ASSESSING THE IMPACT OF NEW TECHNOLOGIES: A CASE STUDY OF BIOCONTROL MEASURE (*Trichoderma harzianum*) FOR *Phytophthora* FOOT ROT IN BLACK PEPPER

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Abstract

Assessments of the economic impact of new technologies provide helpful information to justify investment of scarce resources in research and development to generate new technologies. Using the economic surplus method, the paper examines the impact of a new technology i.e. use of a bio-control agent (*Trichoderma harzianum*) for *Phytophthora* foot rot in black pepper. Parameters such as yield increase (i.e. quantity saved), change in cost of cultivation and improvements in economic returns were used to assess the impact of the project. Adoption of the technology resulted in maximum proportionate productivity increase of 11.6% and the net proportionate reduction in cost per ton output was 78.3%. The internal rate of return to total investment in technology development was 19% with calculated BCR of 2.5. Under various assumptions about the magnitude of the benefits and the research expenditures, the IRR ranged between 10% and 24%, indicating the economic viability of the investment. Further, the research has showed that education of end users was the most important factor in achieving the research output reaching the farm successfully.

Keywords: Biocontrol agent, black pepper, crop loss, economic surplus, ex-post analysis, open economy, *Phytophthora* foot rot, technology impact, *Trichoderma harzianum.*

Introduction

Resources for agricultural research are scarce and research activities and programs often face competition for funding. This has led sponsors to ask hard questions regarding the impact of research findings they have funded or enabled. Efficient resource allocation and the need to justify the choices made to stakeholders and to society, require the assessment of the economic impacts of research. This study is a joint effort of the National Centre for Agricultural Policy Research (NCAP) and the

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Indian Institute of Spices Research (IISR) through a National Agricultural Technology Project (NATP) funded project. The study intends to:

- determine the adoption rates for biocontrol measures (*Trichoderma harzianum)* as technology to manage *Phytophthora* foot rot disease in black pepper.
- estimate the returns to research investment,
- estimate the benefits to producers and consumers from this eco-friendly bio-control technology, and
- document stakeholders opinions about the technology.

Black pepper in India

Black pepper (*Piper nigrum* L.) is one of the most important spice commodities produced and traded in India. The crop is the major source of income and employment for rural households in the State of Kerala, India's main pepper-growing state, with holdings covering 230,900 hectares. The crop is also an important source of foreign exchange. Of the total of more than 65,000 tons produced in the country, over 50% is exported annually in various forms.

- A large proportion of the rural population of Kerala relies on the pepper industry for income and employment (over 40 million man-days).
- Black Pepper accounts for 46.48% of the total value of all spice exports from India, around Rs.18,610.3 million per year (1999-2000).
- Spices as a whole contributed to about 35% of the export earnings of all horticultural commodities.

Table 1. Pepper production and export from India

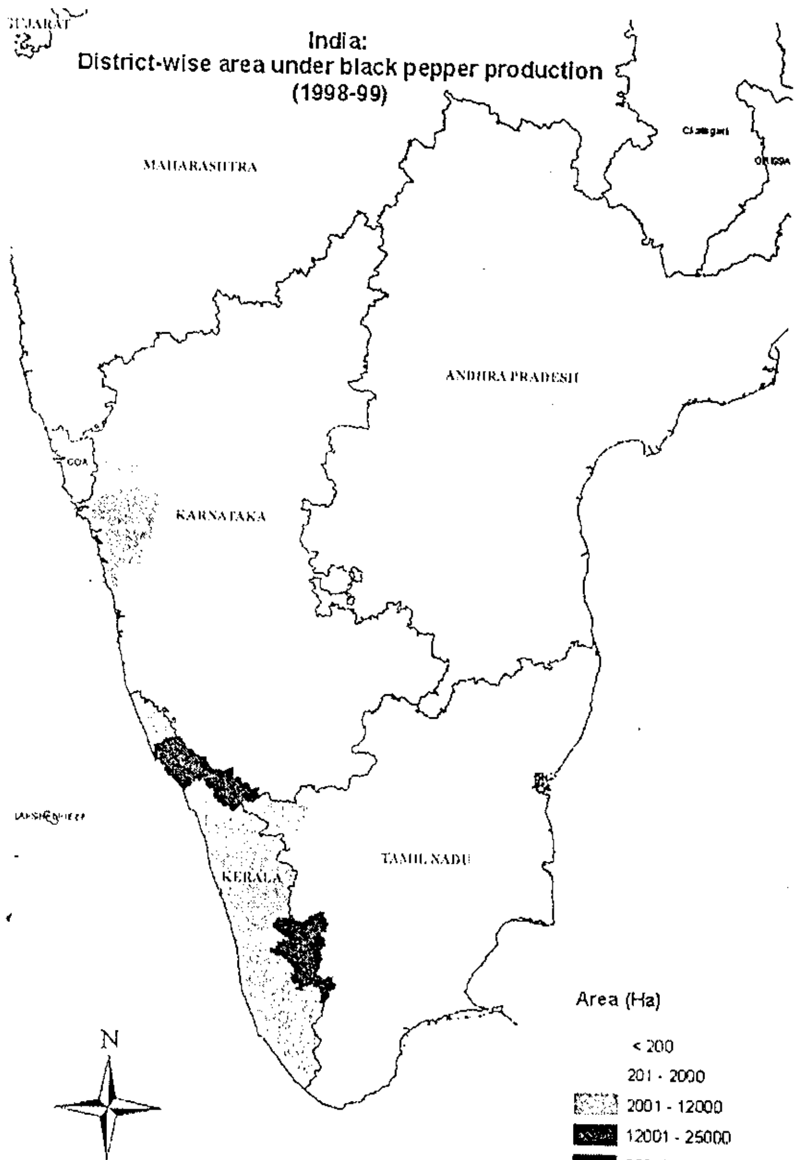
YEAR	Production (t)			Annual Growth Rate		Export		
	India	Kerala	Share in total (%)	India	Kerala	Qty. (t)	Share in prodn. (%)	Price (Rs./kg)
1994-95	60740	59260	97.6	18.4	18.9	37264	61.4	63.50
1995-96	70230	59940	85.3	15.6	1.1	26244	37.4	74.80
1996-97	55590	53770	96.7	-20.8	-10.3	47893	86.2	86.09
1997-98	57330	55520	96.8	3.1	3.3	35907	62.6	138.23
1998-99	70160	64340	91.7	22.4	15.9	35109	50.0	180.81
1999-00	58290	56430	96.8	-16.9	-12.3	42824	85.4	206.73
2000-01	63670	60930	95.7	9.2	8.0	21830	34.3	174.45
2001-02	61460	58240	94.8	-3.5	-4.4	22877	37.2	89.04
2002-03	70600	67360	95.4	14.9	15.7	21609	30.6	82.78
2003-04	71000	68360	96.3	0.6	1.5	16700	23.5	85.99
Average	63907	60415	94.7	4.3	3.7	30826	50.9	118.24

