons ha⁻¹, respectively, in Elakki and Grand Naine banana cultivation, while it was 24 and 48 tons ha⁻¹ in treated plots. The minimum yield in treated plots was more than the maximum yield in diseased plots in both Elakki and Grand Naine banana cultivation.

It is projected that 188 thousand tons of Elakki banana and 443 tons of Grand Naine variety will be lost if the Fusarium wilt is spread across 20% of the total area under cultivation in the three states. Ritter *et al.* (2024) assessed the impact of Foc TR4 based on different scenarios of disease spread (25%, 50%, 75% and 100%) in Magdalena and Antioquia of Colombia and reported that even under moderate spread, significant losses would occur. The additional revenue that could be generated if the total diseased area under Fusarium is treated with ICAR FUSICONT assuming the constant price is Rs. 364.11 crores in Elakki banana and Rs. 335.62 crores in Grand Naine banana. Cook *et al.* (2015) reported that Foc TR4 will cause losses of more than \$138 million per year in Australia despite a slow rate of spread.

Table 4. Stepwise regression analysis of factors influencing the net returns

Variable	Co-efficient	t value
Expenditure on plant protection chemical	0.614	1.78*
Family size	-4522	1.99**
Dummy variable for the use of ICAR-FUSICONT	236824	28.96***
Constant	96961	3.51***

$R^2 = 0.87$ and F value = 303.21 ***

Note: *** indicates significant at 1 %; ** indicates significant at 5% and* indicates significant at 10 %.

Net return function per ha was estimated to capture the influence of socio-economic variables and the dummy variable assigning 0 for control farmers and 1 for FUSICONT adopted farmers. Chandrakanth *et al.* (2013) used per farm net return function to assess the impact of drip irrigation technology using the dummy variable. We used the stepwise regression analysis to see the factors influencing the net returns from banana cultivation. Age, education, sex, land holdings, income from other sources, the dummy variable for using ICAR-FUSICONT, expenditure incurred on labour, plant protection chemicals, planting materials and manures and fertilizers were considered independent variables in the model (Table 4). The coefficient of multiple determination was 0.87, indicating that the variables retained in the step-wise regression model indicate 87% of the total variation in the net returns per ha. The model was highly significant as indicated by the F value. The model can be depicted as $Y = 96961 + 0.614 \times \text{plant protection cost} - 4522 \times \text{family size} + 236824 \times \text{Dummy for technology adoption} + e$, where e indicates error.

The regression coefficient for expenditure on plant protection chemicals and the dummy variable for technology adoption had a positive effect on the net returns while family size had a negative effect on the dependent variable. From the regression, the threshold net return is Rs. 96961 per ha, which is the contribution of inputs other than those included in the model, which is also significant at 1%. The marginal productivity of Plant Protection Chemicals is 0.614 since the estimated model is linear. The marginal productivity of family size is negative, indicating the disguised unemployment *i.e.*, the contribution of additional family members in net returns is not positive. A noteworthy finding is using ICAR-FUSICONT, which has a considerable positive impact and high statistical significance at the 1% level. Due to the use of ICAR-FUSICONT, the threshold net return per ha is shifted by Rs. 2,36,824, as given by the coefficient of the dummy variable used to differentiate adopters and non-adopters. Hence, the threshold net return per ha due to ICAR FUSICONT is Rs. 3,33,785 (2,36,824+96961). This result strongly suggests that

adopting ICAR-FUSICONT is crucial in improving productivity vis-à-vis the net returns through better disease management and plant growth-promoting properties.

Aggregate benefits: The economic surplus approach was used to estimate the economy-wide implications and the returns to research investment on ICAR-FUSICONT under the assumptions of a closed economy, the elasticity of demand as -0.91 (Kumar *et al.*, 2011) and elasticity of supply as 0.40. The total cost incurred in developing and popularising the technology was Rs. 1.2 crore and the information was collected from the lead developer of the technology. The technology ICAR-FUSICONT to manage the Fusarium wilt was released jointly by the ICAR-Central Institute for Subtropical Horticulture, Lucknow and ICAR-Central Soil Salinity Research Institute, Regional Station Lucknow, during the year 2021. The total producer surplus generated out of this technology is Rs. 210 crores (Table 5). This represents the additional income gained by the producers. The use of technology demonstrated the incremental yield over control plots and led to the increase in net returns of the farmers. The increase in yield leads to a rise in the supply of bananas to the markets, increased supply will result in reduced prices for the consumers and the total consumer surplus generated by this technology is Rs. 94 crores. The total economic surplus, which is the combination of producers and consumers, accounts for Rs. 304 crores. This indicates the superiority of the technology in generating the surplus in the economy and the research investment made is worthy. The net social gain from the use of ICAR FUSICONT is Rs. 8,550. Staver *et al.* (2020) assessed the potential returns of research funding to combat Fusarium wilt (TR4 strain), estimating benefits for 2.7 million (GMRC) to 14 million (ESEC) small-scale farmers in Asia/Pacific, Sub-Saharan Africa, and Latin America/Caribbean. The research also emphasized that various strategies for managing Fusarium wilt would generate positive net present values (NPVs), indicating that funding efforts to mitigate the effects of Foc TR4 is a valuable investment.

Table 5. Economic Impact of ICAR-FUSICONT Technology

Particulars	Impact
Year of release	2021-22
Total Area Spread (ha)	8550
Consumer Surplus (₹ Crore)	94
Producer Surplus (₹ Crore)	210
Total Economic Surplus (₹ Crore)	304
Net Economic Surplus (₹ Crore)	302
Net social gain (₹/ha)	8550

The use of bio-pesticide to control the effect of Fusarium wilt is environmentally safe compared to the use of chemicals, which have limited success in controlling the disease caused by Foc TR4 race and yield enhancement. ICAR-FUSICONT is a bio-pesticide with the dual properties of controlling the wilt and promoting plant growth through its growth-promoting properties. ICAR-FUSICONT offers a sustainable alternative to the chemicals, reducing the pesticide load. The technology aligns with global calls for greener agricultural practices. The disease is spreading at a greater phase in other regions of the country, calling the immediate attention of policymakers and other stakeholders to promote sustainable disease control measures.

Grand Naine variety occupying significant area of banana

cultivation in India is under threat because of the Fusarium wilt caused by Foc TR4 and its ability to spread faster. It is important to note that this race also affects banana productivity in many other varieties. The bio-pesticide ICAR-FUSICONT has proven its efficacy in controlling the disease, increasing yields and net returns, besides being environment friendly. The cost and return analysis indicate the cost-effectiveness of the technology. The economy-wide implications analyzed using the economic surplus approach indicate the worth of the investment in research on ICAR FUSICONT as depicted by the total economic surplus generated. The regression analysis confirms the threshold increment in net returns from adopting ICAR FUSICONT technology. The technology improves productivity, besides building resilience in banana farming. Scaling the adoption of ICAR FUSICONT in wilt-affected areas is necessary to retain India's position as the global leader in banana production. The technology also ensures long-term sustainability in enhancing farmer livelihoods. Continued policy support is needed for the wide spread of the technology to mitigate future threats in the Indian banana industry.

The application of ICAR FUSICONT technology has resulted in significant improvement in banana yield and net returns, especially in the scourage area of FW. It shows a combined economic surplus of Rs. 304 crores, with advantages to the producer and the consumer. For the long-term sustainability of banana production and farmer livelihood, large-scale adoption of FUSICONT is essential.

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