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Development of Technology and Popularization of Biological Control Agents for Integrated Management of Coconut Leaf Rot Disease*

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Abstract

Coconut is an important social crop of livelihood concern for millions of small- medium farmers. Leaf rot disease (due to a fungal complex-*Colletotrichum gloeosoprioides*, *Exserohilum rostratum* and *Fusarium solani* as major pathogens), in association with root (wilt), is a major problem of coconut in southern districts of Kerala besides certain districts in Tamil Nadu etc. Central Plantation Crops Research Institute (CPCRI) has evolved biological control technology for integrated management of leaf rot to improve the health of disease affected palms. Application of biocontrol agents in the disease affected areas was aimed for creation of widespread awareness on eco-friendly disease management, crop sustenance and in realizing human resource potential. Effective strains of biocontrol agents-*Bacillus subtilis, Pseudomonas fluorescens* and *Trichoderma viride*-were evolved, their multiplications in media including coconut water standardized and the antagonists' processed into bioformulations (totally 2000 Kg. talc formulations evolved distributed/utilized). Coconut gardens and rural groups in various districts of southern Kerala (Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam, Idukki, Ernakulam and Thrissur), various blocks in Theni district besides specified blocks in Dindigul district of Tamil Nadu could be selected. Through effective contacts with extension-developmental agencies, coconut Research & Development (R&D) meetings etc. reached out to rural people and implemented the technology of mass production-use of biological control agents, and knowledge imparted to rural people. Conducted trainings and allied programmes by on-campus trainings (396 beneficiaries), off-campus trainings (1854 beneficiaries), household/field contacts of rural people (689 beneficiaries) and other awareness programmes encompassing lectures, interfaces etc. (661 beneficiaries) and enlightened women, rural people, youths etc. representing various locations (totally 3600 beneficiaries in three years). Field demonstrations of disease management with biological control agents in coconut gardens (55 units) besides clusters-compact gardens (1850 coconut palms) were also done. Also, promotional materials were made available to various stakeholders. An innovative participatory programme implementation approach for technology transfer was the outcome of the work. Creation of widespread awareness, percolation of knowledge on biocontrol agents to women and other rural people could be visualized that would go a long way.

Keywords: Coconut, root (wilt), leaf rot, biocontrol agents, mass production, rural people, articipatory programmes, technology demonstration, integrated disease management.

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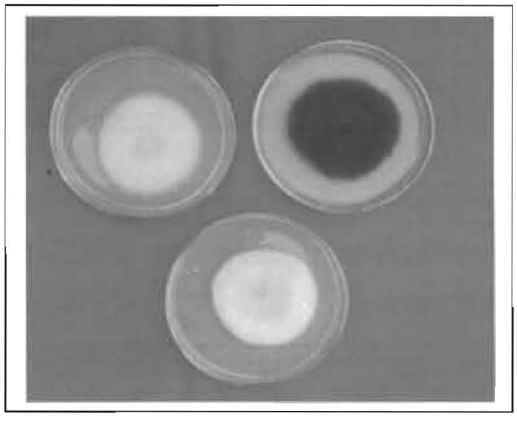
Introduction

Coconut (*Cocos nucifera* L.) is a principal plantation/social crop of livelihood concern for millions of small-medium farmers. The crop is cultivated in India, Indonesia, Philippines and Sri Lanka besides several other countries especially in hot humid tropics. In India, coconut cultivation is concentrated in Kerala, Tamil Nadu, Karnataka and Andhra Pradesh besides several other states. Currently the crop is grown in the country on nearly 1.89 million hectares with an estimated annual production of 15.72 billion nuts per year. The crop plays a major role in social, religious and economical concern of rural people. Even though Kerala occupies pre-eminent position by way of area (7.87 lakhs hectares) and total production of the crop (5802 million nuts/year), the productivity of coconut is less (7365 nuts/hectare) than the national average productivity (8303 nuts/hectare). Several constraints are reported to affect the crop productivity in the state and among them the incidence of pests and diseases are very important. Leaf rot disease (due to a fungal complex-*Colletotrichum gloeosoprioides*, *Exserohilum rostratum* and *Fusarium solani* as major pathogens) in association with root (wilt) is extensively prevalent in southern districts of Kerala state and also in the adjoining state of Tamil Nadu–particularly Theni–Dindigul districts (Srinivasan *et al.*, 2000; Srinivasan and Sasikala, 2001). The root (wilt) affected palm is commonly infected by leaf rot and a strong interrelationship of leaf rot with root (wilt) firmly established (Srinivasan, 1991) - root (wilt) affected palms come to the farmers' attention instantly with the onset of leaf rot and therefore the disease complex economically very important. Integrated management of root (wilt)-leaf rot complex has been recommended for optimizing the productivity of the crop. The knowledge and adoption of scientific parameters practiced, however, are thought to be lower - innovation and technology evolving play a contributory role for sustainable activities/in stabilizing yield potential of the crop in the disease affected regions. Central Plantation Crops Research Institute (CPCRI) established etiology of root (wilt) and leaf rot diseases. While root (wilt) was considered to be due to phytoplasma (Solomon *et al.*, 1999), the leaf rot has been proved to be caused by a group of fungi as already mentioned-Figures 1A to 1B (Srinivasan 1991,

