RPF III

PART - I: GENERAL INFORMATION

800	Project Code	:	Path II.3(813)
8002	ICAR Project Code No.	:	P-1-83/6-ICI-H20/2310
801	**Name of the Institute and Division**	:	
8011	Name and address of Institute	:	Indian Institute of Spices Research, Calicut- 673 012, Kerala
8012	Name of Division/Section	:	Crop Protection/ Pathology
8013	Location of the Project	:	Indian Institute of Spices, Calicut
802	Project Title	:	Disease Management in *Phytophthora* Foot rot (Quick wilt) affected Black Pepper Plantations
803	Priority Area	:	Research
8031	Research Approach	:	

Applied Research	Basic Research	Process/Technology development	Transfer of Technology
√	√	√	√

804	**Specific area**	:	Crop Protection, Spices Research
805	**Duration of Project**	:	23 Years
8051	Date of start of project	:	1983
8052	Date of completion of project	:	2006
8053	Period for which report submitted	:	1983-2006
806	**Total cost of the project/ Expenditure incurred**	:	**Rs. 31, 74, 000**

(Give reasons for variation, if any from original estimated cost)

807 EXECUTIVE SUMMARY

Phytophthora foot rot caused by *Phytophthora capsici* and slow decline primarily caused by plant parasitic nematodes were considered as serious production constraints in black pepper. These two diseases were referred to as 'quick wilt' and 'slow wilt'. At the start of the investigation very little was known about the etiology of slow decline and epidemiology of foot rot An Adhoc recommendation with application of Bordeaux spray (1%), pasting the collar up to 1metre with Bordeaux paste (10%) and drenching the root zone with copper oxychloride (0.1%) were followed.

Etiology and epidemiology

During the course of investigation the etiology of slow decline was investigated and it was proved that the slow decline is the result of feeder root damage caused by *P. capsici, Radopholus similis* and *Meloidogyne incognita* either alone or in various combinations (Anandaraj et al 1991, 1996). The epidemiology of *Phytophthora* foot rot was also investigated and disease management strategies were developed incorporating the knowledge gained. The practice of pasting the collar with Bordeaux paste was discontinued as the infection of the collar is either through the roots or runner shoots. The disease occurrence in the field is initially random and subsequent spread is from the initial focus. Hence, physical removal of affected vines are recommended as phytosanitation. Since humidity build up leads to increased foliar infection, shade regulation is suggested in order to alter the microclimate.

Chemical Control

New systemic fungicides effective against Oomycetes that were introduced in the market were screened in laboratory trials, studies in pots and in field trials. The granular formulations of metalaxyl and combination products with ziram and mancozeb were recommended after field trials and evaluation of pesticide residues. Similar trials were conducted with potassium phosphonate and-recommended as chemical control measures. Studies were undertaken on the uptake, translocation, persistence and distribution of metalaxyl and potassium phosphonate in black pepper. The granular formulations were more effective than the other formulations. Metalaxyl persisted in the plant for over 30 days. The study with potassium phosphonate revealed that higher concentrations of the chemical (6ml/l –10ml/l) gave better protection and the inhibitory effect persisted for longer period (for more than 30 days) whereas in the case of recommended dose the activity declined significantly after 8 days of application .The sensitivity of *P. capsici* obtained from various parts of Kerala and Karnataka to metalaxyl and potassium phosphonate was studied. The estimated ED_{50} and ED_{90} values for different isolates showed that there was a significant variation in the sensitivity of these isolates to the chemical and sporulation was the most sensitive stage(ED_{50} value: 10.3 to 36.3mg/ml and ED90 value 2.1-129.3mg/ml).

Adoption of technology

The chemical control measures with copper based fungicides was adopted by the State Agriculture Department of Kerala and a large scale field demonstrations in five major pepper growing Districts of Kerala was done with financial assistance from Central Government. After the end on the implementation period, an impact analysis was done involving the funding and implementing agencies. The impact analysis revealed that that the adoption level of technology was very high (Madan et al 2005).

A series of experiments were conducted to understand the compatibility of the recommended chemicals with insecticides and nematicides. New biological control organisms were identified and integrated in the disease management strategy that involves phytosanitation, cultural, chemical and biological control measures.

Biological control

Efficient strains of vesicular arbuscular mycorrhiza and biocontrol agents such as *Trichoderma harzianum* and *Pseudomonas fluorescens* were identified and has been tried in various combinations for disease management and rejuvenation of disease affected vines. In vitro studies with vermi wash indicated its inhibitory effect on mycelial growth, sporangial formation and zoospore release of *P. capsici*. Pot culture study with vermicompost showed that vermicompost (6.25%-25% v/v) could check the foot rot and the inhibitory effect was on par with the control obtained with COC and *Trichoderma.* Different proportions of coir compost were mixed with soil and its effect on *P. capsici* was studied. None of the treatment could significantly inhibit the pathogen.

Compatibility of biocontrol agents with agrochemicals

In vitro and *in vivo* compatibility of *Trichoderma harzianum* and the fungicides and insecticides (Bordeaux mixture, copper oxychloride, potassium phosphonate, carbendazim, quinalphos, monocrotophos and dimethoate) used for the management of pests of black pepper was studied. Except potassium phosphonate all other chemicals tested inhibited the growth and sporulation of *T. harzianum.* The pot culture study with higher concentrations of potassium phosphonate and *T. harzianum* indicated that even at 3600 μg/ml, the chemical is compatible with the biocontrol agent. Further studies showed that the chemical is compatible with other fungal biocontrol agents viz., *T .virens, Verticillium chlamydosporium* and *V. tenerum.*

Development of IDM strategy

The integrated disease management (IDM) strategy for foot rot disease management of black pepper was established. Large scale field demonstration trial pointed that the percentage of survival was 94.6% in treated plots compared to 53% in untreated plots. IDM involving potassium phosphonate spraying, application of neem cake at 1kg/vine and biocontrol agents showed the lowest disease incidence in black pepper. For the control of nursery diseases of black pepper solarization of potting mixture and spraying and drenching with 1% Bordeaux mixture at fortnightly intervals was an effective and produced quality cuttings.

Technology transfer

The package of IDM technology for the control of *Phytophthora* foot rot in black pepper developed was demonstrated in large scale field demonstrations to convince the farmers and was recommended for adoption.

808 **Key words:** Black pepper, *Phytophthora capsici*, IPM, IDM, Systemic fungicides, chemical control, biological control, *Phytophthora* foot rot.

PART II: INVESTIGATOR'S PROFILE

810	**Principal Investigator**	:	
8101	Name	:	K K N Nambiar (1983-84)
8102	Designation	:	Scientist-S3, CPCRI Kasaragod
8101	Name	:	N. Ramachandran (1984-88)
8102	Designation	:	Scientist- S1, CPCRI RS Calicut
8101	Name	:	Y R Sarma (1989-1998)
8102	Designation	:	Scientist S2, NRCS, Calicut
8101	Name	:	M. Anandaraj (2003-2006)
8102	Designation	:	Principal Scientist
8103	Division/Section	:	Crop Protection/Pathology
8104	Location	:	IISR, Calicut
8105	Institute Address	:	Indian Institute of Spices Research, P.B. No.1701 Calicut - 673 012, Kerala
811	**Co-investigators :**		
81111	Name	:	N. Ramachandran (1983-1988)
81121	Designation	:	Scientist S1 (Pathology)
81132	Division/Section	:	Crop Protection
81112	Name	:	Y R Sarma (1983-1988)
81122	Designation	:	Scientist S2 (Pathology)
81132	Division/Section	:	Crop Protection
81113	Name	:	M. Anandaraj (1983-2003)
81123	Designation	:	Scientist S1 (Pathology)
81133	Division/Section	:	Crop Protection
81114	Name	:	R. N. Brahma (1983)
81124	Designation	:	Scientist S2
81134	Division/Section	:	Crop Protection
81115	Name	:	K K N Nambiar (1984-85)
81125	Designation	:	Scientist S3
81135	Division/Section	:	Crop Protection
81116	Name	:	K Sivaraman (1984)
81126	Designation	:	Scientist S1 , Agronomy
81236	Division/Section	:	Crop Protection
81117	Name	:	A K Sadanandan (1984)
81127	Designation	:	Scientist S-2 Soil Science
81137	Division/Section	:	Crop Production

