THREE DECADES OF PHYTOPATHOLOGICAL RESEARCH AT COLLEGE OF HORTICULTURE

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FOREWORD

It gives me immense pleasure to scan through this compendium. Definitely, it is a comprehensive treatise on the phytopathological research works conducted over a span of 35 years by the department of Plant Pathology, College of Horticulture, Vellanikkara, and brings out the contributions of the department to the farming community.

The compendium addresses the much felt need for an authentic reference material for the researchers and post graduate students specializing in Plant Pathology. This would also trace the gaps in phytopathological research, so that, newer thrust areas can be identified.

This compendium depicts the milestones of various aspects of basic and applied research conducted by the dedicated scientists of the department and generations of doctoral and post graduate students worked under their expert guidance.

I wish that, the rich treasure of systemic research accomplishments presented in the compendium would be of immense value and use to the entire academic and research community concerned with management of plant diseases.

Dr. C. T. Abraham
Associate Dean

PREFACE

This compendium is an attempt to present all the research works on Plant Pathology done during the last three and a half decades (1976 - 2011) at the College of Horticulture, Vellanikkara by way of various projects and programmes by the scientists, students of doctorate and post- graduate programmes.

This compilation is presented in seven chapters comprising of Plant Pathology, Bacteriology, Mycology, Virology, Microbiology, Seed Pathology and Biocontrol. Very deep description of each research programme has not been attempted, instead, attempts have been made to provide a holistic analysis with the most relevant data and information.

It was a strenuous task to compile the research accomplishments by going through the records, annual reports and theses, so as to document this historic time line of research led by the department.

We place on record our admiration and gratitude to all the scientists and students who had worked in the department over the years with untiring zeal for excellence and made a set of research accomplishments beneficial to farmers, academicians and researchers.

We are grateful to our colleagues and research fellows who have helped a lot in making this compilation worthy.

We are grateful to the Associate Dean for the encouragement and support provided in bringing out this compendium.

Sally K.Mathew
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CONTENTS

Sl NO.		PAGE NO
1	Introduction	1
2	Plant Pathology	2
3	Bacteriology	19
4	Mycology	21
5	Virology	25
6	Microbiology	30
7	Seed Pathology	36
8	Biological control	37
9	List of Theses	47
10	List of Research projects	54

INTRODUCTION

Plant Pathology is a very broad field (an integrative science) comprising with the basic knowledge and technologies of mycology, bacteriology, virology, microbiology, nematology, genetics, molecular biology, biochemistry and many other branches of applied science. In fact, Plant Pathology is a science that deals with the study of plant diseases. Plant diseases are the result of infection by the organisms that adversely affect the growth, physiological functioning and productivity of a plant, manifesting outwardly as visible symptoms. Parasitic organisms that cause diseases are called pathogens, which include, fungi, bacteria, viruses, phytoplasmas, protozoa etc. Plant diseases cause heavy crop losses accounting to several billion dollars every year. Plant disease epidemics can cause famines, eliminate a thriving industry or poison animals and humans. Important historical evidences of plant disease epidemics are Irish Famine due to late blight of potato (Ireland, 1845), Bengal famine due to brown spot of rice (India, 1942) and *Coffee* rust (Sri Lanka, 1967). These epidemics had shattered the economy of those countries. Disease management is still a challenging task and can be achieved by breeding for disease resistance and by plant protection approaches such as cultural methods, by the way of soil solarization, crop rotation, use of disease free seeds etc., chemical and biological means. Control of plant diseases is crucial to the reliable production of food, and it provides significant reductions in agricultural use of land, water, fuel and other inputs. Plant Pathology has been astoundingly successful in providing farmers with methods for managing plant diseases. This success is one of the reasons why famine in today's world is a relatively rare and isolated event.

PLANT PATHOLOGY

Plant Pathology is the science that deals with the study of plant diseases. Plant disease is the malfunctioning process in the plant system due to biotic and abiotic stress which develops as a result of interaction between the host, pathogen and the environment. The plant diseases caused by pathogens are infectious and mainly include fungi, bacteria, viruses and phytoplasmas.

Black pepper, one of the most important spice crops is renowned for its aroma, flavour and pungency. One of the major problems in black pepper production is the incidence of quick wilt (foot root) disease incited by *Phytophthora*, which causes severe crop loss. **Mammooty (1978)** studied the symptomatology and management of this disease. The first visible symptom was noticed with 24 and 48 h after inoculation on leaf and stem and root respectively. A fully developed lesion had dark brown holonecrotic centre and plesionecrotic border surrounded by yellow halo. The yellow halo was not noticed during wet and humid conditions and the lesions were uniformly brown in colour. Zonations were noticed during alternate wet and dry conditions. On stem, branches and roots, the lesions were uniformly brown and dark. Entry of the pathogen was mainly through lower surfaces of the leaves. Defoliation occurred within five to ten days of infection. When stems and roots were infected, flaccidity, drooping, and defoliation were the main symptoms observed. All the fungicides *viz.* Agallol-3G (0.2%), Bayer – 70 WP (0.2%), Thiride – 75 WP (0.2%), Dithane-Z-78 – 75 WP (0.2%), Dithane-M - 45 (0.2%), Ziride – 80 WP (0.2%) and Bordeaux mixture (1%) inhibited the growth of the pathogen *in vitro*. The fungicide acted as protectant when it was applied two hours before inoculation of the pathogen. Soil drenching of all fungicides except Dithane-M – 45 completely controlled the disease.

Ginger is an important spice crop of India. The most serious threat to ginger cultivation is the incidence of soft rot due to its wide spread and devastating nature. **Kuruchev (1980)** made an attempt to find out the pathogen responsible for the soft rot of ginger in the acidic laterite soils of Vellanikkara. *Pythium aphanidermatum* was found to be the causative agent. In the *in vitro* screening of various fungicides, more than 90 per cent inhibition of the fungus was noticed with Agallol, Thiride and Difolatan at 500 ppm concentration and cent per cent inhibition with 2000 ppm of Cheshunt compound and Thiride and with 500 ppm of Agallol. Under field condition, in addition to preplanting treatment, minimum of two post emergence applications as soil drenching at 1 and 3 MAP, either with Cheshunt compound or Agallol were necessary for controlling the disease and increasing the yield. The ginger variety, Maran, was found to be more resistant to the disease as compared to Rio de Janeiro.

The leaf spot disease of **ginger**, a minor disease caused by *Phyllosticta zingiberi*, was found to cause extensive foliar damage, directly leading to reduction in yield. Hence an extensive study on this disease was made by **Premanathan (1981)** regarding the mode of entry of the pathogen to the host, varietal susceptibility and management of the disease. Laboratory and field experiments on this disease were carried out. It was found that, uninjured leaves and the first three leaves failed to express symptoms on inoculation. Conidia of the fungus germinated by single or double germ tubes. Sucrose (1000 ppm) supported faster germination of spores and bipolar germination was maximum at this solution. Initial symptom appeared as chlorotic specks on leaves and fructification during later stages of the crop. Detailed studies on plant environmental factors influencing disease development in field revealed that, average number of leaves per plant had a significant and positive correlation with disease intensity. Fungus entered leaves by direct penetration without formation of appressoria. Mycelia and pycnidiospores survived in soil even after seven months under different depths and moisture conditions. Maran was found tolerant followed by Karakkal. Bajpai and Vengara were highly susceptible. Out of the 12 fungicides tested under *in vitro,* Bordeaux mixture (1%) and Bayer 5072 (2000 ppm) exhibited cent percent inhibition of the pathogen in both liquid and solid media. The fungicides *viz.* Antracol (2000 ppm) and Panolil (above 500 ppm) in liquid medium and Cuman (above 500 ppm) and Bavistin (2000 ppm) in solid media showed cent percent inhibition of fungal growth. Under field condition, Cuman was found to be the most effective fungicide followed by Bordeaux mixture in controlling the disease and increasing rhizome yield.

Rice is the most important staple food in India which constitutes 50 per cent of our total food production. Rice is susceptible to a large number of diseases caused by fungi, bacteria, viruses and phytoplasma. Among the various fungal diseases, blast, brown leaf spot, sheath blight and stack burn are the major ones. **Sheela (1981)** carried out a study to evaluate the efficacy of the newer fungicide guazatine (Panolil), along with organo phosphorus fungicides against these diseases and also to increase the viability of seeds of high yielding varieties in storage by preventing microbial infection. Fungicides *viz.* Panolil, Panoctine and Panoram were evaluated with standard fungicides against major rice diseases namely blast, brown spot, sheath blight and stack burn. *In vitro* evaluation revealed cent per cent inhibition of *Pyricularia oryzae* with Panolil (1000 ppm), Panoctine (2000 ppm), Panoram (500 ppm) and was compatible with standard fungicides *viz.* Hinosan (250 ppm), Kitazin (250 ppm) and Agallol (100 ppm). *Drechslera oryzae* was completely inhibited by Panolil (500 ppm), Panoctine (500 ppm) Panoram (1000 ppm) and was on par with Hinosan (1000 ppm), Kitazin (1000 ppm) and Agallol (100 ppm). Cent per cent inhibition of *Corticium sasakii* was observed with Panoram (250 ppm) and Hinosan (500 ppm) but not with Panolil and Panoctine even at 2000 ppm. Cent per cent inhibition of *Alternaria padwickii* was noticed only with Panolil (2000 ppm), Panoram (1000 ppm) and was on par with Kitazin (2000 ppm) and Agallol (100 ppm). Field studies revealed that, Panolil (1kg/ha) was highly effective in checking leaf blast and was on par with the standard organophosphorus fungicides, where as in case of neck blast, Hinosan and Kitazin were better than Panolil. For the control of brown spot disease, Panolil @1.5 kg/ha was found to be superior to Hinosan and Kitazin. In the case of sheath blight disease, Panolil was as effective as organophosphorus fungicides. Similarly, stack burn was effectively controlled by higher concentration of Panolil. Seed treatment and storage studies of rice seeds against mycoflora were also carried out. Agallol was found to be the best seed dresser followed by higher concentration of Panoram in checking fungal flora with satisfactory germination of above 80 per cent when seeds were treated and dried immediately after harvest. Delayed drying greatly affected seed germination and association of mycoflora.

Black pepper (*Piper nigrum* Linn.), is popular as a prime attachment of foreign traders to this state especially to the Malabar Coast. In Kerala, it is mostly grown as an intercrop with arecanut, coconut, cocoa etc. No attempts have been made so far, to identify the collateral hosts of quick wilt pathogen causing the dreadful disease in pepper gardens and the role played by these collateral hosts in the epidemiology of quick wilt disease was also totally ignored. **Manomohan (1982)** conducted a survey at six locations of North Kerala, at monthly intervals for eight months from May 1981 to December 1981 to identify the collateral hosts of *Phytophthora palmivora*, the causal agent of quick wilt (foot rot), especially the weeds and the economically important plants growing in and around pepper gardens. Pepper was found to be infected by *Phytophthora* sp. in all the locations surveyed. Both aerial and underground parts of the vine gave typical foot rot symptoms. The gardens in the vicinity of arecanut and rubber plantations showed heavy incidence of the disease. All *Phytophthora* sp. collected from pepper from different locations showed similar morphological characters and were identified as *P. palmivora*. None of the isolates produced sexual stages on culture media. Based on the growth characters on carrot agar and L/B ratio and pedicel length of the sporangia, all black pepper isolates of *P. palmivora* obtained in this study were placed in MF_1, MF_2 and MF_3 or group ^{2} or II. None of the weeds growing in and around the pepper gardens were found to be attacked by *Phytophthora* sp. Five economically important plants *viz.* arecanut, rubber, cocoa, coconut, and cardamom were found to be infected by *Phytophthora* sp. and had shown close similarity with the isolates obtained from pepper plantations. Cross inoculation studies with *P. palmivora* isolates from different hosts yielded positive results, which indicated that, arecanut, rubber, cocoa, coconut and cardamom can serve as collateral hosts of *P. palmivora* infecting pepper.

Sebastian (1982) studied the etiology and ecology of fungal pollu in **black pepper** and the pathogen associated with this disease was found to be *Colletotrichum gloeosporioides*. The pathogen was found to be perennial on the host and infected all aerial parts except root and well matured stem. The initial symptom observed on leaves, tender shoots and berries were chlorotic specks and only the physiologically active leaves were infected. The well developed spots were circular to irregular under dry conditions, which enlarged quickly and the holonecrotic areas were with ashy white under humid moist conditions. Pedicel infection caused spike shedding and drying up of the tender shoots. Rachis infections were rarely noticed, berries became dried, shrivelled, dark coloured and light weight. On mature berries, infection caused rind cracking. The fresh leaf infection was found during pre-monsoon period, and the maximum infection was during South- West monsoon and minimum during the warm dry periods. Disease intensity on leaves and pedicel were significantly and positively correlated with number of rainy days, total rainfall and average of maximum and minimum relative humidity. Berry infection commenced during the later part of South- West monsoon and mature berries got more infection than immature ones. Bordeaux mixture (1%), captafol 0.2% (Difolatan), propineb 0.2% (Antracol) and triademefon 0.2% (Bayleton) showed cent per cent inhibition of the pathogen under *in vitro* condition. In the field experiment, Bordeaux mixture (1%) was found to be the most effective fungicide that provided maximum disease control and yield, followed by captafol (0.2%).

Quick wilt (foot rot) disease of **black pepper** caused by *Phytophthora palmivora* (Butler)

Butler is a serious malady of black pepper plantations in Kerala. **Vilasini (1982)** made an attempt to identify the techniques for screening of pepper varieties against quick wilt disease. The study showed that, *P. palmivora* of black pepper is capable of producing a phytotoxin *in vitro*. Five liquid media were tested for the production of toxic metabolite by this pathogen and observed that, Richard's + yeast extract broth followed by potato dextrose broth and thiamine enriched synthetic liquid medium were found to be the best ones. Seventeen pepper types (open pollinated, hybrids and Panniyur - 1) were screened against *P. palmvora* using viable inoculum and propagule free dialysed culture filtrate. In all the pepper types tested by both methods, the entire root system were found decayed within three days after the application of culture filtrate and within five days on inoculation with zoospore suspension. Among the two methods, the propagule free dialysed culture filtrate can be used for screening different pepper types to ascertain their tolerance to the disease.

As a part of Kerala Agriculture Development Programme **(KADP)** project of KAU, an experiment on etiology and management of fruit drop disease of **cocoa** was conducted in Thrissur, Kottayam and Wayanad districts. The plants were taken randomly and observations on pod damage due to pathological and non pathological reasons were recorded at monthly intervals starting from July onwards after the onset of South - West monsoon. The organisms associated with damaged pods were *Monilia* sp, *Cephalosporium* and *Cladosporium*. Among the management practices, adopted in the experiment, phytosanitation showed good reduction in pod's damage due to pathological causes. Among the fungicides tested *viz*. Bordeaux mixture, Dithane M- 45, Alliete, Difolatan and Captan with and without phytosanitation, spraying of Bordeaux mixture along with phytosanitation reduced the disease incidence to the minimum followed by Difolatan treatment. Moreover, the effect due to Captan was found to be better than Alliete. Regarding non-pathological damage, use of fungicide and phytosanitation did not have any effect. The involvement of fungal pathogens in the cherelle wilt disease was thus clearly eliminated (KAU, 1983).

Another experiment on control measure for pink disease of **cocoa** was laid at Mannuthy during June - July, 1983 under the **KADP** project. Observations revealed that, application of Bordeaux paste before the onset of monsoon prevented the occurrence of pink disease of cocoa to a considerable period (KAU, 1983).

As a part of **KADP** project, an experiment on die back disease of **cocoa** was laid out at Instructional Farm, Mannuthy. The association of different fungal flora on the diseased twig was observed by taking representative samples and using standard isolation procedures. In Kerala, vascular streak die back, caused by *Oncobasidium theobromae,* was first reported from Thottakkad area in 1980 and the disease was found to be spreading to Thrissur district also. Among the fungi reported, *Diplodia theobromae* and *Phytophthora palmivora* caused typical dieback symptoms. *Colletotrichum* sp. caused only leaf blight symptoms on artificial inoculation. *Fusarium* sp. was found associated with dried up twigs consistently, however, artificial inoculation failed to induce the disease. *Marasmiellus scandens,* caused typical white thread disease and the disease affected twigs were found to die prematurely. Among the treatments *viz*. Bordeaux mixture, thiride, captafol (Difolatan) and carbendazim (Bavistin), the application of thiride paste (2g thiride + 1kg petroleum jelly) at cut ends along with thiride spray (0.2%) or application of Bordaeux Paste at the cut ends along with Bordaeux mixture spray was found to reduce the disease incidence. But the treatments gave good protection only for three months (KAU, 1983).

As a part of **KADP** project , the experiment on post harvest microbial deterioration of **cocoa** was conducted at College of Horticulture, Vellanikkara. Fermentation of beans was done using mini basket method. The various types of microorganisms associated during different stages of cocoa fermentation revealed that, population of yeast steadily increased upto 33 h and later decreased gradually. During the initial stages, the presence of high sugar content increases yeast population and activity. Depletion of substrates during fermentation might be the cause of lower population of yeasts after 50 h of fermentation. The acid tolerant yeasts also showed the same pattern in their population. Studies on acetic acid bacteria revealed that, their population was very low initially and increased rapidly and reaching a peak at 57^{th} h. Ethanol utilizing yeasts showed maximum population at 81^{st} h and then declined. Population of lactic acid bacteria was initially low and then increased, reaching a peak at 81^{st} h. The initial low growth might be due to the aerobic conditions present (KAU, 1983).

Another experiment under the **KADP** project was done to find out the effect of prophylactic measures of quick wilt disease for the control of fungal pollu of **black pepper** with four treatments *viz.* control measures as per PoP (T_1), spraying 1% Bordeaux mixture and painting the stem with Bordeaux paste to one cm height before the onset of South - West monsoon and one more spray during August-September and soil drenching with 0.1% Agallol -3 ; two sprays of Dithane- Z-78 in June-July and Sept-Oct (T_2) and T_3-combination of T_1 and T_2 . The quick wilt management measures as per PoP were more effective in controlling the fungal pollu disease (KAU, 1983).

Anthracnose is considered as the most important and widely distributed post-harvest disease of **banana**. This disease is also known as black rot, ripe fruit rot and finger stalk rot. **Srinagesh (1984)** studied the etiology, symptomatology and varietal reactions of this disease. The causal organism of the disease is *Colletotrichum gloesporioides* Penz (Sacc) and the imperfect stage is *Glomerella cingulata*. The pathogen attacks young immature fruits in the field. The infection starts at the distal end of the fruits which turned black, shrivelled and mummified. After harvest, the symptom appears as small brown spots which enlarged quickly and coalesced forming larger patches. The affected area was fully covered with orange to salmon pink coloured conidial mass. Twenty five varieties were screened *in vitro* against anthracnose at different stages of development. The varieties showed different degrees of susceptibility at various developmental stages of the fruit. Varieties Nendra padaththi, Palayankodan, Jurmani Kunthali, Boodida bontha bathees, Peyan, Kanchikela, Pisang mas and Kapok were found to be highly resistant, Zanzibar, Adakka Kunnan, Klue teparod, Chinia, Nendran, Veneettu Mannan, Koduppilla Kunnan, Hybrid Sawai, Poocha Kunnan, Red Banana and Bodles Altafort were resistant. Robusta was susceptible and Njalipoovan, Pisang lilin, Dwarf Cavendish, Matti and Gros Michel were found to be highly susceptible. None of the varieties took infection immediately after female phase. Only injured fruits took infection during ¼ and ½ maturity stages and symptom development was also slow. At ¾ and full maturity stages, the pathogen took infection without injury also. Studies on biochemical constituents showed that, reducing sugars and total sugar were found to increase immediately from female phase to ripened stage in all varieties. The starch and crude fibre increased steadily upto full maturity and declined at the ripening stage. The crude protein and tannin content were maximum immediately after female phase, but steadily decreased and were minimum at ripening phase. There was a significant positive correlation between reducing sugar, total sugars and per cent disease intensity at ¾ maturity. High sugars were responsible for susceptibility and high crude protein and tannin were responsible for resistance to the disease.

For control of leaf rot disease of **coconut**, the fungicides *viz.* Bordeaux mixture (1%), Foltaf (0.2%) ediphenphos (Hinosan 0.1%), iprobenphos (Kitazin 0.1%) maneb (0.2%) and Panolil (0.1%) were evaluated in the field condition, as pre monsoon and post monsoon sprays as a part of **Root wilt project** of Kerala Agricultural University. No significant difference was noticed between the two treatments. Maximum per cent disease reduction was noticed with Bordeaux mixture followed by iprobenphos (Kitazin) and ediphenphos (Hinosan 0.1%). The pre monsoon prophylactic sprays showed no leaf rot infection with the fungicide Hinosan, Kitazin and maneb. (KAU,1986).

