KSCSTE project on

Base line studies on vegetable crops under protected cultivation in Kerala as a prelude to precise disease management

PROJECT COMPLETION REPORT (08-08-2014 to 31-12-2017)

DEPARTMENT OF PLANT PATHOLOGY
COLLEGE OF HORTICULTURE
KERALA AGRICULTURAL UNIVERSITY
VELLANIKKARA, THRISSUR

KERALA STATE COUNCIL FOR SCIENCE, TECHNOLOGY AND ENVIRONMENT

Science Research Scheme

PROJECT COMPLETION REPORT

1. Title of the Project: "Base line studies on vegetable crops under protected cultivation in Kerala as a prelude to precise disease management"
2. Principal Investigator(s): Dr. Sainamole Kurian, P.
   Co-Investigator(s): 1. Dr. Anita Cheriyan, K.
   2. Dr. Sreeja P.
   3. Dr. Nirmala Devi, S.

3. Implementing Institution(s) and other collaborating Institution(s): Kerala Agricultural University
4. Date of commencement: 8/8/2014
5. Planned date of completion: 07/08/2017
6. Actual date of completion: 31/12/2017
7. Objectives as stated in the project proposal:

   1. Study the incidence, severity and etiology of diseases of vegetable crops under protected cultivation in various agro climatic zones of Kerala.
   2. Study the influence of microclimatic factors, soil nutrient status and physical properties of soil, rhizosphere and soil micro flora epiphytic and endophytic micro flora on diseases of vegetable crops under protected cultivation.
   3. To develop an effective Integrated Disease Management strategy for the most severe diseases affecting important vegetable crops.

8. Deviation made from original objectives if any, while implementing the project and
reasons thereof: There was no deviation
9. Abstract of the project proposal (Not more than 500 words)

Protected cultivation of vegetable crops is a new technology which is being accepted by farmers with very high expectations about yield and profit. In Kerala it is providing opportunity to grow vegetables during the rainy and summer seasons which otherwise are not so suitable for vegetable cultivation. However, no scientific study has been conducted so far to assess the effect of protected structure on the soil inside it and its surroundings which is the chief factor influencing long term productivity. Reports say that, there are certain diseases commonly present in poly houses. These include mainly soil borne diseases. The present study aims at a baseline research on changes brought about by the specific modified micro climate within the poly houses in Kerala on the soil and plants which lead to specific diseases on crops under cover.

In the present project, survey will be conducted among farmers practicing protected cultivation of vegetables in various agro climatic zones of Kerala to record seasonal incidence, severity of diseases on the crops grown. Diseased plant samples will be collected

to study the etiology of the disease. The microclimatic factors inside the structure and the outside will be recorded. Rhizoshpere and soil samples will be collected from inside and outside the structures which will be analyzed for changes in soil microflora, various macro and micronutrients and physical properties of soil. Plant samples of vegetable crops grown inside and outside the structures will also be collected and will be analyzed for nutrient status and population of epiphytic and endophytic microbes. Population of aerial microflora will also be recorded by installing spore traps. Data on the various aspects will be correlated with the incidence and severity of diseases.

Simultaneously, experiments will be conducted in poly house to develop appropriate IDM strategies giving priority to biological methods for most severe diseases of the most important vegetable crops under protected structures in the state. Based on the preliminary data collected, three vegetable crops and five diseases which are the most severe in these crops are included for disease management experiments.

10. Key words (Not exceeding ten):

Protected cultivation, rain shelter, poly house, cucumber, downy mildew, capsicum Cercospora, powdery mildew, tomato, early blight

11. Achievements:

i. List of Research publications

Sl. No.	Authors	Title of paper	Name of the Journal	Volume	Pages	Year
1.	Reshma Raj T., Sainamole Kurian P.	Study of downy mildew (*Pseudoperonospora cubensis* (Berk. & Curt.) Rostov.) of cucumber (*Cucumis sativus* L.) under polyhouse in relation to weather parameters	*IJAPSA*	2	1- 4	2016
2.	T. Reshma Raj, P. Sainamole Kurian	Effect of foliar treatments on non-target microorganisms on the phylloplane of cucumber (*Cucumis sativus* L.)	NBC		89-96	2017

ii. Manpower trained on the project

a. Research Scientists: Dr. Sainamole Kurian, P.
Research Associates: Mrs. Greeshma, N.T.
Ms. Liji K. O.
Mrs. Fridin Davis

b. No. of Ph.D. produced: One, ongoing.(Miss. Sumbula, V)

c. Other Technical Personnel trained: Mr. Bahulayan

iii. Innovations/Technology developed

In the present study, major crops grown in poly houses were identified and effective management strategies for the most severe diseases affecting these crops were developed.

1. Foliar spray with cymoxanil + mancozeb was identified as the most effective treatment for the management of downy mildew in both polyhouse and rain shelter. However, soil solarization + seed treatment and soil application + foliar spray with *Trichoderma viride* were also equally effective. Moreover, with premium price for organic product, the latter was more economic among all the treatments tried.
2. Soil solarisation + soil application of *Trichoderma viride* +seed treatment with carbendazim+ mancozeb (2g.kg-1) + foliar spray with mancozeb (0.2 %) was the most effective for management of Cercospora leaf spot of capsicum. followed by soil solarisation+ seed treatment and foliar spray with *Pseudomonas fluorescens*(20g.L-1) and soil solarisation+ soil application of *Trichoderma viride* and these were statistically on par.
3. Soil solarisation +soil application of *Trichoderma viride*+ foliar spray with tebuconazole (0.1 %) was the most effective for management of powdery mildew in rain shelter and poly house.
4. For management of early blight of tomato systemic fungicide, Quintal (0.1%) was the most effective in reducing the disease severity closely followed by Propineb (0.2%) which were on par. Among the bio agents, PGPM was more effective than *Trichoderma viride*.
5. It was found that disease severity of downy mildew of cucumber was higher in the polyhouse where relative humidity was higher and RH $\geq$ 79 per cent, resulted in initiation of the disease .
6. *Cercospora capsici* on capsicum was reported for the first time in India.
7. Survival of bio control agents *T. viride* and *P. fluorescens* upto 15 days on the leaf surface was proved.

iv. Patents taken, if any - nil

v. Application potential

The results of the project are useful for all vegetable farmers in general and poly house and hi-tech farmers in particular.

12. Summary of the work done (not more than 500 words) highlighting the outcome

Survey was conducted in 12 districts of Kerala, the data were consolidated. Based on the results obtained in the first year, experiments were designed for management of major diseases affecting the most widely cultivated crops in poly house crops. Accordingly, experiments were formulated for developing eco-friendly strategies for management of downy mildew of cucumber, foliar diseases of capsicum, and early blight of tomato. Construction of the poly house and rain shelter was also completed in the first year. During the second year of the project, a purposive periodical survey was conducted in Thrissur district in poly houses where cucumber was being cultivated. The incidence and severity of

downy mildew of cucumber in polyhouses and the weather parameters were recorded at periodical intervals. Incidence of downy mildew was noticed in all nine polyhouses visited in different locations in Thrissur district irrespective of the season and the disease severity varied from 11.33 to 35.75 per cent. The disease severity of downy mildew of cucumber was higher in the polyhouses where relative humidity was higher and the RH was ≥ 79 per cent in all the polyhouses visited.

Field experiments were conducted simultaneously in the polyhouse and rain shelter for the management of downy mildew with 12 treatments and three replications. The treatments included two bio control agents, cow dung supernatant, two bio fungicides and two systemic and one contact fungicides. Foliar spray with cymoxanil + mancozeb (T10) was the most effective treatment for the management of downy mildew in both polyhouse and rain shelter followed by foliar spray with mancozeb (T11) and soil solarization + seed treatment and soil application + foliar spray with *Trichoderma viride*(T1)and these were on par. Survival of bio control agents on the phylloplane of cucumber was also studied and it was found that both *T. viride* and *P. fluorescens*, survived on leaf surface up to 15 days after foliar application.

During the third year, survey was conducted in three districts of Kerala *viz* Thrissur, Palakkad, and Thiruvananthapuram .by selecting nine poly houses where capsicum was being grown. During the survey, incidence of fungal diseases like powdery mildew, leaf spot, fruit rot, stem and fruit rot were noticed on capsicum under protected structures at various locations. Symptomatology of fungal diseases of capsicum observed during the survey was studied. The fungi associated with the diseases were isolated and the pathogenicity was proved. Cultural and morphological characterization of the pathogens was carried out and the fungi were identified as *Leviellula taurica, Cercospora capsici, Colletotrichum capsici* and *Fusarium* sp. respectively. Field experiments were conducted simultaneously inside the poly house and rain shelter for management of fungal diseases of capsicum with seven treatments and three replications.

Among the treatments, T4 (soil solarisation + soil application of *Trichoderma viride* +seed treatment with carbendazim+ mancozeb (2g.kg-1) + foliar spray with mancozeb (0.2 %) was the most effective one for management of *Cercospora* leaf spot in both poly house and rain shelter, followed by T2 (soil solarisation+ seed treatment and foliar spray with *Pseudomonas fluorescens*(20g.L-1) and T1(soil solarisation+ soil application of *Trichoderma viride* and these were statistically on par. Among the treatments, T5 (soil solarisation +soil application of *Trichoderma viride*+ foliar spray with tebuconazole (0.1 %) was the most effective for management of powdery mildew in rain shelter and poly house, followed by T6(soil solarisation +soil application of *Trichoderma*+ foliar spray with difenoconazole (0.05%) and these were on par. Analysis of population of phylloplane micro flora proved that there was drastic reduction in the population of phylloplane fungi, bacteria and actinomycetes after spraying chemical fungicides whereas the population increased after spraying bio control agents. Survival of biocontrol agents on the phylloplane of capsicum was also studied and it was found that *T. viride* and *P. fluorescens*, survived on the leaf surface up to 15 days after foliar application.

Results of the experiment for management of early blight of tomato showed that, systemic fungicide, Quintal (0.1%) was the most effective in reducing the disease severity closely followed by Propineb (0.2%) which were on par. Among the bio agents, PGPM was more effective than *Trichoderma viride* and the endophytic bacterium *Bacillus subtilis*. The

highest yield was recorded in Quintal -0.1% (9.01 kg/plot) followed by Quintal -0.05% (6.17 kg/plot).

13. Financial Details:

No.	Financial Position/Budget Head	Funds Sanctioned (Rs.)	Expenditure (Rs.)	% of Total cost
I	Salaries/Manpower costs	5,14,800	4,60,632	89%
II	Equipment	2,00,000	1,70,300	85.15%
III	Consumables	1,60,000	1,56,375	97.73%
IV	Contingencies	2,20,000	2,18,926	99.51%
V	Travel	90,000	44,810	49.79%
VI	Overhead Expenses	1,50,000	1,50,000	100%
	Total	**13,34,800**	**12,01,043**	**89%**

14. Procurement/Usage of Equipment:

a)

Sl. No.	Name of Equipment	Make/Model	Cost (FE/Rs.)	Date of Installation	Utilization Rate (%)	Remarks regarding maintenance /breakdown
1.	Laminar Flow	Rotek make Model :120x60x60	56,300/-	14/7/2015	100%	Being used in good condition
2.	Autoclave	Equitron make Model:7440S	1,14,000/-	6/8/2015	100%	-Do-

b) Plans for utilizing the equipment facilities in future

The equipment will be utilized for the research work of PG students of the Dept. of Plant Pathology.