Source: Spices Board, Cochin.

Study region

Kerala State accounts for more than 90% of area and production of black pepper in India (Table 1). Fig 1, shows that the crop is distributed throughout the State, with more concentration in the hill districts of Idukki and Wayanad.

Fig 1. Spatial distribution of pepper in Kerala (India)



The problem

Crop loss due to pests and diseases is considered one of the major reasons for low productivity of spices in general and black pepper in particular. Pepper is prone to various diseases, some of which are of major economic concern, causing serious losses to the Indian pepper economy. Foot rot caused by *Phytophthora capsici* inflicts large scale damage to black pepper vines in the state, causing severe economic losses of around 2000 tons valued at Rs.320 million annually (Sarma and Anandaraj, 1998). Though some chemical control measures have been found effective, they are not economically viable or environmentally safe. Environmental contamination from pesticides range from pollution of water, air and soil to the alteration of the ecosystem, resulting in detrimental effects to non-target organisms. The evidence of pesticide threats to human health, and the trade-offs between health and economic effects have been documented in several studies (Rola and Pingali, 1993, Antle and Pingali, 1994). Pesticide residues also often pose a major threat to pepper exports to some important markets, and as such, eco-friendly disease management is imperative.

Technology development

Even before initiation of this Department of Biotechnology (DBT) sponsored project, considerable research work has been done at the Indian Institute of Spices Research (IISR) to develop eco-friendly biocontrol measures for control of *Phytophthora* foot rot disease in black pepper. *Trichoderma harzianum,* a bio-control agent, was found to be effective against this soil-borne disease (Anandaraj and Sarma, 1994, Sarma et al. 1996). Therefore, research support provided under the present project sharpened and hastened the technology development and adoption process. Table 2 summarizes the history of the development of biocontrol measures for black pepper.

Table 2.
Chronology of developing biocontrol measures for *Phytophthora* foot rot disease in black pepper

Period	Activities
Prior to 1994 (before start of the project)	Collection, identification and isolation of the useful bio-control organisms against *Phytophthora* foot rot.
Up to 1998	Laboratory and field testing of the identified and isolated bio-control organisms (*Trichoderma harzianum)*
After 1998	Demonstration on farmers' fields, standardization of mass multiplication technique and technology transfer

The technology

An isolate of *Trichoderma harzianum* (P26), isolated from healthy disease free black pepper, was developed as an efficient and potential *bio-control* agent against foot rot disease caused by *Phytophthora capsici.* This isolate was recommended for use in the management of *Phytophthora* foot rot disease in pepper as a part of integrated pest management (IPM) programs, as well as under organic farming systems of cultivation.

The large-scale multiplication technology for *T. harzianum* as recommended involves a solid-state method using sterilized sorghum grains or a liquid state technique using molasses in a fermentor. *Trichoderma harzianum* is produced by liquid state fermentation and mixed with talc in order to develop a specific formulation. The solid-state product thus developed is delivered using farmyard manure (FYM) or neem cake or decomposed coir compost. Where FYM or neem cake is used, the product is mixed in the ratio 1:50 and for coir compost, the proportion used is 1:20. The compost mix is incubated for 15 days and applied to pepper vines at 1kg per vine.

Technology dissemination

Initially on-farm trials were conducted on research farms and subsequent demonstration trials were organized in the farmers' fields (Table 3).

Table 3
Large-scale field evaluation of *Trichoderma* spp. against *Phytophthora* foot rot disease in black pepper

District	Without *Trichoderma* spp. (1993-94)			With *Trichoderma* spp. (1995-98)		
	No. of Vines	No. of dead vines	% in total	No. of vines	No. of dead vines	% in total
Wayanad	132200	5300	4.1	16900	142	0.8
Calicut	4025	280	7.0	1320	11	0.8
Total	136225	5580	4.09	18220	153	0.8

Source: Final report of the project submitted to DBT.