Figure 1A. Leaf rot in root (wilt) affected coconut

Figure 1B. Major Pathogens of leaf rot disease (Top-Left: *Colletotrichum gloeosporioides*; Top-Right: *Exserohilum rostratum*; Bottom: *Fusarium solani*)



2004, 2008; Srinivasan and Gunasekaran, 1996a, 2000). Package of integrated management practices for improving the health and productivity of the palm crop has been developed. Even as root (wilt) is not amenable to therapeutic control measures, leaf rot control could be evolved (Srinivasan *et al.*, 2001).

Methods of application of fungicides on to coconut palms has been determined (simple measure of pouring the chemical into the spindle axil standardized and the measure satisfactorily suppressed the disease recurrences in newly emerged leaves) - pouring of Contaf into the axil of spindles along with phytosanitation on the spindle/young leaves significantly aided to cure the palm besides prophylactic protection to emerging leaves (Srinivasan and Gunasekharan, 1996b, 2003).

In control of plant diseases an alternative system of biological control has emerged as an important component in the disease management system-certain antagonistic bacteria (*Pseudomonas fluorescens*, *Bacillus subtilis*) and fungi (*Trichoderma viride*) affect major pathogens of leaf rot (Srinivasan and Bharathi, 2006). Amelioration of leaf rot with a talc-based *P. fluorescens* has been found possible (Srinivasan, 2003; Srinivasan *et al.*, 2006c). As a new technology it was to be widely popularized in the disease affected regions through integrated approach for adoption especially by small-marginal farmers. Application of biocontrol agents involving women and other rural population in the areas was felt necessary. A strategy with programmes for creation of widespread awareness on the disease management besides realizing human resource potential was thought to be adopted in the disease affected regions [southern districts of Kerala besides adjoining districts in Tamil Nadu (Theni, Dindigul)]. Hence, a participatory approach programme-with the objectives such as creating awareness on biocontrol measures and its beneficial effect with integrated management practices and environmental safety; conducting mass production of antagonists for supplying to rural community; conducting field demonstration in collaboration with extension agencies; production-distribution of promotional literature; training rural and unemployed people especially women in mass production etc.-was implemented and the outcome is presented in this paper.

Material and Methods

The work was carried out in a period of three years (October 2004 - February 2008) during which concerned aspects were employed so as to strategically implement the programmes as envisioned.

Selection of biocontrol agents, evaluation and standardization of multiplication

Soil/rhizosphere samples of coconut were collected and utilized for isolations of bacterial and fungal biocontrol agents *viz.*, *B. subtilis, P. fluorescens*, *T. viride* and *T. harzianum* utilizing specific media (Nutrient agar/King's B agar for bacteria; Potato dextrose agar/*Trichoderma* selective media for fungal isolates). A vast number of isolates were made out and bioassay of pure isolates of bioagents against major pathogens of leaf rot (*C. gloeosporioides, E. rostratum* and *F. solani*) performed *in vitro*. Out of isolates of each antagonist short-listed one effective isolate was selected and used. Subsequently *B. subtilis, P. fluorescens* and *T. viride* individually and in combinations (*B. subtilis* + *P. fluorescens*, *B. subtilis* + *T. viride*, *P. fluorescens* + *T. viride* and *B. subtilis* + *P. fluorescens* + *T. viride*) were assessed for confirmatory reactions for exploitation. This formed the basis for mass multiplication/ development of bioformulations/mass production of each antagonist, thereby utilization of the technology. Evaluation of compatibility among biocontrol agents was also carried out. The techniques for multiplication/ mass production of biocontrol agents were also standardized.