Name and Signature with Date

a. ---------- 20/3/16 ---------- (Principal Investigator) Dr. Sainamole kurian,P.

b. ---------- 30/3/16 ---------- (Co-Investigator) Dr. Anita Cheriyan, K.

c. ---------- Nirmala ---------- (Co-Investigator) Dr. Nirmala Devi, S.

d. ---------- (Co-Investigator) Dr. Sreeja P

PROJECT COMPLETION REPORT

1. INTRODUCTION

The project was initiated with a detailed survey in poly houses in different districts of Kerala. Data on various aspects of vegetable cultivation under protected cultivation were collected. The farmers' fields were visited and incidence and severity of diseases of vegetable crops were recorded. Based on the results of the survey, three crops were selected for field experiments for disease management under protected cultivation. Accordingly, experiments were conducted inside protected structures erected during the first year of the project for developing eco-friendly and safe management strategies for major diseases of vegetable crops under protected cultivation. The crops selected were salad cucumber, capsicum and tomato. During second and third year, survey was conducted in poly houses where the selected crops were grown. Field experiments were conducted for management of major diseases of the crops.

2. MATERIALS AND METHODS,

I. SURVEY ON DISEASES OF VEGETABLE CROPS UNDER PROTECTED STRUCTURES (2014-2015)

All Kerala survey was conducted and data on various aspects of vegetable cultivation under protected cultivation were collected. The farmers' fields were visited and incidence and severity of diseases of vegetable crops were recorded. Diseased plant samples were collected and the pathogens were identified. Soil samples were collected from inside and outside the poly houses which were subjected to nutrient and micro flora analyses in the laboratory. Meteorological data *viz.* atmospheric temperature and relative humidity were recorded during the survey.

II. MANAGEMENT OF DOWNY MILDEW (*PSEUDOPERONOSPORA CUBENSIS*) OF SALAD CUCUMBER (*CUCUMIS SATIVUS* L.) UNDER PROTECTED CULTIVATION (2015-2016)

a. Survey on incidence and severity of downy mildew of cucumber under protected and open condition in farmers' fields in Thrissur district.

A survey was conducted in Thrissur district during January-December of 2015 by selecting nine different polyhouses located at Thanniyam, Peringottukara, Manaloor, Chendrapinni, Chavakkad and College of Horticulture, Vellanikkara. Observation on disease incidence and severity were recorded at different stages of the crop during the survey. The major meteorological factors *i.e.*, temperature and relative humidity (RH) influencing the crop and the pathogen prevailing in the structures and open condition were recorded using portable whirling psychrometer.

b. Construction of poly house and rain shelter

Two protected structures, a naturally ventilated poly house of size 300m^2 and a rain shelter of size 200m^2 were constructed to conduct field experiments to manage diseases of vegetable crops under protected condition. Both the structures were constructed in north south direction and with gable type roof.

Plate 1 - Polyhouse -300m^2

Plate 2 - Rain shelter -200m^2

c. Experiment for management of downy mildew of cucumber under polyhouse and rain shelter condition.

Field experiments were conducted under polyhouse and rain shelter during November to May of 2015-2016 to evaluate different treatments for the management of downy mildew of cucumber under protected condition (Plate 3).

Plate 3. Field view of the experiment

d. Treatment details

The details of the experiment are as follows.

Design : RBD
Treatments : 12
Replication : 3
Plot size : 3.0 X 1.0 m^2
Spacing : 1.0 X 0.5 m^2
Variety : Hilton (hybrid for polyhouse condition)
: AAUC-2 (rain shelter)
Season : December to March (2015-2016)

Table 1. Treatments in the experiment (downy mildew of cucumber)

Treatments	Chemical/bio control agents	Concentration (%)
T_1	Soil solarisation + seed treatment and soil application of *Trichoderma viride*+ foliar spray with *Trichoderma viride*	2%
T_2	Soil solarisation + seed treatment and soil application of *Pseudomonas fluorescens* + foliar spray with *Pseudomonas fluorescens*	2%
T_3	Foliar spray with *Trichoderma viride*	2%
T_4	Foliar spray with *Pseudomonas fluorescens*	2%
T_5	Foliar spray with cow dung supernatant	5%
T_6	Foliar spray with cow dung supernatant (5%) + *Pseudomonas fluorescens* (2%)	5% +2%
T_7	Foliar spray with garlic extract	2%
T_8	Foliar spray with Calphomil	0.3%

T_9	Foliar spray with combined formulation of potassium phosphonate + hexaconazole	0.3%
T_{10}	Foliar spray with cymoxanil + mancozeb	0.2%
T_{11}	Foliar spray with mancozeb	0.2%
T_{12}	Control	

e. Details of the plant protection chemicals

Table 2. The following fungicides were used for the experiment

Sl.n	Common name/ General name	Trade name	Contact/ systemic	Concentration (%)
1	Calphomil	Calphomil	contact	0.3%
	Potassium phosphonate + Hexoconazole	Samarth (combined formulation of Potassium phosphonate and Hexoconazole)	systemic	0.3%
3	Cymoxanil+ mancozeb	Curzate M8	systemic	0.2%
4	Mancozeb	Indofil M45 75 WP	systemic	0.2%

f. Details of the bio control agents

Table 3. The following bio control agents were used for the experiment

Sl.no	Common name	Concentration (%)
1	*Trichoderma viride* (KAU)	2%
2	*Pseudomonas fluorescens* (KAU)	2%
3	Cow dung(Fresh cow dung supernatant)	5%
4	Cow dung slurry + *Pseudomonas fluorescens*	5% + 2%
5	Garlic extract	2%

g. Soil solarisation

Beds of 3.0 x 1.0 m^2 size and 10 cm height were taken. Well decomposed FYM and poultry manure were incorporated in the beds and the beds were irrigated using rose can. The beds were perfectly leveled. Transparent polythene sheet of 150 gauge thickness was stretched and spread over the beds so that it is placed touching the surface of the bed and there is no air pocket in between.

Plate 4- Layout of the experiments poly house and rain shelter

The sides of the polythene sheet were sealed by putting soil. Solarisation was carried out in November – December for a period of 60 days in protected structures. Soil thermometers were installed at 10 cm depth in solarized and non- solarized beds in both polyhouse and rain shelter. Soil temperature was recorded at 7.30 am and 2.30 pm daily during the period of solarization.

h. Field studies

On completion of solarization for 60 days, polythene sheet was removed and soil thermometers were dismantled and the beds were mixed with basal dose of fertilizers. Treated seeds of cucumber were sown in the beds at a spacing of 1.0 x 0.5m^2 and 3-4 cm depth and then a thin layer of soil was spread over the beds. Fertigation and irrigation was carried out using drip irrigation system. Relative humidity inside the structure was maintained above 80 percent by operating fogger. Incidence of downy mildew was noticed on cucumber after 49 days after sowing (DAS) in polyhouse and 54 DAS in rain shelter.

i. Management of downy mildew of cucumber

The effectiveness of selected plant protection chemicals and bio control agents was tested against the downy mildew of cucumber under protected condition. The first foliar application was given at the onset of disease. Subsequent sprays were given at 15 days interval. Systemic fungicides were sprayed two times and contact fungicides and bio control agents were sprayed three times. Plants in each plot were separated using plastic screen during foliar spray, in order to avoid drift. Disease severity was recorded using 0-5 scale before spraying and 10 days after each praying. Based on the percentage of leaf area infected, disease severity was calculated. Yield data per plot were also recorded and cost: benefit ratio was worked out.

j. Enumeration of soil micro flora

Soil samples were collected from solarized and non-solarized beds from both polyhouse and rain shelter. The samples (1g) were used for the enumeration of soil micro flora *viz* fungi, bacteria and actinomycetes using serial dilution and plating technique.

k. Recording meteorological data during field experiment

Temperature and relative humidity inside the polyhouse and rain shelter was recorded using temperature and moisture meter which is permanently installed in the protected structures at 7.30 am and 2.30 pm daily during the experiment. Data were compared with daily temperature and RH of open condition, obtained from the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara.

l. Economic analysis

Total cost incurred and total returns were calculated separately for the treatments. The benefit: cost ratio was calculated at market price (Rs.30 kg^{-1}) of cucumber for all treatments as well as at 20 percent premium price for organic treatments alone.

m. Enumeration of phylloplane micro flora of cucumber under protected condition.

The phylloplane micro flora (fungi, bacteria and actinomycetes) of the crop was enumerated after each spray using serial dilution plating to know the changes due to the treatments.

n. Survival of the bio control agents on the phylloplane of cucumber under protected condition.

The bio control agents sprayed on leaves were selectively isolated and enumerated from the leaf surface at periodical intervals of 5, 10, 15 days after spraying using suitable media like TSM (*Trichoderma* selective agar medium base) and King's B for isolation of *Trichoderma viride* and *Pseudomonas fluorescens* respectively.

III. MANAGEMENT OF FUNGAL DISEASES OF CAPSICUM (*CAPSICUM ANNUUM* L.) UNDER PROTECTED CULTIVATION (2016 -2017)

a. Assessment of incidence and severity of fungal diseases of capsicum under protected structures in farmers' field.

A survey was conducted during August 2016 – February 2017 at Vellanikkara, Thanniyam, Elanad, Manalur and Puranattukara, in Thrissur, Chithali, in Palakkad, Plamootikada and Neyyattinkkara in Thiruvanathapuram where capsicum is grown under protected cultivation. Incidence and severity of fungal diseases of capsicum in poly houses were assessed using standard score charts and procedures. The major meteorological factors such as temperature and relative humidity influencing the crop and pathogen prevailing in the structure and open condition were recorded.

b. Correlation analysis of incidence and severity of fungal diseases of capsicum with meteorological factors

Data collected during the survey was subjected to correlation analysis using SPSSv16.0 data editor to assess the influence of meteorological factors on incidence and severity of fungal diseases in protected structures.

c. Experiment for management of fungal diseases of capsicum (*Capsicum annuum* L.) under protected cultivation

Field experiments were conducted under polyhouse and rain shelter during October to January (2016-17) to evaluate different treatments for the management of fungal diseases of capsicum (*Capsicum annuum* L.) under protected cultivation.

The details of the experiment are as follows.