Status and influence of rhizosphere microflora of **coconut** palms in healthy and diseased tracts and the possible role of microbial toxins in relation to root wilt disease were studied as a part of **Root wilt project** of KAU. Microorganisms were isolated from the rhizospere of coconut palm in healthy area, healthy and diseased palms from diseased area. It was observed that, there was a substantial increase in the fungal population during post monsoon period as compared to pre-monsoon, both in healthy and diseased palms. However, there was an increase in the population in diseased palms (137.76 x 10^4 cfu/g) as compared to healthy ones (52-93x10^4 cfu/g). With respect to bacterial population, a decreasing trend was observed during the post monsoon period in both healthy and diseased palms. Same decreasing trend was observed in case of actinomycetes population also and the healthy palms showed higher population than the diseased ones. The toxic effect of culture filtrates of seven fungi *viz. Curvularia clavata, Botryodiplodia thoebromae, Fusarium moniliforme, F. solani, Aspergillus flavus* var *columnaris* , *A. niger* and *Trichoderma harzianum* isolated from rhizosphere of diseased palm were tested on tomato, greengram and rice. Extent of wilting was more in tomato seedlings treated with culture filtrate of *T. harzianum* and no germination was noticed in the tomato seed treated with different filtrates. Maximum inhibition of germination of rice seeds was noticed in the culture filtrate of *Fusarium* (KAU, 1986).

In a study on the etiology of **coconut root (wilt)** disease, two antibiotics namely oxy tetracycline and penicillin were applied to coconut palms of medium disease intensity by spraying and stem injection. The special Terramycin formulation for tree injection against mycoplasma was used for the study. No visible difference was noticed in the symptom expression of the antibiotic treated coconut palms. Nuts from antibiotic treated palms were tested for detecting the presence of antibiotic and its activity was detected in coconut water, eight weeks after the injection (KAU, 1986).

In a study on *In vitro* characterization of mollicutes associated with **coconut root (wilt)** disease, MLO from coconut root (wilt) affected plant parts and collateral hosts,was isolated and cultured on MLO specific medium (KAU, 1987).

Rice sheath blight caused by the soil fungus, *Rhizoctonia solani* Kuhn, is a serious disease in Kerala, especially during Kharif season. A study was undertaken by **Shaji (1987)** to find out the role of physical, chemical and biological factors on the management of this disease. Results of the investigation revealed that, the pathogen could be managed by deeper ploughing followed by submergence of the soil for a minimum period of two months. Application of amendments, like *Glyricidia* leaves, rice husk, lime and oil cakes of marotti, neem and punna, were useful in reducing the severity and spread of the disease. Fungicides like carbendazim (0.1%), ediphenphos (0.1%), benthiocarb (1.5 kg ai/ha) and the bioagent, *Trichoderma viride* were effective in managing the disease. Application of organic amendments also stimulated the population of *Trichoderma viride* which resulted in subsequent reduction in the population of the pathogen. Crop rotation of rice with tapioca, banana and brinjal was also effective in reducing the intensity of sheath blight disease.

The major constraints in production of **rice** are the incidence of diseases and insect pests. Very often, farmers face disease and insect pest problems simultaneously in the field, but the combination of effective fungicide and insecticide have not been formulated as a recommendation which would be more advangeous in a state like Kerala, where the cost of labour is very high. Hence, **Kalpana (1992)** studied the efficacy of four fungicides and four insecticides alone and in combination at different concentrations against two major diseases of rice *viz.* rice blast caused by *Pyricularia grisea* and sheath blight caused by *Rhizoctonia solani* and two major insect pests *viz.* leaf folder (*Cnaphalocrocis medinalis*) and brown plant hopper *Nilaparvata lugens* at tillering, panicle initiation and flowering stages of the crop. It was observed that, combined application of fungicide and insecticide controlled the diseases and pests more effectively than the individual treatments. Among the different combinations tried, tridemorph (0.1%) + monocrotophos (0.0375%) and carbendazim (0.075%) + quinalphos (0.025%) were the best combinations against blast and sheath blight respectively. In case of leaf hopper and brown plant hopper, quinalphos was found to be the best insecticide when it was used alone and also in combination with fungicide. At panicle initiation stage, combined sprays of higher concentrations of carbendazim and monocrotophos was the best combination in controlling *R. solani* and *Nilaparvata lugens*. At flowering stage, captafol (0.225%) + quinalphos (0.0375%) and carbendazim (0.075%) + monocrotophos (0.0375%) were found to be the best combinations against *P. oryzae* and *R. solani*. But the combination of recommended dosages of quinalphos with tridemorph of ediphenphos and phosalone with ediphenphos were the effective treatments in controlling *C. medinalis* and *N. lugens* respectively.

Solarization is a technique of heating the soil by using polyethylene mulch and solar energy which is used as a mean for pathogen control. The effect of solarization on damping off of **chilli** was studied by **Sainamole (1992)**. Both nursery beds and main fields were solarised for 15, 30 and 45days by covering 150 guage transparent polyethylene sheets. The soil temperature in solarized plot was 51°C at 10 cm depth while it was 42°C in non - solarized one. Solarization effectively reduced pre and post emergence damping off in the nursery and also completely checked the soil borne diseases in main field. Better control was observed on increasing the period of solarization. Neemcake ammendment did not improve the disease control even with solarization. The population of fungi, bacteria, actinomycetes and nematodes were significantly reduced by solarization. Root colonization by Vesicular Arbuscular Mycorrhiza (VAM) was significantly higher in solarized plots than the control. Growth parameters *viz.* plant height, number of leaves / plant, shoot and root weight were significantly increased with solarization. Availability of plant nutrients *viz.* P, K, Ca and Mg were found to be more in solarized plots than in control.

Powdery mildew of **cucurbits** is a widespread disease occurring throughout the world. The disease is destructive especially in dry and cool weather conditions. The disease can be recognized by its characteristic powdery growth of the fungus on the host surface. A study on powdery mildew of pumpkin showed that, this disease is caused by *Sphaerotheca fuliginea* which could not infect other cucurbits, except bitter gourd and ivy gourd (**Veena, 1992**). Of the 57 pumpkin lines screened for resistance, only P-30 collected from Palai (Kottayam Dist), showed consistent resistant reaction. Climatic factors like temperature, RH, rainfall and sunshine hours were found to influence the disease development. Incidence of disease was indirectly correlated with rainfall. However, the influence of climatic factors was more pronounced during the initial stages of the crop. Among the five chemicals *viz.* carbendazim 0.1%, tridemorph 0.1%, hexaconazole 0.1%, wettable sulphur 0.2% and sodium thiosulphate 1% tested against the disease under field conditions, carbendazim 0.1% recorded maximum disease reduction (82.6%), whereas maximum yield (5.83 t/ha) was observed with tridemorph spray. However, the cost effective method to check powdery mildew infection was by water spray (B:C ratio 1:6) followed by wettable sulphur (B:C ratio 1:5.6).

Seedling blight of **cocoa** is a serious nursery disease during rainy season. Since this disease causes heavy damage to seedlings and budded plants in nurseries, a better understanding of the disease is essential for proper monitoring and control of the disease. **Edwin (1995)** conducted an experiment to study the etiology and control of seedling blight of cocoa. The pathogen causing seedling blight of cocoa was identified as *Phytophthora palmivora* (Butler). Oat meal agar was found to be the best medium for the maximum growth and sporangial production of this fungus. The fungus produced various types of symptoms on leaves and stem of seedlings like water soaked lesions, leaf blight, defoliation, black discolouration, cotyledon infection, wilting and die back. It was also observed that, stem of budded plants were more prone to infection than seedlings. Among the fungicides tested against the pathogen, copper oxychloride (0.3%), potassium phosphonate (0.3%) and Ridomil MZ-72 completely inhibited the pathogen at 0.1 concentration. Chloramphenicol and Terramycin at 500ppm also completely inhibited the growth of the fungus. Under *in vivo,* potassium phosphonate (0.3%), Foltaf, Fytolan (0.3%) and Bordeaux mixture (1%) were found to be effective in managing the incidence and severity of the disease.

Vascular streak die back (VSD) is a serious disease of **cocoa** causing considerable damage to the crop. **Ajaykumar (1996)** conducted a detailed study on various aspects of this disease. Based on cultural and morphological characters, the causal organism of VSD was identified as *Oncobasidium theobromae* Talbot and Keane. Of the three media tested, potato dextrose agar recorded maximum growth of the pathogen followed by corticium culture and water agar media. Symptoms on seedlings and on older trees were similar. Typical symptoms were, pale green colour on leaves and subsequent yellowing with green islands, defoliation, brown marks on the scars of fallen leaves, axillary bud growth of the infected stem, rusty discoloration of cambium, vascular streak, whitish sporophores on the leaf scar of fallen infected leaves and finally the death of infected twigs. Transmission studies by grafting and budding revealed no establishment of buds or grafts but there was vascular streaking. No seed transmission was observed. Seed treatment with iprobenfos 0.1% (Kitazin) and carbendazim 0.1% (Bavistin) had an effect on plant growth characters. Cocoa genotypes GVI-55, GVI-54, M-13.12 and GVI 18.5 showed comparatively less disease incidence. Tridemorph (0.1%) provided better result in preventing the disease incidence in seedlings.

Chilli, brinjal and tomato are the most popular and commonly cultivated **solanaceous vegetables** in Kerala and damping off disease is a serious problem in raising the seedlings of these crops, especially during monsoon season. **Bindu (1996)** studied the etiology and management of damping off of solanaceous vegetables. Mycoflora associated with tomato, brinjal and chilli seeds were found to be *Aspergillus niger*, *A. flavus*, *Rhizopus stolonifer* and *Penicillium* spp., which caused partial inhibition in germination. Pathogens such as *Pythium aphanidermatum*, *Phytophthora parasitica*, *Drechslera rostrata* (in rainy seasons) and *Rhizoctonia solani* (in summer) were found associated with pre and post-emergence damping off. Damping off incidence was high in rainy season compared to summer. In both seasons, maximum incidence was observed in tomato. In pre-emergence damping off, the young seedlings were killed before they come out of the soil surface, while post-emergence phase was characterized by sudden collapsing of seedlings. Varietal reaction studies showed that, genotypes LCA-304 of chilli, BB-60-C of brinjal and Mukthi of tomato were resistant to damping off in rainy and summer seasons. Among the six fungicides *viz.* thiram, captan, mancozeb, chlorothalonil, copper oxychloride and Bordeaux mixture tested under *in vitro*, Bordeaux mixture (1%) and copper oxychloride (0.3%) resulted cent per cent inhibition of *P. aphanidermatum* and *P. parasitica*. In case of *D. rostrata* and *R. solani*, all treatments were equally effective and maximum inhibition was with Bordeaux mixture (1%). In field studies, maximum germination and minimum pre-emergence damping off was noticed in solarized beds followed by solarization + soil application of *Trichoderma viride*. Among the fungicides, seed treatment with chlorothalonil or thiram @ 2g/kg seed, gave maximum germination in both seasons whereas, Bordeaux mixture (1%) and potassium phosphonate (0.3%) affected seed germination. With regard to post emergence damping off, soil drenching with Bordeaux mixture (1%), seed treatment (2g/kg seed) and soil drenching of captan (2g/l), soil solarization + soil application of *T. viride* were found highly effective in rainy season. In summer, seed treatment and soil drenching of carbendazim (0.1%) was found to be the most effective treatment.

Bitter gourd is one of the most popular cucurbitaceous vegetables cultivated throughout India and downy mildew caused by *Pseudoperonospora cubensis* is one of the most serious disease observed in Kerala. Host range studies conducted by **Mini (1996)** revealed that, all commonly cultivated cucurbitaceous vegetables in Kerala, such as bottle gourd, snake gourd, ash gourd, pumpkin, cucumber, water melon and ivy gourd were collateral hosts of *P. cubensis* infecting bitter gourd. Slight variation in symptom appearance was noticed among different cucurbits. Out of the 182 genotypes of bitter gourd screened against downy mildew, none was found to be highly resistant. However, lowest disease intensity (10.66%) was recorded in genotype 293-G of NBPGR. Among the four fungicides *viz.* chlorothalonil, copper oxychloride, potassium phosphonate and mancozeb tested *in vitro*, pot culture and field conditions, chlorothalonil (2g/l) was found to be most effective, as it gave maximum disease control, maximum yield and highest B:C ratio followed by copper oxychloride (0.3%) and potassium phosphonate (0.3%). Mancozeb (0.2%) was found to be the least effective. Among the botanicals, *Ocimum* leaf extract (10%) gave maximum disease reduction compared to *Lantana,* Neem and *Bougainvillea.* However fungicides were superior to plant extracts. In crop loss assessment, severe infection of downy mildew could cause a yield loss of 45.7 per cent under natural conditions.

Ginger is subjected to a number of diseases leading to varying degrees of crop damage and yield reduction. Among the various diseases, rhizome rot is one of the most destructive diseases inflicting heavy crop loss especially during rainy seasons. The study conducted by **Shanmugham (1996)** established the association of *Pythium aphanidermatum* with rhizome rot disease based on the cultural and morphological characters of the pathogen. Among the rhizosphere microorganisms, *Aspergillus niger, A. fumigatus, A. flavus* and *Trichoderma viride* showed strong antagonistic activity against *P. aphanidermatum* under *in vitro*. Secondary metabolites of *A. niger* and *T. viride* inhibited cent per cent and 62 per cent growth of the pathogen respectively under lab condition. *In vitro* evaluation of fungicides *viz.* Indofil-M-45 (0.3%), Emisan (0.1%), Fytolan (0.2%) and Bordeaux mixture (1%) showed 86.7 to 100 per cent inhibition of *P.aphanidermatum,* of which Fytolan (0.2%) and Bordeaux mixture (1%) gave cent per cent inhibition. Pot culture experiments on the efficacy of the antagonists and fungicides on the pathogen revealed that, seed treatment and soil application at 60 and 120 days after planting with *A.niger* was most effective in checking the incidence and soil drenching with either copper oxychloride (0.3%) or mancozeb (0.3%) just after symptom appearance recorded maximum yield. Hence, seed treatment with *A.niger* followed by soil drenching with either copper oxychloride or mancozeb is suggested for checking the disease incidence and increasing the yield.

Vilasini (1996) studied the effectiveness of soil solarization for the control of soft rot of **ginger**. Maximum soil temperature recorded in solarized and non-solarized soil at 5, 10 and 15 cm depths were 63°C, 59°C and 46.5°C and 49.5°C, 43°C and 40°C respectively Temperature in the solarized soil at 5 cm depth was above 50°C for the entire solarization period and above 55°C for 38 days, while at 10 cm depth the temperature was above 50°C for 35 days and above 55°C for 5 days. The soil temperature at 15 cm depth never reached 50°C during the solarization period. Rate of germination in ginger was enhanced by solarization. Significant effect of solarization was observed in controlling the pre and post - emergence rotting in ginger, increasing the solarization period from 30 to 45 days did not show a corresponding reduction in the pre emergence rotting. *Trichoderma* incorporated neem cake amended 30 days solarized treatment was highly effective and recorded cent per cent control of the soft rot disease. Reduction in *Pythium* population ranged from 79.49 to 99.1 per cent in solarized plots immediately after the removal of polyethylene sheets. Solarization reduced the total fungal, bacterial and *Pseudomonas* sp. population in the field. Plants grown in solarized plots showed better colonization of VAM and *Azospirillum*. Significant reduction in nematode population was also observed due to soil solarization. Solarization had a profound suppressive effect on the weed population and it lasted till harvest. Solarization effect was more pronounced in dicots. Increased response on growth characters was also observed due to solarization. Significant increase in yield was noticed in solarized plots. *Trichoderma* incorporated neem cake amended 30 days of solarized treatment recorded maximum yield (10.160 Kg). Availability of nitrogen, phosphorus and potassium was improved by solarization.

Praveenkumar (1999) conducted an experiment on the anthracnose disease of vegetable cowpea (*Vigna unguiculata*). *Colletotrichum lindemuthianum* (Sacc. and Magn.) Br. And Cav. was found to be the main pathogen causing anthracnose disease popularly known as 'karimban kedu' or 'karivalli' in Kerala. The pathogen was found to be internally seed borne. Among the 50 genotypes screened, Kanakamony, a bush type variety was completely free of disease and seven genotypes (US-25, US-389, US-14, US-29, US-12, US-81 and CWP-16) were highly resistant to this disease. In disease management studies, chlorothalonil (0.2%) was found to be the most effective followed by captan (0.2%) and mancozeb (0.2%) under field condition. However, with respect to disease control, yield and B: C ratio, mancozeb was found to be the best one. As the pathogen was seed borne, seed treatment was found to be effective in reducing the disease incidence. Seed treatment with systemic fungicide, carbendazim and with the antagonist, *Trichoderma viride* gave good control. Additional two foliar sprays at 15 and 30 days after sowing were also effective in case of contact fungicides and botanicals. In case of botanicals, 10% *Lantana* leaf extract showed maximum disease reduction. Summer was found to be the best season for cowpea cultivation in Kerala in areas where anthracnose is a problem. South - West monsoon period should be avoided, as the maximum infection and crop loss were observed during this period. In crop loss assessment, significant difference was noticed between carbendazim treated and untreated plots in case of disease infection and yield. Yield loss of 53.85 per cent was recorded under natural condition due to this disease.

Variability in virulence and aggressiveness of nine isolates of *Ralstonia solanacearum* of **brinjal, chilli** and **tomato** collected from Vellanikkara, Kumarakom and Ambalavayal were studied on their susceptible hosts by **Deepa (2001)**. The findings revealed that, there is variability among the isolates from different locations. All isolates from Kumarakom were highly virulent and highly aggressive whereas Ambalavayal isolates were weakly virulent and less aggressive. Cross inoculability of the isolates revealed that, all Vellanikkara and Kumarakom isolates were found cross inoculable. Isolates were characterized by cultural, morphological and biochemical tests. Biovars III and III A and races 1 and 3 were identified. Vellanikkara and Kumarakom isolates belonged to race 1 whereas Ambalavayal isolates were grouped under race 3. The isolates were resistant to ampicillin and sensitive to chloramphenicol. There was no difference in the plasmid DNA profile of the nine isolates. RAPD profiles exhibited great diversity among biovar III and III A and among race 1 isolates. Race 3 isolates were less polymorphic with certain primers tested. OPF - 8 yielded unique band specific to race 3 isolates. Dendrogram also observed high genetic variability between race 3 isolates. Restriction analysis could not characterize the isolate, since no banding pattern was obtained with restricted DNA. No hybridization signal was detected after southern hybridization in RFLP. To study the role of plasmid in EPS production, plasmid could be observed in both mucoid and non-mucoid type colonies, and smaller size of plasmid was noticed in later case. Thus RAPD technique revealed great diversity among different strains of *R. solanacearum* from different locations.

Sheath blight of rice caused by *Rhizoctonia solani* Kuhn. is one of the dreadful disease of rice causing more than 50 per cent yield loss. Efficacy of selected biopesticides against sheath blight disease studied by **Saifunneesa (2001)** revealed that, the fungi, *viz. Trichoderma viride, Asperzillus niger, A. terreus* and *Cunninghamella bertholletiae* and botanicals *viz. Azadiracta indica, Leucaena leucocephala, Ocimum sanctum, Chromólaena odorata* and *Pongamia glabra* showed significant inhibition of mycelial growth and sclerotial production of *R. solani* under *in vitro*. Aqueous extract of *Ocimum sanctum* (5%) was equally effective as the standard fungicide, carbendazim (0.1%) in *in vitro*. The neem based formulation Nimbicidine (0.75%) gave good inhibition of *R. solani*, both *in vitro* and *in vivo* concentrations. The fungal antagonist, *T. viride* and the botanicals, *O. sanctum* and *C. odorata* were found to be the effective ones when tested under *in vitro* and *in vivo*. Field studies carried out with the selected biocontrol agents revealed that, seed treatment followed by soil and foliar application of *T. viride* was superior with high yield as that of carbendazim (0.1%) and was economically viable. It also enhanced the activity of defense related enzyme, phenylalanine ammonia lyase. In addition, seed treatment and foliar application of Nimbicidine (0.1%) was also effective.