Selection of gardens-rural groups

Surveys were conducted in the disease endemic districts of Kerala (Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Kottayam, Idukki, Ernakulam and Thrissur) besides various blocks in Theni District (Cumbum, Uthamapalayam, Chinnamanur, Bodinayakkanur, Theni, Periyakulam, Andipatti, Kadamalaikundu) and in specified blocks in Dindigul district (Athoor, Palani) of Tamil Nadu, where focus warranted Rural people in these regions were contacted and relevant details especially know-how on biocontrol agents/biocontrol technology collected. Contacts were made with extension & developmental agencies like state Departments

of Agriculture to reach out to rural groups in these regions and their collaboration availed for conduct of awareness cum training programmes on mass production and utilization of biocontrol agents besides other modes of interactions. Services of voluntary agencies, self-help groups, NGOs, Krishi Vigyan Kendras of Alappuzha (CPCRI – RS, Kayangulam) and Theni Districts (CENDECT Krishi Vigyan Kendra, Kamatchipuram, Theni) etc. were also availed for knowledge delivery thereby technology percolation to rural people.

Trainings and promotional literature

Conducting trainings to women, rural people etc. on mass production of biocontrol agents and packaging ought to be important programme. Therefore, based on the theme of mass production and use of biocontrol agents and for societal benefit, various modes of need based programmes viz., On-campus trainings, Off-campus trainings, Household/Field contacts of rural people and other Awareness programmes (lectures, interface etc.) were implemented to enlighten rural people (besides officials, youths etc.). Development of promotional literature on disease Vis-à-Vis biocontrol technology - as effective medium for percolation of knowledge to stakeholders – formed an integral part. Hence training folders on biocontrol agents in integrated management of coconut leaf rot disease was developed. Parameters (such as models of application, involvement level of representative geographical areas/rural people etc. as beneficiaries) as could have been evolved during the course of the work also formed the basis for implementation of such programmes.

Field demonstrations

As coconut farmers particularly in Kerala are small-marginal and farming as such commonly as homestead gardens, and the crop invariably requires climbing for operations such as plant protection measures that requires especially skilled climbers strategic approaches were adopted in demonstrations in such a manner to enable rural people to imbibe the know-how for combating the disease problem in environmentally safe manner.

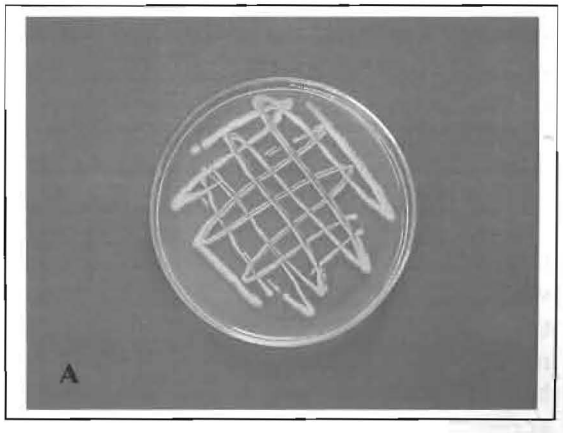
Results and Discussion

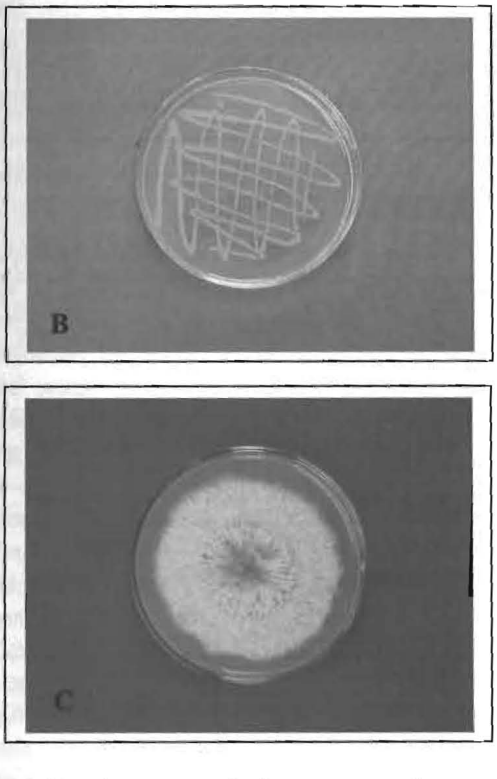
The programme as implemented during the course of the work and the outcome achieved are presented herein.