In line with the objectives of the project, all efforts were made to popularize the technology through different extension activities, after successful trials were completed on the research farms. Successful on-farm trials and demonstration trials in the farmers' fields were followed by standardization of mass multiplication techniques. The Institute, with its in-house facilities, has produced and sold around 2,700kg of *Trichoderma harzianum* in the year 1997-98 and 6,700kgs during 1998-99. The success of the technology has created high demand for the product among pepper growers. The growing demand for the bio-control agent has acted as a catalyst for the development and transfer of the mass multiplication technology to private entrepreneurs. Developing private entrepreneurship popularized the technology. Each entrepreneur is charged a license fee of Rs. 10,000 for a period of 11 months (Sarma and Anandaraj, 2003). All the surveyed industrial units have adopted the technology provided by the Indian Institute of Spices Research. Apart from technical know-how, the technology providers also imparted training to the personnel involved in the actual production of the bio-control agent.

Methodology

In order to measure the impact of research on biocontrol measures for *Phytophthora* foot rot control on black pepper production and productivity, it is first necessary to estimate the adoption rate for the technology. A ratio of the area of pepper farms where the technology has been applied to total area under the crop is taken as an estimate of this rate.

It is difficult to assess the area under the new technology as pepper is being cultivated

- As a homestead crop in compound of houses
- As a mixed or intercrop trailed on various trees (including arecanut and coconut) on agricultural land
- As a pure crop on slopes and valleys of low hills
- As a mixed crop, trailed on shade trees in tea and coffee plantations

The commonly observed cultivation system in rural Kerala is the "extensive homestead cultivation", where pepper is grown as a secondary crop interspersed with several other crops. Thus an estimate of production of T. *harzianum* is obtained by the following method.

Method

Commercial mass multiplication units, including the research and development centers in Kerala and Tamil Nadu, were contacted for the survey in the year 2003. Table 4 provides the quantity produced by the surveyed units during the year of survey and the year before. A Rapid Market Survey (RMS) was carried out in the major growing areas to contact progressive farmers, extension workers and agricultural input suppliers to assess the extent of use of *Trichoderma harzianum* in pepper plantations. This has enabled:

- Estimation of *Trichoderma harzianum* production and the area where the technology has been applied, by dividing total production of *T harzianum* with the quantity required per hectare of pepper plantation.

- Economic assessment of large-scale mass multiplication of *Trichoderma harzianum* and constraints faced by the industry.

Table 4. Production and sale of *Trichoderma*

Year	Production (MT)	Sale of *Trichoderma* (MT)	
		Kerala	Karnataka
2001-02	150	120	30
2002-03	174	157	17

Yield and cost change

Research benefits were computed for both 'with' and 'without' the DBT project and the difference in benefits was attributed to research investment by DBT. Since the project was completed in the year 2002 and the resultant technology was already in the field, the actual data for area, production and price were used in the analysis. As such, the measured benefit is ex-post estimate. The incremental benefit was compared with the research cost incurred under the project. Only the actual amount spent out of the total approved budget for the project period was considered, not including the salary of the project scientist, extension costs and other administrative costs. Net present value (NPV), internal rate of return (IRR) and benefit cost ratio are computed using the above estimates of benefit and project cost.

For ex-post studies that use past prices, it is usually necessary to 'deflate' the prices (i.e. remove the effects of inflation) (Masters *et al., 1996*). This was done by adjusting actual prices using the consumer price index (CPI), which was estimated such that the value of the index in 2003 was equal to one.

Based on the on-farm trial data and post adoption survey data collected from 180 adopted farmers, an average yield saving or enhancement of 33 kg/ha was estimated (Table 5 and 6). Conversion of the expected yield change to per unit (ton) cost change was done by dividing the change per hectare by the elasticity of supply. The technology is expected to reduce the cost of control measures by 31.06% per hectare when compared to chemical control measures commonly used. This cost change per hectare was converted to cost change per unit using the formula as provided by Alston *et al* (1995) and subtracted from the per unit cost change attributed to the yield increase, to arrive at a net per unit cost change due to technology adoption (Table 5).

Data used

Although pepper is an important traded commodity for the country, it is assumed that the Indian exports do not influence the world price (P_w). During the past decade, world production levels of pepper have increased dramatically, from 233,354 tons in 1991 to 327.250 tons in 2003. Unlike India, most producing countries, including the "new" largest exporter, Vietnam, export almost all their entire production to international markets. As such, the share of Indian exports in the world market has come down to a level where these exports are unable to influence world prices. The actual border prices that prevailed during the period 1994-2003 (Table 1) were used in the analysis. The above nominal prices were adjusted using the consumer price index to obtain real prices, keeping the price index in 2003 at one.

Quantity produced refers to production volumes specific to the part of the country (Kerala State), where the ex-post evaluation was carried out. Between 1994-2003 agricultural seasons, an average of 60,415 tons of pepper was produced in the State, accounting for 94.7% of the total production in the country (Table 1). The analysis was done by a schedule developed in a spreadsheet format.

The expected yield losses from *Phytopthora* foot rot in affected areas assumed for the analysis, 11.59%, was derived from the field trial data (Table 3) given in the final project report, while the cost of a commonly used chemical control package was obtained from Madan *et al.* (2001).

Since economic returns accruing at different points of time must be discounted to make them comparable, the issue of lags between the time when costs are incurred and when benefits are experienced is significant in the analysis of research impacts.

With respect to the adjustment against uncertainties, the change in total surplus was adjusted by the levels of adoption, length of the research period and a depreciation factor, to estimate the returns to research investment on developing the technology and its commercialization. Further, it was assumed that new technology, being a biocontrol method, has no residual effects as in the case of chemical control measures and will be a relatively sustainable technology. Thus it was assumed that the benefits would not depreciate substantially (1% per year), and that this depreciation would not commence until 10 years after the new technology became available.