81118	Name	:	T. Premkumar (1988)
81128	Designation	:	Scientist S2 (Entomology)
81138	Division/Section	:	Crop Protection
81119	Name	:	S. S. Veena (1997-2002)
81139	Designation	:	Scientist
81149	Division/Section	:	Crop Protection/Pathology
81125	Institute Address	:	Indian Institute of Spices Research, Calicut 673
81120	Name	:	K. V. Ramana (1989- 2001)
81130	Designation	:	Scientist-S2
81140	Division/Section	:	Crop Protection/Nematology
81125	Institute Address	:	Indian Institute of Spices Research, Calicut
81121	Name	:	V. Srinivasan (1999-2005)
81131	Designation	:	Scientist
81141	Division/Section	:	Crop Production/Soil Science
81125	Institute Address	:	Indian Institute of Spices Research, Calicut
81122	Name	:	C. K. Thankamani (2000-2005)
81132	Designation	:	Scientist
81142	Division/Section	:	Crop Production/Agronomy
81125	Institute Address	:	Indian Institute of Spices Research, Calicut
81124	Name	:	K. Kandiannan (1997-1999)
81134	Designation	:	Scientist
81144	Division/Section	:	Crop Production/Agronomy
81125	Institute Address	:	Indian Institute of Spices Research, Calicut
81125	Name	:	A. Kumar (1997)
81135	Designation	:	Scientist
81145	Division/Section	:	Crop Production/Agronomy
81125	Institute Address	:	Indian Institute of Spices Research, Calicut

822 Final Report on the Project

Detailed report containing all relevant data with a summary of results

8221 Achievements in terms of targets fixed for each activity:

Please See **Annexure 1**

8222 Questions Answered

- The etiology of slow decline is studied and it is the result of feeder root damage caused by *Phytophthora capsici, Meloidogyne incognita* and *Radopholus similis* either alone or in various combinations.
- Incipient infections in the nursery leads to introduction of these pathogens to the main field
- Infections on root system is not expressed till considerable portions of roots are damaged and root infections leads to yellowing and defoliation.
- Foot rot occurs as a result of infections on runner shoots or roots engulfing the collar potion.
- The initial occurrence is random and subsequent occurrence clustering around previously infected vines thus the infected vines serve as focus of secondary spread.
- Screened and identified effective systemic fungicides namely metalaxyl and Potassium phosphonate for managing foot rot disease.
- Evolved integrated disease management strategy involving phytosanitation, cultural, chemical and biological control measures as components
- Identified efficient strains of vesicular arbuscular mycorrhiza (VAM) for promoting growth and suppressing disease in black pepper
- Identified biological control organisms such as *Trichoderma* and *Pseudomonas fluorescens.*
- Developed a consortium of beneficial organisms namely, VAM, *T. harzianum* and *P. fluorescens* for enhancing growth of black pepper cuttings.

- A package has been developed for rejuvenation of foot rot affected black pepper plantations that involves clean cultivation methods such as removing the weeds in the interspaces by digging and following the regular plant protection methods.

8223 Process/Product/Technology/Developed

Developed an integrated management strategy for managing foot rot and slow decline diseases of black pepper.

8224 Practical Utility (Not more than 150 words)

The project envisaged to raise and maintain a healthy pepper garden and to take up effective control measures against the wilt diseases in established plantations. Foot rot (quick wilt) and slow decline (slow wilt) diseases were known to cause severe loses to pepper plantation in endemic areas. All the cultivars grown in Kerala have been screened and have been found to be susceptible to the pathogen in varying degrees. At the start of the project only prophylactic treatment of vines with copper fungicides and nematicides have been recommended. This included application of Bordeaux paste at the collar region, spraying the foliage with Bordeaux mixture and drenching the soil with copper fungicides.

However, the application of Bordeaux paste has been withdrawn as the epidemiology of foot rot has been studied. Based on the finding a set of packages has been developed and been demonstrated in farmers plots and the recommendation has been accepted by the state Agricultural Department. The management practices include improvement of drainage system, phytosanitation, nutrition management, organic amendments, application of fungicides and biocontrol organisms. The recommendations has been popularized by the extension agencies.

8225 Constraints, if any : Nil

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8233 Reports

Annexure 1

Detailed report on Achievements

I. Comprehensive crop management experiments

1. Establishment of a black pepper plot with various standards, spacing and varieties in managing quick wilt disease

The project envisaged to maintain a healthy pepper garden right from planting and to take up effective control measures against the wilt disease in established plantations. Hence a comprehensive management experiment has been laid out at experimental farm Peruvannamuzhi in a quick wilt affected garden after replanting the existing affected vines .

2. Field trials at Calicut and Kasaragod

Field trials were laid out to control quick wilt of pepper at Calicut and Kasaragod . At Calicut experiment was taken up in a pure cropped plantation whereas at Kasaragod both pure and mix-cropped plantations were used for the trial.

(i) Calicut: - Pure crop:

A quick wilt affected garden (the standard cum spacing experiment at Peruvannamuzhi) was replanted in 1983 with Karimunda and Panniyur-1 rooted cuttings after adopting phytosanitory measures. Banana was planted in between pepper plants to serve as shade. The survival of the rooted cuttings after $1_{1/2}$ years was 98%. A comprehensive management experiment was laid out in this plot at Peruvannamuzhi using four live standards viz. Garuga, Erythrina, Glyricidia & Leucaena, with two spacings (3m x 3m; 3m x 2m; 3m along the contour and 2m across) and two varieties viz. Karimunda & Panniyur-1. The standards were planted in 1983 and the pepper rooted cuttings were planted during 1984. The area under trial was around 0.25 ha. The design was in split plot with 4 replications

Fertilizer application was done in two splits. Shade trees were grown over an area of 0.25 acre on the top of the hill. There was minimum tillage and adequate mulch provided. Shade trees like Mesopsis and Albizzia were planted in a standard manner. Calapagonium was grown as cover crop. Neem cake was applied @ 0.5 kg/plant. Planting pits were treated with copper oxychloride and Bavistin separately.

i). Calicut: Two rounds of treatment were given (Puduppadi and Anakampoil plantations) during June and September

(ii) Kasaragod: - The experiment was taken up in pure and mixed cropping patterns in planter's fields. The treatment consisted of;

1. Bordeaux mixture (1%) spraying + pasting in May, August and October.
2. The vines were sprayed with Bordeaux mixture (1%) and up to one metre above ground level applied with Bordeaux paste and the soil drenched with 0.2% copper oxychloride. Furadan @ 33g/vine if nematode attack is present.

   Three rounds in June, August and October were given in Kasaragod (pure plantations in Bandaka and mixed plantations in Kumbala). The experimental vines received fertilizer @ 100 : 40 : 140g NPK and ½ kg neemcake per vine. Phytosanitation was also adopted. The disease incidence in different plots is given in Table1

Foliar infection was recorded in the experimental plots at CPCRI field station Kannara. The disease incidence was recorded in all the treatments. The data indicated that all the treatments were superior to control .

Table 1. Disease incidence in pepper plots treated with Bordeaux mixture and control

Plantations	Disease incidence (%)	
	Treated plot	Control plot
Calicut		
Anakampoil	1.5	26.6
Pudupadi	1.3	33.3
Kasaragod		
Bandaka	0.5	5.0
Kumbla	70.0	70.0

The disease incidence was less in all plots treated with Bordeaux mixture except in Kumbla. In Kumbla, the disease incidence was very high due to poor drainage during the rainy season, very dense mixed cropping pattern with banana, cocoa and under planted with arecanut and high inoculum in the garden due to disease incidence in the preceding year.