Selection of biocontrol agents and their evaluation

Isolates of *B. subtilis, P. fluorescens* and *T. viride* were tested and one representing each selected. *B. subtilis* and *P. fluorescens* were found significantly inhibitory to all pathogens. While the fungal bioagent *T. viride* grew faster limiting the pathogens the inhibition zones developed by bacterial antagonists were invariably higher and more effective and therefore the bacterial antagonists received higher priority. *B. subtilis*, *P. fluorescens* and *T. viride,* were individually and in their combinations were also evaluated *in vitro-B. subtilis* and *P. fluorescens* compatible; *B. subtilis* and *T. viride* also compatible; *P. fluorescens* and *T. viride* not compatible; strains of each species compatible among them; bioagents compatible with minimal concentration of a popular fungicide-Contaf (Hexaconazole). The features were used for bioformulations in the disease management system. Utilization of biocontrol agents in consortium mode bearing synergism is important (Figures 2A to 2C).

Figure 2. A to C: Biological control agents – A. *Bacillus subtilis*; B. *Pseudomonas fluorescens*; C. *Trichoderma viride*





Multiplication techniques and mass production of biocontrol agents

The bacterial and fungal bioagents could be multiplied in conventional media as well as in coconut water based liquid culture media. The coconut water derived particularly from developed nuts performed as a potential multiplication medium for mass multiplication of biocontrol agents. Method was standardized for processing the bioagents into bioformulations principally using talc as a carrier material. Mass production of the bacterial bioagents was undertaken in Fermentor System also, that aided in enriched yield of the organisms and such enriched cultures were also processed in to bioformulations. The mass production of different biopesticides was undertaken during various programmes of implementation through out the period and a total of 2000 Kg of biopesticides thus produced was utilized in various programmes-field demonstrations, as training kits to beneficiary participants etc. Novel methods of production of admixture of talc-based biopesticides with neem cake, organics/farm derivatives and also along with various biofertilizers (neem cake: about 1500 Kg; biofertilizers: about 200 Kg) were also adopted and utilized in programmes.

Gardens and rural groups in Kerala and Tamil Nadu

Analysis of responses showed prevalence of relatively a low level of knowledge with the rural people on biocontrol technology and therefore the scope, and necessity of enlightening rural masses on the production-utilization of biocontrol agents. Extension material/Technical bulletin on the disease complex *vis-à-vis* utilization of bioagents (biopesticides) was provided to rural women and men through various modes of programme implementation. Disease affected coconut gardens on selected locations as identified were subjected to technology demonstration with biocontrol agents for disease management. These measures aided in enlightening rural people on biological control agents (Figures 3A to 3C).

Figure 3. A to C: Involvement of extension agencies in transfer of technology and participatory programmes for rural people, women etc.

Trainings and allied programmes *On-campus trainings*

A total of 15 batches of each one-day on campus trainings on production and use of biocontrol agents were conducted for rural men and women in Kerala (aspects of root (wilt)-leaf rot complex, demonstration *cum* practical session on the preparation of biopesticides, packaging techniques, fortification of bioagents with organics, demonstration of application of biocontrol agents into coconut system, group discussions; providing training materials, sample biopesticides, biotreated coconut seedlings-covered). A total of 396 rural people benefited through these on campus trainings out of which 175 are women beneficiaries (Figures 4A to 4E).

Figure 4. A to E: Participants in *In campus* training on mass production of biological control agents and their utilization

Off-campus trainings

A total of 22 batches of each one-day off-campus programmes were conducted for women and men-1854 rural people benefited through these off campus training programmes out of which 450 women beneficiaries represented (Figures 5A to 5J).