Analytical Method

The economic surplus method (Alston et al., 1995) with ex-post analysis was considered for the present study to estimate the rate of returns to bio-control measures that replaced chemical control measures to control *Phytophthora* foot rot disease in black pepper. This analysis assumes a small open economy. The small open market economy model envisages a small open economy where price is determined exogenously. The price field is labeled as world price, but can be any relevant price determined outside the region of interest and that will remain unaffected by changes within the single market region.

Economic Surplus Model

The concept of economic surplus has been used to measure economic welfare and the changes in economic welfare arising from policy and other interventions. This methodology permits the estimation of the economic benefits generated by adoption of technological innovations, compared to the situation before (without) the adoption, where only traditional technology was available. What is needed is information on productivity in areas affected by the research, the equilibrium price of the product being assessed, adoption rates and costs, the time frame between research and adoption, and the price elasticity of supply and demand. With this information, available it is possible to calculate the magnitude of change of the supply curve as a result of the adoption of technological innovations (Maredia *et al.*, 2000).

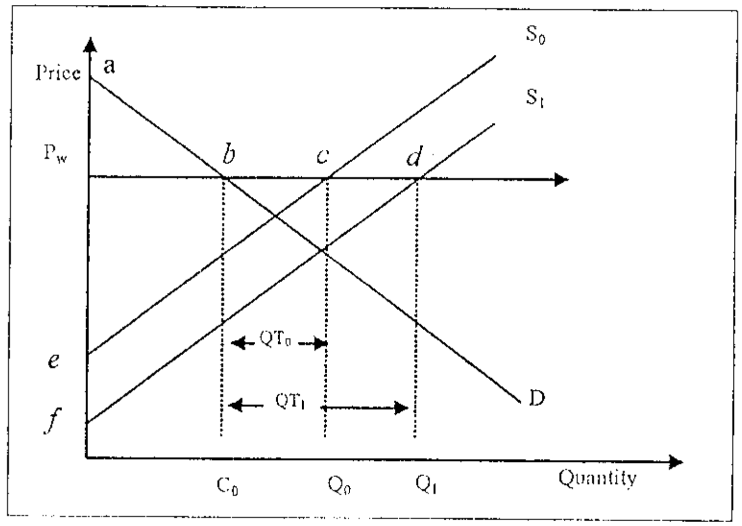
In this study, the analysis was attempted with small open economy model, because the target domain, Kerala State, is not only the main production area for black pepper but is also a consumer of black pepper. Produce from the State moves to other markets in the country and to international markets. On an average, more than 50% of the production in the country is exported annually to international markets (Table 1). Thus the open economy framework operates under the assumption of a small market relative to the international market in the rest of the world (ROW), defined as all areas outside of Kerala, including international markets. In other words, quantity marketed abroad does not affect international prices, and any quantity can be sold in the international market at the prevailing world price. To simplify the model, no transportation costs were assumed, resulting in constant price in both the regions. The local market therefore faces an infinitely elastic external demand. The partial equilibrium approach assumes that no other adjustments are made in the economy.

Small open economy models - Pepper exports at the world price

Figure 2 reflects the case of small open economy, where the economic surplus changes because of a parallel shift of the supply curve. Though there is a possibility of a pivotal shift of the supply curve, only the parallel shift is considered for further analysis in this case. The evaluation of research benefits is done at the world price but at the domestic market level.

In Figure 2, the impact of research on a small open economy is explained. The initial equilibrium without technology is defined by consumption (C_0) and production (Q_0) at the world market price (P_w) with a traded quantity (QT_0). Consumer surplus is measured by area abP_w and producer surplus is measured by area P_wce. With a new technology, producer surplus increases by area *ecdf* with a parallel shift of the supply curve from S_0 to S_1. Consumer surplus is not affected; consumers continue to pay the same price and to consume the same quantity. However, the increase in supply (Q_1-Q_0) results in exportable quantity of QT_1 to ROW market.

Figure 2:
Black pepper: Change in economic surplus when a new technology is adopted in a small open economy (parallel shift of the supply curve)



With no changes in consumer surplus, the total change in economic surplus is measured by the change in producer surplus, which corresponds to the area delimited by curves S_0, S_1, and P_w. Using the world price P_w, the changes in economic surpluses in an open economy model is estimated using the following equations:

1) Parallel shift of the supply curve

K: Vertical shift of the supply function ($)

$\Delta CS = (P-P')Q+½(P-P')(Q'-Q) = 0$ because $\Delta P = \Delta Q = 0$ ------------------------(1)

$\Delta TS = \Delta PS = KQ + ½ K (Q'-Q) = KQ (1 + ½ (Q'-Q)/Q) = KQ (1 + ½ \varepsilon K/P_w)$ (2)

2) Pivotal shift of the supply curve

$\Delta PS = ½ KQ (1 + K \varepsilon /P_w)$ (pivotal shift) -- (3)

$\Delta TS = \Delta CS + \Delta PS$ --- (4)