3. Effect of different levels of phosphorous on the incidence of quick wilt

Pot culture experiment

A pot culture experiment was also started besides the field experiment. A set of plants maintained in pots were applied with corresponding doses of phosphorous. All the potted plants have taken up infection irrespective of treatments.

Field experiment

A field experiment was initiated to study the effect of different levels of phosphorous on the incidence of quick wilt. Before starting the experiment soil samples were collected for estimating the phosphorous-fixing capacity of the soil. The P fixing capacity of the soil was estimated as 300kg/ha.

Four levels of P representing at P fixation level and 50% below and above *viz*., 0, 150, 300 and 450kg/ha, were applied as super phosphate. Based on this, the doses of phosphorous applied were, 0, 75, 125, 173 and 275g of super phosphate/ vine.

The experiment was continued for 5 years and every year the Phosphorus was applied after soil analysis. There was severe foliar infection and vine death in the phosphorous amendment plot treated with different levels of phosphorous; thereby indicating that application of different levels of phosphorous had no effect on the disease incidence. This plot was used for collecting epidemiological data. The involvement of root infection in slow decline was established (Anandaraj et al 1996).The spatio-temporal disease spread was studied and it was concluded that the initial occurrence of the disease at random and subsequent spread tend to cluster around infected vines. Thus the importance of phytosanitation as a first step in foot rot disease management was emphasized (Anandaraj and Sarma, 2000, 2002).

4. Managing a diseased garden through soil solarization

An observational trial was taken up with the objective of exploring the possibility of managing a diseased garden through soil solarization. The trial consisted of three treatments namely

1. Hand weeding + solarization,
2. Hand weeding alone
3. Routine operations

Solarization was done for 45 days. Solarization done in the existing garden resulted in death of existing vines due to heat build up. However, in disease affected plot, where replanting was done after soil solarization, growth of vines was better compared to plots under clean cultivation and with weeds. The population of *Trichoderma* was also higher in solarized plots (28.80 x 10^3 cfu/g) when compared with (15.84x10^3 cfu/g) weeds and under clean cultivation (12.49x10^3 cfu/g) where hand weeding alone was done. The result showed the efficacy of solarization in disease management.

A new observational trial was initiated to study the effect of solarization in the spread of foot rot disease. The growth of vines and number of leaves produced were highest in the plot where weeding and solarization was done (124.2 cm and 45.1, respectively) followed by clean cultivation (64.9 cm and 23.6) and the least was where the weeds were retained (51.1 cm and 20.4). The proliferation of *Trichoderma* spp. was more in solarized plots followed by plots with weeds and the least multiplication was observed in plots with weeding alone.

5. Effect of management practices on disease management

Observational trial on maintenance of grass cover and pruning of runner shoots

Effect of management practices like (i) growing grass and legumes *Mimosa* sp. and (ii) pruning of runner shoots on the initiation and spread of the disease was studied at in a farmer's plot at Chemberi in Kannur District.. The incidence of the disease was less in plots with undisturbed undergrowth (Table 2).

Table 2. Effect of undergrowth (grass and *Mimosa* sp) on the incidence of quick wilt of black pepper.

Treatments	No. of plants observed	Vine death (%)
With under growth		
Block A	94	4.2
Block B	56	8.9
Without under growth		
Block A	89	10.1
Block B	88	13.6

6. Rejuvenation of black pepper in diseased garden

The observational trial indicated that there is reduction in disease with grass cover. A detailed study on the effect of root exudates on survival of *P. capsici* indicated that the organism could survive and proliferate on the root exudates of grass and legumes (Anandaraj 1997). In order to identify the ideal combination of cultural practices a new field trial was started during 1999-2000. This involved, maintenance of weed cover in the plot and clean cultivation, use of two varieties of black pepper cultivars one tolerant another susceptible, use of banana as intercrop and shade, organic and inorganic nutrients and chemical and biological means of control. This trail consisted of 32 treatments and treatments were imposed after analyzing the soil for nutrient status. Appropriate quantities of nutrients were supplied through organic and inorganic means. The initial growth and establishment of vines in clean cultivation was better than with retention of weed cover. In the initial year, 61 out of 288 plants succumbed to infection in the plots with weeds compared to 20/288 in plots with clean cultivation. Growth parameters such as height (75.7-133.6 cm) number of leaves (9.6-18.1) girth (5.9mm-10.0mm) and mortality (0-36.6/6 plants) were recorded. The nutrient status of the soil were also recorded (Table 3)

Table 3. Nutrient status of rejuvenation plot (Values in ppm)

	Clean cultivation			Retaining weeds			Mean		
	N	P	K	N	P	K	N	P	K
Inorganic	194	20.7	99.9	159	34.3	79.4	176.7	27.5	89.6*
Organic	142	18.2	68.5	169	32.3	61.0	155.3	25.2	64.8*
Mean	167.8	19.5	84.0	164	33.3	70.0			

CD = 10.5

After four years, the crop stand was better in plots with clean cultivation compared to plants in plots with maintenance of weed cover. The disease incidence was 20.84% under clean cultivation as against 33.17% in plots with weeds (Table 4). The plants under clean cultivation has recorded higher yield (738g/vine) when compared to the plants under weed cover (607g/vine, Table 5).

Table 4. Incidence of foot rot and slow decline in rejuvenation plot

Treatments			Mortality of vines %		
			Weed	Clean cultivation	**Mean**
Susceptible	Organic	Biocontrol	33.5	27.9	30.7
		Chemical	43.3	38.2	40.7
	Inorganic	Biocontrol	49.9	38.1	44.0
		Chemical	29.0	29.9	29.5
Tolerant	Organic	Biocontrol	24.8	12.7	18.5
		Chemical	20.8	4.0	12.4
	Inorganic	Biocontrol	34.2	4.0	12.4
		Chemical	29.5	12.7	20.8
		Mean	**33.17**	**20.84**	-

Table 5. Yield of black pepper vines in rejuvenation plot

Treatments			Yield of vines (g)/vine		
			Weed	Clean cultivation	**Mean**
Susceptible	Organic	Biocontrol	744	652	698bc
		Chemical	237	732	485d
	Inorganic	Biocontrol	991	394	692bc
		Chemical	744	826	785b
Tolerant	Organic	Biocontrol	476	485	480d
		Chemical	792	1203	998a
	Inorganic	Biocontrol	354	840	597cd
		Chemical	517	774	645bcd
		Mean	**607**	**738**	

LSD- Main plot = 92.7, Subplots= 185.2, MP x SP= 303.5

It is concluded that rejuvenation of foot rot affected black pepper plantations could be done by following clean cultivation methods such as removing the weeds in the interspaces by digging and following the regular plant protection methods and planting *Phytophthora* tolerant variety. *Phytophthora* and *Trichoderma* population were also monitored. After the imposition of treatments, the highest *Trichoderma* population was recorded in a plot with the combination with weeds, tolerant line, organic fertilizer and biocontrol. The proliferation of BCA was more in plots with weeds.

Recommendation

Trials on rejuvenation of *Phytophthora* foot rot affected garden (it includes the effects of weeds, susceptible and tolerant lines, organic and inorganic nutrition, chemical and biological control) indicated that the establishment and yield of vines was high in plots under clean cultivation (91.6%-100% and 226g/vine – 669.5 g/vine) compared to plot with weeds (80.5% - 97.2 % and 64.3g/vine – 330.3g/vine). Hence, while rejuvenating disease affected black pepper plantations, it is advisable to follow clean cultivation methods.

II. Experiments on Chemical Control

1. Screening of systemic fungicides

A series of experiments were conducted to screen the systemic fungicides against foot rot of black pepper. Metalaxyl either pure formulation or in combination with contact fungicides gave good control (Ramachandran and Sarma 1988a,1988b, Ramachandran et al 1988).

