"INTEGRATED DISEASE MANAGEMENT OF EARLY BLIGHT IN TOMATO CAUSED BY *Alternaria solani* Sorauer"

Thesis

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By

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Place: Bharsar **Suraj Biswas**
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CERTIFICATE

This is to certify that the thesis entitled **"Integrated disease management of early blight in tomato caused by *Alternaria solani* Sorauer"** submitted in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** with major in **Plant Pathology** of the College of Horticulture, VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, is a record of ***bona fide*** research carried out by **Mr. Suraj Biswas, Id. No. 14176** under my supervision and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the course of this investigation have been acknowledged.

Prof. B. P. Nautiyal
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CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Mr. Suraj Biswas, Id. No. 14176** a candidate for the degree of **Master of Science (Agriculture)** with major in **Plant Pathology** agree that the thesis entitled **"Integrated disease management of early blight in tomato caused by *Alternaria solani* Sorauer"** may be submitted in partial fulfillment of the requirements for the degree.

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ABBREVIATIONS

Cm	=	Centimeter
CD	=	Critical Difference
DAT	=	Date after transplanting
°C	=	Degree centigrade
e.g	=	Example
FAO	=	Food Agriculture Organization
G	=	Gram
gl^{-1}	=	gm per litre
Ha	=	Hectare
Hrs	=	Hours
i.e	=	id est (that is)
IMD	=	Indian Meteorological Department
Kg	=	Kilogram
L	=	Litre
Ml	=	Millilitre
Mm	=	Millimetre
ml^{-1}	=	ml per litre
NHB	=	National Horticulture Board
No.	=	Number
Ppm	=	Parts per million
%	=	per cent
PDI	=	Percent Disease Index
PDA	=	Potato Dextrose Agar
Q	=	Quintal
SE (m)	=	Standard error of mean
S.E.(d)	=	Standard error of deviation
sp.	=	Species
T	=	Tonnes
Viz	=	Namely
WP	=	Wettable powder

INTRODUCTION

Chapter 1

INTRODUCTION

Tomato, ranking first in the world for vegetables, accounts for 14% of world vegetable production (FAO, 2010). Tomato is cultivated in 186 thousand ha area in India with annual production of 7 million tons, which is consumed either fresh or processed (Ramadan *et al*, 2008). Tomato (*Solanum lycopersicum* L.) is an important vegetable crop grown worldwide for fresh and processing due to its wider adaptability in various agro-climatic conditions. It is a rich source of vitamins A, B and C and used for different food purposes, no culinary preparation is completed without tomato (Smith, 1994).

The Tomato (*Lycoperiscum esculantum* L.) is a diploid species with 2n=24 chromosomes and belongs to the family Solanaceae. It is the world's largest vegetable crop after potato (Maya and Thippanna 2013). Tomato is one of the most popular warm season fruit vegetable crop grown throughout the world because of its wider adaptability, high yielding potential and suitability for variety of cuisines in fresh as well as in preserved form. It is mostly considered as "Protective food" based on its nutritive value, antioxidant molecules such as carotenoids, particularly lycopene, ascorbic acid, vitamin E and phenol compounds, particularly flavonoids (Sepat *et al*., 2013). Lycopene has important dietetic properties since it reduces the risk of several types of cancers and heart attacks (Clinton, 2005).

Tomato belongs to the family Solanaceae and is native of Andeman region that includes parts of Colombia, Ecuador, Peru, Bolivia and Chile. All tomato wild relatives are native to this area (Rick, 1973) and (Taylor, 1986). It is a typical day neutral herbaceous annual plant and is mainly self-pollinated, but a certain percentage of cross-pollination also occurs.

The area under tomato cultivation in India is 777.46 thousand hectares with an annual production of 18286.39 thousand metric tonnes and area under tomato cultivation in Uttarakhand is 9.08 thousand hectares with annual production of 113.65 thousand metric tonnes (NHB, 2014-2015).

In fact, it is able to produce more protein and carbohydrates per unit area than cereals and some leguminous crops like soybeans (Crowell *et al.*, 2008). It provides a substantial amount of vitamins and minerals (Horton, 1987). Ripe tomatoes have a high content of the antioxidant lycopene which plays a possible role in the prevention of certain forms of cancer (Agarwal and Rao 2000). Another important antioxidant is carotene also noted for its cancer prevention properties (Radzevicius *et al.,* 2009).