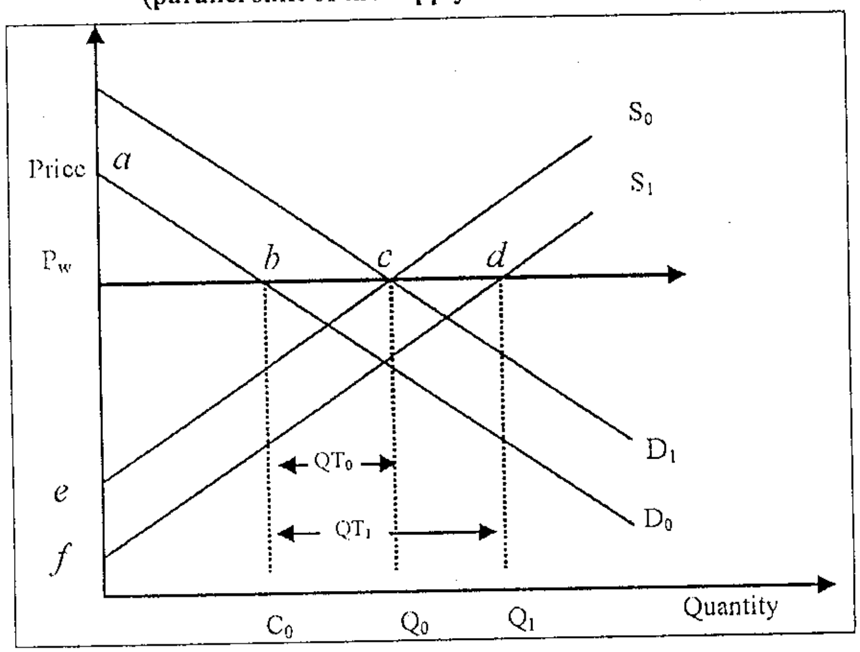
Where,

P_w = World price
K = Supply shift
Q_0 = Quantity consumed
Q = Quantity supplied before supply shift
ε = Supply elasticity
e = Demand elasticity
ε = $[(Q'-Q\}/K]*[P_w/Q] > (Q'-Q)/Q = \varepsilon K/P_w$

In Figure 3, the consumer surplus doesn't change when the supply curve shifts. The producer surplus is affected by the supply shift, but is invariant to the demand shift. Therefore, the change in total economic surplus is only affected by the supply shift. Thus, the change in demand is not considered in the small open economy models.

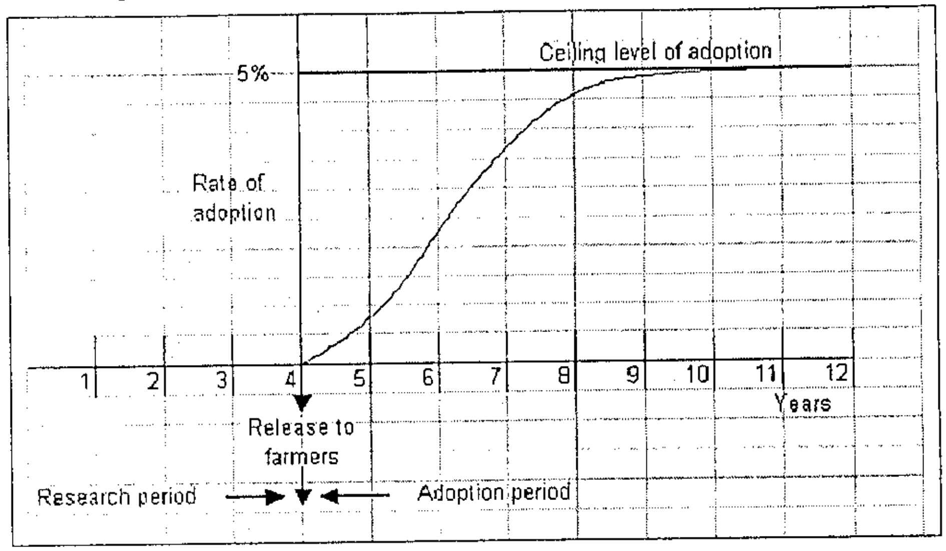
Higher prices induce farmers to produce more by giving extra-care and inputs to the crop resulting in increased production. Better prices are always followed by bumper crops (Radhakrishnan, 1993). Though it has no substitute, the purchase of black pepper can be avoided when the price increases, as it is a spice and not an essential food item.

Figure 3: Pepper exports: Change in economic surplus when a new technology is adopted in a small open economy (parallel shift of the supply and demand curve)



Figures 2 & 3 represent research benefits for one year. A successful research investment will yield benefits over a number of years. As the level of adoption increases there will be a further shift in the supply curve and a corresponding change in benefits. This adoption process was assumed to follow a typical S-shaped curve approximated by a discrete time distribution (Jacobson and Norton 1996) (Fig 4).

Fig 4. Research continuum: research lag and adoption process



Assumptions

It was assumed for ease of analysis that the output supply function was unitary elastic and linear with a parallel research induced supply shift, and the demand function was linearly inelastic. The assumption of a simple case of linear supply and demand functions with parallel shift have been applied in most of the studies on research benefits (Alston *et al.,* 1995). It may be noted that it is a realistic assumption in the absence of availability of reliable estimates of economies of scale and size in agricultural production influenced by the technologies.