Design:	RBD
Treatments:	7
Replication:	3
Plot size:	3X1.0m^2
Spacing:	0.5X0.5m^2
Variety:	Indra
Season:	October to January (2016-17)

Table 4. Treatment details (foliar diseases of capsicum)

Treatment	Description	Concentration (%)
T1	Soil solarisation+ soil application of *Trichoderma*(as per POP) -	2%
T2	T1+Seed treatment and foliar spray with *Pseudomonas fluorescens*	2%
T3	T1+Seed treatment with carbendazim+ mancozeb +foliar spray with copper hydroxide	0.2%
T4	T1+Seed treatment with carbendazim +mancozeb+ foliar spray with mancozeb	0.2%
T5	T1+Foliar spray with tebuconazole	0.1%
T6	T1+Foliar spray with difenoconazole	0.05%
T7	Untreated Control	

Table 5. Fungicides used for the experiment

Sl.	Chemical name	Trade name	Contact/ systemic	Concentration (%)
1	Carbendazim(12%)+mancozeb(63%)	Saaf	Systemic	0.2%
2	Copper hydroxide	Kocide	Contact	0.2%
3	Mancozeb	Indofil M 5%	Contact	0.2%
4	Tebuconazole	Folicur-25EC	Systemic	0.1%
5	Difenoconazole	Score-25WP	Systemic	0.05%

Table 6. Bio control agents used for the experiment

Sl. No	Concentration (%)
Trichoderma viride(KAU)	2%
Pseudomonas fluorescens	2%
Cow dung + Neem cake Trichoderma	1kg/m^2

d. Field preparation

Field experiments were conducted in polyhouse and rain shelter simultaneously. Land inside the structure was ploughed and thoroughly prepared into beds of size 3.0x1.0 m^2. In treatments T1 to T6 the beds were subjected to soil solarization for 90 days, then polythene sheets were removed, and seedlings were transplanted at a spacing of 0.5mx0.5m and 3-4cm depth. Fertigation and irrigation were carried out using drip irrigation system.

Soil solarization

Soil solarization was carried out during June-August for a period of 90 days in protected structures. Soil thermometers were installed at 10cm depth in solarized and

non-solarized beds in polyhouse and rain shelter (Plate 1) and soil temperature was recorded at 7:30 am and 2:30 pm daily during the period of solarization.

Plate 5- Layout of the experiments poly house and rain shelter

e. Management of fungal diseases of capsicum under protected cultivation

The effectiveness of selected plant protection chemicals, bio control agents as per Table 1 was tested against fungal diseases of capsicum under protected condition (Plate 1 & 2). Application of treatments was given at the onset of the disease. Subsequent sprays were given at 15 days interval. Systemic fungicides were sprayed twice times, and contact fungicides and bio control agents were applied thrice. Disease severity of *cercospora* leaf spot was recorded using 0-5 scale before spraying and 15 days after each spraying.

Plate 6. Field view of the experiment in polyhouse(capsicum)

f. Meteorological parameters

Temperature and relative humidity inside the polyhouse and rain shelter were recorded at 7.30am and 2.30pm daily during the experiment using temperature and moisture meter which are permanently installed in the structures. Correlation analysis was performed between major meteorological factors and disease severity using SPSS

v16.0 data editor. Per cent disease severity in control, recorded at 15 days interval and temperature and relative humidity during the week prior to the date of observation of the disease were utilized for the analysis.

g. Economic analysis

Total cost incurred and total returns per plot ($3m^2$) were calculated separately for the treatments. The cost: benefit ratio was calculated at market price ($Rs.50kg^{-1}$) of capsicum.

h. Enumeration of soil micro flora

Soil samples were collected from solarized and non-solarized beds from both polyhouse and rain shelter. The samples (1g) were used for the enumeration of soil micro flora *viz* fungi, bacteria and actinomycetes using serial dilution and plating technique.

i. Enumeration of phylloplane micro flora of cucumber under protected condition.

The phylloplane micro flora (fungi, bacteria and actinomycetes) of the crop was enumerated after each spray using serial dilution plating to know the changes due to the treatments.Population of the phylloplane micro flora was expressed as number of cfu cm^{-2} area of leaf.

j. Survival of the *Pseudomonas fluorescens* on phylloplane of capsicum

The population of bio control agent sprayed on leaves was estimated at periodical intervals of 5, 10, 15, days after spraying. The diluted leaf washings were plated and colonies of *P. fluorescens* were counted at 48hours of incubation. The Population was expressed as cfu cm^{-2} area of leaf.

IV. MANAGEMENT OF EARLY BLIGHT DISEASE OF TOMATO (*SOLANUM LYCOPERSICUM* L.) UNDER PROTECTED CULTIVATION

a. Experiment for management of early blight of capsicum (*Solanum lycopersicum L.*) under protected cultivation

Field experiments were conducted under polyhouse and rain shelter during June to December (2017) to evaluate different treatments for the management of early blight of tomato (*Solanum lycopersicum L.)* under protected cultivation.

The details of the experiment are as follows.

Design:	RBD
Treatments:	11
Replication:	3
Plot size:	$3X1.0m^2$
Spacing:	$0.6X0.6m^2$
Variety:	Akshaya
Season:	June to December, 2017

Table 7. Treatment details (early blight of tomato)

Treatment	Description	Concentration (%)
T1	Soil solarisation + Seed treatment and foliar spray Propineb	0.05%
T2	Soil solarisation + Seed treatment and foliar spray Propineb	0.2%
T3	solarisation + Seed treatment and foliar spray Hexaconazole	0.05%
T4	solarisation + Seed treatment and foliar spray Hexaconazole	0.1%
T5	Soil solarisation + Seed treatment and foliar spray Difenoconazole	0.05%
T6	Soil solarisation + Seed treatment and foliar spray Quintal	0.05%
T7	Soil solarisation + Seed treatment and foliar spray Quintal	0.1%
T8	solarisation + Seed treatment and foliar spray *Trichoderma viride*	2%
T9	Soil solarisation + Seed treatment and foliar spray PGPM	2%
T10	solarisation + Seed treatment and foliar spray Endophytic bacteria	
T11	Control	

b. Field preparation

Field experiments were conducted in polyhouse and rain shelter simultaneously. Land inside the structure was ploughed and thoroughly prepared into beds of size 3.0x1.0 m^2. In treatments T1 to T11 the beds were subjected to soil solarization for 90 days, then polythene sheets were removed, and seedlings were transplanted at a spacing of 0.6X0.6 m2 and 3-4cm depth. Fertigation and irrigation were carried out using drip irrigation system.

c. Soil solarization

Soil solarization was carried out during June-August for a period of 60 days in protected structures. Soil thermometers were installed at 10cm depth in solarized and non-solarized beds in polyhouse and rain shelter and soil temperature was recorded at 7:30 am and 2:30 pm daily during the period of solarization.

d. Management of early blight disease of tomato under protected cultivation

The effectiveness of selected plant protection chemicals, bio control agents as per Table 6 was tested against early blight diseases of tomato under protected condition (Plate 1 & 2). Application of treatments was given at the onset of the disease. Subsequent sprays were given at 15 days interval. Systemic fungicides were sprayed twice times, and contact fungicides and bio control agents were applied thrice.

Plate 7. General view of field(tomato)

Plate 8. The crop at fruiting stage
a) rainshelter **b) polyhouse**

Plate 9. Symptoms of early blight of tomato

3. RESULTS

I. SURVEY ON DISEASES OF VEGETABLE CROPS UNDER PROTECTED STRUCTURES (2014-2015)

Survey on diseases of vegetable crops

Survey was conducted in 12 districts of Kerala including different agro climatic zones of the state. A total of 53 farmers' polyhouses were visited in different locations. Eleven different vegetable crops are being cultivated in polyhouses in Kerala. Cowpea (yard long bean) is the most widely grown (15 locations) crop followed by cucumber (14 locations). Tomato is being grown in three locations, but in general, the crop is not remunerative because of very less fruit set compared to open cultivation. Crops like bitter gourd, crucifers, chillies, summer squash, bottle gourd, amaranth and ginger are also being cultivated in polyhouses to limited extent. The consolidated data collected during the survey are given below.

Table 8-THRISSUR

Date of survey: 14/11/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Manaloor	1	cucumber	Downy mildew (*Pseudoperonospora cubensis*)	0-20	cow pea	No disease	nil
					chillies	No disease	nil
Peringottukara	3	chillies	Powdery mildew *Leveillula taurica*)	0-80	brinjal	Powdery mildew (*Leveillula taurica*)	0-80
						Fruit rot *Phomopsis vexans*)	10-50
Guruvayoor	2	cucumber	Powdery mildew *Erysiphe cihoracearum)*	0-13.7	No crop	No disease	nil
		amaranth	white rust (*Albugo bliti*)	0-9.7			

Table 9-KOTTAYAM
Date of survey: 17/04/2015,18/04/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Kottayam	4	cow pea	Powdery mildew (*Erysiphe olygoni*)	30-85	No crop	No disease	Nil
			anthracnose (*Colletotrichum* sp.)	0-35			
		cucumber	collar rot (*Pythium phanidermatum*)	0-10			
Pala	3	cowpea	Powdery mildew (*Erysiphe olygoni*)	0-80	No crop	No disease	Nil
			anthracnose (*Colletotrichum* sp.)	>20			
		bhindi	leaf spot (*Cercopsora alayensis*)	0-10			
			Powdery mildew	0-40			
Erattupetta	2	cowpea	anthracnose (*Colletotrichum* sp.)	0-40	No crop	No disease	Nil
		tomato	No disease	Nil			

Table 10- ALAPPUZHA, PATHANAMTHITTA & KOLLAM
Date of survey: 14/02/2015-16/02/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Chengannur	1	cow pea	No disease	NIL	Tapioca & brinjal	No disease	nil
Kayankulam	2	cucumber	collar rot (*Pythium phanidermatum*)	0-20.4	No crop	No disease	nil
			Downy mildew *Pseudoperonospora cubensis*)	0-22.2			
Mavellikkara	1	cow pea	No disease	Nil	No crop	No disease	nil
iv)PATHANAMTHITTA-15/02/2015							
Adoor	1	cow pea	Powdery mildew (*Erysiphe olygoni*)	0-56.8	No crop	No disease	nil
			Mosaic (cowpea mosaic virus)	0-25			
v) KOLLAM-16/02/2015							
Kottarakkara	2	cowpea	Powdery mildew (*Erysiphe polygoni*)	0-10	No crop	No disease	nil
		tomato	early blight (*Alternaria solani*)	0-67.5			
		cabbage & cauliflower	Rotting of foliage (*Rhizopus* sp.)	0-10			

Table 11- PALAKKAD
Date of survey :27/02/2015, 11/03/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Kadumthuruthi	2	cow pea	Powdery mildew (*Erysiphe polygoni*)	0-5	No crop	No disease	nil
		cucumber	Downy mildew (*Pseudoperonospora cubensis*)	20-60			
Mannarkad	3	cow pea	Powdery mildew (*Erysiphe polygoni*)	0-5	brinjal	Cercospora leaf spot	60-65
		cucumber	Damping off (*Pythium aphanidermatum*)	0-10	tapioca	mosaic	0-70
Perumatty	5	cucumber	leaf blight (*Alternaria* sp.)	0-10	No crop	No disease	nil
Thannissery	1	cucumber	No disease	nil	No crop	No disease	nil

Table 12- ERNAKULAM
Date of survey: 20/05/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Kothamangalam	2	cow pea	No disease	nil	marigold	No disease	nil
					amaranth	No disease	nil
		cucumber	No disease		bhindi	No disease	nil