Persistence of systemic fungicides (Metalaxyl) in pepper using potted plants

Studies on uptake, translocation and persistence of systemic fungicide and residue analysis were carried out using leaf-lesion bioassay under pot culture conditions. The persistence of Metalaxyl on soil was carried out using a procedure wherein soil extracts was incorporated into corn meal agar and a sensitive isolate of *Phytophthora* was grown in it.

A GLC procedure for estimating the residues of Ridomil was standardized with the scientific help of 'The Pesticide Residue Laboratory', Tamil Nadu Agricultural University, Coimbatore. Black pepper samples collected from the treated vines were analyzed during 1985. Pepper plants were maintained in pots and were used for studies in the persistence of Ridomil. A similar experiment was conducted under field conditions also. Based on the bio assay the chemical showed a longer persistence in the plant system than in soil. When applied @ 40 g of Ridomil 5 G per vine, the activity of the fungicide was seen up to 30 days in soil and for over 50 days in the plant.

Analysis of pepper samples for residue of Ridomil

Dried black pepper berries from Metalaxyl-Ziram (100 ppm Metalaxyl) treated vines (treated twice @ 5 l/vines), four months after the second spray did not show detectable levels of Metalaxyl residues.

Recommendation: Metalaxyl has got longer persistence in the plant system than in soil and when applied @.40 g of Ridomil 5 G per vine, the activity of the fungicide was seen up to 30 days in soil and for over 50 days in the plant. The chemical was recommended for use against foot rot of black pepper as a prophylactic application at the onset of monsoon.

Field control trials with systemic fungicides for the control of quick wilt of black pepper

Field control was taken up in Calicut, Kannara and Kasaragod for the control of quick wilt of black pepper. The trial included three systemic fungicides and Bordeaux mixture. Three systemic used were viz., Metalaxyl -Ziram (100 ppm), Fosetyl-Al (2000 ppm) and Terrazole (777ppm) . The fungicides were applied both as foliar sprays and soil drenching during June and September months. Incidence and intensity of the disease were recorded at weekly intervals during the season. There was no wilt incidence in the experimental plots during the first year The intensity of foliar infection was estimated by counting the number of infected leaves in two half meter square areas per vine . The disease incidence was lowest in Ridomil treated plants at Kannara (Table 6, 7). Ridomil offered better control of the disease consistently for two years.

Table 6. Incidence and intensity of leaf infection in different fungicidal treatments

Chemical	No. of plants infected	% infection	Disease intensity*
Ridomil	20	50.00	21.05
Aliette	24	60.0	26.58
Terrazole	27	67.5	37.66
Bordeaux mixture	25	62.5	32.6
Control	22	55.0	42.0

* Mean No. of Leaves infected in two ½ meter square areas per plant

The field experiments were continued for the third consecutive year also Application of three systemic fungicides was undertaken in the first fortnights and six replications at Thiruvampady were maintained for each treatment. The incidence and intensity of disease were recorded at weekly intervals at Kannara, where foliar infection was noticed during the third year also although to a lesser extent. At Thiruvampady, where only collar infection was noticed, the death of the vines was recorded (Table 7.)

Table 7 . Cumulative efficacy of systemic fungicides in the control of quick wilt of black pepper

Treatments	Percentage of disease	
	Thiruvampady	Kannara
Ridomil	1.6	5.0
Aliette	10.0	10.0
Terrazole	11.6	30.0
Bordeaux mixture	13.3	20.0
Control	20.0	27.5

Values indicate cumulative vine death (%) during 1984 – 86

Chemical control trials were undertaken at Thiruvampady, Peechi and Ajjrakod (Kasaragod). Three systemic viz., Metalaxyl (100 ppm), -Ziram, Fosetyl-AL (2000 ppm) and Terrazole (777ppm) and Bordeaux mixture were used both as foliar sprays as well as soil drenches. The disease incidence both at Peechi and Thiruvampady clearly indicated the superiority of Metalaxyl protection against *Phytophthora* infections.

Studies on metalaxyl residues

In an observational trial two concentrations of Ridomil MZ 72 WP (100 and 200 ppm of Metalaxyl) were sprayed and drenched (one to four rounds) during the season and the berries were harvested for residue analysis.Dried black pepper berries from Metalaxyl-Ziram (100 ppm Metalaxyl) treated vines (twice treated @ 5 1/vines), four months after the second spray did not show detectable levels of Metalaxyl residues.

Recommendation: Based on the three years field trial at Thiruvampadi and Kannara Ridomil was recommended as a control measure for managing quick wilt of black pepper. The residue analysis was also done for the same indicated that at the recommended level metalaxyl was not detectable in the samples of the produce.

Efficacy of Ridomil 5G granules in the control of quick wilt of black pepper

The field experiment initiated during 1986 to evaluate the efficacy of Ridomil 5G granules in controlling *Phytophthora* infection was continued at Chemberi. The treatment included two doses of Ridomil 5G viz., 10 and 20g /vine applied once during June, besides Bordeaux mixture and untreated control. The incidence of foliar infection was recorded at fortnightly intervals (Table 8).The intensity of foliar and collar infection was recorded. The disease was less severe during the year and good control was obtained with Ridomil 5G (20g/vine). Black pepper samples were collected from vines treated with Ridomil 5G at different time intervals for estimating the fungicides residues. The disease incidence was minimum in pepper vines treated @ 20g/vine of Ridomil 5G compared to control.

Table 8. Efficacy of Ridomil 5G granules in the control of quick wilt of black pepper.

Treatments	Vine death (%)
Ridomil 5G -10g/vine	13.3
Ridomil 5G - 20g/vine	6.6
Bordeaux mixture	30.0
Control	40.0

Compatibility of Ridomil with insecticides endosulfan and quinalphos

The compatibility of Ridomil with two insecticides viz. endosulfan and quinalphos, which are commonly used against 'pollu' beetle in black pepper, was studied. The insecticide was toxic to *Phytophthora palmivora* both under *in vitro* and *in vivo* conditions. Using their fungitoxicity, interaction ratios were worked out taking different ratios of binary mixtures of fungicides and insecticides; both the insecticides were found to be compatible with Ridomil. Studies were also conducted on the physical and chemical compatibility of Ridomil with the nematicide such as furadan and phorate. The fungicide was found compatible with all these chemicals.

Recommendation: Ridomil was found compatible with insecticides viz. endosulfan, quinalphos furadan and phorate. All the chemicals could be used together if there is problem of foot rot, slow decline and insect pests as an integrated pest management strategy.

Study on the Phytotoxicity of oil based copper fungicides.

An observational trial was taken up to test the Phytotoxicity, if any, of the oil based copper fungicides. No phytotoxic symptoms were noticed in sprayed plots even after three months of spraying.

2. Uptake, translocation, persistence and distribution of potassium phosphonate in black pepper

A study was undertaken on the uptake, translocation, persistence and distribution of potassium phosphonate in black pepper. The chemical was tested at concentrations at 500 1000 and 2000 ppm separately for its effect on foliar and root infections. Maximum inhibition of foliar lesion was at 2000 pip spray (94.6%) followed by 1000 ppm spray (86.4). In both cases, the peak activity was noted on 4th day and declined with time. Spraying and drenching at 500 ppm failed to check the root infection. The maximum inhibitory effect on root infection was with 2000 ppm (spray and drench) and with 1000 (spray). In case of spray, the peak activity was on 16th day while it was on 4th day in case of drenching (Table 9).

Table 9. Effect of potassium phosphonate on foliar infection in black pepper caused by *Phytophthora capsici*

Concentration (ppm)	Days after treatment			
	2	4	8	16
500 Spray	54.2*	51.4	46.0	12.8
500 drench	27.9	37.3	27.0	2.9
1000 Spray	84.7	86.4	82.2	71.6
1000 Drench	41.7	53.8	64.9	43.3
2000 Spray	94.3	94.6	86.6	78.3
2000 Drench	59.9	64.5	69.8	62.4

* per cent inhibition of foliar infection over control.