Other assumptions

i. *There are two markets for Indian black pepper - Domestic and Rest of the world (ROW).*
   This assumption is purely a reflection of reality. It is expected that black pepper of grades that meet importers' requirements will be exported, while the rest will be supplied to the domestic market. The major destinations for India's pepper are USA, East European countries and Japan. A sizeable quantity goes to the processing industry both in domestic and international market.

ii. *The demand curve for the domestic market is downward sloping*

iii. *The supply curves for the two markets are upward sloping.*
   This is a standard assumption based on the fact that an increase in the price of pepper will, all other things being equal, induce farmers to allocate more resources to the production of the crop. Similarly, a fall in the price of pepper

will serve as disincentive to farmers leading to a reallocation of inputs away from pepper production. As pepper is a perennial crop, any changes in inputs to the crop may not be reflected in output in the same year, while price changes related to production changes are immediate.

iv. *The demand and supply functions are linear in the two markets.*
This assumption eases the task of compiling the geometric areas of economic surplus changes; it facilitates the use of basic algebra for the calculation. As noted by Alston, Norton, and Pardey (1995), since linear demand and supply curves are characterized by varying elasticities, it is important to be explicit about where any assumed elasticities apply. Not withstanding the criticisms of the use of linear supply and demand models within the economic surplus framework, it has been suggested (Alston and Wohlgenant, 1990, cited in Alston, Norton and Pardey 1995), that where a parallel supply shift is used, a linear supply model is a valid approximation, regardless of the true functional form.

v. *The adoption of biocontrol program leads to a parallel downward shift in the supply curve for the export market.*
It is implicitly assumed that the adoption of the technology would lead to a reduction in production cost per unit of pepper exports. The technology-induced reduction in cost per unit is linked to the price premium enjoyed by farmers from selling in the world market. As a result, profits will increase owing to the price premium derived from selling to the export market. Higher profits for farmers would eventually induce them to allocate more resources to pepper production, resulting in a downward shift of the export supply curve. In other wards incentives for adoption lie in the price premium on export, the ability to increase sales, and the resulting reduction in cost per unit. Thus, the adoption of the program will lead to the pepper export supply curve shifting downwards to the right.

vi. *The demand curves in the two markets are unaffected by the adoption of the biocontrol program.*
The implicit assumption here is that, the adoption of the program affects neither the performance nor the income of consumers and it also does not affect the prices of commodities related to pepper.

There is no effect on the input and output markets as there are no changes in output prices. The production technology is the same for both adopted and non-adopted farms, except for the reduced cost of resulting from the new technology in the adopted farms. Thus there would be no increased demand for other inputs.

The analysis was carried out using a spreadsheet model designed to take into account the impacts of the technology. The conceptual model is based on the one suggested by Alston *et al., (*1995). Further, the analysis had to be adapted to accommodate the parallel shifts in supply associated with the technology impact.

The difference between the gains and the costs of generation and transfer represents the net benefit of the technology, explained by IRR, NPV and BCR (Gittinger, 1982). To enable calculations with present values, a discount rate of 8% is used in this paper. Since many of the baseline assumptions are debatable, sensitivity analysis was undertaken to assess the effect of different discount rates, adoption levels, research timing and cost assumptions, the probability of variations in research timing and cost assumptions, as well as the probability of research success on the NPV, IRR and BCR.

Results and discussion

Economic and Eco-friendly factor

An industrial unit that started with newly developed mass multiplication technique, an outcome of the project under study, earned a NPW of Rs.242,618 at the end of 10 years, with a BCR of 1.84. Further, the new entrepreneur was able to recover the initial investment in the second year, while the factory can be operated for more than 10 years (Table 5). The profitability of the venture and increasing demand for the end product i.e., *Trichoderma harzianum,* brought about movements in industrial developments in Kerala. Being an eco-friendly and nonpolluting industry, it was well accepted with the Kerala State government supporting this industry by providing land facilities, etc. In the context of strict sanitary and phytosanitary (SPS) measures implemented in the importing developed countries, the momentum for organic spice cultivation has picked up in the State. In organic pepper cultivation, application of *Trichoderma* is the only measure available for control of crop losses due to *Phytophthora capsici*. This advantage also contributed to the success of the technology.

Table 5. Measures of project worth

No.	Criteria	Results
1.	Pay-back period (years)	<2
2.	Net Present Worth (NPW) at 11% discount rate (Rs.)	242.618
3.	Benefit Cost Ratio (BCR) at 11% discount rate	1.84
4.	Internal Rate of Return (IRR) %	121

Estimation of economic surplus

Estimation of gross annual benefits in terms of increased production as a result of adoption of the technology is presented in Table 6. The estimated potential productivity gain (quantity saved from *phytophthora* disease) would result in 17.3 % reduction in cost per ton of producing pepper. The lower cost of production results in an increased amount of pepper supplied by farmers. The estimated maximum proportionate productivity increase is 11.59%.

Table 6. Economic surplus model: Potential maximum benefits (change in total surplus) within the domain

Open economy	Black pepper
ε = Elasticity of supply[1]	0.23
η = Elasticity of demand[1]	0.16
Maximum proportionate productivity increase (%)[2]	11.59
Gross cost change per ton (%)	50.40
Reduction in cost or input cost change per ha (%)[2]	-31.06
Reduction in cost or input cost change per ton (%)[2]	-27.9
Net proportionate reduction in cost per ton output	78.30
Relative reduction in price (%)[2]	46.0
Price per ton (Rs./ton)[3]	63,500
Quantity ('000t)[3]	60.7
Change in total surplus (Rs. thousands)	2,804
Change in consumer surplus (Rs. thousands)	-
Change in producer surplus (Rs. thousands)	2,804

Source:
1. Based on the study by Bade and Smit (1995).
2. Worked out from the data given in the final report of the DBT project.
3. Actual time series data collected from Spices Board is used.