Table 13- MALAPPURAM
Date of survey : 28/05/2015,26/07/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Parappanagadi	1	cow pea	No disease	nil	No crop	No disease	nil
Thirur	3	chilli	Powdery mildew (*Leveillula taurica*)	0-15	banana	No disease	nil
		cowpea	anthracnose (*Colletotrichum* sp.)	10-20	pepper		
		bottle gourd	Downy mildew (*Pseudoperonospora cubensis*)	75-80	yam		

Table 14- WAYANAD
Date of survey: 13/07/2015 -15/07/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Sulthanbathery	4	tomato	bacterial wilt (*Ralstonia solanacearum*)	0-20	banana	No disease	nil
		cauliflower	Black rot (*Xanthomonas campestris* pv. *campestris*)	0-10			
		ginger	Mosaic (virus)	10-20			
Kalpetta	2	cucumber	Downy mildew (*Pseudoperonospora cubensis*)	70-80	No crop	No disease	nil
			Powdery mildew (*Erysiphe cihoracearum*)	70-80			
		strawberry	leaf blight	45-60			
		cowpea	Cowpea mosaic virus	0-5			
		bitter gourd	-Do-	20-25			

Table 15- KOZHIKODE
Date of survey : 30/07/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Kundamangalam	2	cowpea	No disease	nil	No crop	No disease	nil
Kappad	1	summer squash	Powdery mildew (*Erysiphe cihoracearum*)	70-80	No crop	No disease	nil
		cucumber	Powdery mildew (*Erysiphe cihoracearum*)	10-20			

Table 16- KANNUR
Date of survey : 30/07/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Parassinikadavu	3	cow pea	Powdery mildew (*Erysiphe polygoni*)	60-75	amaranth	No disease	nil
		cucumber	Mosaic (virus)	15-20	marigold		
		bitter gourd	Mosaic (virus)	10-20			

Table 17- KASARGOD
Date of survey : 31/07/2015-1/08/2015

	No	Inside			Outside		
		Crops	Diseases	PDS	Crops	Diseases	PDS
Kasargod	2	cucumber	Downy mildew (*Pseudoperonospora cubensis*)	10-20	No crop	No disease	nil

3. B. Soil nutrient status, soil micro flora and meteorological data

The soil samples collected from inside and outside of poly houses were analysed for different soil nutrients, soil reaction, electrical conductivity *etc.* The results varied widely for different locations surveyed.

The data on nutrient and miroflora analyses are presented below district wise. In most of the locations, the nutrient status is sufficient or higher than needed inside the polyhouses compared to the outside soil. But nutrient deficiencies are common in polyhouse crops. The fast growth rate of the crops may be the reason for the same. Hence it is required to fix separate nutrient status for polyhouse cultivation. Meteorological data showed wide variation among poly houses. It varied mainly with the crop, irrigation schedule, type of the structure, location etc.

3. B. 1. Soil nutrient and micro flora analyses

Table 18. THRISSUR

	Poly house 1		Poly house 2		Poly house 3		Poly house 4			Poly house 5			Poly house 6		
Parameter	**TH_1O^***	**TH_1I^***	**TH_2**	**TH_2I**	**TH_3O**	**TH_3I**	**GR_1gs**	**GR_1O**	**GR_1I**	**GR_2O**	**GR_2I**	**GR_3I**	**PN_1O**	**PN_1I**	**PN_2I**
pH	6.2	7.6	6.7	7.6	6.1	6.8	7.3	6.4	8.1	6.6	7.1	6.9	6.6	6.7	7.4
El C (dS/m)	0.03 (N) **	0.839(N)	0.03 (N)	2.23 (H)	0.06 (N)	1.43 (H)	2.76 (H)	0.05 (N)	0.70 (L)	0.03 (N)	1.11 (H)	0.40 (N)	0.04 (N)	0.55 (N)	0.91 (N)
OrganicC (%)	0.47 (L)	1.38(M)	0.29 (L)	0.52 (L)	0.95 (M)	1.09 (M)	7.76 (H)	0.50 (L)	1.03 (M)	0.41 (L)	1.20 (M)	1.22 (M)	0.85 (M)	0.97 (M)	0.66 (L)
Available P (kg/ha)	44.34 (H)	187.06(H)	37.41 (H)	51.27 (H)	34.64 (H)	367.19 (H)	705.28 (H)	55.42 (H)	238.33 (H)	58.20 (H)	358.67 (H)	248.0 (H)	77.59 (H)	471.1 (H)	99.76 (H)
Available K (kg/ha)	43.70 (L)	862.40(H)	34.70 (L)	1359.7 (H)	68.30 (L)	813.10 (H)	1671.04 (H)	45.90 (L)	673.10 (H)	64.90 (L)	800.80 (H)	386.4 (H)	42.60 (L)	357.3 (H)	355.04 (H)
Available Ca (mg/kg)	192.00 (D)	1686.5(S)	465.7 (S)	1024.0(S)	877.25 (S)	1909.2 (S)	2095.00 (S)	282.75 (D)	1778.25 (S)	434.50 (S)	1414.25 (S)	924.5 (S)	666.75 (S)	1004. (S)	1462.5 (S)
Available Mg (mg/kg)	37.50 (D)	149.50 (S)	374.2 (S)	34.75 (D)	33.25 (D)	173.75 (D)	253.25(S)	111.00 (D)	111.00 (S)	94.50 (S)	78.50 (S)	45.50 (D)	144.25(D)	152.5 (S)	75.50 (D)
Available S (mg/kg)	5.11 (S)	78.90 (S)	9.38 (S)	96.60 (S)	4.94 (D)	11.40 (S)	100.60 (S)	5.10 (S)	48.30 (D)	6.50 (S)	163.10(S)	27.80 (S)	24.7 (S)	80.40 (S)	38.10 (S)
Micronutrients															
Cu(mg/kg)	0.55 (S)	0.95 (S)	0.84 (S)	0.62 (S)	3.09 (S)	8.31 (S)	-	1.40 (S)	0.82 (S)	0.69 (S)	0.71 (S)	1.14 (S)	1.50 (S)	5.90 (S)	0.58 (S)
Fe(mg/kg)	133.50 (S)	11.69 (S)	19.30 (S)	18.37 (S)	39.81 (S)	23.25 (S)	5.66 (S)	9.02 (S)	6.88 (S)	37.12 (S)	7.29 (S)	26.80 (S)	17.94 (S)	18.87 (S)	29.42 (S)
Zn (mg/kg)	0.80 (S)	1.70 (S)	0.53 (D)	1.00 (S)	1.92 (S)	23.20 (S)	-	4.41 (S)	3.20 (S)	2.14 (S)	3.28 (S)	7.44 (S)	22.68 (S)	18.41 (S)	1.89 (S)
Mn (mg/kg)	4.84 (S)	7.47 (S)	2.09 (S)	40.98 (S)	5.27 (S)	32.02 (S)	-	13.58 (S)	10.05 (S)	3.26 (S)	3.92 (S)	6.02 (S)	4.64 (S)	18.09 (S)	19.76 (S)
B (mg/kg)	0.12 (D)	0.86 (S)	0.18 (D)	2.56 (S)	0.24 (D)	6.71 (S)	4.70 (S)	0.15 (D)	0.69 (S)	0.14 (D)	0.39 (D)	0.28 (D)	0.14 (D)	0.15 (D)	0.15 (D)
Population of soil microflora															
Fungi ($x10^3$cfu g^{-1})	171	162	93	7	440	233	--	9	33	539	470	-	53	273	347
Bacteria ($x10^6$cfu g^{-1})	0	3	2	22	2	13	-	11	1	25	1	-	3	10	0
Actinomycetes($x 10^3$cfu g^{-1})	20	9	8	0	13	5	-	7	2	31	13	-	0	15	5

****N-Normal, M-Medium, L-Low, H-High, D-Deficient, S-SufficientO-Outside I-Inside TH_1O^* & TH_1I -Thanniyam 1, TH_2O & TH_2I - Thanniyam 2, TH_3O & TH_3I - Thanniyam 3GR_1gs - Guruvayoor grow bag soil, GR_1O& GR_1I – Guruvayoor 1, GR_2O& GR_2I – Guruvayoor 2GR_3I – Guruvayoor amaranth soil, PN_1O & PN_1I – Peringottukara 1, PN_2I-Peringottukara chilli**

Table 19. KOTTAYAM

	Poly house 1		Poly house 2		Poly house 4		Poly house 5		Poly house 6	
Parameter	**KPKO***	**KPKI***	**CHTERO**	**CHTERI**	**KKLO**	**KKLI**	**SGCATAO**	**SGCATAI**	**JJAMRLO**	**JJAMRLI**
pH	5.1	8.0	8.2	6.9	5.5	7.6	7.1	7.1	7.7	7.3
El C (dS/m)	0.08 (N)**	1.80 (H)	0.22(N)	1.19(H)	0.04(N)	0.58(N)	0.21(N)	0.72(N)	0.35(N)	1.64 (H)
Organic C (%)	1.21 (M)	2.34 (H)	1.04(M)	3.88(H)	1.52(H)	1.61(H)	0.85(M)	1.42(M)	1.66 (H)	3.82 (H)
Available P (kg/ha)	7.07 (L)	38.91 (H)	38.91 (H)	1273.26 (H)	8.84(L)	98.44(H)	10.61(M)	300.63(H)	229.89 (M)	1550.32 (H)
Available K (kg/ha)	420.00 (H)	4950.4 (H)	285.60 (H)	940.80 (H)	112.00 (L)	638.40 (H)	163.52 (M)	364.00 (H)	862.40 (H)	3113.60 (H)
Available Ca (mg/kg)	282.25 (D)	1546.5 (S)	1925.25 (S)	1844.00(S)	559.00(S)	1882.50 (S)	905.75(S)	1072.75 (S)	1470.75 (S)	1465.75 (S)
Available Mg (mg/kg)	59.00 (D)	173.25 (S)	58.75(D)	757.50(S)	43.25(D)	114.50 (D)	91.00(D)	201.50(S)	265.50(S)	506.25(S)
Available S (mg/kg)	9.32(S)	161.29 (S)	19.15(S)	127.27(S)	16.13(S)	93.49(S)	9.07(S)	45.36(S)	37.30(S)	198.59(S)
Micronutrients										
Cu(mg/kg)	31.28 (S)	2.51 (S)	4.41(S)	53.49(S)	1.18(S)	3.77(S)	2.51(S)	1.82(S)	2.55(S)	1.11 (S)
Fe(mg/kg)	1.61(S)	44.26 (S)	27.68(S)	36.39(S)	45.78(S)	26.44(S)	44.39(S)	32.06(S)	36.16(S)	45.19(S)
Zn (mg/kg)	4.94 (S)	19.46 (S)	13.54(S)	30.90(S)	1.59(S)	4.94(S)	4.27(S)	19.18(S)	13.30(S)	8.67(S)
Mn (mg/kg)	0.22 (D)	18.02 (S)	12.07(S)	50.38(S)	1.37(S)	22.80(S)	8.85(S)	10.85(S)	33.17(S)	26.02(S)
B (mg/kg)	1.52(S)	1.78 (S)	0.19(D)	26.67(S)	0.29(D)	0.14(D)	0.12(D)	0.40(D)	0.40(D)	0.07(D)
Population of soil microflora										
Fungi($x10^3$cfu g^{-1})	6	5	86	122	81	86	18	82	63	104
Bacteria($x10^6$cfu g^{-1})	4	5	12	16	5	8	3	24	11	12
Actinomycetes($x10^5$cfu g^{-1})	4	5	6	8	12	25	3	6	12	13