Early blight is one of the most destructive fungal diseases affecting potato, tomato, and other solanaceous plants like eggplant and pepper. This disease can destroy a tomato field in two or three weeks. Tomato leaflet shows target-ring lesions characteristic of early blight early in the season, but the greatest damage usually appears after fruit set. Severe defoliation may occur during periods of high temperature and high humidity. On stems, lesions are initially small, dark, and slightly sunken, small spots enlarge to form elongated lesions with concentric markings similar to those on the leaves that occur on the stem near the ground line can cause partial girdling or collar rot. Early blight also affects the fruit. Heavily infected fruit usually drop. Infected tomatoes that reach maturity are not marketable. Under favourable environmental conditions for disease development, the fungus may also cause spotting of the fruit stems and blossoms and drop of young fruit.

Alternaria blight is most important problems of tomato in Varanasi region and average disease intensity vary from 35-40 per cent and 80-86 per cent losses caused by early blight in every year (Pandey and Pandey 2003). The disease had resulted of 78% loss in yield of fruit caused by *Alternaria solani* (Saad *et al*., 2014).

Early blight caused by *Alternaria solani* is the most destructive disease reducing yield of tomato throughout the tomato growing areas of the world (Waals *et al.,* 2001, Tomescu and Negru, 2003). Saha and Das (2012) reported yield loss of 0.76 t/ha for every 1% increase in disease severity.

Alternaria solani belongs to phylum: *Deuteromycetes,* class: *Dothideomycetes,* order: *Pleosporales* and family: *Pleosporaceae* (L.R. Jones and Grout 1896).

There are many factors involved in such low yield of tomato in India among them fungi, bacteria, nematodes, viruses and the competing weeds are predominant (Villaral, 1980). Early blight is one of the most important foliar diseases of tomato it is caused by *Alternaria solani* Sorauer, *A. solani* very contagious and destructive one in tomato crop both under protected and opens cultivated condition. This disease in severe cases can lead to complete defoliation and is most damaging on tomato in regions with heavy rainfall, high humidity and fairly high temperatures 24^{o}C-29^{o}C (Calis and Tokaya, 2011). *A. solani* is characterized by septate beaked muriform conidia borne singly on simple conidiophores (Maya and Thippanna 2013). The disease appears every year in Uttarakhand and causes huge loss to the growers. In Uttarakhand major tomato producing districts are Nanital, Udham Singh Nagar, Dehradun and Haridwar.

Considering the importance of early blight of tomato in Bharsar region, the proposed study was undertaken on integrated disease management of early blight disease of tomato with the following objectives.

1. Isolation of pathogen from diseased plant and their identification.
2. *In vitro* and *In vivo* evaluation of chemicals, bio control agents, botanicals and animal products.
3. Integrated disease management of early blight of tomato.

REVIEW
OF
LITERATURE

Chapter 2
REVIEW OF LITERATURE

Pandey and Pandey (2003) reported that tomato crop is damaged due to severe infection of *Alternaria solani* every year in India. The disease severity was recorded up to 90 per cent in Varanasi region. It is also one of the commonest causes of seedling blight or damping off in tomato causing dark lesion in rootlets.

Patil *et al.* (2003) reported that carbendazim as the best fungicide among different fungicide tested in reducing incidence of early blight with highest fruit yield of tomato.

Akbari and Parakhia (2007) reported that systemic fungicide hexaconazole completely inhibited the mycelial growth of *A. Alternata* even at a minimum concentration of 50 ppm. While non-systemic fungicides thiram and mancozeb gave percent inhibition of *A. Alternata* at a minimum concentration of 500 ppm.

Pandey *et al.* (2003) studied seven different treatments viz., mancozeb, copper oxychloride, hexaconazole, azoxystrobin, *A. niger*-V, *A. niger*-V + sticker, removal of lower infected leaves and control treatment and found that the hexaconazole was best for maximum healthy fruit yield followed by azoxystrobin. The bioagents, *A. niger* along with sticker have given satisfactory result in reducing the disease.

Gondal *et al.* (2012) found that the different doses of mancozeb (4 g/L, 8 g/L, 12 g/L and 16 g/L of water) on five tomato varieties with one standard check in tunnel at 7 days intervals and found that the all fungicide doses reduce the disease severity as compared to untreated check. The highest reduction in the disease was achieved by applying mancozeb 12 g/l of water at an interval of 7, 14, 21 and 28 days.