Figure 5. A to J: Participants in *Off campus* training on mass production of biological control agents and their utilization

Household/field contacts of rural people

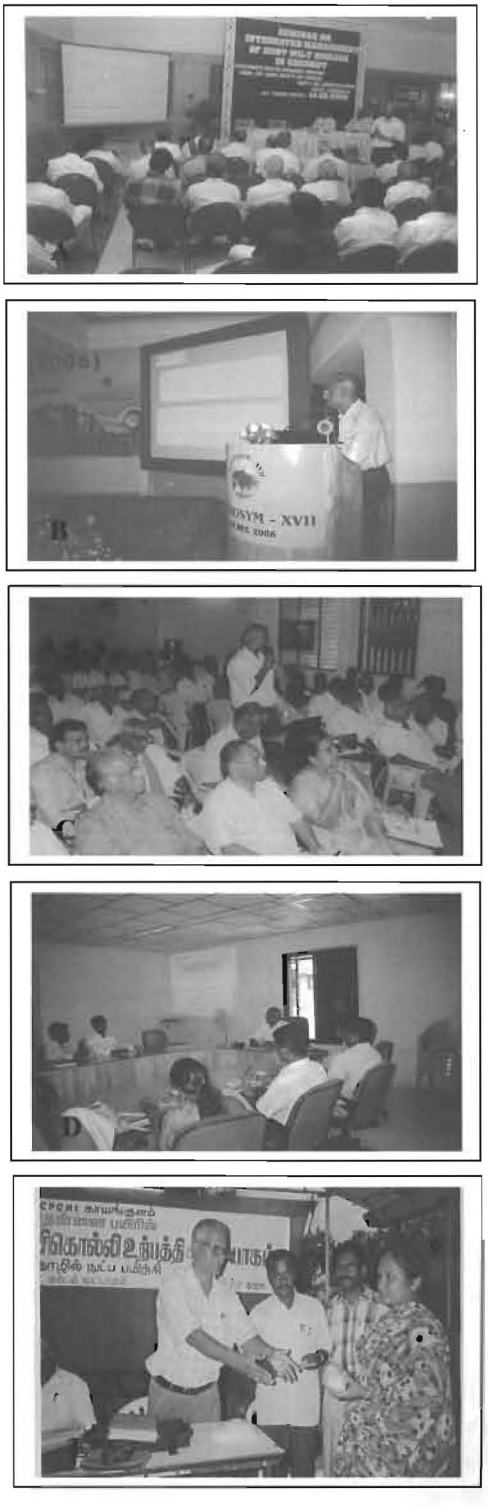
Representative rural households/ homesteads/fields in various districts of southern Kerala were contacted-details on root (wilt)–leaf rot, production/use of biocontrol agents in management of the disease complex presented and 689 rural people benefited through these measures out of which 237 were women beneficiaries (Figures 6A to 6E).

Figure 6. A to E: Out reach programme implemented through household/ field contacts of rural people

Awareness programmes

Need based lectures, interface meetings etc. were also implemented and in such programme rural people/women/farmers, youths (Agriculture graduate students), youths (Other graduate students), Agriculture Department Officials (representing the disease affected regions) and certain other Officials were involved-661 persons got benefited out of which women constituted 50% (Figures 7A to 7G).

Figure 7. A to G: Out reach programme as implemented through various other awareness programmes



Promotional literature on disease management

Training folders on biocontrol agents in integrated management of coconut leaf rot disease was developed and copies of the same were widely distributed during various stages of programmes implementation to stack holders in the disease-affected region. Various other promotional literatures on coconut root (wilt) - leaf rot disease complex, as evolved, were also strategically utilized for dissemination of knowledge to beneficiaries of the programmes that played in successful conduct of various models of programmes (Srinivasan *et al.*, 2005, 2006, 2007).

Field demonstrations

Multilocational field demonstrations of technology involving biocontrol agents were conducted during three years of programme (Figures 8A to 8D; Figures 9A to 9D):

Figure 8. A to D: Programme on utilization of organics with bio agents – Recycling of Coir pith into useful organic carrier material (conversion of waste to wealth in Coconut industry!)