Table 7. Summary of assumptions and results of economic analysis

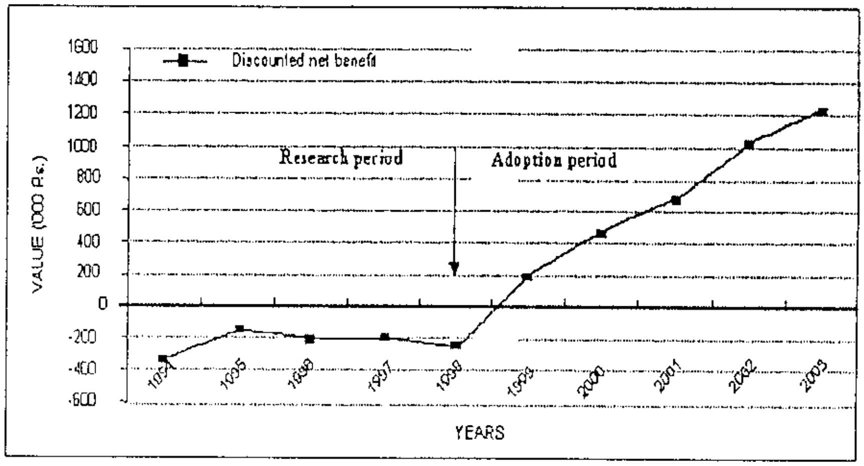
Time to release of technology to farmers (Yrs)[1]	4
Adoption period – time to maximum/ceiling adoption level (yrs)[1]	6
Maximum adoption level - percentage of farmers expected to adopt by the end of the adoption period[1]	5
Probability of research success[1]	100
Research period within the research institute[1]	4
Research and development period – private and/or public sector[1]	2
Net Present Value (NPV) of the research ('000 Rs.)	1,139
Internal Rate of Return (IRR) (%)	19
Benefit cost ratio (BCR)	2.5

Source:
1. Information given in the final report of the DBT project.

The net benefit stream (i.e. benefits minus costs) over the next 6 years is shown in Figure 5. The NPV of the research is estimated to be Rs.1.139 million, with an IRR of 19% and a benefit cost ratio of 2.5.

An IRR of 19% for the base parameter indicates that, on an average, for each rupee invested, returns came to 19% per year from the time of investment until the year 2003. The BCR of 2.5 indicates that Rs.1 invested in developing and disseminating the technology produced an average benefit of Rs.2.5 throughout the period.

Fig 5. Flow of cost and benefits



Sensitivity analysis

Potential change in income

With a supply elasticity of 0.23, the net present value (total change in economic surplus minus research costs from 1994 to 2003) is estimated to be Rs. 1.139 million, Rs.698,000 and Rs.-71,000 at the 8 per cent, 11 percent and 20 per cent discount rates respectively. These net present values are equivalent to the sum of area *ecdf* calculated for each year in Figure 3 and plotted in Figure 5 (minus the research costs which are applicable only in the early years), discounted over the 10-year period.

Estimation of potential maximum or gross annual benefit in terms of increased production is shown in Table 6. The estimated potential productivity gains could result in a 31% reduction in the cost per ton of production. Further, adoption of the technology has brought about a saving of 11.59% per hectare where the technology has been adopted, and this can be considered as yield increase. The saved quantity of 33kg/ha would have been lost as pre-harvest losses due to *Phytophthora* foot rot in the absence of adoption of plant protection measures (technology). Levels of technology adoption, the probability of research success and a depreciation factor affect the change in total surplus (Table 7). These uncertainty-adjusted benefits generated over the period were then compared with the research investment.

Adoption levels

Assumptions about the maximum level of adoption of the new technology strongly affected returns on research investment. The estimated actual adoption level was 1% at the beginning and was at a maximum of 5% after 6 years. This was increased to 10% and 20% to examine the implications for research returns. The increase in adoption level to 10% increased the NPV substantially to Rs.1.804 million, with an internal rate of return of 22% and benefit-cost ratio of 1.9. Increasing the adoption level to 10%, with a 10% increase in expenditure on extension, resulted in net returns of Rs.1.637 million, with IRR of 20 and BCR 2.1. This indicates that higher returns from may be obtained by investing in extension activities to increase adoption levels for the technology

Table 8. Sensitivity of estimated return to various assumptions

Assumptions	Level	Net Present Value (Rs. '000) *(NPV)*	Internal Rate of Return *(IRR)*	Benefit : Cost Ratio *(BCR)*
Maximum/ceiling adoption level (%)				
Baseline	5	1,139	19	2.5
Medium	10	1,804	22	1.9
10% higher cost +	10	1,637	20	2.1
Research period: years for output to reach farmers				
Baseline	4	1,139	19	2.5
Longer research period	6	181	10	10.2
Research cost (Rs. '000)				
Baseline	1,419.0	1,139	19	2.5
Decrease by 20%	1,135.2	1,474	24	1.9
Increase of 20%	1,702.8	808	15	3.5
Discount rate (%)				
Base line	8	1,139	19	2.5
Medium	11	698	19	3.2
Higher	20	-71	19	-17.2

Though the main objective of the project was technology development, equal effort was taken to extend the technology to farmers through on-farm trials, workshops, training to farmers, etc. As such no expenditure was allocated exclusively towards extension activities during the project period. The beginning of the organic movement in 1999-2000 in the major pepper growing districts in the State worked as a catalyst to increase the demand for biocontrol agents. To check the result, the cost of research expenditure was increased by 20% to 1996 thousands (to be spent towards extension) and the result was encouraging, with better returns over the investment.