Initial study with potassium phosphonate (3ml/l) showed that inhibitory effect on root rot caused by *P. capsici* declined considerably 8 days after application. An experiment was conducted to find out the effect of higher concentration on disease suppression and persistence. The higher concentrations (7ml/1-10ml/l) showed significantly effective protection even after 30 days and none of the concentration showed phytotoxic effect (Table 10).

Table 10. Effect of potassium phosphonate on *P. capsici* in black pepper

Treatment Number	Conc. ml/l	Healthy plants % * 10 days	20 days	30 days
1	3	53.3(46.9) c	39.3(38.8) d	32.9(35.0) c
2	4	53.3(46.9) c	46.7(43.1) d	40.1(39.2) c
3	5	67.0(54.9) c	54.0(47.3) cd	46.7(43.1) c
4	6	90.7(72.3) b	79.9(63.4) bc	73.7(59.2)ab
5	7	100(90.0) a	97.6(81.1) ab	86.0(68.0) a
6	8	100(90.0) a	97.6(81.1) ab	79.9(63.4) a
7	9	100(90.0) a	100(90.0) a	90.7(72.3) a
8	10	100(90.0) a	100(90.0) a	90.7(72.3) a
9	Control	19.9(26.6) LSD-11.10	26.2(30.80) LSD-17.25	19.9(26.6) c lsd-18.36

Figures followed by same letters within a column are not significant in DMRT
Values in parentheses are transformed values

Pot culture studies with potassium phosphonate

A pot culture experiment was conducted to study the effect of various concentration of potassium phosphonate on *Trichoderma population.* Population was enumerated at weekly interval. *Trichoderma* was applied along with different concentrations of potassium phosphonate i.e., 3ml/l, 6ml/l and COC 0.2%. No statistically significant reduction in *Trichoderma* proliferation was observed, when *Trichoderma* was applied along with different concentrations of potassium phosphonate, whereas copper oxychloride reduced the multiplication.

The plants were challenge inoculated with *P. capsici* and the survival percentage was recorded (Table. 11).

Table11. Effect of *Trichoderma* and potassium phosphonate in checking foot rot infection in black pepper

No.	Treatment	Survival (%)
1	*Trichoderma*+Potassium phosphonate 3ml	44d
2	Potassium phosphonate 3ml/l	44d
3	*Trichoderma*+Potassium phosphonate 6ml/l	58abc
4	Potassium phosphonate 6ml/l	56bc
5	*Trichoderma*+Potassium phosphonate 9ml/l	67a
6	Potassium phosphonate 9ml/l	64ab
7	*Trichoderma*+COC 0.2%	33e
8	COC (0.2%)	53cd
9	*Trichoderma*	31e
10	Control	17f
	LSD (p. 0.05)	5.89

All the treatments were statistically significant in checking the pathogen compared to control. The highest survival % was noted with the treatment *Trichoderma* + Potassium phosphonate 9ml/l and it was on par with the treatment, *Trichoderma* + Potassium phosphonate 6ml/l and Potassium phosphonate 9ml/l.

Recommendation:

The study on uptake, translocation, persistence and distribution of potassium phosphonate in black pepper revealed that higher concentrations of the chemical (6ml/l –10ml/l) gave better protection and the inhibitory effect persisted for longer period (for more than 30 days) whereas in the case of recommended dose the activity declined significantly after 8 days of application .

3. Sensitivity of *Phytophthora capsici*

The sensitivity of 29 isolates of *P. capsici* obtained from different parts of Kerala and Karnataka to potassium phosphonate was studied. The sensitivity was tested at four critical stages of the life cycle of *P. capsici,* namely, mycelial growth, sporulation, zoospore release and zoospore germination. The estimated ED_{50} and Ed_{90} values for different isolates showed that there was a significant variation in the sensitivity of these isolates to the chemical and sporulation was the most sensitive stage(ED 50 value: 10.3 to 36.3mg/ml and ED90 value 2.1-

129.3mg/ml). Among the four stages of *P. capsici*, sporulation was the most sensitive stage to potassium phosphonate and mycelial growth was least affected (Table 12)..

Table 12. Variability in sensitivity of *Phytophthora capsici* isolates to potassium phosphonate

Stage of P. capsici	ED_{50} (μg/ml)	ED_{90} (μg/ml)
Mycelial growth	89.3-603.0	573.5-1635.2
Sporulation	0.3-36.3	2.1-129.3
Zoospore release	0.8-27.9	14.3-72.8
Zoospore germination	1.6-37.3	5.7-79.2

4. Studies on slow decline disease

A field control trial was laid out at CPCRI Regional Station, Vittal, Dakhina Kannada District. Karnataka against slow decline with fungicide (Bavistin) and phorate (Thimmet) alone and in combination did not alleviate the symptoms. Vine death was more in Bavistin treated plots compared to untreated control plot. This indicates the probable preponderance of *Phytophthora* propagules in the soil and consequent root infection. This also might be due to suppression of natural antagonists of *Phytophthora*.

Effect of Metalaxyl and phorate granules on slow decline

An observational trial on the effect of Metalaxyl and phorate granules alone and in combination was tested on vines showing slow decline symptoms. The recovery of the vines was 42% in Metalaxyl-phorate treatment compared to 18% and 30% in phorate and Metalaxyl treated vines respectively. This indicated the combined action of Metalaxyl-phorate on *Phytophthora* and nematodes which are not specially separated under field conditions.

5. Integrated field control trial with fungicides, nematicides and organic amendments

Field trials were undertaken at 3 locations viz. Idukki , Wynad and Peruvannamuzhi with 13 treatments, with three systemic fungicides (Ridomil MZ 72 WP, Aliette and Akomin), with and without Nematicide (Phorate). The death of vines in treatments viz. Ridomil MZ 72 WP (100ppm Metalaxyl) + Phorate (two rounds) Ridomil MZ 72 WP (100ppm

Metalaxyl three rounds), Ridomil MZ 72 WP (200ppm Metalaxyl) and Akomin (2 rounds) were 30, 31, 32. 32% respectively and were superior to Bordeaux mixture (36% treatment and control 53.3%). The experiments also indicated infectiveness of fungicidal treatment on disease control under poor drainage conditions. In an observational trial two concentrations of Ridomil MZ 72 WP (100 and 200 ppm of Metalaxyl) were sprayed and drenched (one to four rounds) during season and the berries were harvested for residue analysis. Three field trials laid out at Peruvannamuzhi, Wynad and Idukki during 1990 with 12 treatments each in Wynad and Idukki and 14 at Peruvannamuzhi, consisting of systemic and non systemic fungicides, with different frequencies. Appreciable remission of foliar yellowing and defoliation were not noticed. However, systemic fungicides either alone or in combination with Bordeaux mixture were effective (Table13) and superior to control.

Table13.. Effect of systemic and contact fungicides on foot rot disease of black pepper

	Treatments	Vine death (%)		
		Nedumkandan	Kuppady	Mean
1.	Control	10.00	30.00	20.00
2.	Cultural	23.3	13.3	18.3
3	RMZ -2 rounds	10.00	3.3	6.7
4	BM -2r	16.6	13.3	15.0
5	RMZ-BM	13.3	0.0	6.7
6	BM-RMZ	0.00	10.00	5.0
7	BM-AK	6.6	6.6	6.6
8	BM-RMZ AK	20.0	0.0	10.00
9	AK-BM	13.3	0.0	6.6
10	AK-2r	6.6	23.3	14.9
11	AK-RMZ	10.00	10.00	10.00
12	RMZ-AK	0.0	3.3	1.6

RMZ = Ridomil MZ 72 WP, AK = Akomin, BM = Bordeaux mixture,
2r = Two rounds.