O-Outside I-Inside **KPK***-kattampack, **CHTER**- Chythanya Trust,Ettumanoor **KKL**- KarukachalSGCATA- St. George college ,Aruvithara, **JJAMRL** - Jose Joseph,Ambaranireppel

Table 20. ALAPPUZHA, PATHANAMTHITTA, KOLLAM

O-Outside I-Inside CGMR*- Chengamanoor, WGADR- Wilson George,Adoor.,MKTKRA- Mathew Sam , Kottarakkara, BPPTR- Balachandran Pillai, Thevalappuram**N-Normal, M-Medium, L-Low, H-High, D-Deficient, S-Sufficient

Parameters	CGMRO*	CGMRI*	WGADRO	WGADRI	MKTKRAO	MKTKRI	BPPTRO	BPPTRI
	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity
pH	6.5	6.2	7.0	6.5	5.1	6.8	6.1	6.8
El C (dS/m)	0.15(N)**	1.13(H)	0.46(N)	1.07(H)	0.03(N)	1.24(H)	0.17(N)	0.34(N)
Organic C %)	1.34(M)	1.71(H)	4.52(H)	3.35(H)	0.94(M)	4.45(H)	1.15(M)	1.63(H)
AvailableP (kg/ha)	483.37(H)	341.89(H)	135.58(H)	306.53(H)	5.15(L)	689.68(H)	20.63(M)	140.88(H)
AvailableK (kg/ha)	174.72(M)	935.20(H)	828.80(H)	1332.80H)	105.28(L)	1747.20(H)	677.60(H)	1041.60(H
Available Ca g/kg)	501.50(S)	1050.25(S)	1761.25(S)	1459.50(S)	250.25(D)	1726.75(S)	475.50(S)	725.00(S)
Available Mg mg/kg)	45.75(D)	161.00(S)	155.75(S)	200.00(S)	69.75(D)	741.50(S)	86.75(D)	141.00(S)
AvailableS (mg/kg)	28.98(S)	47.13(S)	45.36(S)	125.00(S)	9.83(S)	157.01(S)	23.18(S)	39.31(S)
Micronutrients								
Cu(mg/kg)	2.99(S)	1.83(S)	2.47(S)	8.77(S)	2.27(S)	28.80(S)	1.49(S)	1.44(S)
Fe(mg/kg)	42.70(S)	66.17(S)	50.34(S)	71.29(S)	17.40(S)	38.75(S)	20.93(S)	42.96(S)
Zn (mg/kg)	6.53(S)	3.78(S)	7.80(S)	17.30(S)	0.46(D)	35.40(S)	2.30(S)	1.72(S)
Mn (mg/kg)	28.30(S)	21.62(S)	5.43(S)	14.95(S)	10.10(S)	32.81(S)	9.45(S)	13.31(S)
B (mg/kg)	0.36(D)	0.47(D)	0.33(D)	0.19(D)	0.26(D)	1.87(S)	0.36(D)	0.55(S)
Population of soil microflora								
Fungi($x10^3$cfu g^{-1})	81	98	69	71	0	19	0	5
Bacteria($x10^6$cfu g^{-1})	6	16	2	3	2	13	7	14
Actinomycetes($x10^5$cfu g^{-1})	2	3	23	32	0	7	4	15

Table 21. PALAKKAD

Parameters	KDHRIO*	KDHRII*	MNRKDO	MNRKDI
	Quantity	Quantity	Quantity	Quantity
pH	6.8	7.1	6.7	7.3
El C (dS/m)	0.20(N)**	1.20(H)	0.06(N)	1.50(H)
Organic C (%)	0.78 (M)	0.73(L)	1.00(M)	1.73(H)
Available P (kg/ha)	46.57(H)	73.68(H)	21.22(M)	107.87(H)
Available K (kg/ha)	280.00(H)	127.68(M)	143.36(M)	1209.60(H)
Available Ca (mg/kg)	1572.00(S)	1483.25(S)	745.25(S)	1783.00(S)
Available Mg (mg/kg)	641.00(S)	692.75(S)	129.25(S)	280.25(S)
Available S (mg/kg)	19.65(S)	116.43(S)	8.06(S)	265.37(S)
Micronutrients				
Cu(mg/kg)	3.63(S)	1.50(S)	2.80(S)	6.41(S)
Fe(mg/kg)	64.08(S)	36.38(S)	17.73(S)	37.58(S)
Zn (mg/kg)	3.77(S)	3.47(S)	4.09(S)	10.12(S)
Mn (mg/kg)	61.83(S)	14.37(S)	6.75(S)	6.49(S)
B (mg/kg)	0.19(D)	0.48(D)	0.28(D)	0.41(D)
Population of soil microflora				
Fungi($x10^3$cfu g^{-1})	0	2	3	1
Bacteria($x10^6$cfu g^{-1})	28	100<(Numerous)	2	11
Actinomycetes($x10^5$cfu g^{-1})	18	15	-	8

O-Outside I-Inside KDHRI*- Kadumthuruthi MNRKD- Moyidheen , Mannarkad **N-Normal, M-Medium, L-Low, H-High, D-Deficient, S-Sufficient

.Table 22. ERNAKULAM

Parameters	Poly house 1		Poly house 2	
	PMKYO*	PMKYI	KOPDIO*	KOPDII
	Quantity	Quantity	Quantity	Quantity
pH	4.7	5.9	4.6	5.7
El C (dS/m)	0.06(N)**	0.12(N)	0.39(N)	1.53(H)
Organic C (%)	1.75(H)	1.67(H)	1.31(M)	1.27(M)
Available P (kg/ha)	66.61(H)	38.91(H)	16.51(M)	459.79(H)
Available K (kg/ha)	95.20(L)	157.92(M)	655.20(H)	2016.00(H)
Available Ca (mg/kg)	286.25(D)	657.25(S)	255.00(D)	622.00(S)
Available Mg mg/kg)	49.25(D)	90.50(D)	110.00(D)	190.25(S)
Available S (mg/kg)	7.81(S)	7.56(S)	6.05(S)	70.81(S)
Micronutrients				
Cu(mg/kg)	3.31(S)	5.03(S)	2.31(S)	6.49(S)
Fe(mg/kg)	37.81(S)	39.43(S)	41.89(S)	44.22(S)
Zn (mg/kg)	1.62(S)	1.84(S)	1.03(S)	15.90(S)
Mn (mg/kg)	3.94(S)	8.27(S)	15.38(S)	11.51(S)
B (mg/kg)	0.31(D)	0.35(D)	0.33(D)	0.85(S)
Population of soil microflora				
Fungi($x10^3$cfu g^{-1})	11	10	29	17
Bacteria($x10^6$cfu g^{-1})	2	23	9	32
Actinomycetes($x10^5$cfu g^{-1})	9	15	6	9

O-Outside I-Inside **PMKY*-** Pannamkuzhy. **KOPDI-** Kottapady.
**N-Normal, M-Medium, L-Low, H-High, D-Deficient, S-Sufficient

Table 23. MALAPPURAM

Parameters	Poly house 1		Poly house 2 a		Poly house 2 b	
	PRPGDIO*	PRPGDII	VTMO*	VTMI	VTMO*	VTMI (Curry leaf)
	Quantity	Quantity	Quantity	Quantity	Quantity	Quantity
pH	6.7	7.1	7.0	6.7	7.0	7.1
El C (dS/m)	0.07(N)**	1.87(H)	0.16(N)	4.70(H)	0.16(N)	1.68(H)
Organic C (%)	0.54(L)	1.48(M)	1.19(M)	2.15(H)	1.19(M)	2.65(H)
Available P (kg/ha)	92.55(H)	341.89(H)	318.22(H)	1367.58(H)	318.22(H)	1114.11(H)
Available K (kg/ha)	174.72(M)	1209.60(H)	414.40(H)	5241.60(H)	414.40(H)	3158.40(H)
Available Ca (mg/kg)	775.50(S)	947.75(S)	1032.25(S)	1972.50(S)	1032.25(S)	1541.25(S)
Available Mg (mg/kg)	63.75(D)	156.25(S)	111.00(D)	759.75(S)	111.00(D)	190.25(S)
Available S (mg/kg)	10.33(S)	111.64(S)	11.34(S)	439.26(S)	11.34(S)	151.21(S)
Micronutrients						
Cu(mg/kg)	1.81(S)	1.23(S)	1.55(S)	1.45(S)	1.55(S)	1.97(S)
Fe(mg/kg)	27.61(S)	28.97(S)	45.07(S)	45.60(S)	45.07(S)	48.43(S)
Zn (mg/kg)	10.12(S)	1.04(S)	26.26(S)	5.04(S)	26.26(S)	0.51(D)
Mn (mg/kg)	8.09(S)	26.57(S)	11.53(S)	49.83(S)	11.53(S)	77.27(S)
B (mg/kg)	0.21(D)	0.52(S)	0.26(D)	3.15(S)	0.26(D)	0.54(S)
Population of soil microflora						
Fungi($x10^3$cfu g^{-1})	3	4	4	15	4	3
Bacteria($x10^6$cfu g^{-1})	3	6	11	31	11	35
Actinomycetes($x10^5$cfu g^{-1})	1	2	10	29	10	48

O-Outside I-Inside **PRPGDI*-** Parappanagadi. **VTM-** Vettam **N-Normal, M-Medium, L-Low, H-High, D-Deficient, S-Sufficient.

3. B.2. Meteorological data inside and outside the poly houses

Based on the data collected during survey, we could conclude that in general, relative humidity is higher inside the poly house. However, the RH inside the polyhouse depended on the irrigation pattern which varied widely. Hence periodical data recorded in a poly house will be needed in order to arrive at a conclusion.

II. MANAGEMENT OF DOWNY MILDEW (*PSEUDOPERONOSPORA CUBENSIS*) OF SALAD CUCUMBER (*CUCUMIS SATIVUS* L.) UNDER PROTECTED CULTIVATION (2015-2016)

a. Survey on incidence and severity of downy mildew of cucumber under protected and open condition in farmers' fields in Thrissur district.

A survey was conducted in Thrissur district during January-December of 2015. Data presented in the table shows that high humidity and low temperature influences the development of downy mildew of cucumber inside polyhouse.

Table 24. Incidence and severity of downy mildew of cucumber under polyhouses in farmers' fields in Thrissur district.