Banana is an important fruit crop of Kerala which is commonly and severely affected by yellow sigatoka leaf disease caused by *Mycosphaerella musicola*, which was noticed maximum in the peak monsoon month of July, followed by October and minimum in January. Meteorological data correlated with disease incidence showed a positive correlation with relative humidity and rainfall and negative correlation with temperature. Potato glucose yeast extract agar was the best medium for the growth of *M. musicola*. Red pigmentation was observed in all the artificial media tested. Study on anatomical and biochemical bases of resistance to this disease revealed that, the resistant variety, Manoranjitham (AAA) was characterized by thick cuticle, medium sized epidermal cells on adaxial surface and denser cuticle on abaxial leaf surface. Thin spongy palisade tissues, numerous large and closely placed vascular bundles, thick lower epidermis and lesser number of stomata was observed on abaxial and adaxial surfaces of leaves. In susceptible variety, Grand Naine (AAA), thinner cuticle, thickened and large sized epidermal cells on abaxial surface and faint wax deposition on adaxial surface were noticed. Less number of small and distantly placed vascular bundles, thick spongy and palisade tissues and maximum number of stomata per unit area of leaves was observed. After infection, the resistant variety Manoranjitham

(AAA) showed partial disintegration of spongy mesophyll tissues and susceptible variety Grand Naine (AAA) which showed complete disintegration of chloroplast and mesophyll tissue with necrotic and vascular bundles. Resistant variety Manoranjitham (AAA) possessed higher quantities of total phenol, OD phenol, non reducing and total sugars, higher protein and peroxidase activity. Susceptible variety Grand Naine (AAA) was characterized by higher reducing sugar and average of total phenol, non reducing and total sugars, lower quantities of proline, protein and increased activities of defense enzymes **(Sairabanu 2001).**

Phytophthora rot is the most destructive disease of **black pepper** nursery inflicting heavy crop losses. Considering the seriousness of the disease, an investigation was carried out to isolate and select efficient antagonists from black pepper nurseries and use them alone or in combination with fungicides in the integrated management of the disease **(Reshmy 2003)**. The pathogen causing the disease was isolated and identified as *Phytophthora capsici* Leonian emend A. Alizadeh and P.H.Tsao based on the cultural and morphological characters. Quantitative estimation of rhizosphere microflora from different pepper nurseries yielded more soil bacteria followed by fungi and actinomycetes of the organism tested and five bacteria were found antagonistic to *P. capsici*. Among the fungal isolates, 13 isolates including standard culture of *T. harzianum* recorded cent per cent inhibition of the pathogen. Further, selection of the efficient isolates was carried out based on the antagonistic index (AI). The isolates 22 F and 34 F recorded an AI of 3000 and 1500 respectively and these were identified as *Trichoderma longibrachiatum* and *Trichoderma viride*. The standard culture of *T. harzianum* also recorded an AI of 1500. The three antagonists were found parasitic on the pathogen *P .capsici* as evidenced by excessive coiling, penetration and disintegration of the hyphae. The fungicides *viz.* Bordeaux mixture, Kocide, Captaf and Kavach were incompatible with the three antagonists, while, Indofil M-45, Ridomil MZ, Akomin and Anthracol were compatible. Fytolan showed partial compatibility with *T.viride* and *T. harzianum* but incompatible with *T. longibrachiatum*. Among the eight insecticides tested, phorate and carbofuran showed compatibility with the antagonists, whereas monocrotophos, quinalphos, endosulfan, dimethoate, cypermethrin and higher concentration of chlorpyriphos were incompatible. Fertilizers like urea, Rajphos, ammonium sulphate and muriate of potash (MoP) were compatible with antagonists, while, factomphos and higher concentration of urea did not support the growth of antagonists. Bordeaux mixture, Fytolan, Kocide, Indofil M-45, Ridomil MZ-72 and Captaf at all concentrations. Higher concentration of Akomin-40 and Anthracol were inhibitory to *P. capsici*. The insecticides, phorate, carbofuran and chlorpyriphos showed comparatively good inhibitory effect against the pathogen but complete inhibition of pathogen was noticed with monocrotophos, endosulfan, quinalphos, dimethoate and cypermethrin. The fertilizers *viz.* urea, MoP, Rajphos supported growth of the pathogen while, factomphos and ammonium sulphate exerted an inhibitory effect. Solarization of potting mixture resulted in the build up of soil temperature and the temperature was more in the upper layer of soil. Solarization of potting mixture and application of biocontrol agents had a positive effect in increasing the sprouting and reducing the pre-sprouting mortality of cuttings and is comparable to plants raised as per the package of practices of Kerala Agricultural University (KAU). Observations on the incidence and severity of *Phytophthora* rot in black pepper showed that, in general soil solarization, application of antagonists and spraying of Ridomil MZ-72 had a favourable effect in checking the disease and the effect is almost similar to that of disease management as per PoP of KAU. A variation in the population of soil microflora in different treatments was observed. The cuttings raised in solarized potting mixture incorporated with native antagonists had significant effect in increasing the plant height and number of leaves/ plant.

Ivy gourd, an under exploited vegetable has gained importance in recent years as the fruits are rich source of Vitamin A, C, minerals like iron and calcium and has got therapeutic value particularly in the treatment of diabetes, bronchitis and skin diseases. The plant is infected by many leaf spot diseases and hence **Deepa (2003)** carried out a study to find out the etiology of leaf spot diseases of Ivy gourd and to evolve an effective management practice by the use of biocontrol agents and plant extracts. Etiological studies revealed that, *Cercospora cocciniae*, *Colletotrichum gloeosporioides* and *Alternaria alternata* were the main pathogens causing different leaf spot diseases of Ivy gourd. Among the 19 genotypes tested, eight were highly resistant to leaf spots. Low temperature, high rainfall and high humidity favoured infection by *Cercospora* and *Colletotrichum,* whereas *Alternaria* infection was noticed in summer months favoured by high temperature, moderate relative humidity and moderate rainfall. Selected fungicides, botanicals and antagonists were tested under *in vitro*, *in vivo* and field conditions. Spraying copper oxychloride (0.2%), copper hydroxide or garlic (10%) or *T.viride* (0.4%) were found to be equally effective in checking leaf spot and fruit infection in ivy gourd.

Black pepper, an important export oriented spice crop of India is propagated through rooted cuttings in nurseries. However, heavy casualities do occur in pepper nurseries every year, as black pepper is affected by many diseases, of which *Phytophthora* rot causes extensive damage to the nursery during South-West monsoon period. **Mammootty (2003)** studied various diseases occuring in black pepper nurseries in Kerala to evolve an integrated management strategy against *Phytophthora* rot. The survey of various nurseries revealed the occurrence of many diseases *viz. Phytophthora* rot, *Colletotrichum* rot, *Rhizoctonia* rot and *Sclerotium* rot, in which *Phytophthora* rot being the predominant one. Among the various nursery practices followed for raising pepper nurseries, cuttings raised under high density polyethylene sheet did not show any incidence of diseases. Screening for host resistance indicated, tolerant and moderately susceptible reactions of Kalluvally – II and Panniyur – 5 against many diseases which was due to the enhanced in production of total phenols, OD phenol, total free amino acid contents, peroxidase, catalase and esterase activity in tolerant Kalluvally – II, whereas total carbohydrate, starch and acid phosphatase activity was maximum in susceptible Pannniyur – I. The native antagonists *Trichoderma harzianum* and *T. viride* isolated in this study were found compatible with Akomin – 40 and Ridomil MZ – 72, but not with Bordeaux mixture. Better sprouting, growth and minimum disease incidence were observed in cuttings raised in solarized potting mixture during February – March. In general, solarization of potting mixture, application of *Trichoderma* sp and fungicides like, Akomin- 40 or Ridomil MZ -72 can be used for managing the incidence of *Phytophthora* rot in black pepper nursery.

Cocoa ranks third as a beverage crop in the world, next to tea and coffee. Kerala is a principal cocoa growing state of India accounting for more than 50 per cent area under cultivation. Among the various diseases affecting cocoa, *Phytophthora* pod rot caused by *Phytophthora palmivora* is the most serious one which accounts for 44 per cent of the global crop loss. Many fungicides are reported to be effective for the management of *Phytophthora* pod rot, but indiscriminate use of fungicides may pose many ecological problems. Hence a study was undertaken on biological management of *Phytophthora* pod rot of cocoa using epiphytic antagonistic microorganisms from cocoa **(Bhavani 2004)**. The pathogen causing pod rot in cocoa was identified as *Phytophthora palmivora.* Among 225 cocoa types, eight types showed moderate resistance, 63 types were moderately susceptible and remaining were highly susceptible. The epiphytic microflora from cocoa pods yielded more bacteria than fungi and actinomycetes. However, seven bacterial and eight fungal isolates exhibited maximum inhibition on *P. palmivora.* Among the isolates, *Trichoderma viride* (20 F isolate) and *Pseudomonas fluorescens* (23 B and 24 B isolates) were found to be highly effective antagonists against *P. palmivora*. These two antagonists (*Trichoderma viride & Pseudomonas fluorescens*) were compatible with potassium phosphate and mancozeb (Indofil M 45). In the field studies, *Pseudomonas fluorescens* was effective in reducing *Phytophthora* rot in cocoa which was on par with the recommended fungicide, Bordeaux mixture (1%).

Kacholam (*Kaempferia galanga* L.) is an important medicinal herb, in which the rhizome is used for treatments of skin disorders, piles, oedema, fever, epilepsy, asthma etc. It is found to be affected by bacterial and fungal diseases which causes severe damage to leaves and to rhizomes resulting in yield loss especially the oil yield. Bacterial wilt caused by *Ralstonia solanacearum* and leaf spot caused by *Colletotrichum gloeosporioides* and *Colletotrichum capsici* were the major diseases observed in Kacholam from the surveys conducted at different places of Kerala *viz.* Asamannur, Koothattukulam and Odakkali in Ernakulam district and Varikulam, Chuvannamannu, Pattikkad and Vellanikkara in Thrissur district. Bacterial wilt incidence was noticed only in Odakkali, Chuvannamannu and Vellanikkara. The pathogen *R. solanacearum* belonged to Race I, biovar III (Vellanikkara) and biovar III A (Odakkali). Among the 12 genotypes screened against bacterial wilt and leaf spot, Echippara and Chittoor were completely free of wilt disease and showed resistant reaction to leaf spot disease. The genotype Thodupuzha was highly susceptible to bacterial wilt. The disease management studies under *in vitro* condition revealed that, all three antagonists *viz. Pseudomanas fluorescens, Trichoderma viride* and *Aspergillus niger* were highly effective against both bacterial wilt and leaf spot pathogens. Among the three fungicides tested, Bordeaux mixture 1% was most effective against leaf spot pathogens. Copper hydroxide (Kocide) 0.2 – 0.3% against *R. solanacearum* and copper oxychloride was least effective. The field experiments, showed *Trichoderma viride* as the efficient antagonist and coir pith as the best soil amendment with respect to maximum germination, yield and disease control **(Priya 2005).**

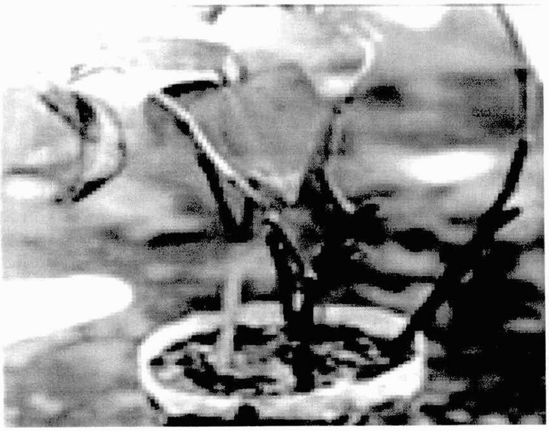
Vanilla is one of the important spices traded in the global market. *Phytophthora* rot is one of the serious diseases affecting vanilla both in nurseries and plantations. A study was conducted by **Shahida (2007)** to find out the effect of bio fertilizers, bio agents and fungicides on the management of the disease as well as on the plant growth enhancement. The pathogen causing *Phytophthora* rot in vanilla was identified as *Phytophthora meadii* Mc. Rae based on cultural and morphological characters. Among the various isolates of AMF, *Azospirillum, Trichoderma* and *Rhizobacteria* obtained from the soils collected from Vellanikkara, Perumbavoor and Mazhuvannur areas, AMF from Perumbavoor and *Azospirillum* from Mazhuvannur were the effective isolates for enhancing the growth and nutrient contents in **vanilla**. Among the antagonists, *Trichoderma* from Vellanikkara were most effective against *P .meadii*. Of the five fungicides tested against the pathogen under *in vitro* condition. Bordeaux mixture (0.5 to 1.5%) copper o xychloride, copper hydroxide (0.1 to 0.3%) and potassium phosphonate (0.3 to 0.4 %) showed complete inhibition of pathogen. Mancozeb was least effective. Studies on compatibility of bio agents with fungicides revealed that Bordeaux mixture, copper hydroxide and higher concentration of copper oxy chloride was inhibitory to *Trichoderma* and *Rhizobacteria.* However potassium phosphonate (0.3 and 0.4%) and low concentrations of mancozeb (0.1 and 0.2%) were compatible to both antagonists. In pot culture experiment *Piriformospora indica* showed highest per cent germination followed by *Trichoderma harzianum* and *Azospirillum* (MVR) which gave maximum vine length. potassium phosphonate (0.3%) recorded maximum disease control (91%) followed by Bordeaux mixture. The microbial isolates AMF (Perumbavoor) and *P.fluorescens* (KAU) also showed control of *Phytophthora* rot to certain extent.

Mushroom is a good source of quality proteins, minerals, vitamins and having excellent medicinal properties. Milky mushroom is a new introduction among the commercially domesticated mushrooms. Mushrooms are proned to a number of biotic and abotic stresses. **Sameera (2007)** conducted a study to identify the major diseases of milky mushrooms (*Calocybe indica*) and to evolve suitable eco-friendly management practices to combat these diseases. During the survey conducted at four mushroom farms in Thrissur district of Kerala (Eravimangalam, Kodungallur, Kattilapoovam and Vellanikkara), the diseases *viz.* bacterial blotch, malformation, scaling and splitting of sporophores were identified as the major problems. In addition, cobweb disease and infection of small pinheads were also noticed. Incidence of weed fungi during the spawn running stage was another serious problem observed in these farms. Two bacterial pathogens *viz. Pseudomonas* sp. and *Bacillus* sp. were found associated with bacterial blotch, and fungi *Dactylium dendroides* and *Penicillium* sp. were found causing cobweb and brown discolouration of young pinheads respectively. Weed fungi found interfering with spawn running were, *Trichoderma* sp, *Coprinus* sp, *Chaetomium indicum, Rhizoctonia solani. Curvularia* sp, *Sclerotium* sp *and Aspergillus* sp. *In vitro* interaction studies also showed that, these organisms could inhibit the mycelia growth of milky mushroom on artificial medium and on paddy straw substrate. Culture filtrate of weed fungi also had inhibitory effect on *Calocybe indica* and maximum inhibition was recorded with metabolite of *Chaetomium indicum*. *Sclerotium* sp. recorded maximum reduction in mycelial growth and cent per cent reduction in yield followed by *Chaetomium indicum*. Seasonal effect in the incidence of weed fungi showed that, it was maximum during the month of June, and the major weed fungus observed was *Rhizoctonia solani* which occurred throughout the year. Paddy straw sterilized with carbendazim (75 ppm) formaldehyde (500 ppm) and calcium carbonate (0.2%) for 18 h. was the best treatment with maximum mycelial growth and yield of milky mushroom. Among phytoextracts tested against the pathogens, turmeric (5%), garlic (10%) and neem leaves (10%) extracts showed cent per cent inhibition of bacterial pathogens and garlic (5%) and *Ocimum* leaves (5%) extract were found to be most inhibitory to all fungal pathogen under *in vitro*. *In vivo* evaluation of the selected phytoextracts revealed that, garlic extract (5%) sprayed on substrates sterilized by chemicals (carbendazim 75 ppm, formaldehyde 500 ppm and 0.2 % $CaCO_3$) recorded maximum mycelial growth and the yield followed by *Ocimum* extract (5%) and were free from natural incidence of weed fungi also. Spray of garlic or turmeric extract on sporophores after 2nd and 3rd pin head emergence reduced the bacterial blotch incidence. Increase of crude protein and decrease of phenol and crude fibre contents were observed in infected mushroom as compared to healthy one. General cleaning, use of good quality substrate, maintanence of optimum conditions will help to get good yield and to minimise disease incidence. It is desirable to provide a short break of two or three days after each crop and prophylactic spray of phytoextract on sterilized substrate will also help in the management of both fungal and bacterial diseases.

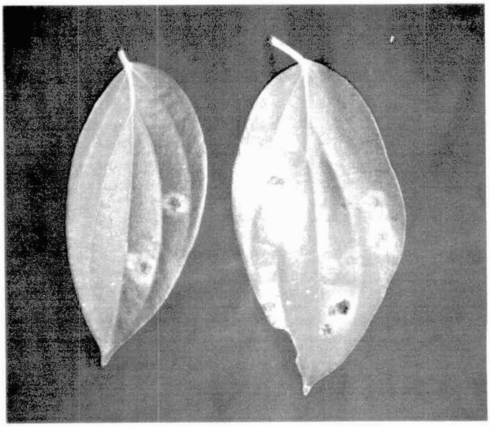
Leaf blight is a serious disease of **Amaranth** in Kerala. The pathogen isolated from both red and green amaranth types from different locations were identified as *Rhizoctonia solani* Kuhn. **(Saisree, 2007)**. In red amaranth, symptoms initiated as small irregular white spots on the leaves and enlarged under high humid condition. Gradually it became translucent green and later turned grey. Severely infected leaves showed shot hole symptoms and finally defoliated. In green amaranth, symptoms initiated as papery white spots which spread and showed shot hole symptoms. Infected leaves dried up and defoliated. Enumeration of endophytes from red, green and wild types revealed abundance of bacteria than fungi and association of endophytes was more in older plants than young ones. Of the 63 organisms isolated, fungus EF-2 (*Trichoderma harzianum*) and bacteria *viz*. EB-22 and EB-45 belonged to *Pseudomonas* sp. and EB-4, EB-20, EB-38 and EB-43 belonged to *Bacillus* sp. showed antagonistic activity against *Rhizoctonia solani*. In the pot culture experiment, *Pseudomonas* sp., EB-22 and *Bacillus* sp., EB-43 were more efficient in reducing leaf blight severity and promoting plant growth characters. With regard to oxidative enzymes, maximum peroxidase and polyphenol oxidase activities were observed in plants treated with EB-20 (*Bacillus* sp.) and EB-22 (*Pseudomonas* sp.) respectively.

Die back is one of the important diseases of **mango** occuring both in nursery and plantation. Study conducted by **Sangeetha (2009)** revealed the association of *Colletotrichum gloeosporioides* Penz.sacc and *Botryodiplodia theobromae* Pat with the die back of mango grafts. In addition, *C.gloeosporioides*, *Pestalotiopsis mangiferae*, *Cylindrocladium mangiferae*, *Drechslera australiensis* and *Alternaria alternata* were isolated from leaf blight symptoms. Among the eight fungicides tested against the dieback pathogens under *in vitro* condition, Bordeaux mixture 0.5-1.5% and carbendazim 0.1-0.2% showed cent per cent inhibition of both *C.gloeosporioides* and *B. theobromae*, Mancozeb and zineb even at high concentration of 0.4% were least effective. In pot culture experiment, Bordeaux mixture (1%) was most effective against both die back and leaf blight disease. In addition, spraying of hexaconazole (0.1%), carbendazim (0.1%), copper hydroxide (0.1%), quinalphos (0.05%) and *Pseudomonas fluorescens* were also equally effective in the management of dieback and leaf blight disease. Alphonso and Mulgoa varieties were found resistant to both diseases and the total phenol content of these varieties were 393.69 ìg/g and 283.59 ìg/g respectively.