Figure 9. A to D: Technology demonstration in field level for the benefit of various stakeholders of the programme

- 2005-06 - Representative coconut gardens/coconut based cropping system in the districts of Thiruvananthapuram (3 units), Kollam (6 units) and Alappuzha (6 units) in Kerala and in each one unit (garden) in Cumbum, Uthamapalayam, Chinnamanur and Bodinayakkanur blocks of Theni district of Tamil Nadu (Total 19 units).
- 2006-07 - In each two gardens in Elanthoor, Thiruvalla (Pathanamthitta district) Alappuzha, Cherthala (Alappuzha district), Kaduthuruthy, Pallom (Kottayam district) blocks of Kerala and also in each two gardens of Periyakulam, Theni, Andipatti, Kadamalaikundu (Theni district), Athoor and Palani (Dindigul district) blocks of Tamil Nadu (Total 24 units).
- 2007-08 - In each one-coconut garden in certain specific blocks of Alappuzha (Muthukulam, Mavelikara, Haripad, Bharanikavu, Ambalapuzha) and Kollam (Oachira) districts of Kerala, besides in each two gardens in Peermade (Idukki district), Paravoor and Narakkal blocks (Ernakulam district) (Total 12 units).
- Demonstrations in clusters of coconut based homesteads in Alappuzha district and in compact gardens in Theni district (total of 1850 palms) were also done by treatment of biocontrol agents.
- Integration of organics – neem cake, coir pith compost, vermicompost, in situ farm wastes etc. and their effective utilization was also elaborated to stakeholders.
- Also given the knowledge of biotreatment of coconut seeds and seedlings with biocontrol agents (nursery raising), technical details on the disease complex/disease management measures for large-scale percolation in to rural people.

The need for effective percolation of scientific know-how for adoption is critical and R & D efforts could be channeled in bridging the gap (Anithakumari and Manoj, 2004). Over-all evaluation from rural community showed enhancement of knowledge on biocontrol agents (the chain in biopesticide production-utilization) through implementation of current programme. Further, the rural people could be encouraged through programme activities on biopesticides cum organics production. As such the programmes benefited the rural population and this approach of biocontrol technology forms first of its kind (phase I) in the disease affected region - a road map laid through disseminated scientific know-how (Table 1). Amelioration in biotreated palms from the disease could be evidenced to the stakeholders for evolving palms free from the disease, creating awareness widely about the use of biopesticides in integrated disease management practices with environmental benefits. As coconut based cropping system is common in the region enterprises involving integration of biopesticides with organics could also be modeled during the course of this work – as for example, the coconut byproduct of coir pith could be integrated with biopesticide utilization. Utilization of coconut water in mass production of biocontrol agents, generation of coconut system based organics for biopesticides, evolving value added coconut seedling with biocontrol agents are also made possible (Srinivasan, 2008, 2010a, b). Being

Table 1. Consolidated data on number of participants/beneficiaries availed through various programmes of the project implementation

First year (2005-06):

S. No.	Type of Training	No. of participants/ beneficiaries		
		Men	Women	Total
1	On campus trainings	037	045	082
2	Off campus trainings	423	108	531
3	House hold/Field visits	072	077	149
4	Awareness programmes	070	129	199
Total		**602**	**359**	**961**

Second year (2006-07):

S. No.	Type of Training	No. of participants/ beneficiaries		
		Men	Women	Total
1	On campus trainings	0	43	43
2	Off campus trainings	838	258	1096
3	House hold/Field visits	202	61	263
4	Awareness programmes	151	69	220
Total		**1191**	**431**	**1622**

Third year (2007-08):

S. No.	Type of Training	No. of participants/ beneficiaries		
		Men	Women	Total
1	On campus trainings	184	087	271
2	Off campus trainings	135	092	227
3	House hold/Field visits	178	099	277
4	Awareness programmes	117	125	242
Total		**614**	**403**	**1017**

Grand Total for all years	**2407**	**1193**	**3600**

perennial nature of the crop the benefits accrual may be realizable on long term basis and hence it may be expected that the current efforts would go a long way in coconut based cultivation. The Institute – CPCRI - is constantly endeavoring through implementation of various programmes for sustainable cultivation of coconut in the root (wilt)-leaf rot affected regions. In continuation of the present work new programme - phase II - of demonstrating latest technologies on integrated management of coconut leaf rot disease with farmer participation is being undertaken and the impact of the technology analyzed.

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