	Polyhouse			Disease		Meteorological parameters			
Sl.	Location	Area (m^2) of polyhouse	Period (2015)	PDI	PDS	Inside polyhouse		Outside polyhouse	
						Temp. (^{0}C)	RH	Temp. (^{0}C)	RH
1	Peringottukara(1)	220	January	12.70	24.56	30.5	93	31.1	93
2	Manaloor	400	March	4.67	11.33	29.4	79	28.0	81
3	Thanniyam (1)	365	May	13.34	25.00	31.6	87	30.5	86
4	Chenthrapinni(1)	420	June	15.45	35.75	24.7	97	23.3	91
5	Chenthrapinni (2)	400	July	12.67	28.90	26.4	95	24.6	93
6	Thanniyam (2)	400	August	5.33	15.67	33.8	81	32.7	80
7	Peringottukara(2)	180	September	6.98	16.17	32.0	83	28.1	81
8	Vellanikkara	200	November	11.33	14.67	32.7	83	31.2	82
9	Chavakkad	400	December	9.75	22.39	30.0	87	26.1	79

PDI-Per cent disease incidence, PDS-Per cent disease severity, Temp.-Temperature, RH-Relative humidity

The temperature inside the polyhouse varied from 24.7 to 33.8°C and the increase in temperature inside the polyhouse compared to outside varied from 0.6 to 3.9°C.The RH inside the polyhouse varied from 79 to 97 per cent and the increase in RH inside the polyhouse varied from 0 to 8 per cent.

b. Correlation analysis of incidence and severity of downy mildew with meteorological factors

Correlation analysis of disease incidence and severity with major meteorological parameters inside the polyhouse was performed.

Table 25. Correlation analysis of disease incidence and severity with major meteorological parameters.

Correlation coefficients	PDS	PDI	RH
PDI	0.859**		
RH	0.956**	0.845**	
Temperature	-0.757*	-0.546*	-0.768*

*Correlation is significant at 0.05 level ** Correlation is significant at 0.01 level

It is observed that there is a significant positive correlation between PDI/PDS with RH inside the polyhouse whereas they are negatively correlated with temperature. There is a significant positive correlation between PDI and PDS also.

c. Soil solarisation inside the structures

In general, soil temperature is found to be high in polyhouse compared to rain shelter, and in both the structures, temperature in solarized beds was higher than nonsolarized beds.

Table 26. Soil temperature of solarized and nonsolarized beds in polyhouse and rain shelter

Std week	Polyhouse				Rain shelter			
	7.30 am		2.30 pm		7.30 am		2.30 pm	
	S (^{0}C)	NS(^{0}C)	S(^{0}C)	NS(^{0}C)	S(^{0}C)	NS(^{0}C)	S(^{0}C)	NS(^{0}C)
41	30.5	30.0	37.0	33.5	29.5	28.5	36.0	32.5
42	32.0	30.5	35.0	32.0	31.0	29.0	36.0	33.0
43	32.0	30.5	35.5	33.0	31.0	29.0	34.0	31.5
44	32.5	31.0	37.5	33.5	31.5	30.0	36.0	33.0
45	32.5	30.5	37.0	34.0	30.0	28.5	32.0	30.0
46	31.0	30.0	35.5	33.0	31.5	30.0	34.0	31.0
47	32.0	30.5	36.5	34.0	31.5	29.0	36.5	33.5
48	31.0	30.0	37.5	34.0	31.0	29.0	35.5	32.5
49	31.0	30.0	37.0	33.5	31.5	30.0	35.5	33.0
50	32.5	31.0	37.0	33.5	31.0	29.0	35.0	32.0
51	30.0	28.5	37.5	34.0	31.0	29.0	34.5	33.5
52	30.0	28.5	37.0	34.0	31.0	30.0	36.0	33.5

S-solarized soil NS-non solarized soil

In polyhouse there is an increase in soil temperature up to of 4^{0}C in solarized beds over nonsolarized beds at 2.30 pm. During this period, temperature in solarized beds ranged from 33.5-37.5^{0}C in solarized beds, whereas in nonsolarized beds from 32-34^{0}C. At 7.30 am, soil temperature in solarized beds inside the polyhouse varied from 30-32.5^{0}C, whereas in nonsolarized beds it ranged from 28.5-31^{0}C. In rain shelter, there is an increase in soil temperature up to of 3.5^{0}C in solarized beds over nonsolarized beds at 2.30 pm and the temperature varied from 34 to 36.5 ^{0}C, whereas in nonsolarized beds

it ranged from 30-33.5^{0}C. At 7.30 am, soil temperature in rain shelter varied from 29.5-31.5 ^{0}C, whereas in nonsolarized beds from 28.5-30^{0}C.

d. Management of downy mildew of cucumber under polyhouse and rain shelter

The crop was raised in polyhouse and rain shelter during January to May of 2016. Relative humidity inside the structures was maintained >80 per cent by operating fogger. Incidence of downy mildew was noticed at 49 days after sowing (DAS) in polyhouse and at 54 DAS in rain shelter. The first foliar application was given at the onset of disease. Subsequent sprays were given at 15 days interval. Disease severity was recorded using 0-5 scale before spraying and 15 days after each praying.

Table 27. Effect of different treatments on downy mildew and yield of cucumber under polyhouse

Treatment	Per cent disease severity*						
	Before treatment	After first treatment	After second treatment	After third treatment	Per cent reduction over control	Mean yield (kg plot^{-1})**	Per cent increase over control
T_1 -S + ST + SA + foliar spray - *T. viride*	4.33	12.67^{abc}	16.67^{ab}	23.67^{abc}	60.99	23.40^{a}	71.01
T_2 -S + ST + SA + foliar spray - *P. fluorescens)*	5.00	13.67^{abcd}	17.00^{abc}	24.67^{abcd}	59.34	22.60^{ab}	65.16
T_3 -*T. viride*	6.67	15b^{cde}	18.33^{abcd}	26.67^{bcd}	56.15	20.63^{abc}	50.79
T_4 -*P. fluorescens*	6.33	15.67^{cde}	20.33^{bcd}	26.00^{abcd}	57.15	19.14^{c}	39.85
T_5 –cow dung supernatant	7.00	17.33^{c}	22.33^{d}	28.33^{d}	53.30	20.93^{abc}	52.98
T_6 –cow dung supernatant + *P. fluorescens*	6.00	17.00^{e}	20.33^{bcd}	28.00^{d}	53.85	20.32^{bc}	48.47
T_7 -garlic extract	6.33	16.00d^{e}	21.00^{cd}	27.33^{cd}	54.95	19.87^{bc}	45.19
T_8 –Calphomil	7.00	16.00d^{e}	20.33^{bcd}	27.00^{bcd}	55.50	20.47^{bc}	49.57
T_9 -potassium phosphonate + hexaconazole	5.67	16.33d^{e}	20.00^{abcd}	27.00^{bcd}	55.50	20.48^{bc}	49.69
T_{10}-cymoxanil + mancozeb	6.00	11.67^{a}	16.00^{a}	22.67^{a}	62.63	22.53^{ab}	64.68
T_{11} –mancozeb	7.00	12.33^{ab}	16.33^{ab}	22.33^{ab}	61.55	21.75^{abc}	58.95
T_{12} –control	6.67	22.33^{f}	36.33^{e}	60.67^{e}	-	13.68^{d}	-
CV	15.96	12.25	12.45	8.15		8.16	
CD	NS	3.22	4.31	3.97		2.83	

*Mean of three replications, values followed by same superscript are not significantly different by DMRT P=0.05) **plot size 3m^2. S-Soil solarization, ST- Seed treatment, SA-Soil application

All the treatments recorded lower disease severity compared to control (Table 4). Lowest disease severity was recorded in the systemic fungicide, T_{10} (cymoxanil + mancozeb) and the per cent reduction was found to be 62.63 per cent after the third spray.

Among the bio-fungicides, Calphomil and garlic recorded 55.50 and 54.95 per cent reduction of disease severity over control. Among treatments involving bio control agents, *Trichoderma viride* along with soil solarization(T_1) gave the best result in the reduction of downy mildew which accounts for 60.99 per cent and this is followed by T_2 *i.e.,* solarization + foliar spray of *Pseudomonas fluorescens* (59.34%). Effect of treatments was reflected on yield of cucumber. Even though the lowest PDS was recorded in T_{10} (cymoxanil + mancozeb), mean yield was found to be more in the treatments in which solarisation is carried out *i.e.,* in T_1 and T_2.

Table 28. Effect of different treatments on downy mildew and yield of cucumber under rain shelter

Treatment	Per cent disease severity*						
	Before treatment	After first treatment	After second treatment	After third treatment	Per cent reduction over control	Mean yield (kg.plot^{-1})**	Per cent increase over control
T_1 -S + ST + SA + foliar spray - *T. viride*	4.33	7.67^{abc}	10.67^{abc}	11.67^{abc}	52.70	16.78^{a}	54.92
T_2 -S + ST + SA + foliar spray - *P. fluorescens)*	4.00	8.00^{abc}	11.00^{abc}	12.00^{abc}	51.35	16.03^{ab}	48.00
T_3 -*T. viride*	5.00	8.00^{abc}	11.67^{bcd}	12.33^{abc}	50.00	15.15^{abc}	39.85
T_4 -*P. fluorescens*	6.00	8.67^{bc}	11.67^{bcd}	12.67^{abc}	48.65	14.88^{abc}	37.38
T_5 –cow dung supernatant	6.00	9.00^{c}	13.33^{de}	13.67^{c}	44.60	13.93^{bc}	28.62
T_6 –cow dung supernatant + *P. fluorescens*	5.33	8.67^{bc}	12.67^{cde}	13.00^{bc}	47.30	14.02^{bc}	29.38
T_7 -garlic extract	6.00	9.00^{c}	14.33^{e}	13.67^{c}	44.60	13.77^{c}	27.08
T_8 –Calphomil	5.67	8.67^{bc}	12.67^{cde}	13.33^{bc}	45.95	13.97^{bc}	28.92
T_9 -potassium phosphonate + hexaconazole	5.67	8.67^{bc}	11.67^{bcd}	13.00^{bc}	47.30	14.20^{bc}	31.08
T_{10}-cymoxanil + mancozeb	6.67	7.00^{a}	9.33^{a}	11.00^{a}	55.41	15.38^{abc}	41.97
T_{11} –mancozeb	5.67	7.33^{ab}	10.33^{ab}	11.33^{ab}	54.05	15.18^{abc}	40.09
T_{12} –control	6.33	13.00^{d}	20.00^{f}	24.67^{d}	-	10.83^{d}	-
CV	16.85	9.75	9.78	9.86		8.55	
CD	NS	1.43	2.06	2.26		2.10	

*Mean of three replications, values followed by same superscript are not significantly different by DMRT (P=0.05) **plot size 3m^2
S-Soil solarization, ST- Seed treatment, SA-Soil application

In rain shelter also, all the treatments at all the stages of treatment application were found to be superior over the control (Table 5). After the third treatment application, lowest disease severity was recorded in the systemic fungicide, T_{10} (cymoxanil + mancozeb) in all the treatment application and the percent reduction was found to be 55.41% followed by T_{11} (Mancozeb) which shows 54.05% reduction. Effect of treatments was reflected on yield. Even though lowest PDS was recorded in T_{10} (cymoxanil + mancozeb), mean yield was found to be more in solarized beds. Treatment T_1 (solarisation+ *Trichoderma viride)* was found to be the best treatment followed by T_2 (solarisation + foliar spray of *Pseudomonas fluorescens).*

e. Enumeration of soil micro flora in polyhouse

The population of fungi, bacteria and actinomycetes in solarized and non-solarized soil was enumerated in polyhouse and rain shelter. The results are presented in Table 6. During the period of solarization, there was reduction in the population of soil micro flora in all the plots, but it was highly prominent in solarized beds.