Phytophthora rot of black pepper

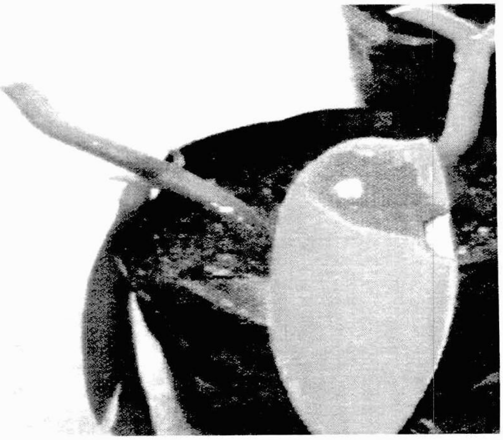


Phytophthora rot in black pepper nursery



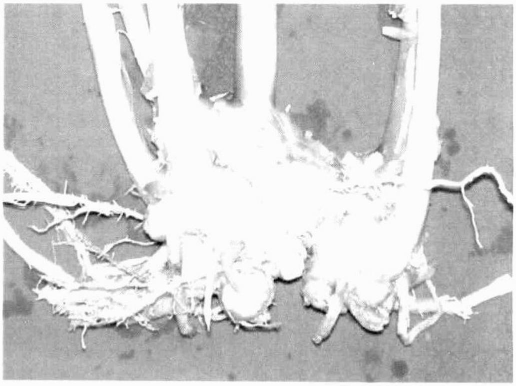
Pollu disease of black pepper

Little leaf of black pepper

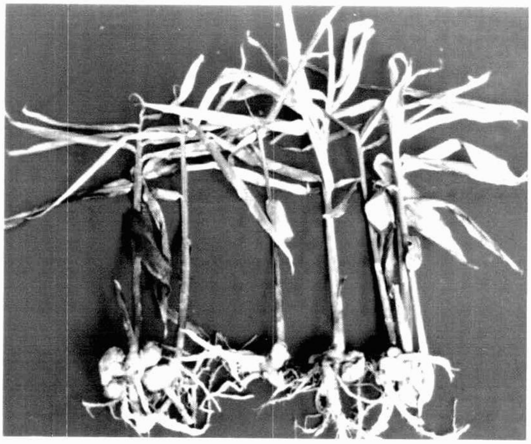


Phytophthora rot of vanilla

Plate I



Soft rot of ginger



Bacterial wilt of ginger

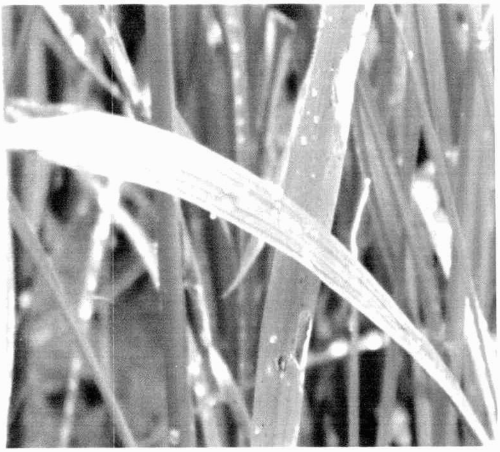
***Phyllosticta* leaf spot of ginger**

Root(wilt) of coconut

Plate II

Vascular Streak Dieback of cocoa

Pod rot of cocoa



Blast of rice

Sheath blight of rice

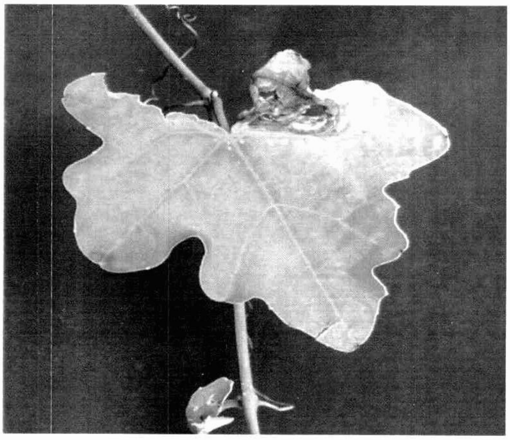
Bacterial wilt of chilli

Bacterial wilt of tomato

Plate III

Downy mildew of bittergourd

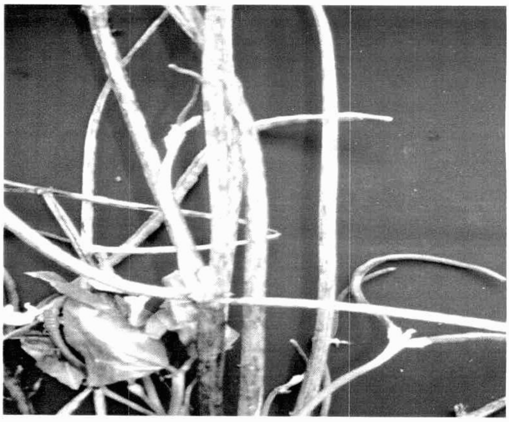
Alternaria leaf blight of cucurbits



Alternaria leaf blight of *Coccinia*

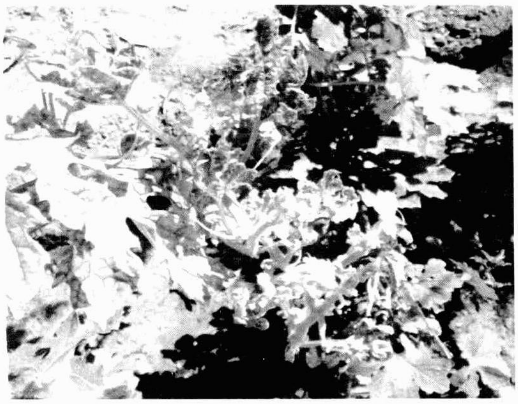
Cercospora leaf spot of *Coccinia*

Leaf blight of amaranth



Anthracnose of cowpea

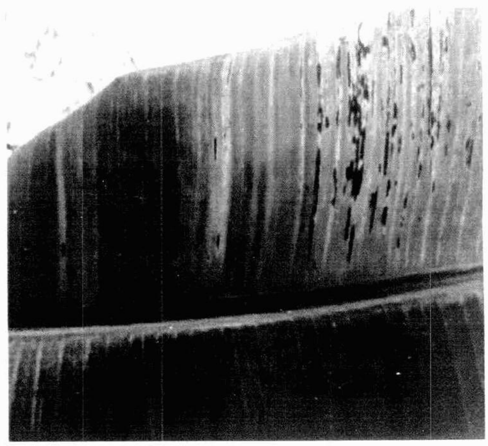
Plate IV



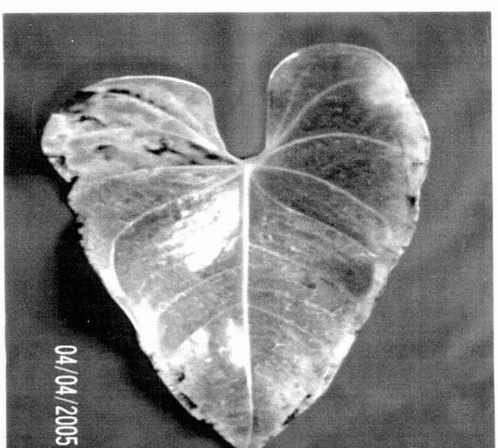
Distortion mosaic of bittergourd

Sigatoka of banana

Bunchy top of banana



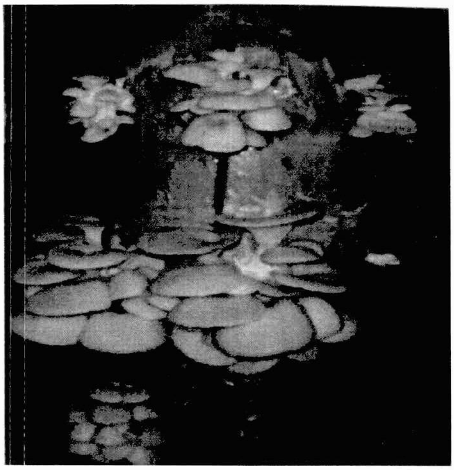
Banana streak virus



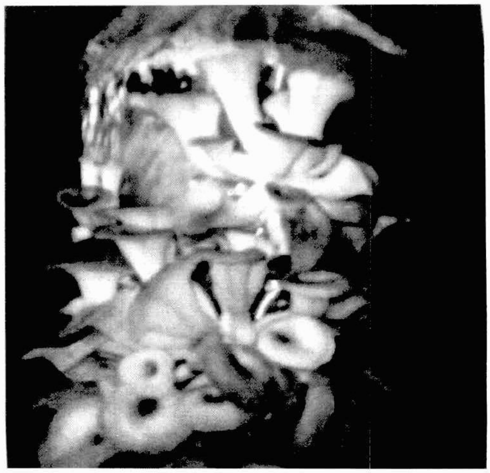
Bacterial leaf blight of anthurium

Soil solarisation

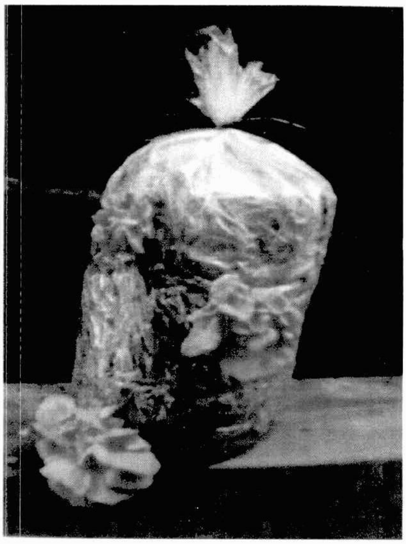
Plate V



Pleurotus florida

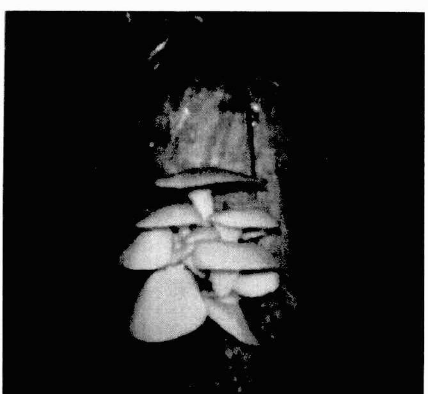


Pleurotus sajor - caju



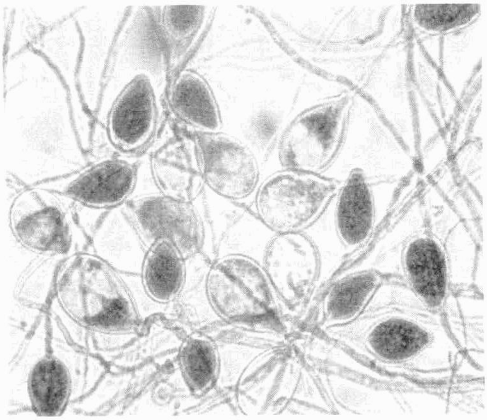
Pleurotus eous

Pleurotus tuberregium

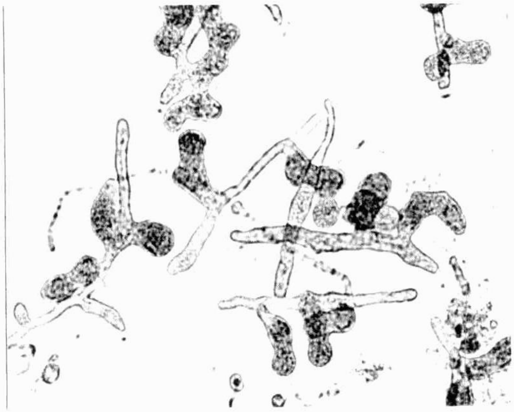


Hypsizygus ulmarius

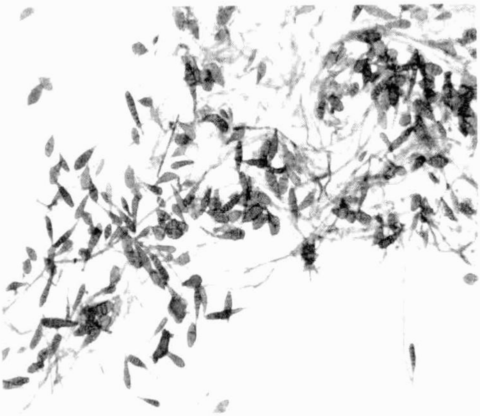
Plate VI



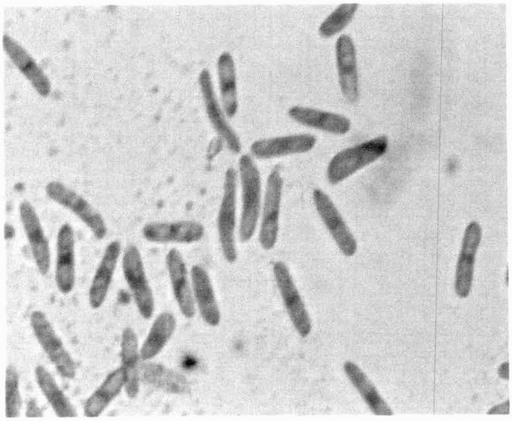
Phytophthora



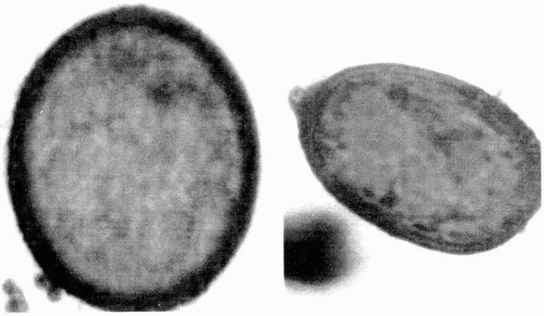
Pythium aphanidermatum



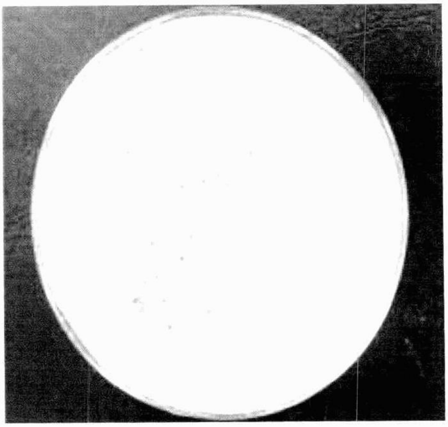
Alternaria



Colletotrichum

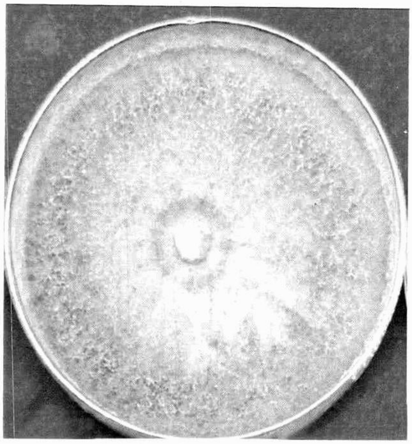


Mycorrhiza spores (*Glomus* sp.)

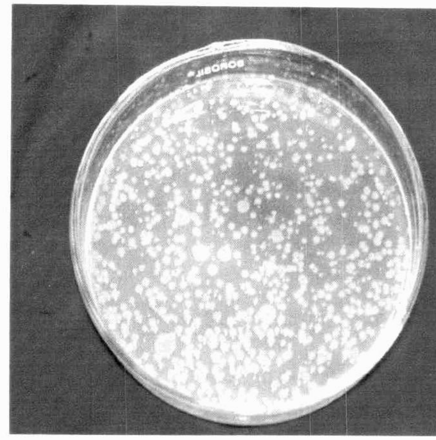


Ralstonia solanacearum

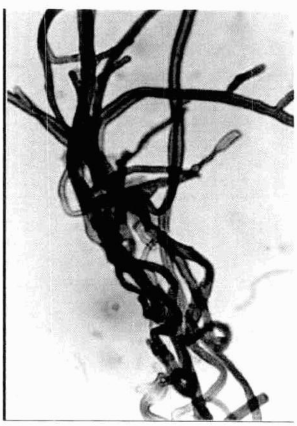
Plate VII



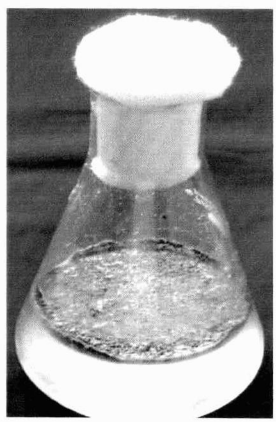
Trichoderma sp.



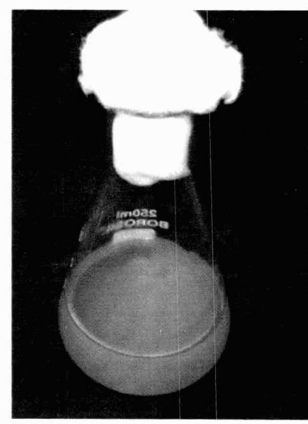
Pseudomonas fluorescens



Coiling- mechanism of antagonism

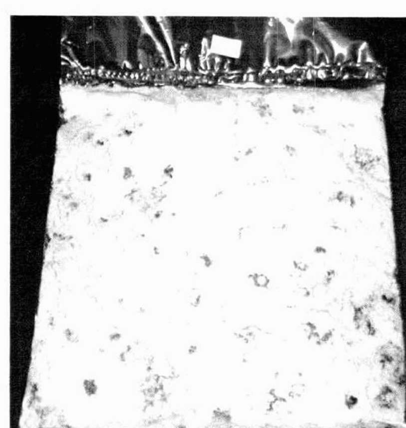


Multiplication of *Trichoderma* in 50% coconut water



Multiplication of *Pseudomonas* in 50% coconut water

Trichoderma multiplied in dried coconut leaf bits



Nutrient supplemented formulation of *Trichoderma*

Plate VIII

BACTERIOLOGY

Plant bacteriology is a branch of Plant Pathology which deals with plant diseases caused by prokaryotes. Several bacterial diseases like wilt of solanaceaous vegetables, leaf blight of rice cause enormous economic losses in Kerala.

Bacterial wilt caused by *Pseudomonas solanacearum* (Smith) Smith is one of the most severe disease of **chilli. Jyothi (1992)** carried out a study to characterize the pathogen, varietal screening and to find out suitable management practices for the disease. The bacterial wilt pathogen isolated from chilli, tomato, brinjal and ginger were characterised and were found similar to each other with respect to biochemical and physiological properties and identified as biovar III of *P. solanacearum*. Cross inoculation of different isolates showed that, chilli isolate caused infection in brinjal, tomato and ginger and *vice versa*. Likewise, brinjal and tomato isolates were also cross infectable to each other whereas brinjal and tomato isolates could not cause infection in ginger and *vice versa*. Of the 29 chilli genotypes screened against *P solanacearum*, variety 'Manjari' was resistant to bacterial wilt, while accessions CA 205 and CA207 were moderately resistant. In addition, the evaluation of 121 chilli accessions maintained at NBPGR, Vellanikkara showed 54 accessions free of bacterial wilt. In *in vitro* screening of antibiotics and fungicides, Chloromycetin and Streptocycline antibiotics exhibited maximum inhibition of the bacterium. Among the different fungicides, Bordeaux mixture showed maximum inhibition followed by thiride and copper oxychloride. In the field experiment, plants treated with cow dung and two applications of Streptocycline (1000 ppm) as minor treatment showed reduction in wilt incidence.

Ginger, an important commercial spice crop esteemed for its aroma, flavour and purgency, ranks fourth among the important spices of India. A number of pathogens are reported to infect ginger causing several diseases. One such disease is the bacterial wilt disease incited by *Pseudomonas solanacearum,* which is one of the most infective pathogen in warm tropical regions of the world. Hence, a study was undertaken by **Alli Rani (1994)** to characterize the pathogen and evolve a suitable management practice for the disease. *In vitro* studies revealed that, Ambistryn – S and Chloromycetin – 1000 ppm exhibited maximum inhibition of bacterium. Among the fungicides tested, Bordeaux mixture 1% gave maximum inhibition. Among the botanicals, water extract of *Ocimum* spp. and garlic at 50g/l showed maximum inhibition of the pathogen. Pot culture study revealed that plants treated with Bordeaux mixture, Ambistryn – S, Terramycin and Chloromycetin showed minimum wilt incidence. It was also observed that colonies of VAM was greater in roots of healthy plants than roots of infected plants. Bordeaux mixture and Ambistryn – S treated plants also showed maximum plant height, more number of tillers and better yield than other treatments. In field experiment, though none of the treatments gave an absolute control of the disease. Ambistryn – S and Bordeaux mixture showed minimum wilt incidence. When the population of total rhizosphere microflora and the pathogen were estimated, it was observed that Ambistryn–S, Bordeaux mixture and Chloromycetin effectively reduced population of *P. solanacearum*. Fungal population was reduced in Bordeaux mixture and Ambistryn – S treated plots. Actinomycetes population was minimum in plots treated with garlic. Incidence of Phyllosticta leaf spot was minimum in plants treated with Bordeaux mixture, Ambistryn - S, Calixin and Chloromycetin both in pot culture and field experiments.

Bacterial wilt caused by *Ralstonia solanacearum* is one of the most important diseases in the cultivation of tomato, brinjal and chilli and the crop loss due to this vary from 20-100 percent. Among the different approaches to control the bacterial wilt disease, genetic host resistance seems to be the ideal method. The genetic factors play a role in the basic physiological and biochemical activities of the plant and the pathogen. Hence, a study was undertaken by **Sheela (1998)** on the biochemical and biological resistance in **solanaceous vegetables** against *Ralstonia solanacearum* (Smith) Yabuchi *et al.* Among the biochemical factors, O.D - phenol activity increased due to infection and the content was higher in the resistant genotype (LE 79-5) of tomato. In brinjal, polyphenol oxide activity and peroxidise increased due to infection in resistant genotype (Swetha). In chilli, total phenol and OD phenol were higher in resistant plant (Ujwala). Among the biological factors, the total fungi and actinomycetes, *Pseudomonas* and parasitic nematodes increased due to infection in resistant genotypes, whereas beneficial microbes recorded decrease in population. Tomato resistant genotypes recorded higher nematode population under healthy condition and higher total microflora, virulent *Ralstonia* and avirulent *Pseudomonas* under diseased conditions. However in the case of brinjal, resistant genotype recorded higher population of fungi, avirulent *Pseudomonas,* mycorrhiza and saprophytic nematodes under healthy conditions whereas fungi, virulent *Ralstonia* and avirulent *Pseudomonas* and nematodes under diseased condition. In chilli, resistant genotype recorded higher population of avirulent *Pseudomonas* and mycorrhiza and nematodes under healthy conditions whereas fungi, avirulent *Pseudomonas* and mycorrhiza under diseased condition. Among the nutritional factors, tomato resistant genotype recorded high potassium and calcium (healthy condition) and iron, zinc and magnesium in diseased condition. In brinjal, resistant genotype recorded high N,Ca, Mg and Zn in healthy condition whereas K, Mg and iron in diseased condition. However, chilli resistant genotype recorded high P, Ca and Fe in healthy condition with high N,K, Mg and Zn under diseased condition.

The bacterial wilt caused by *Ralstonia solanacearum* is the most devastating disease which affects **tomato** production in humid tropical region. The judicious use of chemicals or antibiotics may result in accumulation of toxic materials in the soil. Integrated disease management is an ecological approach to maintain plant health equilibrium. IDM comprises of the cultivation of resistant or tolerant varieties, adoption of agronomic practices, use of natural antagonists and use of chemicals. Hence, a study was undertaken by **Akbar (2001)** on integrated management of bacterial wilt of tomato. The pathogen causing bacterial wilt of tomato isolated from Vellayani (south zone), Vellanikkara (central zone), Pilicode (north zone) and Moncompu (problem zone) of Kerala revealed that the isolates belonged to Race I and Biovar 3. The antagonistic bacteria *Pseudomonas aeruginosa* was found to be effective against *R. solanacearum.* Seed treatment with *P. aeruginosa* (10^7 cfu/ml) resulted in early germination and enhancing seedling vigour. The field studies indicated that, combined application of *P. aeruginosa* and garlic extract (10%) or Bordeaux mixture 1% or copper hydroxide (0.15 %) were effective in reducing wilt incidence in the variety Sakthi.