Research period

As noted earlier, the research on biocontrol methods for management of *Phytophthora* disease in black pepper was being undertaken even before the start of this DBT sponsored project. This project has sharpened the research outcome and has helped in hastening transfer of the resultant technology to stakeholders. During the final year of the project i.e. the 5th year, the technology has been applied to 1% of the total area under pepper in the state. During this period, the supply of inoculums (*Trichoderma harzianum)* was only from the institute. Therefore the total 'research lag' was estimated at 4 years in the base line analysis. When this is increased to 6 years, returns fell drastically from Rs.1.139 millions to 0.181 millions, the IRR decreased from 19% to 10% and the benefic cost ratio (BCR) rose to 10.2% from 2.5%. This analysis indicates that the expected returns are much more sensitive to changes in the research period than they are to changes in the adoption levels.

Discount rate

Cost of capital or the choice of an appropriate discount rate has a significant impact on the net returns. The discount rate is a time preference concept. We have used 8% as the baseline discount rate, as this was the rate used to evaluate the returns on research investment by NATP on various agricultural projects (Mruthyunjaya et al., 2004). We assessed the effects of the discount rate on returns by increasing it from 8% to 11% (medium and commercial rate) and 20% (maximum). The NPV fell to Rs.698 thousand and a negative Rs. –71 thousands respectively, while the benefit-cost ratio rose to 3.2 and -17.2 respectively indicating the fact, that still it is beneficial to invest on the project at the slightly higher rate of interest (11%).

In this ex-post analysis only the direct benefits from the increased yield (or quantity saved) was considered. The aspect of returns on maintenance research and the increase in quality or acceptability of the commodity through research has not been taken into account.

Conclusion

Plant protection technology poses certain challenges for program evaluation and impact assessment compared to technical interventions such as release of new varieties. However, the effort has brought out some interesting findings, which will help both the funding and implementing agencies (research institutes) involved in the field. The link between the Research Institute and the small-scale entrepreneurs involved in large-scale multiplication of *Trichoderma harzianum* has been of tremendous benefit to the pepper industry. The commitment and scientific and technological capability of the private entrepreneurs enabled this useful technology to reach at least 5% of the total cultivators. An increased investment outlay for the extension activity could have helped in increasing the adoption level, leading to augmented returns to the research investment. In the light of increased levels of SPS related restrictions and increased demand for organic spices in world markets, there is likely to be increased demand for biofertilizers and biocontrol measures to manage the organic or alternative cultivation of pepper. Further, the technology promotes both socio-economic and environmental sustainability.

Results of the present study should encourage not only small-scale entrepreneurs to venture into large-scale multiplication of *Trichoderma* but also the farming community to bring more production areas under bio-control. Government sponsored developmental programmes aimed at increasing spice production in the country may promote this technology as one of the major components for sustainable pepper production. Further, funding agencies should consider such projects for sponsorship, expecting better returns from research investments.

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Reference

Alston, J.M., G.W.Norton and P.G.Pardey, (1995). Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting. Cornell University Press, Ithaka.

Anandaraj, M. and Sarma, Y.R. (1994). Biological control of black pepper diseases. *Indian cocoa arecanut spices J.* 18: 22-23.

Antle, J.M. and P.L.Pingali, (1994). Pesticides, productivity, and farmer health: A Filipino case study. *American Journal of Agricultural Economics,* 76p:418-430.

Bade, Jan and Hidde P. Smit (1995). Analysis, projections and supply management policies for the world pepper economy. In: Towards a more vibrant pepper economy. Studies in Trade and Investment 4. United Nations, New York. pp.31-111.

Gittinger, J. Price. (1976). Economic Analysis of Agricultural Projects. World Bank, Washington D.C. pp.221.

Madan, M.S. and M.Tamil Selvan (2001). Indian Black pepper: Changing Scenario. *Indian Jn. of Arecanut, Spices and Medicinal Plants,* 3 (1) : 262-269.

Madan, M.S., Peter,K.V., Sarma, Y.R.Sivaraman, K. S.Varma, Srinivasan V. and P. Singh (2000). Impact Assessment of Improved Management Measures for *Phytophthora* Foot Rot Disease of Black Pepper. Workshop on Impact of Agricultural Research. ICRISAT, Hyderabad.

Maredia, Mywish, Byerlee, Derek, Anderson Jock (2000). Ex Pot Evaluation of Economic Impacts of Agricultural Research Programs: A Tour of Good Practice. Paper presented to the Workshop on "The Future of Impact Assessment in CGIAR: Needs, Constraints, and Options", Standing Panel on Impact Assessment (SPIA) of the Technical Advisory Committee, Rome, May 3-5, 2000.

Masters, William et al. (1996). The Economic Impact of Agricultural Research: A Practical Guide. Department of Agricultural Economics, Purdue University, West Lafayette, IN.

Radhakrishnan, C. 1993. Economics of pepper production in India. Department of Economics, University of Kerala, Trivandrum.

Rola, A.C. and P.L. Pingali, (1993). Pesticides, Rice Productivity, and Farmers' Health: An Economic Assessment, Manila, The Philippines: International Rice Research Institute, and Washington DC: World Resources Institute.

Sarma, Y.R. and Anandaraj, M. (1998). *Phytophthora* foot rot of black pepper. In Management of threatening plant diseases of National importance. (Eds. Agnihotrhiri, V.P. Sarabhoy, A.K. and D.V.Singh., Malhotra Publishing House, New Delhi) pp.237-248.

Sarma, Y.R. and Anandaraj,M. (2003). Development, production and demonstration of biocontrol agents under integrated pest management. Final report on the mission mode project. Indian Institute of Spices Research, Calicut.

Sarma, Y.R., Anandaraj, M. and Venugopal, M.N. (1996). Biological control of disease of spices, pp 1-17. In Biological control in spices (Eds. Anandaraj, M. and Peter, K.V.) Indian Institute of Spices Research, Calicut.