The percentage reduction in the fungal flora in polyhouse was 79.34, whereas in nonsolarized beds it was only 28.18 per cent. Similarly the bacterial population was reduced by 77.50 per cent in solarized beds, while in nonsolarized beds the reduction was only 31.33 per cent. The population of actinomycetes was also reduced by 67.85 per cent in solarized beds, compared to 25.92 per cent in nonsolarised soil.

Table 29. Population of soil micro flora in polyhouse and rain shelter

Soil micro flora	Polyhouse						Rain shelter					
	Solarised soil			Non solarized soil			Solarised soil			Non solarized soil		
	Before	After	% reduction	Before	After	% reduction	Before	After	% reduction	Before	After	% reduction
Fungi $x10^{-3}cfug^{-1}$	151.67	31.33	79.34	145.89	104.78	28.18	133.45	35.66	73.28	128.89	89.00	30.95
Bacteria $x10^{-6}cfug^{-1}$	56.30	12.67	77.50	52.45	31.33	40.27	34.89	9.34	73.23	32.45	18.33	43.51
Actinomycetes $x10^{-5}cfug^{-1}$	9.33	3.00	67.85	10.34	7.66	25.92	12.34	4.30	65.15	11.66	8.56	26.59

*Mean of three replication

In rain shelter also the same trend was observed and the per cent reduction in fungal flora in solarized beds was found to be 73.28, whereas in nonsolarized beds the reduction was only 30.95. Similarly the bacterial population was reduced by 73.23 per cent in solarized beds, while in nonsolarized beds the reduction was only 43.51per cent. In the case of actinomycetes the reduction was 65.15and 26.59 per cent, in solarized and nonsolarized beds respectively.

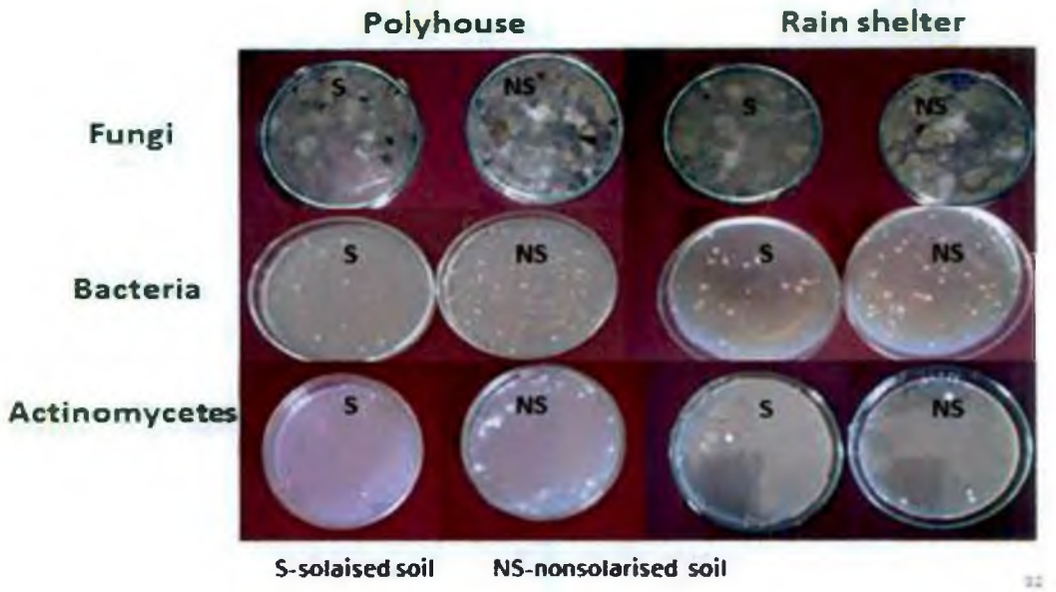

Plate 10. Population of soil micro flora

f. Meteorological parameters

Temperature and relative humidity inside the polyhouse and rain shelter was recorded at 7.30 am and 2.30 pm daily during the experiment (Table 7). Temperature was found to be higher in rain shelter compared to polyhouse. Inside the polyhouse the temperature varied from 22.6 to 29.6°C at 7.30 am and during this period, in rain shelter it varied from 23.2 to 30.4°C. At 2.30 pm, the temperature inside the polyhouse and rain shelter varied from 36.6 to 42.5°C and 40.6 to 44.1°C respectively.

Table 30. Meteorological data during the period of experiments in polyhouse and rain shelter

Std. week *	Meteorological parameters											
	Polyhouse				Rain shelter				Open			
	7.30 am		2.30 pm		7.30 am		2.30 pm		7.30 am		2.30 pm	
	Temp. (°C)	RH	Temp. (°C)	RH	Temp. (°C)	RH	Temp. (°C)	RH	Temp. (°C)	RH	Temp. (°C)	RH
1	27.0	71	42.5	42	27.8	61	42.1	37	22.5	72	32.5	41
2	25.1	74	39.9	42	25.8	66	40.9	32	22.7	75	32.7	46
3	26.6	76	36.6	40	27.2	70	41.2	32	24.2	72	34.1	42
4	24.9	65	40.5	33	25.4	64	40.9	25	22.1	66	34.5	26
5	22.6	80	40.1	41	23.2	80	42.1	37	22.2	82	34.9	39
6	25.8	80	40.3	37	26.3	78	40.6	32	24.1	79	35.1	36
7	29.6	81	40.1	39	30.4	80	42.1	32	24.6	82	36.2	44
8	27.5	84	41.2	46	28.1	83	42.6	41	24.8	84	36.0	34
9	24.7	81	40.0	67	25.2	80	40.6	46	25.0	81	36.7	42
10	29.1	80	39.8	76	28.7	80	40.7	54	25.0	81	36.7	42
11	27.5	89	40.1	64	27.9	87	40.7	50	25.0	90	36.1	51
12	29.3	91	40.1	60	29.8	90	42.7	46	27.3	92	35.8	56
13	28.3	89	41.1	61	28.6	88	44.1	45	25.5	90	36.8	51
14	29.6	87	41.2	62	30.4	86	43.1	46	25.8	87	36.4	52
15	30.7	85	41.6	52	31.2	83	44.1	46	26.3	86	35.0	59

Inside the polyhouse, relative humidity varied from 65 to 91 per cent at 7.30 am and during this period, in rain shelter it varied from 64 to 90 per cent. At 2.30 pm, RH inside the polyhouse and rain shelter varied from 33 to 76 per cent and 32 to 54 per cent respectively.

Table 31. Correlation analysis of disease severity with major meteorological parameters.

Per cent disease severity / Meteorological parameters	Correlation coefficients			
	Polyhouse		Rain shelter	
	PDS	RH	PDS	RH
RH	0.933**		0.803**	
Temperature	-0.283*	0.082	-0.427*	0.196

PDS-Per cent disease incidence RH- Relative humidity*Correlation is significant at 0.05 level ** Correlation is significant at 0.01 level

Correlation analysis was performed utilizing the data collected during the field experiment, and here also it was observed that there is a significant positive correlation between PDS and RH inside the polyhouse and rain shelter and it is negatively correlated with temperature.

g. Effect of treatments on the biometric characters

Biometric characters of cucumber such as days to flower, days to harvest, vine length, fruit weight, fruit length and shelf life of cucumber in poly house & rain shelter was recorded during the field experiments.

Table 32. Effect of treatments on biometric characters of cucumber in polyhouse & rain shelter

Treatment	polyhouse						ain shelter					
	Days to flowering	Days to harvest	Vine length (m)	Fruit weight (kg)	Fruit length (cm)	Shelf life (days)	Days to flowering	Days to harvest	Vine length (m)	Fruit weight (kg)	Fruit length (cm)	Shelf life (days)
T_1 -S + ST + SA + foliar spray - *T. viride*	27.33	37.33	5.00	0.15	17.17	2.33^{de}	33.67	42.33	4.90	0.24	8.17	2.00
T_2 -S + ST + SA + foliar spray - *P. fluorescens)*	27.33	37.33	4.88	0.14	17.83	2.67^{edc}	32.67	42.67	4.73	0.25	8.00	2.00
T_3 -*T. viride*	27.33	38.00	4.75	0.15	17.00	2.67^{cde}	32.67	42.67	4.46	0.22	8.00	1.67
T_4 -*P. fluorescens*	27.33	37.67	4.88	0.14	17.67	3.00^{bcd}	32.33	42.67	4.03	0.23	7.50	2.33
T_5 –cow dung supernatant	28.00	37.67	4.87	0.14	16.50	2.33^{de}	33.00	43.33	4.55	0.23	8.00	2.00
T_6 –cow dung supernatant + *P. fluorescens*	27.67	38.00	4.75	0.14	17.67	2.67^{cde}	32.67	42.67	4.00	0.23	7.83	1.67
T_7 -garlic extract	27.67	37.67	4.61	0.12	17.50	2.00^{e}	33.00	43.33	4.51	0.22	8.00	1.33
T_8 –Calphomil	27.67	38.00	4.63	0.13	17.50	4.33^{a}	33.33	43.00	4.71	0.23	17.83	2.67
T_9 -potassium phosphonate + hexaconazole	27.67	37.67	4.90	0.14	17.67	3.33^{bc}	33.00	43.00	4.24	0.23	17.83	2.33
T_{10}-cymoxanil + mancozeb	27.67	37.67	4.81	0.14	17.67	3.67^{ab}	33.00	43.00	4.63	0.23	17.67	3.33
T_{11} -mancozeb	28.00	37.67	4.76	0.13	16.83	2.67^{cde}	33.67	43.33	4.49	0.23	17.50	2.33
T_{12} –control	28.00	37.67	4.69	0.12	17.00	2.00^{e}	33.67	43.33	4.53	0.22	17.67	2.00
CV	2.80	1.92	4.52	9.22	3.69	18.53	2.43	1.92	11.14	3.45	3.66	38.10
CD	NS	NS	NS	NS	NS	0.88	NS	NS		NS	NS	NS

*Mean of three replications, values followed by same superscript are not significantly different by DMRT (P=0.05) S-Soil solarization, ST- Seed treatment, SA-Soil application

Observations like days to flower, days to harvest, vine length, fruit length, fruit weight and shelf life was tabulated. All the biometric observations except shelf life were found to be nonsignificant. Shelf life was more for treatment T_8 (calphomil) followed by T_{10} (Curzate). Fruit weight and vine length was more in cucumber grown in solarized beds.

h. Economic analysis

Benefit: cost ratio was calculated at the market price *i.e.*, Rs.30 kg^{-1} for all the treatments and also with 20 per cent premium price for nonchemical treatments.