Banana is the most important economically profitable fruit crop grown in Kerala, mainly by small and marginal farmers, providing vital source of income. Rhizome rot disease caused by *Erwinia carotovora* has become a serious problem to the commercial cultivation of banana in the southern states of India. **Usha (2003)** carried out investigations on the etiology and management of rhizome rot of banana. The pathogen *E. carotovora* was isolated from rhizome of banana var. Nendran and its pathogenecity was established after standardizing the method of inoculation. The first visible symptom of the disease was flaccidity and yellowing of leaves. The infected plants became weak and such plants toppled down within a week or two. Rhizome showed extensive rotting, tissues become soft with a foul smell. On Logan's differential medium, specific to *Erwinia,* the bacterium produced pale white, small, circular raised colonies with purple centre. Growth of bacterium on different solid media revealed that, sucrose peptone agar and King's B medium were the most suitable ones. Bacterium recorded good growth at pH range of 6-7 and the maximum at pH 7. Among the different temperatures tested, the isolate showed maximum growth at 28^{0}C. The pathogen was found to be gram –ve, small rods and facultative anaerobic. Of the 10 carbon sources tested, the isolate produced acid from glucose, ribose, maltose, glycerol, mannitol, lactose, galactose and sorbitol in aerobic and anaerobic conditions. It did not utilize dulcitol. Of the five host isolates tested *viz. Heliconia*, *Canna*, ginger, turmeric and *Colocasia* under field conditions, none of them were found to be the collateral hosts of the pathogen. But it caused typical soft rot symptoms on potato tubers and carrot under *in vitro*. The pathogen survived in sterilized soil in presence of infected rhizome for 180-185 days. Out of the 240 accessions of banana screened for the resistance to the rhizome rot disease, 11 were found to be susceptible to the disease under natural field condition. The genome AAB (the variety Poppoulu) was highly susceptible. *In vitro* inhibitory effect of antibiotics, fungicides, botanicals and bio agents on the pathogen revealed that, among the fungicides, copper oxychloride 0.4 per cent gave maximum inhibition followed by copper oxychloride (0.3%). Among the antibiotics, Streptocycline 300 ppm and among the botanicals, garlic extract (100 %) were found to be the best ones. Pot culture experiment on the management of the disease showed that, copper oxychloride 0.4% and Streptocycline 300 ppm were the most effective treatments in controlling disease. Garlic extract (100 %) was found to be effective in managing the disease under field conditions, which was on par with *Pseudomonas fluorescens* and bleaching powder treatments.

Bacterial wilt cause by *Ralstonia solanacearum* is one of the serious constraints in the cultivation of **ginger** in Kerala. Conventional grouping of the pathogen into different races and biovars based on morphological and biochemical characters are often time consuming and tedious. **Sambasivan (2003)** made an attempt for molecular characterization of *R. solanacearum* using RAPD and plasmid profile techniques. The isolates of *R. solanacearum* obtained from Palakkad and Ernakulam of Kerala were found to be Gram negative and showed positive reaction for solubility in KOH, nitrate reduction, production of catalase and oxidase enzyme. All isolates utilized lactose, maltose, cellobiose, manitol but not dulcitol and were grouped as biovar III A. Tomato and brinjal were found to be collateral hosts of the pathogen. Based on hypersensitive reaction on capsicum leaves, the isolates were identified as race 3 and was later confirmed by RAPD assay using OPF-8 primer. RAPD analysis using 16 primers showed much diversity among the isolates. Primers OPU 13, OPU 17 and OPX 9 showed cent per cent polymorphism. Dendrogram obtained through cluster analysis showed one major and one sub cluster and all Palakkad isolates were grouped under a single cluster. Plasmid profile developed for the isolates showed presence of two bands of approximately 21 kb size. Plasmids when transformed to *Escherichia.coli* DH 52 cells conferred resistance to Ampicillin and Rifampicin indicating that, the genes encoding resistance to these antibiotics are located on the plasmid.

Anthurium is one of the important commercial cut flower crops of Kerala. Bacterial blight disease is a major constraint affecting the cultivation of anthurium. **Sanju (2009)** studied the role of endophytic antagonists in the management of this disease. The pathogen causing bacterial blight disease was identified as *Xanthomonas axonopodis* pv. *diffenbachiae* based on cultural, morphological and biochemical characters. Symptom appeared as irregular water soaked lesions on leaf margin and lamina, which increased in size and turned dark brown surrounded by prominent yellow halo. On spathe, brownish black lesion with wavy fringed margin were observed and affected spadix turned to black candle like structure. Systemic infection started as water soaked lesion at collar region leading to rotting leaves, later turned yellow and brown and finally the whole plant dried up. Of the 51 endophytes isolated from anthurium collected from various locations of Thrissur, Kannur, Kasargod and Thiruvananthapuram districts of Kerala, only eight bacterial isolates showed effective antagonistic activity against the pathogen. These antagonists varied in their ability to promote plant vigour, HCN, IAA, ammonia, siderophore productions and phosphorus solubilization capacity. All isolates produced IAA and ammonia but only two isolates EB-14 and EB-13 were cyanogenic and four isolates EB-15, EB-31, EB-26 and EB were capable of solubilizing phosphorus. All isolates were compatible with carbendazim, potassium phosphonate and hexaconazole and incompatible with mancozeb, carbendazim + mancozeb and captan. They were also compatible with insecticides *viz.* chlorpyriphos, dimethoate, quinalphos, malathion, monocrotophos, triazophos and with fertilizers like urea, Rajphos, MOP and factomphos. The pathogen was highly sensitive to Streptomycin, mancozeb, captan and turmeric sodium bicarbonate mixture in *in vitro* condition. In pot culture experiment, two pre-inoculation and two post-inoculation spray (5 days interval) with antagonist EB-15, followed by Streptocycline (300 ppm) and EB-31 showed maximum effect. These two isolates were tentatively identified as *Bacillus* sp. (EB-15) and *Pseudomaonas* sp. (EB-31).

MYCOLOGY

Mycology is a branch of science, deals with the study of fungi. The fungi constitute one of the largest group of microorganisms with a number of genera and species.

The moist evergreen forests in the Western Ghats of Kerala with their unique edaphic and agro climatic features are treasure houses of many medicinally important plant species. Intensive cultivation of medicinal plants is widely practiced in Kerala to cater the needs of ayurvedic and other systems of indigenous medicine. Under cultivation, the **medicinal plants** are found to be proned to a variety of diseases and became a problem for the successful cultivation of these plants. **Varma (1991)** made an attempt to study the fungal diseases of certain medicinal plants in Kerala. Samples were collected from three agroclimatic regions of Kerala, *viz* herbal gardens of TBGRI, Palode, College of Horticulture, Vellanikkara and Kottakkal Aryavaidyasala, Kottakkal. A total of 90 diseases on 72 species of selected medicinal plants, caused by 60 species of fungi belonging to 21 genera were recorded. Investigations on fungal diseases of selected medicinal plants revealed that, the fungi exhibited three behavioral patterns *viz.* infection during monsoon, during cool dry and warm dry period and perennial infection. *Alternaria, Cercospora, Cercosporella, Colletotrichum, Corynespora, Curvularia, Drechslera, Leptosphaeria, Myrothecium, Phaeoramularia, Phyllosticta, Pyricularia, Pseudocercospora, Rhizoctonia* and *Stignima* infected their host during monsoon period. *Glomerella, Mycosphaerella, Oidium, Puccinia* and *Uromyces* infected during cool dry and warm dry period and a perennial nature of infection was observed in the case of *Pestalotiopsis*. The morphology and taxonomy of the different fungi infected on the medicinal plants showed that, they belonged to Ascomycetes (three species in three genera), *Basidiomycetes* (three species in two genera), *Deuteromycetes* (53 species in 15 genera) and mycelia sterilia (one species in one genus). Histopathological studies revealed that, the tissues of the necrotic region were without intercellular spaces and there was little differentiation between palisade and spongy parenchyma. The toxic principle in the culture filtrate was thermostable.

Cucurbits are important vegetable crop cultivated extensively in the tropics. They are prone to many diseases. Leaf blight caused by *Alternaria* sp. is a serious problem especially in summer season. A study was undertaken by **Reshmi (2005)** to study variability of *Alternaria* causing leaf blight disease in cucurbits. *Alternaria* isolates obtained from diseased samples of different cucurbits from Vellanikkara and Ellanad revealed variation in symptoms with respect to appearance of concentric zonations in ash gourd, bitter gourd and ivy gourd. *Alternaria* isolates of various hosts from Vellanikkara and Ellanad locations showed variation only in the case of concentric zonation in the culture. All isolates of *Alternaria* sporulated well on PDA medium (2.5 to 4.9×10^5 spores/ml). *Alternaria* isolates from ridge gourd produced maximum spores and ivy gourd produced minimum spores. Variations among the isolates was noticed in the size and branching of conidial chain. Thus the study revealed that, there is variability among different *Alternaria* isolates. The temperature of 25 to 30^0C, pH 6 to 7, full intensity light and alternate light and dark favoured the growth of *Alternaria* isolates. Culture media with starch, KNO_3 and

$MgNO_3$ supported maximum growth of different isolates. All *Alternaria* isolates tested were compatible to each other. Host range studies revealed that, all *Alternaria* isolates produced symptoms on cross- inoculated on cucurbits, amaranthus, cowpea and bhindi.

Oyster mushroom is regarded as one of the commercially important edible mushrooms throughout the world. It grows on agricultural wastes which are rich in cellulose, hemicellulose and lignin. **Julie (2009)** conducted a study to find out the efficiency of different locally available agro wastes in oyster mushroom cultivation and effect of various organic amendments in increasing the yield and nutritional qualities of mushroom. Substrates such as paddy straw, sawdust, banana sheath, arecanut, coir pith, rice husk and the organic amendments like rice bran, neem cake, dry azolla, vermiwash and dry biogas slurry were used for the cultivation of five species of oyster mushrooms *viz. Pleurotus florida, P.sajor-caju, P.eous, P.tuberrgium* and *Hypsizygus ulmarius.* The study revealed that, paddy straw was the best substrate for cultivation of all species of oyster mushroom giving early spawn run, mushroom production and maximum yield. The minimum pest incidence was observed in paddy straw followed by sawdust and among the mushroom species minimum was in *P. tuberregium*. The bacterial population increased with time *ie.*, from spawn run to harvest stage, whereas fungi was maximum during spawn run than harvest stage. Bacterial population was maximum in sawdust during harvesting stage, whereas weed fungi (*Pencillium, Aspergillus* and *Trichoderma*) was maximum in saw dust in the case of *P.florida* and in paddy straw for *P. sajor-caju.* Among the substrates and species, paddy straw and sporophores of *P.florida* recorded highest amount of crude protein. Total carbohydrate content was maximum in mushroom grown on sawdust whereas mushrooms grown on banana sheath showed maximum total free aminoacid. Among the species, *P.sajor-caju* gave higher amount of total carbohydrate and free aminoacid. *P. tuberregium* recorded higher amount of moisture and crude fibre. Nutrient components N, P, Fe, Zn were found maximum in mushrooms grown on paddy straw, where K, Mg and Mn were in those grown on arecanut and rice husk respectively. Sporophores of *P.florida* recorded higher amount of N, P, Mg, Zn and Mn whereas K and Fe contents were high in *P.sajor-caju* and *P.eous* respectively. All organic amendments except dry biogas slurry had superior effect in reducing the time for spawn run and increasing the yield. Maximum yield was obtained with 15% vermiwash followed by 4% dry azolla and *P.sajor-caju* recorded maximum yield followed by *P.eous.* Shelf life studies showed that, mushroom stored under refrigerated condition gave maximum shelf life upto seven days. Mushrooms packed in polypropylene (PP) bags without ventilation, mushroom kept under vacuum packing and mushroom packed in pin pricked PP bags were found to be best treatments with respect to physiological loss in weight (PLW) and decay. Under refrigerated conditions, mushrooms packed in pin pricked PP bag and in PP bags without ventilation were found to have maximum shelf life.

VIROLOGY

Virus is a nucleoprotein, which multiplies only in living cells and has the ability to cause disease. Virus diseases affect most of the economic crops causing reduction in yield and quality of produce.

Pumpkin, an important vegetable crop cultivated in Kerala for its mature and immature fruits which are rich sources of carotene, the precursor of Vitamin A. Though a number of diseases are reported to affect the crop, viral diseases are known to cause severe loss, of which pumpkin mosaic is the most serious one. Many medicinal plant extracts are known to induce resistance in host plants against viruses as they possess antiviral and insecticidal properties thereby, prevent the spread of vector borne viral diseases. Hence an investigation was carried out by **Vimi (1994)** to screen 30 species of plants for their antiviral properties against pumpkin mosaic virus and the promising ones were tested at different concentration at different times of application for their effect on vector transmission. Out of 30 medicinal plants tested against *Pumpkin Mosaic Virus* (PMV), eight plants showed more than 80 per cent inhibition of infection. Among the eight, five medicinal plants which showed high inhibition were selected for further studies. When the systemic effect of medicinal plants were tested against PMV, extracts of *Basella alba* showed maximum effect (88.09%) followed by *Glycyrrhiza glabra* (78.57%). All the five selected medicinal plants were capable of decreasing the percentage of transmission of PMV by *Aphis gossypii*. Plant extracts of *Phyllanthus fraternus* and *Plumbago rosea* showed maximum reduction in per cent transmission of PMV when inoculated before acquisition and inoculation feeding of the vector respectively. Plant extracts showed more inhibition with mechanical transmission and the spread of disease was not random but was more or less concentrated around initially infected plants.

Cassava mosaic virus is a serious problem for the cultivation of tapioca in Kerala. Use of resistant variety is the cheapest method to tackle this disease. A varietal evaluation study was conducted during 1991-94 as a KAU project to find out a resistant source. 108 cassava lines/ types available in NBPGR were evaluated for resistance to mosaic disease under field condition during 1991-92. Of these, 11 were found completely free from mosaic. These lines were then subjected to artificial inoculation. Two lines, Malanthari (No.5) and Karuthakattan (No.82) were found immune to the disease by grafting method and in Blackkattan (No.4), infection was very late and was observed 71 days after inoculation. In bombardment method, disease appeared only in Ethakkakamban (No. 91) and Ethakkapurukkan (No.93). In Ethakkapurukkan, disease appeared very late (117 days after planting) and also in very mild form. In white fly transmission, no lines showed infection whereas susceptible check showed mosaic symptoms. During the field evaluation of 135 lines in 1993-94 at NBPGR, in 11 lines selected from earlier screening 2six lines (2,5,57,61,82,49) were free of disease, but lines 4,68,91,93,99 were found susceptible during this period. In addition, lines 163,174,140 were also free of disease and lines 141,142 were found resistant. Nineteen lines selected from first and second evaluations were again screened for mosaic resistance at College of Horticulture, From the final evaluation, cassava lines-2 (Pathinettu- Uduvoorkkara), 5 (Malanthari-Uduvoorkkara), 42 (Rottikkappa-Mala) 49 (Aramaram kappa – Vellanikkara), 57 (Ornamental – Mysore), 80 (Ramanthala – Piravam) and line 163, were found resistant to cassava mosaic virus disease (**Sally 1993**).

Little leaf of **black pepper** was first observed in 1975 in Pulpally (Wayanad) and Neriyamangalam (Ernakulam). It is commonly known by the name, '*Kathi*' means knife because of the characteristic symptoms exhibited on leaves. Infected leaves were chlorotic, distorted, curled downward and brittle with wire net veinlets. Internodal length was reduced giving a bushy appearance. Infected plants had poor root system with brown discoloration. Flowers were less and mainly aborted. Plants at all age groups were infected, but the intensity increased with the age. Karimunda was highly susceptible to the disease while Arakukkulammunda, Aimpiriyan and Vellanamban showed less infection. Panniyur-I was comparatively tolerant to the disease. Application of zinc sulphate did not show remission of symptoms. Staining using 0.2% Diene's stain indicated the presence of mycoplasma like organism (MLO) in phloem tissues. The disease was not transmitted through sap or dodder, but found transmitted through cuttings and grafting. Insects, *Austroagallia* sp. and *Manderabeta* were found constantly associated with diseased plants, but transmission studies using these insects and thrips, *Liothrips karnyi,* were not successful. Remission of the symptom was observed with oxytetracycline hydrochloride at concentration of 500 ppm and above, but was phytotoxic at more than 750 ppm. Applications of tetracycline by soil drenching, foliar spray, dipping of cuttings and wick feeding were effective. However, wick feeding was found to be the best one, as the symptoms did not reappear even after two years, whereas in all other methods, symptom remission lasted for less than six months. Considerable yield loss was also observed due to this disease **(Sreekumari 1995).**

Banana bunchy top disease (BBTV) is the most serious threat to banana cultivation in Kerala. Infected suckers are the primary source of inoculum and the secondary spread of disease is through the aphid, *Pentalonia nigronervosa*. Early detection of the virus in the planting material will check the spread of the disease. **Estellita (1998)** had undertaken a study on banana bunchy top virus with prime importance to serodiagnosis. A survey conducted in Thrissur district revealed that, the disease incidence and aphid population varied with seasons and maximum incidence was during August to November. The virus was not mechanically transmitted and tissue culture plants were more susceptible to aphid transmission. The study also revealed that *Canna, Colocasia* and *Hedychium* plants are neither collateral hosts nor symptomless carriers of BBTV. Virus vector relationship studies showed that, BBTV was transmitted in a persistent manner by *P. nigronervosa* and both adults and nymphs were able to transmit the virus and the adults were found to be the effective vectors. Among the different portions of the banana plants used for purification studies, the mid ribs of younger leaves yielded high concentration of virus and the tissue culture plants yielded more concentrations than other planting materials. Electron microscopy of the purified BBTV preparation revealed isometric particle of 18-22 nm size. Antiserum of BBTV was tested with virus specific antigens in different plant parts (midrib, petiole, leaf sheath and rhizome) by chloroplast agglutination, agar gel diffusion, tube precipitin and ELISA methods. Among these, ELISA was found to be highly sensitive for identification of the virus. Nucleic acids extracted from both healthy and infected samples were compared. The bands obtained were sensitive to DNase 1 and SI nuclease but not to RNase A confirming that, the nucleic acid of BBTV is SS DNA. SDS-PAGE analysis of BBTV coat protein revealed that, it contained a major protein component of Mr 21000 with RF value between that of β - lactoglobulin (Mr 18400) and α chymotrypsinogen (Mr 25700).

Cucurbits, the popular summer crop vegetable are attacked by different types of viruses belonging to cucumo , poty and tobamo virus groups. All these viruses produce varied types of mosaic symptoms resulting in considerable yield loss. Pumpkin, popularly known as 'Mathan' in Kerala is an important cucurbitaceous vegetable, cultivated extensively in summer rice fallows and in garden lands. Major mosaic diseases of pumpkin are yellow vein mosaic, cucumber mosaic, bottle gourd mosaic and pumpkin mosaic. Of these *Pumpkin Mosaic Viruses* (PMV) occur in severe form wherever the crop is cultivated. Climatic factors prevailing in Kerala helps to build up the vector population and faster spread of the disease. A study was undertaken by **Vimi (2003)** to study the antiviral principles of certain medicinal plants against PMV. In addition, symptoms, etiology, transmission, host range, serology and electron microscopy of PMV were also studied. Symptoms appeared as typical mosaic mottling with light green and dark green patches, vein banding and deformation of leaves. Reduction in flowering and fruiting were also noticed. Fruits were smaller and often malformed. PMV was found transmitted through sap (85-90%) and through vector *Aphis gosypii* (60-65%). Host range studies recorded its systemic infection on watermelon, snake gourd, bitter gourd, winter squash (cucurbitaceae), chilli and Datura (solanaceae) soybean and cowpea (fabaceae) and papaya (caricaceae). Bottlegourd and ridgegourd were the symptomless carriers of the virus. Electron microscopic studies showed that, PMV particles were flexuous elongated rods of 700-800 x11 nm in size. Serodiagnostic Ouchterlony's double diffusion tests by DAC - ELISA revealed the relationship of PMV with poty viruses infecting snakegourd, wild ashgourd, cowpea, soybean, chilli and papaya. Based on the symptomatology, particle morphology and host range studies it was confirmed that the isolate of PMV is a strain of *Water Melon Mosaic Virus* (WMV). Biochemical analysis of PMV infected plants showed reduction in protein, phenol levels, catalase and PAL activities. An increase in case of chlorophyll content and peroxidase activity were also noticed. Inhibitory properties of five medicinal plants *viz. Basella alba* (leaf), *Glycyrrhiza glabra* (dried stem), *Phyllanthus fraternus* (whole plant), *Plumbago rosea* (root) and *Thespesia populnea* (leaf) was studied against PMV by extracting with different solvents *viz.* chloroform, ethyl acetate, petroleum ether and distilled water at concentrations of 1,2,5 and 10 per cent. Chloroform was found to be suitable for extracting PMV inhibitory principle of *B.alba, G.glabra, P.fraternus* and *P.rosea*. Distilled water was effective for all plants except *B.alba*, ethyl acetate for all plants except *P.rosea* whereas, petroleum ether was effective only for *P.fraternus*. Effect of various concentrations of medicinal plant extracts revealed that, higher dilution (2%) have more inhibitory effect than lower dilutions in the case of chloroform extract of *B. alba, G. glabra, P. fraternus and P. rosea* ethylene extract of *G. glabra, T. populnea,* distilled water extract of *P. rosea, P. fraternus* and petroleum ether extract of *P. fraternus*. Lower dilutions (1%) showed more inhibitory effects in the case of ethylene extract of *B. alba* and *P. fraternus* , distilled water extract of G. *glabra, P. fraternus* and *T. populnea*. The high inhibitory property of one per cent distilled water extract of *P. rosea* found out from the study had practical importance because of the easiness in preparation of the extract. Effect of different plant parts extract on PMV inhibitory property of *P. rosea* revealed high inhibitory effect at temperatures of 30°-70°C & 30°- 80°C by roots and mature leaf extracts respectively. Extract of mature stem showed this effect at 30°- 40°C and tender leaf and stem at 60°-70°C. Studies on the effect of *P. rosea* extract on vector transmission showed that, application of extract before inoculation was more effective than before acquisition and the effect was decreased with increase in time interval between spray and the inoculation. The inhibitory effect of one per cent water extract was tested on artificially inoculated healthy pumpkin seedlings at weekly, monthly and bimonthly by single application. Weekly spray was effective to reduce disease severity of artificially inoculated and naturally infected pumpkin seedlings. Delayed symptom expression and enhanced yield in infected plants were also observed after weekly spray of the extract. Enzyme, protein, chlorophyll and phenol estimation revealed that, spray of *P. rosea* extract favoured the resistance and thereby suppressed symptoms. DAC - ELISA of infected samples showed lower concentration of virus in *P. rosea* treated plants.