6. Comparative efficacy of different fungicides

Metalaxyl formulations

Metalaxyl-chlorothalonil, Metalaxyl-copper, Metalaxyl-ziram and Metalaxyl-mancozeb were tested for their comparative efficacy in pot culture @ 10 pots/treatment with 3 rounds of soil drenching at 100 ppm Metalaxyl concentration. Of these, Metalaxyl ziram and Metalaxyl-mancozeb gave comparatively better disease suppression. (Table 14) Dimethomorph, a new anti-oomycetes systemic fungicide inhibits growth and sporulation of *P. capsici* even at 5 ppm.

Table 14. Efficacy of Metalaxyl formulations on *Phytophthora* foot rot

Treatment	*Number infected
1. Metalaxyl-ziram (4:24)	0
2.Metalaxyl-copper (5:40)	1
3. Metalaxyl-mancozeb	2
4.Metalaxyl-chlorothalonil (10:50)	`4
5. Control	10

* No of plants infected out of 10 plants treated

Effect of Dimethomorph on P.capsici

A new systemic fungicide Viz., Dimethomorph was tested against *Phytophthora capsici* in *vitro* and in pot culture conditions. Dimethomorph was inhibitory to *P.capsici* even at 1 ppm under *in vitro* conditions. However in pot culture about 50% per cent mortality was noticed at 200 ppm. This indicates the need to use higher concentration for *in vivo* studies (Table 15). All treatments except control received neem cake @ 1 kg/vine as a pre-monsoon treatment.

Table 15 Effect of Dimethomorph on *Phytophthora* infection in black pepper

Concentration(ppm)	Plants Inoculated	Plants Infected	Survival %
200	20	10	50
100	20	11	45
50	20	15	25
Control	20	20	0

5. Efficacy of frequency and concentration of fungicides on disease incidence

A field trial conducted at NRCS experimental farm, Peruvannamuzhi was concluded after three years. Apart from all cultural practices, the treatments with two systemic fungicides viz., Metalaxyl mancozeb (Ridomil MZ 72 WP) and Potassium phosphonate (Akomin) and Bordeaux mixture both as foliar spray and soil drench were tested at different frequencies of application of both as premonsoon and post monsoon treatments. The results indicated the superiority of Potassium phosphonate (Table 16)

Table 16. Effect of frequency of application of fungicides on foot rot black pepper

Treatments	Vine death		Foliar yellowing	Defoliation
	Total	Percentage	(0.4 scale)	(0-4 scale)
Control	9	37.5	1.25	1.66
Neem cake	5	20.5	1.05	1.88
Phorate	7	29.1	1.14	2.30
BM + COC 2R	3	12.5	1.00	2.16
BM + COC 3R	3	12.5	1.00	1.41
RMZ 3R	3	12.5	1.00	1.95
Akomin 3R	1	04.1	1.00	1.41
Akomin 4R	0	00.0	0.08	1.29

6. Sensitivity of *Phytophthora capsici*

The sensitivity of 29 isolates of *P. capsici* obtained from different parts of Kerala and Karnataka to potassium phosphonate was studied. The sensitivity was tested at four critical stages of the life cycle of *P. capsici,* namely, mycelial growth, sporulation, zoospore release and zoospore germination. The estimated ED_{50} and Ed_{90} values for different isolates showed that there was a significant variation in the sensitivity of these isolates to the chemical and sporulation was the most sensitive stage(ED 50 value: 10.3 to 36.3mg/ml and ED90 value 2.1-129.3mg/ml).Table 17). Among the four stages of *P. capsici*, sporulation was the most sensitive stage to potassium phosphonate and mycelial growth was least affected.

Table17. Variability in sensitivity of *Phytophthora capsici* isolates to potassium phosphonate

Stage of P. capsici	ED_{50} (µg/ml)	ED_{90} (µg/ml)
Mycelial growth	89.3-603.0	573.5-1635.2
Sporulation	0.3-36.3	2.1-129.3
Zoospore release	0.8-27.9	14.3-72.8
Zoospore germination	1.6-37.3	5.7-79.2

III. Experiments on Biological control

1. Isolation of Biocontrol agents

Two bacterial isolates *Pseudomonas* and *Trichoderma* sp. showed *in vitro* inhibition of *P. capsici* and also protective effects in vivo in pot culture with pepper seedlings.

Effect of soil amendments on Phytophthora foot rot

In a pot culture experiment at Calicut, vines were amended with groundnut cake, neem cake, pongamia cake and leaves of Eupatorium, Glycosmis and Nux vomica @ 180g per pot. The vines were later inoculated with pepper *Phytophthora*. There was no disease in the pots treated with Nux vomica, while 50 – 80% infection was observed in pots treated with different types of cakes.

2. Compatibility of biocontrol agents with agrochemicals

In vitro and *in vivo* compatibility of *Trichoderma harzianum* and the fungicides and insecticides (Bordeaux mixture, copper oxychloride, potassium phosphonate, carbendazim, quinalphos, monocrotophos and dimethoate) used for the management of pests of black pepper was studied. Except potassium phosphonate all other chemicals tested inhibited the growth and sporulation of *T. harzianum*. The pot culture study with higher concentrations of potassium phosphonate and *T. harzianum* indicated that even at 3600 µg/ml, the chemical is compatible with the biocontrol agent. Further studies showed that the chemical is compatible with other fungal biocontrol agents viz., *T .virens, Verticillium chlamydosporium* and *V. tenerum.*

3. Compatibility of pesticides

The *in vitro* and *in vivo* compatibility of *T. harzianum* (IISR-1369, a potential biocontrol agent) with fungicides and insecticides (Bordeaux mixture, copper oxychloride, potassium phosphonate, Carbendazim, quinalphos, monocrotophos and dimethoate) used for management of pests and diseases of black pepper was studied. Potassium phosphonate did not show any deleterious effect on *T. harzianum* (in vitro up to 60µg/ml and in vivo up to 1200µg/ml). All the other chemicals showed adverse effect on growth and sporulation of *T. harzianum* and Carbendazim and quinalphos exhibited maximum adverse effect.

4. Effect of coir compost on *P. capsici* population

Soil and coir compost mixture of different proportion (60:40, 70:30, 80:20 and 90:10) was used for the study. None of the treatments could significantly inhibit the pathogen. Different proportions of coir compost were mixed with soil and its effect on *P. capsici* was studied. None of the treatment could significantly inhibit the pathogen.

5. Efficacy of biocontrol agents and their compatibility with potassium phosphonate.

A pot culture experiment with fungal biocontrol agents (*T. harzianum, T virens, Verticillium tenerum, V. chlamydosporium*), and fluorescent pseudomonads alone and in combination with potassium phosphonate was conducted to study their efficacy and compatibility. All the treatments, except the treatments with fluorescent pseudomonads, showed more than 75% control of Phytophthora infection in black pepper. The result clearly showed the efficiency of BCA's and their compatibility with potassium phosphonate (Table 18)

Table 18. Effect of BCA potassium phosphonate and their combination on *P. capsici*

Treatment	Healthy (%)
Pseudomonas fluorescens	77.7 (61.8) ABC
Treatment 1 + potassium phosphonate	77.7 (61.8) ABC
T. harzianum	65.9 (54.3) BCD
Treatment 3 + potassium phosphonate	82.9 (65.6) AB
T. virens	65.9 (54.3) BCD
Treatment 5 + potassium phosphonate	82.9(65.6) AB
Verticillium chlamydosporium	77.7 (61.8) ABC
Treatment 7 + potassium phosphonate	38.5 (38.4) EF
V. tenerum	38.5 (38.4) EF
Treatment 9 + potassium phosphonate	91.7 (73.37) A
Treatment 1+3 and 5	42.9 (40.9) EF
Treatment 2 + potassium phosphonate	44.2 (41.6) DE
COC	72.0 (58.0) BC
Potassium phosphonate	55.3 (48.1) CDE
Control	21.1 (27.3) F
LSD	12.10

Figures followed by same letters within a column are not significant in DMRT Values in parentheses are transformed values.