Table 33. Economic analysis of treatments in polyhouse

Treatment	Benefit : Cost ratio					
	Total cost (Rs.)	Yield (kg)	@ Rs.30 kg^{-1}		@ 20% premium price for nonchemical produce	
			Total returns Rs.)	B:C ratio	Total returns (Rs.)	B: C ratio
T_1 -S + ST + SA + foliar spray - *T. viride*	1342	70.2	2106	1.57:1	2527.2	1.88:1
T_2 -S + ST + SA + foliar spray - *P. fluorescens)*	1271.5	67.8	2034	1.60:1	2440.8	1.92:1
T_3 -*T. viride*	1417	61.9	1857	1.31:1	2228.4	1.57:1
T_4 -*P. fluorescens*	1471.5	57.41	1722.3	1.17:1	2066.76	1.40:1
T_5 –cow dung supernatant	1539	62.8	1884	1.22:1	2260.8	1.47:1
T_6 –cow dung supernatant + *P. fluorescens*	1571.5	60.95	1828.5	1.16:1	2194.2	1.40:1
T_7 -garlic extract	1567	59.6	1788	1.14:1	2145.6	1.37:1
T_8 –Calphomil	1617	61.4	1842	1.14:1	2210.4	1.37:1
T_9 -potassium phosphonate + hexaconazole	1527	61.45	1843.5	1.21:1	1843.5	1.21:1
T_{10}-cymoxanil + mancozeb	1149	67.60	2028	1.77:1	2028	1.77:1
T_{11} -mancozeb	1290	65.25	1957.5	1.52:1	1957.5	1.52:1
T_{12} –control	1159	41.05	1231.5	1.06:1	1477.8	1.28:1

S-Soil solarization, ST- Seed treatment, SA-Soil application

On comparing between polyhouse and rain shelter it is found that B: C ratios more in all the treatments in polyhouse than rain shelter (Table 12). At the same price for all treatments, the highest B: C ratio was observed in treatment T_{10} (cymoxanil + mancozeb) *i.e.,* 1.77:1. However when calculated with 20 per cent premium price, treatment T_2 (solarisation+ *Psuedomonas fluorescens*) is found to be highly economic with B: C ratio (1.92:1).However, all the treatments recorded a B: C ratio, higher than control in both the structure.

Table 34. Economic analysis of treatments in rain shelter

Treatments	Total cost (Rs.)	Yield (kg)	@ Rs.30 kg^{-1}		@ 20% premium price for safe to eat products	
			Total returns(Rs.)	B. C ratio	Total returns(Rs.)	B. C ratio
T_1 -S + ST + SA + foliar spray - *T.viride*	1227	50.34	1510.2	1.23:1	1812.24	1.48:1
T_2 -S + ST + SA + foliar spray - *P. fluorescens)*	1112.55	48.09	1442.7	1.30:1	1731.24	1.56:1
T_3 -*T. viride*	1198	45.45	1363.5	1.14:1	1636.2	1.37:1
T_4 -*P. fluorescens*	1153	44.64	1339.2	1.16:1	1607.04	1.39:1
T_5 –cow dung supernatant	1089	41.79	1253.7	1.15:1	1504.44	1.38:1
T_6 –cow dung supernatant + *P. fluorescens*	1136.5	42.06	1261.8	1.11:1	1514.16	1.33:1
T_7 -garlic extract	1122	41.31	1239.3	1.11:1	1487.16	1.33:1
T_8 –Calphomil	1102	41.91	1257.3	1.14:1	1508.76	1.39:1
T_9 -potassium phosphonate + hexaconazole	1012	42.60	1278	1.26:1	1278.00	1.26:1
T_{10}-cymoxanil + mancozeb	956	46.14	1384.2	1.45:1	1384.2	1.45:1
T_{11} -mancozeb	1034	45.53	1365.93	1.32:1	1365.93	1.32:1
T_{12} –control	944	32.49	974.7	1.03:1	1169.64	1.23:1

i. Enumeration of phylloplane micro flora under protected condition.

The phylloplane micro flora (fungi and bacteria) of the crop was enumerated before and after each spray using serial dilution plating in both polyhouse and rain shelter. Actinomycetes could not be isolated from any of the samples.

Plate 11. Preparation of leaf washings

Phylloplane fungi

Phylloplane bacteria

(i) Population of phylloplane fungi

There was more or less uniform population of phylloplane fungi, But immediately after spraying, there is a drastic reduction in the population in fungicide treatments. However, the population slightly increased at 15 days after spraying. Again after second spray, it came down and then, the population continuously increased at 45 DAS.

Table 35. Effect of different treatments on phylloplane fungi of cucumber in polyhouse

Treatment	Fungi (x 10 cfu cm^{-2})*						
	Pre treatment	First spraying		Second spraying		Third spraying	
		1DAS	15DAS	1DAS	15DAS	1DAS	15DAS
T_1 -S + ST + SA + foliar spray - *T. viride*	68.63	108.84	66.34	117.68	67.45	121.67	64.96
T_2 -S + ST + SA + foliar spray - *P. fluorescens)*	66.67	38.57	62.86	34.32	65.87	33.42	64.81
T_3 -*T. viride*	64.81	105.65	65.76	113.65	69.66	123.65	68.52
T_4 -*P. fluorescens*	68.57	34.24	63.52	37.43	65.67	36.54	63.89
T_5 –cow dung supernatant	67.59	89.86	67.14	87.56	68.18	86.83	63.52
T_6 –cow dung supernatant + *P. fluorescens*	69.52	78.61	63.33	76.53	65.34	76.23	67.34
T_7 -garlic extract	62.86	46.19	68.48	46.19	70.48	46.19	69.78
T_8 –Calphomil	64.76	37.14	61.43	37.14	71.43	37.14	68.74
T_9 -potassium phosphonate + hexaconazole	67.62	25.52	29.05	20.95	27.62	34.52	39.56
T_{10}-cymoxanil + mancozeb	69.61	17.14	21.43	11.57	14.29	21.19	28.64
T_{11} -mancozeb	62.04	23.81	28.10	22.24	29.52	21.90	31.11
T_{12} –control	63.81	65.71	67.89	68.76	66.19	65.10	69.11

*Mean of three replications DAS-Days after spraying S-Soil solarization, ST- Seed treatment, SA-Soil application

In treatments T_1 and T_3, where *Trichoderma* was sprayed on leaves, there is a drastic increase in the population of phylloplane fungal flora immediately after spraying. In T_5(cow dung) and T_6 (cow dung +*Pseudomonas*)also there was increase in phylloplane fungal population However in all these treatments, the population came back to initial level after 15 days of spraying. In T_7 (garlic) and T_8 (Calphomil) there was reduction in the population immediately after spraying, but not up to the level of chemical treatments and after 15 days, the population gradually got built up to original level. It was noticed that the trend in the variation of population of phylloplane fungal flora in rain shelter is same as that of polyhouse.

Table 36. Effect of different treatments on phylloplane fungi of cucumber in rain shelter

Treatment	Fungi (x 10 cfu cm^{-2})*						
	Pre treatment	First spraying		Second spraying		Third spraying	
		1DAS	15DAS	1DAS	15DAS	1DAS	15DAS
T_1 -S + ST + SA + foliar spray - *T. viride*	85.71	133.67	80.77	138.34	83.33	136.26	84.94
T_2 -S + ST + SA + foliar spray - *P. fluorescens*	86.90	48.46	84.62	49.85	86.67	45.38	86.36
T_3 -*T. viride*	86.67	138.46	86.42	134.80	85.56	139.23	87.92
T_4 -*P. fluorescens*	84.52	47.44	83.59	48.97	84.44	49.23	86.07
T_5 –cow dung supernatant	89.29	102.82	88.97	105.64	87.78	104.36	87.78
T_6 –cow dung supernatant + *P. fluorescens*	85.71	92.56	87.72	97.95	88.89	97.03	85.61
T_7 -garlic extract	85.92	68.97	85.13	69.49	84.44	73.08	82.22
T_8 –Calphomil	83.33	50.70	86.15	51.38	86.67	49.87	87.78
T_9 -potassium phosphonate + hexaconazole	81.61	36.15	38.56	37.54	38.33	40.77	46.56
T_{10}-cymoxanil + mancozeb	84.52	23.08	25.23	23.46	26.17	27.72	31.78
T_{11} -mancozeb	87.18	32.05	35.21	33.44	36.11	32.41	36.00
T_{12} –control	83.33	88.46	87.23	89.65	84.44	89.49	90.60

*Mean of three replications DAS-Days after spraying S-Soil solarization, ST- Seed treatment, SA-Soil application

(ii) Population of phylloplane bacteria

It was observed that the population of phylloplane bacteria is always higher compared to fungi. Inside the polyhouse there was more or less uniform population of phylloplane bacteria on the crop before spraying (Table 15). But immediately after spraying, there is a drastic reduction in the population in T_{10}, T_{11} and T_9. However, the population slightly increased at 15 days after spraying. Again after second spray it came down and then in the case of T_{10} and T_9, since there was no third spray, the population continuously increased at 45 DAS. In the case of T_{11}, the same trend is observed after third spray also. As in the case of phylloplane fungal population, bacteria also did not change in control.

Table 37. Effect of different treatments on phylloplane bacteria of cucumber in polyhouse

Treatment	Bacteria (x 10^3cfu cm^{-2})						
	Pre treatment	First spraying		Second spraying		Third spraying	
		1DAS	15DAS	1DAS	15DAS	1DAS	15DAS
T_1 -S + ST + SA + foliar spray - *T. viride*	19.05	11.90	18.24	14.29	19.07	13.57	18.82
T_2 -S + ST + SA + foliar spray - *P. fluorescens)*	19.19	42.02	19.39	46.16	19.00	49.31	18.73
T_3 -*T. viride*	17.32	12.80	19.24	13.72	17.22	11.63	19.78
T_4 -*P. fluorescens*	18.18	42.86	18.10	45.10	18.85	47.48	19.69
T_5 –cow dung supernatant	16.19	34.76	17.38	39.05	18.74	38.10	18.39
T_6 –cow dung supernatant + *P. fluorescens*	19.05	55.56	19.05	56.71	18.41	56.76	19.57
T_7 -garlic extract	17.65	19.90	18.14	19.38	17.48	18.33	17.59
T_8 –Calphomil	18.44	14.85	20.76	15.22	19.78	16.52	19.67
T_9 -potassium phosphonate + hexaconazole	17.50	0.87	6.95	0.98	4.63	5.67	8.63
T_{10}-cymoxanil + mancozeb	18.10	0.00	2.14	0.03	1.70	3.52	4.94
T_{11} –mancozeb	19.05	0.27	5.81	0.45	4.67	1.28	5.90
T_{12} –control	17.14	18.10	18.38	17.14	19.44	20.95	19.84

*Mean of three replications DAS-Days after spraying S-Soil solarization, ST- Seed treatment, SA-Soil application