Bittergourd is the most important cucurbitaceous vegetable in Kerala. Among the various diseases affecting the crop, virus diseases are important especially distortion mosaic which causes severe crop loss. **Reeny (2006)** made an attempt to study about the transmission, identification and management of *Bittergourd Distortion Mosaic Virus* (BGDMV). Transmission studies showed that this virus was not transmitted through seed and sap. However the infected seeds produced pale, lanky and non-vigorous seedlings. Common symptoms observed were stunting of the plant, light and dark green mosaic pattern, curling, crinkling, distortion of leaves, reduction in number of flowers and fruits and reduction in fruit size. The virus was found transmitted only through white fly, *Bemisia tabaci*. Minimum acquisition and inoculation feeding periods for the transmission of BGDMV were found to be 15 min. Average incubation period of BGDMV in the host was 14 days and was found to decrease with increase in acquisition and inoculation feeding and number of viruliferous insects. A single viruliferous whitefly was capable of giving 33 per cent transmission and cent per cent was obtained with 10 numbers. Other cucurbitaceous plants were not collateral hosts of this virus. Electron microscopic observations showed monomers of size 18nm diameter and geminate particles of size 18 – 20 x 30 nm and flexous rod shaped particles of size 750 nm indicating mixed infection of gemini and poty viruses. Serological tests showed close relation to *Squash leaf curl virus* and was negative to Indian *Cassava Mosaic Virus*. Based on these, the virus was identified belonging to genus *Begomovirus* of family Germiniviridae. Management studies revealed that, application of imidachloprid (0.025%) was effective in reducing infection followed by 1% coconut vinegar. In addition, homeopathic drugs, *Apis melliphica* 30 potency and *Arsenicum album* 30 potency also showed some effectiveness in reducing the infection and thereby increasing the yield. Studies on weather parameters showed that, maximum temperature of 31-35°C and RH of 75-90% favoured the disease incidence.

Banana the crop of global importance is infected by several viral diseases, among which, banana streak disease is a serious threat to its productivity. Detailed studies were carried out by **Divya (2011)** on the symptomatology, transmission, molecular based virus indexing and the sources of resistance against this disease. Symptomatology of *Banana Streak Virus* (BSV) infection was studied on varieties Mysore poovan (AAB), Mottappoovan (AAB), Kalibale (AAB), Nendran (AAB) and Chandrabale (AAB). Symptoms were observed on leaf lamina, midrib, pseudostem and bunches. Discontinuous or continuous linear small chlorotic streaks were developed on leaf lamina which later turned necrotic, blackened and running parallel to leaf axis from midrib to leaf margin. Linear mosaic patterns were developed on older leaves. In advanced cases, necrosis on the cigar leaf caused death of the plant. Dark brown linear lesions were developed on other parts of the plant. Infected plants produced small sized bunches with distorted fingers or failed to produce any bunches. A significant correlation was observed between symptom expression and with rainfall and temperature. Disease incidence was more in the months of June- December and less during January- May. The field gene bank of 290 accessions at BRS, Kannara was screened at monthly intervals from planting till harvest for the natural occurrence of the disease. Out of these, 283 accessions were free of BSV, whereas disease incidence was recorded on seven accessions *viz.* Mottappoovan (AAB), Mysore poovan (AAB), Kalibale (AAB), Chandrabale (AAB), Chinali (AAB), Nendran (AAB) and FHIA -3 (AAAB) and the per cent incidence ranged from 13.25 to 32.16. Transmission studies of BSV proved that, it was transmitted by *Dysmicoccus brevipes* and *Ferrisia virgata* while root mealy bug *Geococcus* sp and banana aphid, *Pentalonia nigronervosa,* were nonvectors of BSV. It was also naturally transmitted through planting materials and was not transmitted mechanically or through soil. Studies on the vector-virus relationship revealed that, maximum acquisition feeding period, pre- acquisition fasting and inoculation access periods were three days, one hour and seven hours respectively for the successful transmission of the virus. Nymphs were more efficient than adults and minimum of 30 nymphs were required for effective transmission of BSV. Plants inoculated with *Dysmicoccus brevipes* produced symptoms four weeks after inoculation while *Ferrisia virgata* took six weeks for symptom expression. Electron microscopic studies on the morphology of BSV showed typical bacilliform particles of size 130-150nm. Molecular diagnosis of BSV using polymerase chain reaction (PCR) from infected samples was standardized using specific primers, at an annealing temperature of 59°C. Immunocapture (IC) – PCR of BSV infected samples were also standardized using antiserum of BSV. By IC-PCR, detection of episomal virus infection could be done directly from the crude sap, without DNA isolation. This study would be useful for early detection of BSV infected plants and would be helpful in a long way to distribute healthy suckers and tissue culture plants to the farming community.

MICROBIOLOGY

Microbiology is a branch of biology which deals with the study of microorganisms which include beneficial as well as harmful ones. The soil microorganisms are mainly involved in nutrient transformation process, decomposition of resistant components of plant and animal tissues and management of plant diseases through microbial antagonism. Some soil bacteria and fungi form symbiotic relationships with plant roots that provide important nutrients like nitrogen or phosphorus. Fungi can colonize plants and provide many benefits, including drought tolerance, resistance to pest and diseases. Hence, there is a need to utilize and exploit the beneficial microorganisms for the benefit of plants.

Sunitha (1992) studied the associative effect of *Azospirillum* and *Bradyrhizobium* on nodulation and growth of **cowpea** variety, Pusa Komal. Of the 25 *Azospirillum* isolates obtained from different types of soil of various locations in Kerala, four isolates A-9, A-10, A-11 and A-20 isolated from laterite soils of Thrissur were found promising with respect to biometric characters and nitrogen contents in inoculated plants. Commercial *Bradyrhizobium* cultures B-1 and B-2, isolated from laterite soil of Thrissur were used for the interactive studies. Interaction of *Azospirillum* and *Bradyrhizobum* had significant effect only on the number of nodules of cowpea. Combined inoculation with *Azospirillum* inhibited the nodulation by *Bradyrhizobium* isolate B-1, whereas it enhanced the nodulation by B-2. Among the different combinations, A-10 + B-2 combination showed maximum number of nodules and nitrogen content of cowpea. Plants inoculated with A-9+B-1, A-10+ B-1 and A-9+B-2 combinations had better shoot, fresh and dry weight, where as those inoculated with A-10+B-2, A-11+B-2 and A-20+ B-2 had better root (fresh and dry) weight. *In vitro* study of pH tolerance revealed that the optimum growth of *Azospirillum* and *Bradyrhizobium* isolates were 7.5 and 6.5 respectively.

The use of plant protection chemicals are the integral part of modern agriculture for the control of pest and diseases. Though it helps to protect the crop, plant protection chemicals enter the soil ecosystem and affects the non-target organisms, especially beneficial microorganisms. The beneficial microorganisms in soil includes biofertilizers, biocontrol agents and PGPR which not only improve the plant growth but also manage diseases. The application of plant protection chemicals will affect this beneficial microflora which ultimately affects the plant growth in the long term. **Cowpea**, an important crop of Kerala is immensely benefited by *Bradyrhizobium* and *Azospirillum*. Hence, a study was undertaken by **Raji (1995)** to determine the effect of selected plant protection chemicals at recommended doses on these beneficial microflora inhabiting cowpea rhizosphere. Under field condition *Azospirillum* and *Bradyrhizobium* were tolerant to three insecticides *viz.* carbofuran, phorate and HCN even at their highest doses tested. Among the fungicides tested *in vitro*, carbendazim showed no inhibition of both bacteria. Thiram was inhibitory to both *Azospirillum* and *Bradyrhizobium*. Bordeaux mixture and Fytolan were not inhibitory to *Azospirillum* but inhibited the growth of *Bradyrhizobium*. The combination of fungicides and insecticides were tested and it was observed that the combination of all insecticides with carbendazim did not show inhibition of *Azospirillum* and *Bradyrhizobium*. In the field experiment, Thiram caused a slight reduction in rhizosphere population of *Azospirillum* immediately after the application but later on, an increase in *Azospirillum* population was noticed. The combination of all fungicides with all insecticides showed no reduction in *Azospirillum* population except in the combination of all insecticides with the fungicide, Thiram.

Cowpea, one of the most important legumes, used both as vegetable and grain is well established in fixing atmospheric nitrogen by cowpea- *Rhizobium* symbiosis. Hence, a study was conducted by **Asha (1997)** to utilize the beneficial effects of phylloplane application of *Bradyrhizobium* instead of soil inoculation so as to bypass the acidity problem of Kerala. A pot culture experiment was conducted to find out the most suitable method of application for the best performance in terms of foliar nitrogen fixation. It was observed that, soil inoculation of *Bradyrhizobium* was suppressive than foliar application, however foliar application also showed better performance over control plants in improving the number of leaves, dry weight of roots, chlorophyll and nitrogen contents of the plant. The promising isolate was KAU isolate followed by CB – 756 (I_{14}). Hence, foliar application of *Bradyrhizobium* can also be resorted to improving the performance of cowpea plants instead of seed or soil inoculation.

Cowpea is an important legume vegetable cultivated in Kerala which enrich the soil fertility by fixing atmospheric nitrogen. Vesicular arbuscular mycorrhiza (VAM) is already proved to enhance the absorption of nutrients like P and many micro nutrients. The symbiotic activity of *Bradyrhizobium* is well established in fixing elemental nitrogen. Therefore, an ecofriendly crop cultivation practices with low cost inputs will help to reduce the use of chemical fertilizers. Hence, the study was undertaken by **Beena (1999)** on the interaction between VAM and *Bradyrhizobium* in cowpea. VAM colonization was found more in lateral roots than tap root and the predominant one was *Glomus* sp. VAM colonization and spore count were more during rainy season compared to summer. Nodule formation and VAM colonization in the roots of inoculated plants were observed 10 days after sowing (DAS) and reached peak at 40 DAS. Electron microscopy of VAM revealed two types of fungal penetrations into the roots, which showed the terminal attachment of oval shaped vesicles and highly branched arbuscules with short twisted branches with bulged tips in the root cortex, and the study of the nodules showed that, the nodule surface was free of VAM hypha, but present in the inner tissues of nodules. The dual inoculation was found to have synergistic effect on nodulation and VAM colonization. In pot culture experiment, dual inoculation of VAM and *Bradyrhizobium* enhanced the biometric characters like number of leaves, fresh and dry weight of plants, number of nodules and fresh weight of nodules. It also improved the level of nitrogen, phosphorus, magnesium, calcium, zinc and manganese nutrients in cowpea. Dual inoculation along with ½ N + P + K increased the soil nitrogen to the maximum but had no influence in phosphorus content. The result of the field experiment revealed that the treatment of VAM + *Bradyrhizobium* with ½ N + ½ P + K was the best treatment for improving the biometric characters, yield and the nutrient status of the plants and this treatment reduced nitrogen and phosphorus fertilizers to half of the recommended dose.

Biofertilizers have emerged as a promising component of integrated nutrient supply system. Biofertilizers are not only cost effective but improves and maintain soil fertility. *Azospirillum* and VA mycorrhiza are very prominent and efficient biofertilizers for many crops. **Cocoa** is a cross pollinated crop and high yielding disease tolerant type was multiplied by clonal propagation using budding. Budding is done on 4-6 months old root stock of cocoa but the establishment of cocoa seedlings needs more time. Early maturity of root stock seedlings can be enhanced by the application of *Azospirillum* and VA mycorrhiza, thereby reduce the cost of production and time required for production of budded plants. Hence, **Sunitha (2001)** had undertaken a study to find the effectiveness of *Azospirillum* and VA mycorrhiza on the growth and seedling blight disease of cocoa. *Azospirillum* and VA mycorrhiza were isolated from rhizosphere soil of cocoa plantation at Vellanikkara. The native *Azospirillum* isolate (A_1) and native mycorrhizal isolate (M_1) were superior in improving the biomass and nutrient contents in cocoa plants. Dual inoculation of *Azospirillum* and mycorrhiza showed maximum reduction in seedling blight severity (0.77) which was better than the fungicide, potassium phosphonate 0.3% application.

The possibility of using VAM fungi for increasing crop production has received considerable attention. It plays both the roles of biofertilizer and biocontrol agent. **Raji (2002)** conducted a study to find out the influence of VAM for improving nutrient uptake, growth, yield and to reduce bacterial wilt in **tomato**. The survey conducted on the natural occurrence of VAM association in tomato in 15 locations of Thrissur, Palakkad, Malappuram, Wayanad, Kannur and Kasargode districts revealed, variation in VAM colonization and rhizosphere spore count among the locations and the predominant one was *Glomus* sp. Of the 15 native isolates and four standard cultures screened, isolate from Eruthempathi of Palakkad District, Kerala was found to be the best in improving nutrient uptake, particularly P, K and Ca and increasing root colonization, spore count, shoot and root biomass and yield. It also induced seven day early flowering and increased ascorbic acid content of the fruits in tomato variety, Sakthi. In pot and field experiments, the plants inoculated with VAM recorded highest root colonization and rhizosphere spore count as compared to uninoculated ones and the variety Sakthi showed the highest colonization followed by BWR-1 and Pusa Ruby.The treatments consisting of VAM + FYM + N+ 50 % superphosphate + K and VAM + FYM+ N + 75 % mussorie rock phosphate were significantly superior as compared to PoP recommendation of KAU, which indicated that VAM applications could substitute the phosphorus fertilizer to the extent of 50 per cent and 25 per cent of the recommended dose as super phosphate and mussorie rock phosphate respectively. Application of the isolate from Eruthempathi also showed appreciable reduction in bacterial wilt incidence.

Plant growth promoting rhizobacteria **(PGPR)** play a major role in modern ecofriendly agriculture as it reduces disease severity and enhances growth and yield of many crops. **Beethi (2007)** studied the compatibility aspects of PGPR *viz. Azospirillum, Pseudomonas fluorescens* and *Bacillus subtilis* with commonly used agrochemicals such as fungicides (mancozeb, carbendazim, metalaxyl, copper oxychloride, tridemorph), insecticides (lindane, chlorpyriphos, carbaryl, lamda cyhalothrin, imidachloprid) and herbicides (glyphosate, 2,4-D, butachlor, pretilachlor, paraquat). The studies revealed that, copper oxychloride was most deleterious·to the growth of *Azospirillum* sp and *P. fluorescens* and tridemorph on *B. subtilis* under *in vitro* condition. In combination studies, mancozeb with all above herbicides and insecticides inhibited the growth of *Azospirillum*. The combination of all fungicides with paraquat, copper oxychloride with carbaryl and carbaryl with paraquat were highly inhibitory to *B. subtilis*. It is also observed that, the fungicide carbendazim, all insecticides and herbicides except carbaryl and paraquat were least inhibitory to all the test organisms at their recommended doses. Combination of carbendazim with all insecticides and herbicides also showed less inhibition of PGPR. Combination of lindane, lamda cyhalothrin and chlorpyriphos with herbicide 2, 4-D were least inhibitory to the growth of these beneficial rhizobacteria. Evaluation of carbendazim, chlorpyriphos and 2, 4-D against PGPR in pot culture experiments showed that, these chemicals affected the bacterial population immediately after the application to soil and a decreasing trend was noticed with advancing plant growth. The same trend was noticed in case of PGPR application alone. All treatments significantly influenced the growth parameters of rice plants and PGPR applied in combinations with chlorpyriphos was the best one, however, the panicle weight and nutrient contents were maximum with the treatment of PGPR alone.

Biosurfactants (BS) or the surface active compounds produced by microorganisms have wide range of applications in agriculture and industries. Their properties of interests are (i) changing surface and interfacial tensions (ii) wetting, penetrating and spreading actions (iii) hydrophobicity and hydrophilicity actions (iv) growth enhancement and (v) anti microbial actions. Biosurfactant producing bacteria are also known as efficient degraders of pesticides. Out of the 92 heterotrophic bacteria isolated from different hydrocarbon contaminated fields *viz.* forest lands, automobile spill-overs, ayurveda nursing homes and pesticide contaminated fields, 60 were biosurfactant (BS) bacteria which were selected based on drop collapse and xylene spray assays **(Remya, 2007)**. Per cent biosurfactant bacterial population was maximum in fungicide contaminated plots (45.4%) followed by forest soils of Peechi and Wayanad (37.5%). Of the 60 BS bacterial isolates, eight promising ones were identified as KCC-2 (*Pseudomonas* sp.), MCC-2 (*Pseudomonas* sp.), KFS-1 (*Pseudomonas* sp.), KFN-2 (*Pseudomonas* sp.), DTSC-3 (*Pseudomonas* sp.), DTSC-5 (*Pseudomonas* sp.), MCN-3 (*Geobacillus kaustophilus* – MTCC-8517) and PFC-4 (*Pseudomonas fluorescens* – MTCC-8518). Estimation of BS production revealed that the isolate KFS-1 (*Pseudomonas* sp.) from Peechi forest soil recorded maximum BS production (7.95 g/L) followed by the isolate from pesticide contaminated plot (6.45 g/L). All the eight isolates recorded good xylene emulsification property, and reduced tension of the various liquids tested. Optimum nutritional and cultural conditions for maximum BS production varied depending on the bacterial isolates. Pesticide degradation studies revealed that bacterial isolate KFS-1 (*Pseudomonas* sp.) from forest soil caused 71.29 per cent degradation of chlorpyriphos, whereas the isolate DTSC-3 (*Pseudomonas* sp.) reduced mancozeb concentration upto 28.4 per cent over control. It also showed good antimicrobial action against the pathogen *Phytophthora capsici* (55.5% inhibition). The bacterial isolate MCN-3 (*Geobacillus kaustophulus)* from pesticide contaminated soil showed maximum inhibition (66.3%) of *Rhizoctonia solani* followed by 52.2 per cent inhibition of *P. capsici*. All the eight BS bacterial isolates were compatible with *Trichoderma harzianum, T. viride* and *P. fluorescens*. They also enhanced seed germination and vigour of sorghum seedlings.

Plant growth promoting microorganisms (PGPM) are abundant in the rhizosphere region of the crop. They enhance plant growth, induce systemic resistance against pathogen and also control soil borne pathogens. **Dhanya (2007)** studied the consortial effect of PGPM on growth enhancement of **vanilla**. Selected PGPM like *Pseudomonas sp. Bacillus sp.* and *Trichoderma* sp. isolated from the soils of various locations of Thrissur and Wayanad districts of Kerala were evaluated for its efficiency in production of IAA and salicylic acid. *Pseudomonas sp.* was found to be the most effective one. All isolates of *Pseudomonas* sp., *Bacillus* sp., *Trichoderma* sp. were mutually compatible under *in vitro* condition and screening for their effectiveness in growth promotion of vanilla cuttings, indicated that individual treatment especially *Bacillus sp.* was better than consortial treatment with respect to various biometric characters of vanilla cuttings in nursery. Among these, *Bacillus subtilis* (Chengaloor) was found to be the most efficient one.