Recommendation: The biocontrol agents recommended for black pepper are compatible with potassium phosphonate

6. Study on the phytotoxicity of oil based copper fungicides.

An observational trial was taken up to test the phytotoxicity, if any, of the oil based copper fungicides. No phytotoxic symptoms were noticed in sprayed plots even after three months of spraying.

7. Effect of vermicompost on foot rot caused by *P. capsici*

The treatment consisted of 7 treatments as follows:

1). Vermicompost 100%, 2) Vermicompost 50%, 3) Vermicompost 25%

4). *T. harzianum* (P-26), 5) *T. harzianum* + Vermicompost, 6) Ridomil,

7) Control

The initial studies with different proportions of vermicompost showed that vermicompost 25% (75% soil) could check foot rot in black pepper to certain extent.

To continue with the study, a pot culture experiment was conducted and the detail of the experiment is given (Table 19).

Table 19. Effect of Vermicompost on root rot caused by *P. capsici*

Treatment number	Treatment	Survival (%)	Root rot index
1	Vermicompost 100%	54.0(47.3) A	2.7
2	Vermicompost 50%	49.3(44.6) A	3.2
3	Vermicompost 25%	74.3(59.6) A	2.5
4	*T.harzianum* (P-26)	72.2(58.2) A	2.4
5	*T. harzianum* Vermicompost	40.9(39.7) A	3.0
6	Ridomil	62.6(52.3) A	2.6
7	Control	35.7(36.7) A	3.5
Figures followed by same letters within a column are not significant in DMRT (Duncan's Multiple Range Test).Values in parentheses are transformed values.			

Figures followed by same letters within a column are not significant in DMRT (Duncan's Multiple Range Test).Values in parentheses are transformed values.

Root rot index: 0-Healthy, 1-Upto 25% rotting, 3-Upto 75% rotting, 4- Above 75% rotting.

The root rot index was minimum (2.4) in *T. harzianum* and vermicompost (25%) and maximum (3.5) in control (Table 20).

Table 20. Effect of vermicompost on survival of *P. capsici*

Treatments	Survival %
Vermicompost 25 %	58.3 (50) abc
Vermicompost 12.5 %	66.6 (55) ab
Vermicompost 6.25 %	66.6 (55) ab
Vermicompost 3.125 %	50 (45) bc
Trichoderma	75.0 (60) a
Copper oxychloride	75.0 (60) a
Control	41.6 (40) c

The highest survival % was noted with the treatments, *Trichoderma* and copper oxychloride;. Hence from the pot culture study with vermicompost it was found that vermicompost (6.25%-25% v/v) could check the foot rot and the inhibitory effect was on par with the control obtained with COC and *Trichoderma.*

Effect of vermiwash

In vitro studies with vermiwash revealed its inhibitory effect on mycelial growth, sporangial formation and zoospore liberation of *P. capsici* (Table 21)

Table.21. Effect of vermiwash on *P.capsici*

Treatment concentration	Mycelial growth (diameter in mm)	Sporangial production/ microscopic field (20X)	Zoospore liberation %
Fresh vermicompost			
1%	54c	72.0b	61.5ab
2%	45.5d	54.6b	51.0bc
5%	29.5e	42.40b	24.8e
4 months old			
1%	64.7b	68.8b	43.6c
2%	60bc	57.8b	30.4d
5%	45d	43.8b	16.2e
Control	90a	107.0a	70.6a
LSD	6.96	31.17	7.344

8. Demonstration trial with Akomin& BM

A demonstration trial was taken up with Akomin and Bordeaux mixture to find out their comparative efficacy against *P.capsici* infection.

Effect of VAM against P.capsici, Radopholus similis and M. incognita

In view of the protective effect of VAM against *P.capsici*, *Radopholus similis* and *M. incognita*. an observational trial was laid out in an infected field to study the performance of VAM inoculated black pepper. VAM inoculum was applied to nursery bags and was planted in the field. Initial indications showed better growth of treated plants compared to untreated plants.

9. Integrated disease management programme on a large scale in farmers' plots

Demonstration trial at Meppadi (2001)

As a part of the integrated disease management programme on a large scale in farmers' plots, an experiment was conducted at Mepadi, Wynad. The treatments included two rounds of spraying and drenching with Potassium Phosphonate as premonsoon and post monsoon treatments followed by soil application of biocontrol inoculum of *Trichoderma harzianum* multiplied in coffee husk. The disease incidence showed a marginal reduction from 25% to 15% during the year. Similar experiment was conducted at IISR Farm, Peruvannamuzhi with 400 vines of 10 cultivars. Foliar yellowing noticed during April showed remission with irrigation and no disease incidence was noticed. The field trails at Valparai and Pulpally are being continued.

Demonstration trial at Peruvannamuzhi

Integrated disease management trail involving soil drench and spray with potassium phosphonate and soil application of biocontrol inoculum along with neem cake was carried out at IISR Farm, Peruvannamuzhi. The plot consisted of 10 cultivars with 40 plants each. During the year vine death was not noticed in the plot. About 83.5% of the vines were totally free from the disease symptoms while 16.5% of vines showed varying degrees of foliar yellowing ranging from 2.5% to 37.5%. Among the cultivars, P 24, A *Phytophthora* tolerant line was free from foliar yellowing.

Demonstration trial at Pulpally

In a large scale field demonstration trail at Pulpally, the percentage of survival was 94.46% in treated plots compared to 53% in untreated plots and thus confirming the efficacy of disease management.

Effect of potassium phosphonate, Gliocladium virens and Trichoderma harzianum

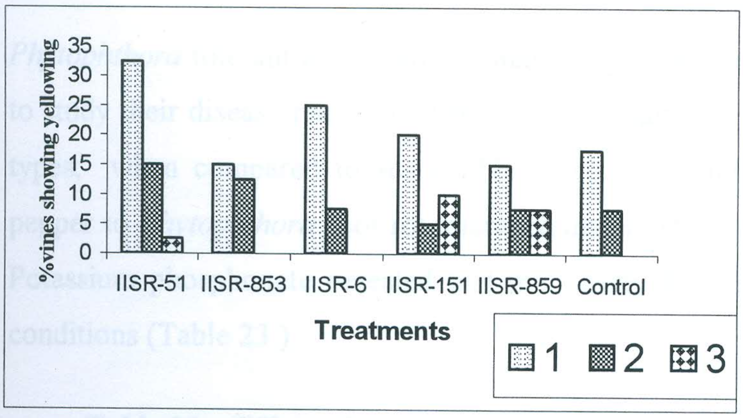
The plot culture experiment with potassium phosphonate and *Gliocladium* virens and *Trichoderma harzianum* alone and in combination showed that the *G. virens* was superior to all and was on par with *G. virens* + potassium phosphonate in reducing root rot caused by *P. capsici*.

10. Rejuvenation of slow decline affected black pepper garden using PGPR.

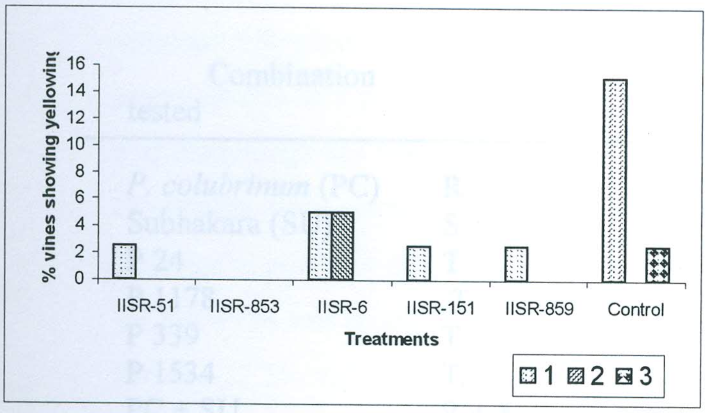
A study was conducted to rejuvenate slow decline affected black pepper garden by using PGP. This was conducted in an existing garden in IISR research farm, Peruvannamuzhi The garden consisted of a total of 270 pepper vines of 6 years old vines showing different stages of yellowing due to feeder root damage. Five efficient strains of PGPR which were short listed based on in vitro and pot culture studies were used in the study. The physical conditions of the vines were recorded at the start of the experiment and at fortnightly interval. There was gradual reduction of yellowing of the vines and after 60 days most of the vines showed remission of yellowing (Table 22, Fig. 1)