One of the important applications of plant biotechnology is its use in the micro propagation of plants. It is being applied for large-scale production of quality planting material. However, one of the major constraints to the success of micropropagation of horticultural crops is the acclimatization phase or during transfers to the field condition. This is mainly due to some physiological features, which are characteristic of *in vitro* derived plantlets. Among various spices cultivated in Kerala, vanilla and ginger are the two important spices with an export potential. The tissue cultured vanilla and ginger plants have constraints in the hardening and *ex vitro* establishment with several problems particularly low plant- out success. The plant growth promoting microorganisms **(PGPM)** are abundant in the rhizosphere region, which produce various growth promoting substances which promotes the growth of roots, absorbs sufficient nutrients and increase the activity of beneficial organisms in the rhizosphere. Moreover, it has been well established that the mixtures/consortia of PGPM are known to have a better effect on the plants than individuals as the consortia broaden the spectrum of combination of various mechanisms to increase the plant growth. Hence, a study was conducted during 2005 – 2008 as a part of Kerala State Council for Science, Technology and Environment (KSCSTE) project to find out the most effective PGPM consortia and optimum dosage for the growth and establishment of micropropagated vanilla and ginger under field conditions **(Surendra Gopal, 2008)**. A survey was conducted in five districts each for vanilla (Thrissur, Ernakulam, Wyanad, Idukki and Kottayam) and ginger (Thrissur, Ernakulam,Wyanad, Idukki, Palakkad) and the rhizosphere soils were collected from these locations. A total of 66 PGPM isolates from vanilla and 83 isolates from ginger were isolated from rhizosphere soil. The predominant isolates of *Bacillus* spp., Fluorescent pseudomonads, *Azotobactor* spp., *Azospirillum* spp., *Trichoderma* spp. and arbuscular mycorrhizal fungi (ginger) were identified. The orchid mycorrhiza was not detected in the roots of vanilla. The selected isolates of vanilla and ginger were screened separately for efficiency and mutual compatibility, selection of suitable carrier material for mass production, optimization of inoculum dosage. Based on the compatibility studies under *in vitro* conditions, the three most compatible PGPM isolates of vanilla were AZB_{11} (*Azotobacter*) x FP_{13} (Fluorescent pseudomonads), B_2 (*Bacillus* spp.) x Tr_{14} (*Trichoderma* spp.) and Tr_{14} (*Trichoderma* spp.) x Tr_{12} (*Trichoderma* spp.). Three most compatible PGPM isolates of ginger were *Bacillus* spp. + Fluorescent pseudomonads, Fluorescent pseudomonads + *Trichoderma* sp. and *Trichoderma* sp. + *Trichoderma* sp. Under field evaluation trial for *ex-vitro* establishment, consortia of *Azotobacter* spp. (Valathala) + Fluorescent Pseudomonads from (Ettumannur) and *Bacillus* sp. (Kolavayal) + Fluorescent pseudomonads (Ambalavayal) were found to be the most efficient PGPM consortia for the growth and establishment of micropropagated vanilla and ginger respectively. These results indicated variation in the efficiency of isolates depending on the location from which it is isolated. Hence, there is a need to identify suitable PGPM for different crops of Kerala.

The cucurbits such as **ivy gourd and bitter gourd** are important vegetable crops of Kerala. As these are directly consumed vegetables, the use of agrochemicals will have adverse effect on the human health due to residual problem. Moreover, the application of chemical fertilizers will be expensive and it will also cause soil and water pollution. In order to overcome these problems, biofertilizers can be used which are living organisms containing strains of specific microorganisms and enhances nutrient uptake by plants and provide physical barriers against pathogens to improve the overall growth of plants. *Azospirillum* and phosphate solubilizing bacteria (PSB) are two popular biofertilizers in Kerala. Hence, a KAU project was undertaken during 2005 – 2008, to screen the isolates of *Azospirillum* and PSB for its efficiency in nitrogen fixation and P solubilization respectively under *in vitro* condition and pot culture experiment. *Azospirillum* sp and phosphate solubilising bacteria / fungus were isolated from ivy gourd and bitter gourd growing areas of Thrissur district. The isolates of *Azospirillum* and PSB were screened for its efficiency in nitrogen fixation and P solubilization respectively under *in vitro* condition. The most promising isolates of each were evaluated for growth enhancement of ivy gourd and bitter gourd under pot culture condition. Based on the various biometric parameters, PSB-3 (Phosphate solubilising bacteria from Payannam-I) and CASP-13 (*Azospirillum* sp. from Payannam -I) were found to be the most promising isolates for enhancing the growth of Ivy gourd. However, PSB-12 (Phosphate solubilizing bacteria from Vellanikkara) and PSF-2 (Phosphate solubilizing bacteria from Malamukku) were found to be the most promising isolates of phosphate solubilisers for bitter gourd. Among the *Azospirillum* isolates, BASP 7 (Payannam I) and BASP 20 (Chuvannamannu) were found to be most efficient isolates in enhancing the growth of bitter gourd (**Surendra Gopal 2009**)

Arbuscular mycorrhizal fugai **(AMF)** symbiosis is considered to be the most important terrestrial symbiosis that help the majority of plants by increasing growth and yield, and confer resistance against biotic and abiotic stresses. Hence, the use of these plant-beneficial symbionts in agro-environments is of high environmental relevance and economic value. A KAU project was conducted during 2003 – 2009, to determine a suitable AMF cultures for ivy gourd and bitter gourd. AMF isolates obtained from ivy gourd and bitter gourd growing areas of Thrissur district were purified, mass-multiplied and screened for efficiency in enhancing the growth of ivy gourd and bitter gourd under pot-culture studies. The studies on the efficiency of AMF cultures on growth of ivy gourd and bitter gourd revealed that, AMF-2 (Payannam –II isolate) was the most promising isolate for enhancing the growth of ivy gourd and AMF-3 (Malamukku isolate) for bitter gourd (**Surendra Gopal 2009**)

SEED PATHOLOGY

The science dealing with the interactive relation between the seed and the disease causing agents is 'Seed Pathology'. Seeds are the most important means of perpetuation of plant pathogenic fungi. The fungi affect seed germination, by making it nutritionally poor thereby lowering the viability or by secreting certain mycotoxic substances deleterious to seed.

Black pepper (*Piper nigrum* L) known as the "King of Spices" occupies the most important place in world spice trade and accounts for nearly 35-40 crores of foreign exchange annually. Like other agricultural products, pepper is also affected by microorganisms before and after harvest which deteriorate the quality of the product. Hence a study was undertaken by **Estellita (1982)** to estimate the deterioration of quality of stored black pepper in terms of oleoresin, piperine and starch contents due to microbial infection and assessing the role of microorganisms in changing the quality of the product. It was observed that, fungal microorganisms like *Aspergillus niger, A. candidus, A. nidulans, A. versicolor, Curvularia lunata, Penicillium citrinum, Fusarium moniliforme, Rhizopus nigricans* and Gram negative bacteria were found associated with all grades of black pepper in all seasons. There was no growth of microflora upto 66.8 per cent RH, whereas profused growth was observed at saturation level of humidity. Oleoresin, piperine and starch content reduced considerably when the samples were inoculated with different microorganisms at different levels of humidity.

Seed borne fungi constituted the main group of pathogen which reduce the viability of seeds. In a study on association of mycoflora with **bittergourd, pumpkin and cucumber** seeds, maximum fungal population was observed on seed coat and in endosperm and least in embryo. The predominant externally seed borne fungi were *Aspergillus* sp., *Penicillium* sp. and *Rhizopus stolonifer* and internally predominant ones were *Fusarium solani, A. flavus* and *R. stolonifer.* Humidity level of 66.8 per cent supported longer storage period and storage at 82.9 per cent above was not suitable as none of the seeds showed germination. Among the seed dressing fungicides, thiride, methoxy ethyl mercuric chloride (Emisan) and captafol showed maximum viability of seeds after storage of 12 months **(Saleena, 1990)**.

Ambika (1991) conducted a study on association of mycoflora with **cowpea, *Dolichos* bean and bhindi** seeds, which revealed that, fungal population was maximum on seed coat as compared to endosperm and embryo. Maximum inhibition in seed germination was caused by *Aspergillus flavus, A. fumigatus, A. niger* in cowpea, *Botryodiplodia* sp in *Dolichos* bean and *Fusarium solani* and *Syncephalastrum racemosum* in bhindi. Even after a storage of 12 months, *A. flavus, F. oxysporum* and *Rhizopus* sp. were found associated with all seeds. In addition, *Chaetomium brasiliense* and *A. fumigatus* were also isolated from cowpea and bhindi respectively. Among the different humidity levels tried, maximum germination was in seeds stored at humidity level of 66.8% and thiride and captafol (2g/ kg seed) were the best fungicides for keeping the viability of seeds under normal storage condition.

BIOLOGICAL CONTROL

Biocontrol potentially offers solution to many of the persistent problems in agriculture including the problems of resource limitation, non-sustainable agricultural systems, and over reliance on pesticides. In view of hazardous impact of pesticides in the ecosystem, bio control is becoming increasingly important as a potential mode to manage the plant diseases. Research on this field has clearly demonstrated the potentiality of microorganisms to suppress crop diseases and are summarised here.

The evergreen virgin forest soils of Kerala are the treasure house of antagonistic and antibiotic producing microorganisms. A study was conducted by **Vinod (1988)** to explore the presence of antagonistic and antibiotic producing organisms from the soils of Ladysmith forest of Thariyode (Wayanad Dist.) and Cheriyakonam forest of Thekkadi (Idukki Dist.) of Kerala for utilizing in the biological control of important soil borne plant pathogens like *Pythium, Phytophthora* and *Rhizoctonia.* It was observed that, the microbial population was maximum in the top layer and decreased with increase in depth of soil. Microbial population was higher in Idukki. In both districts the population of bacteria was maximum, followed by actinomycetes and fungi. A diversified group of fungi consisting of *Mucor, Syncephalastrum, Trichoderma, Microascus, Cunninghamella, Absidia, Paecelomyces* and *Fusarium* were observed. Three types of actinomycetes belonged to *Streptomyces* sp. and four types of bacteria identified as *Bacillus* sp. and *B. subtilis* were also noticed. Antagonistic properties of these isolates were studied against three major soil borne pathogens *viz. Pythium myriotylum, Phytophthora palmivora* and *Rhizoctonia solani* and showed conspicuous antagonistic characters against all the three pathogens, but varied in their mechanisms. Three species of *Trichoderma viz. T. harzianum, T. koningii* and *T. longibracheatum* showed the reaction of die back and disintegration of the test organisms. *Aspergillus niger, Penicillium simplicissium, P. citrinum, T. longibracheatum*, and *Bacillus subtilis* produced powerful toxic metabolites which inhibited 67 to 100 per cent growth of the three test pathogens. *P. citrinum* produced maximum antibiotic which is equivalent to 325 ppm of tetracycline hydrochloride followed by *Streptomyces* sp. equivalent to 250 ppm and *T. longibracheatum, P. simplicissimum* and *Aspergillus versicolor* produced equivalent to 750 ppm of tetracycline hydrochloride.

Mini (1990) tried various food bases *viz.* milled rice, wheat bran, paddy straw, rice bran, cowpea, forest soil and soil + cow dung for the mass multiplication of antagonistic microflora such as *Trichoderma harzianum, T. longibrachiatum, Aspergillus terreus, Pencillium citrinum, P. simplicissimum* and *Bacillus subtilis*. Milled rice was found to be the promising food base for all the above antagonists tested. Wheat bran was also found to be equally good for all the fungi except *T. longibrachiatum*. Rice bran was found to encourage the growth of *T. longibrachiatum* as well as *B. subtilis*. Good growth of *A. terreus* and *P. citrinum* and moderate growth of *T. longibrachiatum* and *P. simplicissimum* were recorded with cowpea. In general, paddy straw, forest soil and soil + cow dung were found to be poor substrates compared to others. However, paddy straw was found to be a good food base for the long survival of antagonists especially for

T. harzianum, A. terreus, P.citrinum and *B. subtilis*. Wheat bran, rice bran and milled rice food bases supported long survivability of antagonists in the rhizosphere soils. *T. harzianum* in wheat bran preparation was found to harbour the maximum number of propagules in the rhizosphere of ginger and black pepper upto 60th day of soil inoculation. The survivability of *T. longibrachiatum* grown in rice bran was better in ginger and cowpea rhizosphere while rice recorded maximum population in black pepper rhizosphere. Wheat bran was found to be the best food base for the survival of *A.terreus* in cowpea, *P. simplicissimum* and *B. subtilis* in ginger and *P. citrinum* in black pepper rhizospheres. A decline in the population of pathogen was observed in ginger, cowpea and black pepper rhizosphere amended with carrier based antagonists. *P. simplicissimum* and *T. longibrachiatum* grown in rice was found to be most effective in suppressing the collar rot of cowpea and the soft rot of ginger.

One of the major constraints in the cultivation of **ginger** in Kerala is the rhizome rot caused by *Pythium aphanidermatum*. Because of the various factors involved in the disease development, satisfactory control is rarely acheived by any single measure. Biological control of plant diseases is a promising alternative to the chemical control. Considerable success have been acheived in checking *Pythium* population in soil by native antagonists. **Julie (1999)** conducted a field experiment to study the effect of *Trichoderma viride, Aspergillus niger* and *A. flavus* on the management of rhizome rot of ginger. The results indicated that, soil incorporation of *T. viride* and *A. niger* @ 250g m^{-2} at 60 and 120 Days After Planting (DAP) recorded minimum incidence of rhizome rot of ginger and maximum yield. Among the various food bases tested for the mass multiplication of selected antagonists, rice hull was found to be superior. *T. viride* recorded maximum growth in rice hull, whereas rice bran supported effective growth of *A. niger*. Effect of antagonists in checking pre-emergence and post-emergence rotting (rhizome rot) revealed that, the antagonists *viz. T. viride, A. flavus* or *A. niger* and the fungicides *viz.* mancozeb or copper oxychloride either as seed treatment or soil application, effectively controlled pre-emergence rotting. Field application of a consortium of *T. viride, A. niger* and *A. flavus* at 60 and 120 DAP recorded minimum rhizome rot incidence with increased yield. Population studies of the candidates of the microbial consortium in soil recorded maximum proliferation of all the three antagonists with minimum pathogen count.

Phytophthora rot causes high mortality of **black pepper** cuttings in nurseries. Sometimes, the fungus is carried to healthy area through planting materials. In order to manage the disease, an integrated approach is to be followed in the nursery itself. Since, the healthy planting material is a pre- requisite to raise a healthy plantation, a study was under taken by **Binimol (2000)** to assess the effectiveness of soil solarization and efficiency of *Trichoderma viride* and *T. harzianum* in the control of *Phytophthora* rot in black pepper nursery. It was observed that, maximum soil temperature recorded at 10 cm depth in solarized potting mixture was 51^{0}C while it was 42^{0}C in non-solarized one. Soil temperature in solarized potting mixture was more than 45^{0}C for 40 days and above 50^{0}C for four days. Solarization was effective in reducing the pre-sprouting mortality and mortality of rooted cuttings by the pathogen. Among the various treatments, *T. viride* incorporated in 45 days solarised potting mixture + copper oxychloride drenching recorded cent per cent control. Solarization significantly reduced the foliar infection of the cuttings. The treatment with *T. viride* incorporated in 45 days solarised potting mixture alone was also effective which recorded 97.22 per cent control of the disease. Maximum disease incidence (87.58 %) was noticed in the non-solarized one. Reduction in *Phytophthora* population ranged from 94.41 to 97.35 per cent in solarized potting mixture immediately after the removal of polythene sheets. Maximum population of *Trichoderma* sp. was observed in solarized and *Trichoderma* incorporated treatment. Solarization reduced fungal, bacterial and actinomycetes population of potting mixture. Plants grown in solarised potting mixture exhibited better colonization of *Azospirillum*. However, root colonization of VAM in pepper cuttings was less in solarised treatments. Availability of nitrogen, phosphorus and potassium was increased by solarization. Solarization effectively reduced the weed population also. The studies found that, solarization increased all growth parameters like height of plant, number of leaves, length and breadth of leaves and development of root system in pepper cuttings.

Coconut eriophyid mite, *Aceria guerreronis* is a recent important pest of **coconut** in Kerala which causes yield loss of about 40 per cent in terms of copra output. Many attempts were made to control the mite with acaricides and neem based pesticides. The management of mite with pesticide spraying is very difficult because of its specific nature of breeding beneath the tightly packed bracts. As an alternative control measure, use of bioagent *Hirsutella thompsonii* var *synnematosa* has been suggested for the management of this minute pest. **Shabnaz (2002)** studied the various characters of this entemopathogenic fungus and found that Sabourauds maltose agar + yeast was the most suitable solid medium for the growth and sporulation of the fungus. But Richards medium supported maximum production of fruiting bodies called synnemata. The fungus preferred an alkaline pH of 9, temperature of 25-30^{0}C and humidity level of 50-90 per cent. Hyphae are hyaline, septate and branched producing conical to flask shaped phialides with narrow neck. Spores are spherical, verrucose, hyaline measuring 3.33 μm-3.75 μm. Inhibition of fungal growth was observed with insecticides, dicofol (0.6%), carbaryl (0.2%), triazophos (0.05%), neem oil – garlic emulsion. The fungicides Bordeaux mixture (1%), copper oxychloride (0.3%), wettable sulphur (0.4%), mancozeb (0.3%) and potassium phosphonate (0.3%) showed least inhibition. Raw wheat was found to be the most suitable substrate for the mass multiplication of this fungus as it supported maximum sporulation and viability of the spores. In the powdered substrates, growth was observed only in loose substrates like rice bran and tea waste, of which rice bran recorded maximum colony count.

Among the biocontrol agents, Arbuscular Mycorrizal Fungi (AMF) could be a potentional biocontrol fungi which not only improves the growth of the plants but also suppress the soil-borne pathogens. In India, not much studies have been conducted on the effect of AMF on the management of bacterial wilt in **tomato**. The work related to the screening of AMF for the disease management is very scanty in Kerala particularly on the bacterial wilt diseases. Hence, a study was conducted by **Nandakumar (2003)** to identify an AM fungi for the management of bacterial wilt in tomato. The soil samples were collected from high and low wilt incidence areas of Thrissur and Palakkad district of Kerala and the isolated AM fungi were screened against *Ralstonia solanacearum*. The studies revealed that the native AM fungi combination of *Glomus* sp. (tomato isolate from Ozhalapathy) + *Glomus* sp. (maize isolate from Vellanikkara) was the most promising isolate and could delay the disease incidence in Pusa Ruby, a susceptible variety of tomato, upto 82 days under pot culture condition. However, under field condition, the disease incidence in this variety was delayed only upto 32 days, whereas in the case of resistant variety Mukthi, the incidence was delayed upto 50 days. The application of AM fungi 15 days before transplanting @ 75 g/kg soil delayed the wilt appearance and increased the biometric characters of tomato.

Bacterial wilt caused by *Ralstonia solanacearum,* is one of the major constraints in cultivation of **brinjal, chillies** and **tomato** in Kerala. **Manimala (2003)** studied the management of this pathogen using microbial antagonists isolated from high wilt incidence (Vellanikkara) and low wilt incidence (Ozhalapathy) areas of Kerala. *R. solanacearum* population was high in Vellanikkara and low in Ozhalapathy soils. But the total microflora was highest in Ozhalapathy and these organisms exhibited better antagonistic activity than those isolated from Vellanikkara soils. Resistant varieties of these three crops recorded better association of microflora than the susceptible ones. Among the antagonists, fungi were most effective than bacteria and actinomycetes. The major fungal antagonists identified were *Trichoderma viride, T. pseudokoningii, Aspergillus niger* and the bacterial antagonists were *Pseudomonas aeruginosa* and *Bacillus subtilis*. Culture filtrates of *T. virens* and *B. subtilis* showed good inhibition of the pathogen under *in vitro.* Among the different methods of application of antagonists adopted, seed treatment + soil drenching or root dipping were effective in reducing wilt incidence and in delaying the wilt appearance. Application of antagonists also enhanced plant growth and yield. Under field condition, treatments with antagonists in highly susceptible varieties did not give a promising control of bacterial wilt in brinjal and tomato. However, treatments with *T. viride, T. pseudokoningii* and *P. aeruginosa* proved its effectiveness in chilli crop. Combined effect of host resistance and antagonists are necessary to achieve better management of bacterial wilt under natural condition.

As a part of the state wide project – Technology mission on Black Pepper (TMBP), field experiments were conducted during 2001-2004 to evolve an effective biocontrol method for the management of *Phytophthora* foot rot of **black pepper (Rehumathniza, 2004).** These experiments were conducted in the selected pepper gardens in five districts *viz.* Ernakulam, Idukki, Kottayam, Kollam and Pathanamthitta of Kerala. Various treatment combinations were tried in the existing pepper gardens and in newly planted gardens. Out of the 32 fungi isolated from various pepper fields, the fungi *viz. Trichoderma* spp., *Aspergillus* sp., *Pencillium* sp., *Fusarium* spp., *Pythium* sp., *Cunnighamella* sp., and *Rhizopus* sp, showed antagonistic property against foot rot pathogen, *Phytophthora capsici.* The antagonists which showed maximum inhibition against the foot rot pathogen were identified as *Trichoderma koningii* (Kollam); *Trichoderma longibrachiatum* (Idukki) and *Trichoderma polysporum* (Thrissur and Ernakulam). These native antagonists were compared with the standard cultures in the pepper fields. In the existing pepper gardens, where disease incidence was moderate, plants which received treatments of *Trichoderma* local isolate and potassium phosphonate (0.3%) showed minimum disease incidence. In severely affected grown up plants, drenching with copper oxychloride and spraying Bordeaux mixture gave maximum control. In newly planted pepper gardens, minimum wilt incidence was noticed in the plot which received *Trichoderma* local isolate and potassium phosphonate (0.3%) in all the five districts. Quality analysis of pepper such as oleoresin and piperine contents were estimated as per the standard procedure. The oleoresin content varied from 8.8 to 11.9 per cent, and piperine from 3.6 to 4.5% which showed that quality remained good and unchanged due to various treatments.