Table 22 Percent of plants showing yellowing

Treatment	Interval of observation on yellowing				
	0 DAT	15 DAT	30 DAT	45 DAT	60 DAT
IISR 51	47.8	30.0	9.5	4.5	2.3
IISR 853	28.5	19.9	13.2	4.7	0
IISR 6	34.6	26.6	13.3	8.9	9.1
IISR151	34.9	15.9	4.4	2.2	2.3
IISR 859	37.8	30.5	12.4	5.7	2.3
Control	24.3	22.5	17.9	15.5	18.1
CD 5%	NS	NS	NS	NS	10



a



b

Fig.1 Percentage of vines showing yellowing

a. At the start of the experiment b. 60 days after treatment

A study was conducted at Peruvannamuzhi to rejuvenate slow decline affected black pepper gardens by using five promising isolates of Plant Growth Promoting Rhizobacteria (PGPR). The physical condition of the vines was recorded at the start of the experiment and at fortnightly intervals. There was gradual reduction of yellowing of the vines and after 60 days most of the vines showed remission of yellowing.

IV. Effect of varietal mixtures of black pepper on *Phytophthora* infection in sick plot.

Effect of varietal mixtures on foot rot

Phytophthora tolerant lines were planted along with resistant *P .colubrinum* in sick soils to study their disease reaction . The surviving plants were more in a mixture of tolerant types, when compared to susceptible types. The study on varietal response of black pepper to *Phytophthora* foot rot tolerance under IDM strategy involving neem cake and Potassium phosphonate revealed that the variety P-24 is highly tolerant under the said conditions (Table 23).

Table 23 . Effect of varietal mixtures of black pepper on *Phytophthora* infection in sick plot

Combination tested	Reaction type	Healthy/total
P. colubrinum (PC)	R	6/6
Subhakara (SU)	S	6/6
P 24	T	3/6
P 1178	T	2/6
P 339	T	5/6
P 1534	T	1/6
PC + SU	R + S	* 1/6
PC + P 24	R + T	* 4/6
PC + P 1178	R + T	* 2/6
P 1178 + P 24	T + T	4/6 (2+2)
P 1534 + P 24	T + T	4/6 (2+2)
P 339 + P 24	T + T	4/6 (2+2)

* All the six plants of PC remained healthy. Figure indicate black pepper alone
R= Resistant S= Susceptible T= Tolerant

Field trials with Varietal mixtures

A field trail was laid out to study the effect of varietal mixture on the disease development. It consists of 3 main plots with six varietal mixtures involving *Piper colubrinum* as resistant line with one highly susceptible line Subhakara and other *Phytophthora* tolerant lines viz. P 24, P 339, P 1534, H 780 and C 847 with three replications. The initial establishment of vines ranged from 88.8% to 100.0% in the plot where *piper colubrinum* and Karimunda were planted with *Phytophthora* tolerant lines. The population of *Trichoderma* ranged from 1.3 x 10^3 to 6.3 x 10^3 cfu/g soil. The establishment of vines ranged from 86.1% to 100.0% in the plot where biocontrol and chemical control were superimposed with different proportions of Karimunda and the plants exhibited yellowing. Though there was positive baiting indicating the presence of the pathogen, there was no incidence of the disease in any of the treatments. After the end of five years there was no significant difference in the survival of vines in the experiment with *Phytophthora* resistant line *P. colubrinum* and susceptible Subhakara.

Integrated Disease management(IDM)

Integrated disease management trial at IISR farm, Peruvannamuzhi with ten cultivars (40 plants each) involving cultural practices, application of biocontrol agents (twice in a year) and also application of potassium phosphonate (spraying and drenching) has been conducted with regular pre-monsoon and post-monsoon treatments with neem cake and potassium phosphonate. The varieties showed differential response to these treatments and the death of the vines ranged from 0-22.5%. P-24 was totally free from the disease whereas, Panchami and Panniyur-3 showed 22.5% vine death (Table 24)

Table 24. Reaction of black pepper varieties to foot rot incidence

SI. No.	Variety	No. of plants showing yellowing	No. of plants replanted	No. of plants died	Disease incidence (death) (%)	Death + Foliar yellowing (%)	Healthy (%)
1.	Subhakara	1(2.5%)	4	1	12.5	15	85
2.	Panniyur-1	6(15.0%)	4	1	12.5	27.5	72.5
3.	Panniyur-4	9(22.5%)	3	1	10	32.5	67.5
4.	P-24	0	0	0	0	0	100
5.	Panniyur-2	15(37.5%)	5	1	15	52.5	47.5
6.	Pournami	27(42.5%)	5	0	12.5	55	45
7.	Panniyur-3	26(65.0%)	5	4	22.5	87.5	12.5
8.	Panchami	21(52.5%)	7	2	22.5	75	25
9.	Panniyur-5	21(52.5%)	6	1	17.5	70	30
10.	Sreekara	16(40.0%)	8	2	25.0	65	35

Plots were treated with Potassium phosphonate twice and 1kg neem cake.

A new field trial of IDM in areca based black pepper cropping system with 9 *Phytophthora* tolerant lines along with susceptible KS-27 (Subhakara) was conducted. After five years there was no significant difference in the mortality of vines.

V. Evaluation of Technology Adoption

A study carried out to assess the level of adoption, diffusion and the impact of integrated disease management of foot rot disease of black pepper in Wynad district indicated that since intervention by IISR, 75 percent of farmers adopted application of biocontrol agents and other integrated management practices for the control of the disease

Fifty farmers selected randomly from a list of farmers who sought information and inputs on the said technology from IISR constituted the sample for the study. Following are the results, major conclusions and implications from the study.

Farmers were well aware about the symptoms and devastating nature of the disease. However, their level of knowledge on scientific concepts like etiology, epidemiology and scientific management of disease is relatively low.

Seventy three percent of farmers in the sample opted for the use of one or other chemical prior to intervention by IISR. Twenty seven percent farmers were not resorting to any chemical control other cultural practices.

Since intervention by IISR, 75 percent of farmers adopted application of biocontrol agents and other integrated management practices for the control of the disease. One fourth of the sample discontinued the practice after one time application. However, adoption of the practice was limited only to symbolic and partial level as against precise scientific recommendations.

The mean adoption index score of the sample for the total package of integrated disease management methods was only 0.61 indicative of only partial adoption.

The farmers reported a mean yield loss of 37.43% prior to the technology. The yield loss reported after the adoption of technology was 32.9%. The difference in yield reduction due to the adoption of technology was 4.53%.

The crop loss due to disease reduced by 8.43% in case of respondents who adopted the technology. At the same time, the farmers who discontinued the technology reported an increased loss in yield from 40.66 to 52.27%.

Organic agriculture movement which is gaining momentum especially in Wynad district at grass roots was one of the factors, which favored the adoption of alternative methods of disease control other than conventional chemical control methods. Development agencies, local organizations and NGOs are promoting the protective and conservationist management as against input intensive agriculture.

Traditionally farmers were following low external input agriculture especially in black pepper as compared to other cash crops in the region. Farmers generally lack interest in replanting of old and senile plantations.

The trade-off between technology 'push' and market 'pull' factors strongly influenced the investment options on technology and labor in the "cropping systems". Drastic fluctuations in prices and consequent lack of willingness of farmers to bear the uncertainty evidently hampered the continued adoption of the technology.

The study clearly implies the need for supportive policies, reforms and programmes from the part of development stakeholders. Realistic market interventions in the form of products procurement, assured market and price support are the need of the hour.

Education and training programmes that will reinforce farmer's decisions on appropriate scientific technology from that of a "trial" mode to "confirmation" mode should be implemented.