As a part of TMBP, another project was carried out during 2001- 2004with the objective of developing suitable biocontrol strategies against *Phytophthora* disease in **pepper** nursery using antagonistic microflora **(Koshy 2004)**. Soil samples were collected from pepper gardens in five southern districts of Kerala *viz.* Ernakulam, Idukki, Kottayam, Kollam and Pathanamthitta and the population of soil microflora such fungi, bacteria and actiomycetes were estimated. Soil microflora from different locations were screened for their antagonistic effect against *Phytophthora capsici*. Experiments were laid out in farmers' fields in the selected districts of Kerala and at College of Horticulture, Vellanikkara. The antagonists *Trichoderma viride, T. harzianum* and *T. longibrachiatum* were used in 20 different treatments. The pepper variety Panniyur I, was used for the study. Soil was solarised for a period of 30 days before planting. The sprouting percentage was recorded at 20, 30 and 45 days after planting. At 45 DAP, the treatment T_{20} (soil solarization for 30 days + *T. longibrachiatum* + potassium phosphonate) recorded the maximum percentage of sprouting (90.33%). Disease incidence was recorded at four intervals – 14, 15, 16 and 17 weeks after planting (WAP). At 17 WAP, the minimum incidence (17.67%) was recorded in treatment as per PoP of KAU. The biometric characters such as height of plants and number of leaves were recorded at three months after planting. The maximum plant height (19 cm) was observed in treatment consisted of soil solarization for 30 days + *T. viride* and maximum leaf number (20.67) was in treatment of soil solarization for 30 days + *T. longibrachiatum*. The microbial population in soil was recorded for three months at monthly intervals. The fungal count was maximum (15 x 10^2 cfu/g of soil) in soil solarization for 30 days + *T. harzianum* and *T. harzianum* + potassium phosphonate. Maximum bacterial population (153 x 10^4 cfu/g of soil) was in *T. longibrachiatum* + Ridomil MZ-72 and actinomycetes in soil solarization for 30 days + *T. viride* + Ridomil MZ -72 treatments. Compatibility of three different *Trichoderma* spp. with commonly used fungicides, insecticide and fertilizers was evaluated *in vitro*. *T. harzianum* showed maximum compatibility with the fungicide captafol (0.2%), insecticides phorate (1, 1.5 and 2 kg a.i./ha), and with the fertilizer MoP at 2% concentration. *T. viride* was compatible with the fungicides Indofil M-45 (0.2%) and Ridomil MZ-72 (0.2%), with insecticides phorate (1, 1.5 and 2 kg a.i./ha) and the fertilizer MoP at 2.0 and 2.5 per cent concentrations. *T. longibrachiatum* was found compatible with Akomin - 40 (0.2%). The insecticide and fertilizer compatibility was similar to that of *T. viride*.

Bacterial wilt caused by *Ralstonia solanacearum* is a major constraint for the cultivation of **solanaceous crops** in Kerala. Breeding for host resistance has provided some substantial success in Kerala. In the recent years, biocontrol is gaining much importance to achieve the control of soil borne pathogens. As a part of ICAR project, an investigation was carried out during 2000 - 2004 for the management of the bacterial wilt disease through biological means **(Sally 2004)**. Studies on cultural and biochemical characters showed variability among the different strains of *R. solanacearum* of brinjal, chilli and tomato collected from Thrissur and Palakkad districts of Kerala. Vellanikkara isolates of *R. solanacearum* was highly virulent and aggressive than others. *R. solanacearum* of this area found belonged to Race I, biovar III, III A & V, *R. solanacearum* population was found to be low, where as microflora and mycorrhizal population were high in the rhizosphere soils of Palakkad areas. Fresh bacterial ooze of OD_{600} = 0.3 was the best inoculum for the artificial inoculation than the culture suspension. Out of the 383 microbial antagonists tested under laboratory condition, 32 fungi, 12 bacteria and 15 actinomycetes exhibited antagonistic effect on different strains of *R. solanacearum*. The antagonists isolated from low wilt incidence area (Palakkad) were more effective as compared to those from high wilt incidence areas. Among the different organisms isolated, fungal antagonists especially *Trichoderma* spp. (*T. viride, T. pseudokoningii, T. harzianum,T. virens*) were effective against different isolates of *R. solanacearum*. *T. viride* and *T. pseudokoningii* were the most promising antagonists. Mutants and interspecific hybrids of these fungi were also effective. Among the bacterial isolates, *Pseudomonas aeruginosa* and *Bacillus subtilis* were the most effective ones. All commercial antagonists *T. viride* and *T. harzianum*, *Aspergillus niger*, *B. subtilis* and *P. fluorescens* were also found effective against the pathogen. Among the different chemicals tested, Streptocycline (500 ppm) was found to be the best followed by copper hydroxide (0.2%) in lab studies. Among the different botanicals tried, *Adhathoda vasica* and *Chromolaena odorata* (10 and 20%) were found to be more effective in the lab studies. Among the solanaceous crops, mycorrhizal population was high in brinjal and chilli as compared to tomato. *Catharanthus roseus* (Vinca) and *Lantana camera* were good hosts of mycorrhiza as the spore count was maximum in these hosts. *Glomus* spp. *Acaulospora* spp. and *Sclerocystis* spp. were the major species of mycorrhiza observed in these areas. Of these, *Glomus* was the most predominant one. In pot culture studies, combinations of *Glomus* spp. of different hosts and different locations were more effective than individual species. The application of AMF, 15 days before transplanting @ 75 g/ kg soil delayed the wilt appearance and increased the biometric characters of the plants. Among the 25 microbial antagonists, *T. pseudokoningii, Aspergillus niger* different isolates of *T. viride, T. harzianum, Pseudomonas aeruginosa, P. fluorescens, B. subtilis* were found effective against bacterial wilt of three crops. Application of antagonist by root dipping or seed treatment + soil drenching were found best in reducing incidence as well as delaying the wilt appearance. Root dipping of seedlings in *Adathoda vasica* extract (20%), mulching with *Chromolaena odorata*, soil drenching with Streptocycline (500 ppm) in combination with copper oxychloride, combined application of urea + lime were the other most effective treatments in pot culture studies. In field condition, treatments with antagonists *T.viride, T. pseudokoningii, P.aeruginosa*, root dipping with *Adathoda* extract 20 per cent, mulching with *Chromolaena*, application of urea + lime, Streptocycline + copper oxychloride were found to be more effective as compared to control plots. Application of microbial antagonists enhanced the plant growth under pot culture and field conditions.

Bacterial wilt is considered as one of the major constraints in the cultivation of **ginger** in Kerala. Considering the serious nature of the disease, **Reshmy (2006)** had carried out a study to harness the potential of Plant Growth Promoting Rhizobacteria (PGPR) in promoting growth of ginger as well as in inducing systemic resistance against the bacterial wilt disease. The pathogen causing bacterial wilt of ginger was isolated and identified as *Ralstonia solanacearum*, biovar III. Out of the 163 rhizosphere isolates from different locations of Thrissur, Wayanad and Palakkad districts, only 11 isolates including the two reference cultures of *P. fluorescens* had growth promoting effect as evidenced in terms of yield attributing characters of ginger. Out of the 11 isolates RB-22 followed by RB-11, RB-144 and RB-66 produced more number of antibiotics which include pyoluteorin, pyrrolnitrin, 2,4 - DAPG etc. Similarly, isolate RB-22 and RB-11 produced maximum siderophores. The isolates varied in their ability to produce salicylic acid. Moreover, the potential of these 11 rhizobacterial isolates in imparting resistance against the disease was assessed in another pot culture experiment by estimating phenol, proteins and amino acid contents of ginger upon challenge inoculation. There was no natural incidence of bacterial wilt in plants treated with RB-11 and RB-22. Upon challenge inoculation also, plants bacterized with RB-11 showed the least incidence. In general, rhizobacterial treated plants contained more amount of phenol, protein and amino acids than untreated ones. In another pot culture experiment to assess the effect of rhizobacterial treatments on defense related enzymes of ginger revealed more activity of peroxidase (PO), polyphenol oxidase (PPO) and phenylalanine ammonia lyase (PAL) in rhizobacterial treated plants after challenge inoculation. Native PAGE analysis revealed six isoforms of PO and four isoforms of PPO in majority of the rhizobacterial treated plants, whereas only three were noticed in control. Chlorophyll, NPK, oil and oleoresin contents varied among treatments in which the highest was observed in rhizobacterial treated plants. An attempt was made to elucidate the molecular mechanism of induced systemic resistance (ISR) in ginger by synthesizing cDNA and was subjected to RAPD assay. However, no conclusive evidence on ISR was observed. The compatibility of eight rhizobacterial isolates including the two reference cultures with antibiotics, fungicides, insecticides and fertilizers were assessed which revealed variation in their sensitivity. Mutual compatibility of the rhizobacterial isolates and compatibility with *Trichoderma* spp. were also studied and it was observed that all bacterial isolates were mutually compatible. However, *Pseudomonas aeruginosa*, *P. fluorescens* (RB-66) and the reference culture of *P. fluorescens* (P.f2) were found incompatible with *Trichoderma* spp. The promising six rhizobacteria isolates were tentatively identified as *Pseudomonas aeruginosa* (RB-22), *Pseudomonas fluorescens* (RB-82, RB-66, RB-11) and the remaining two, RB-144 and RB-77, as non-fluorescent *Pseudomonas* sp.

Nisha (2007) studied the role of microflora of vermiproducts in improving the plant growth of **amaranth** and also its effect on *Rhizoctonia solani* causing leaf blight disease. Microflora associated with the surface and gut of the earthworm, *Eisenia foetida* and different vermiproducts *viz*. vermicompost, vermicasting and vermiwash were isolated. Quantitative estimation of microflora revealed that, bacterial population was high in vermiproducts followed by actinomycetes and fungi. Altogether 32 fungi and 39 bacteria including five nitrogen fixing and three phosphorus solubilizing bacteria and four actinomycetes were tested for their efficiency in nitrogen fixation, phosphorus solubilization and antagonistic activity against *R. solani*. Among these, *Azotobacter* sp. (NB-2-vermiwash) and *Pseudomonas* sp. were efficient nitrogen fixing and phosphorus solubilizing isolates respectively. Seven isolates of fungi, identified as *Trichoderma harzianum* (VF-5-vermicast; VF-22-vermicompost; VF-25- vermiwash) *T. viride* (VF-8-vermiwash and VF-16-vermicompost), *Aspergillus niger* (VF-2-vermiwash), *A. flavus*

(VF-15-vermicompopst) and two bacterial isolates *Bacillus* sp. (VB-4-vermicast) and *Pseudomonas* (VB-26-vermicompost) recorded highest per cent inhibition of *R. solani*. The pot culture experiment conducted to evaluate the efficiency of these consortia in plant growth promotion and disease management in comparison with vermiproducts revealed that the consortium of fungal and bacterial isolates was more effective in enhancing plant growth, yield and also in checking the leaf blight infection. But uptake of major nutrients was found to be more in treatments applied with vermicompost and vermicasting.

Biocontrol has been widely adopted as safe, cost effective and eco friendly approach for the management of several diseases. Recently, a greater thrust has been given for the microbial consortium which provides better management of diseases by the way of synergistic effect and multiple mode of action. As a part of Kerala State Council for Science, Technology and Environment (KSCSTE) project, a study was carried out during 2005 – 2008, to find out the consortial effect of bioagents in the management of *Phytophthora* rot of **black pepper** and **vanilla** and bacterial wilt of **chilli (Sally, 2008)**. Four consortial formulations of bioagents with shelf life of 6-12 months *viz. Trichoderma harzianum* + *Bacillus megaterium*, *T.harzianum* + T. *viride*, *T harzianum*+ *Pseudomonas fluorescens* and *B. megaterium* + *P. fluorescens*_ for the management of *Phytophthora* rot of black pepper, vanilla and bacterial wilt of chilli were developed. Potential antagonistic endophytic fungi, *T. viride* and *T. pseudokoningii* from black pepper have been isolated for the first time. Potential antagonistic endophytic bacteria, *Bacillus megaterium*, which is reported to be a phosphorus solubilizing bacterium was isolated from black pepper for the first time. Coconut water supplemented with nutritional substrates like tapioca powder @ 5g/l or magnesium sulphate @ 2g/l reduced the concentration from 50 to 25 per cent. Tapioca broth was found to be a good substitute for potato broth for the mass multiplication of *Trichoderma*. Dried coconut leaf bits + neem cake @ 9:1 was found to be a good economic solid substrate for the large scale production of *Trichoderma* sp. Addition of nutritional supplements *viz*. ragi powder, $MgSO_4$ to talc, enhanced the quality and shelf life of *Trichoderma* and *Pseudomonas* formulations. Low cost liquid formulations of *Trichoderma* and *P.fluorescens* were also developed.

Spices are the important economic crops of Kerala. Diseases caused by soil borne pathogens are causing considerable damage to these crops. Biocontrol is preferred as an important ecologically safer crop protection strategy in many crops. Generally, the application of single antagonist leads to inconsistent performance. The combination of antagonistic organisms may broaden the spectrum activity which enhances the efficacy and consistency of bioagents in suppression of disease. Hence a study on the management of rhizome rot and bacterial wilt of ginger and chilli using microbial consortium was undertaken during 2005-2009 as a part of Department of Biotechnology (DBT) project **(Sally, 2009)**. Four potential native antagonists, *Trichoderma harzianum* and *Bacillus subtilis* of chilli, *T. virens* and *Pseudomonas fluorescens* of ginger, effective against rhizome rot (*Pythium aphanidermatum*) and bacterial wilt of **ginger and chilli** (*Ralstonia solanacearum*) were identified. Potential antagonistic *Trichoderma aureoviride* and endophytic bacteria, *P. fluorescens* and *P. stutzeri* were isolated from ginger. *Trichoderma aureoviride* and *P. stutzeri* are the first reports from ginger. A cheap liquid medium *viz.* 50%

coconut water, 25 % coconut water with sugar @ 15 g/l was developed for the mass multiplication of *Trichoderma* and bacterial bioagents. In addition, 25% coconut water + magnesium sulphate @ 2g/l were also found to be good medium for mass multiplication of *Trichoderma* and *Pseudomonas* Ragi grains, dried coconut or banana leaves were found to be an economic solid substrate for the large scale production of *Trichoderma*. Addition of nutritional supplements *viz.* tapioca powder and $MgSO_4$ to talc, improved quality and shelf life of bioformulations. Consortial formulation of *T. harzianum* + *P. fluorescens*, *T. harzianum* + *T. virens*, *Bacillus subtilis* + *P. fluorescens* for the management of major soil borne pathogens (*Pythium* spp. and *R. solanacearum*) causing rhizome rot of ginger and bacterial wilt of chilli and ginger were developed.Addition of 1% coconut water enhanced the concentration of *Pseudomonas* suspension and reduced the quantity of formulation to onefourth.

Sainamole (2011) conducted a study on " Endophytic microorganism mediated systemic resistance in **cocoa** against *Phytophthora palmivora* (Butler) Butler" . Endophytes were isolated from samples of feeder roots, tender shoots, leaves and pods of cocoa collected from various locations of major cocoa growing areas of Kerala. The population of endophytic microflora varied among different locations and parts of the plant, and in general, the population was more in roots. Bacteria and fluorescent pseudomonds were more abundant than fungi and yeasts. Out of the 325 endophytic isolates comprising of 116 bacteria, 153 fluorescent pseudomonads, 34 yeasts and 22 fungi, 82 were found exerting antagonism towards the pathogen. Twenty five promising endophytic antagonists selected from *in vitro* screening were evaluated for growth promoting ability in cocoa seedlings. Eight isolates which had profound effect on growth promotion were selected to study their antagonistic and growth promoting effects. These eight potential endophytes consisted of two bacteria, five fluorescent pseudomonads and one fungus were evaluated along with two reference cultures of *Pseudomonas fluorescens* (KAU and TNAU) in *in vitro* for various attributes, which underlay their beneficial effects. It was observed that, isolates EB- 35, EB- 40 and EF- 81 produced more ammonia and the phosphate solubilising ability was maximum for EB- 35. The isolates EB- 35, EB- 40 and EB- 65 produced high quantity of IAA. High score for antagonistic index was also for EB- 31 and EB- 35. The plant growth promoting index worked out based on aforementioned attributes was high for five isolates *viz.* EB- 31, EB- 35, EB- 40 EB- 65 and EF – 81, which were selected as promising endophytes and were subjected to further studies under *in vivo* evaluation. The promising endophytes were found to produce volatile and non- volatile inhibitory metabolites against the pathogen. Maximum inhibition through volatile production was with EB- 35 and EB- 31 and through non-volatile by EB- 35 and EB- 41. EB – 31 and EB- 65 produced more siderophores under iron limiting condition. A pot culture experiment conducted to study the induction of systemic resistance and suppression of *Phytophthora* infection in cocoa seedlings by the endophytes, showed growth promotion and reduction of disease. Induction of systemic resistance study revealed more accumulation of phenols, proteins and higher activity of PO, PPO and 5-1, 3- glucanase in treated seedlings . Native PAGE analysis revealed six isoforms of PO and seven of PPO in endophyte treated plants. Promising endophytes were evaluated for their efficacy against *Phytophthora* pod rot along with two reference cultures of *Pseudomonas fluorescens* and chemicals. After first spraying, minimum disease incidence was noticed in EB- 65 and EF- 81 whereas after second spray, lowest was in EB- 31. However after two weeks of third spray maximum disease reduction was observed with Pf_1 (KAU) and EB- 35. However isolate EB- 31 was the most efficient one which recorded the lowest incidence during the peak period of infection. Based on cultural, morphological and biochemical characters coupled with the results of molecular characterisation, the promising bacterial endophytes were identified as *Pseudomonas putida* (EB - 31), *Bacillus subtilis* (EB- 35), *P. plecoglossicida* (EB -40) and *P. aeruginosa* (EB- 65) and the isolate EF – 81 as *Penicillium miniobuteum.* In the radiolabeling study, it was found that, EB - 35 and EB- 65 entered the cocoa seedlings when applied on leaves and also inside the pods on application on the intact surface.

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Major Advisor - Dr. Anita Cherian.

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Major Advisor - Dr. Koshy Abraham.

LIST OF RESEARCH PROJECTS

1. KAU, 1983. Effect of prophylactic control measures of quick wilt (stem rot) disease on the control of fungal pollu (anthracnose) disease of pepper, (*KADP Project*), *Research Report,* Kerala Agricultural University, Thrissur, p.193
2. KAU, 1983. Investigations on etiology of fruit drop disease and their management. (*KADP Project*), *Research Report,* Kerala Agricultural University, Thrissur, p.338
3. KAU, 1983. Post harvest microbial deterioration of cocoa. (*KADP Project*), *Research Report,* Kerala Agricultural University, Thrissur, p.338
4. KAU, 1983. Control measures for pink disease. (*KADP Project*), *Research Report,* Kerala Agricultural University, Thrissur, p.339
5. KAU, 1983. Studies on die back of cocoa- causes and control. (*KADP Project*), *Research Report,* Kerala Agricultural University, Thrissur, p. 339
6. KAU, 1986. Control leaf rot disease of coconut. (*Root wilt project*), *Research Report,* Kerala Agricultural University, Thrissur, p. 162
7. KAU, 1986. Status and influence of rhizosphere microflora of coconut palms in healthy and diseases tracts and the possible role of microbial toxins produced outside the plant in relation to root (wilt) disease. (*Root wilt project*), *Research Report,* Kerala Agricultural University, Thrissur, p. 162
8. KAU, 1986. Mycoplasma as possible casual agent of the coconut root (wilt) disease. (*Root wilt project*), *Research Report,* Kerala Agricultural University, Thrissur, p. 162
9. KAU, 1987. *In vitro* characterization of mollicutes associated with coconut root (wilt) disease. (*Root wilt project*), *Research Report,* Kerala Agricultural University, Thrissur, p.163
10. Sally K Mathew, 1993. Evaluation of cassava varieties/lines/types resistant to cassava mosaic virus, (*KAU project*), *KAU Research Report,* p.39
11. Rehumath Niza, 2004. Use of biocontrol for checking *Phytophthora* disease in black pepper. (*TMBP project*), *Final Report*, Kerala Agricultural University, Thrissur, pp 133-149.
12. Koshy Abraham, 2004. Incorporation of biocontrol in black pepper nursery for checking *Phytophthora* disease. (*TMBP project*), *Final Report*, Kerala Agricultural University, Thrissur, pp 150-183.
13. Sally K Mathew, 2004. Biocontrol of *Ralstonia solanecearum* E.F. Smith. causing bacterial wilt in solanaeceous vegetable crops. (*ICAR project), Final Report*, Kerala Agricultural University, Thrissur, 64p.

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18. Surendra Gopal, K. 2009. Isolation and screening of different AMF cultures for selected cucurbitaceous crops. *(KAU project)*, *KAU Annual Report,* p.61.

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1.	Dr. M. Chandrashekaran Nair	Feb 1972	-	Jan 1977
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3.	Dr. K. I. Wilson	29.07.1983	-	23.11.1984
4.	Dr. Abi Cheeran	24.11.1984	-	07.11.1989
5.	Sri. P. C. Jose	08.11.1989	-	05.07.1992
6.	Sri. C. K. Ramakrishnan	06.07.1992	-	14.06.1994
7.	Dr. James Mathew	15.06.1994	-	21.03.1998
8.	Dr. A. Sukumara Varma	22.03.1998	-	16.08.2001
9.	Dr. Koshy Abraham	17.08.2001	-	11.06.2008
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