Ganie *et al.* (2013) evaluated five non-systemic fungitoxicants viz., chlorothalonil, mancozeb, captan, propineb and copper oxychloride and five systemic fungitoxicants viz., thiophanate methyl, carbendazim, hexaconazole, fenarimol and difenoconazole under *in vitro* conditions against *A. solani* and found that, among non-systemic fungitoxicants mancozeb 75 WP, was most effective and resulted in maximum mean mycelial growth inhibition of 75.46 per cent. Among systemic fungitoxicants, hexaconazole was most effective and exhibited a maximum mean mycelial growth inhibition of 84.19 per cent.

Sail *et al.* (2010) concluded that combination of carbendazim + mancozeb 0.20% was found significantly superior over the treatments which gave (12.26 mm) radial growth.

Dushyant *et al.* (2014) reported that five fungicides viz, chlrothalonil 75% WP, mancozeb 63% WP, iprodione + carbendazim 25+25 WP, metalaxyl + mancozeb 72% WP and carbendazim + mancozeb 12+63% WP were tested and of which carbendazim + mancozeb (91.1%) was most inhibitory for mycelial growth of *A. solani* followed by mancozeb (85.5%) at 300 ppm. Management of early blight was better with increase in concentration of fungicides under field conditions. The minimum disease intensity was 8.2% with carbendazim + mancozeb @ 0.2% concentration followed by 11.4% with mancozeb @ 0.2%, 15.2% with iprodione + carbendazim 0.2%, 18.4% with metalaxyl + mancozeb 0.2% and 20.8% chlorothalonil 0.2% in field.

Tetarwal and Rai (2007) reported that minimum disease intensity was observed in carbendazim @ (0.1%) maximum plant height (52.42 cm) at 60, 75 and 90 DAT, respectively and fruit yield 6.17 kg/plot. It was found to be most effective followed by mancozeb and copper oxychloride which were next best treatments. It can be concluded that carbendazim was highly effective against early blight of tomato. It showed significant decrease in disease intensity compared to all other treatments including control.

Sudarshana *et al.* (2012) observed the efficacy of two non systemic fungicides mancozeb (0.2%), copper oxychloride (0.25%) one systemic fungicide, carbendazim (0.1%) and two botanicals, neem oil (0.5%) and tulsi leaf extract (0.5%) was tested in field with three sprays at 15 days interval. The incidence and severity of early blight disease on tomato in field was recorded on four plants selected randomly and disease severity was assessed by using 0-5 scale and Percent Disease Index (PDI) was worked out. All the treatments were found significantly effective in reducing the disease intensity when compared to control. Minimum disease intensity was observed in carbendazim (27.2%) maximum plant height (52.42 cm) at 60, 75 and 90 DAT, respectively. and fruit yield (6.17 kg/plot. It was found to be most effective followed by mancozeb and copper oxychloride which were next best treatments.

Chohan *et al.* (2015) carried out efficacy of three fungicides Topsin M, Bavistin and Ridomil Gold MZ at 1, 2 and 3 gl^{-1} concentration respectively and two bio-agents *Trichoderma harzianum* and *T. viride* was evaluated against *A. solani in vitro* and under tunnel cultivation. In *in vitro* assay Ridomil Gold MZ inhibited *A. solani* (47.06%) at 2 g/L, while at 3 g/L concentration Topsin M was more effective (64.71%) as compared to control.

Ramanujam *et al.* (2015) reported that the different concentrations of plant extract (5%, 10%, 15% and 20%) concentrations and *Pseudomonas fluorescens* secondary metabolites and salicylic acid, indole acetic acid, siderophore, indole acetic acid and enzymes such as lipase, protease were produced. among the 10 isolates AP5 showed maximum production of secondary metabolites. *Pseudomonas aeruginosa* inhibited the radial growth of *M. phaseolina, F. solani* and *F. oxysporum* by producing a zone of inhibition of 2, 6 and 10 mm respectively. *P. lilacinus* also showed an inhibitory effect on these root infecting fungi and produced 7, 9 and 2 mm zone of inhibition respectively against *M. phaseolina, F. solani* and *F. oxysporum*.

Sundaramoorthy and Balabaskar (2012) reported that an effective ecofriendly strategy to manage the disease by using the combined application of *Bacillus subtilis*+ *Pseudomonas fluorescens* (linear growth 58.8 cm) was found to effectively reduction of 31.5 per cent the mycelial growth of the pathogen and promote the growth of tomato seedlings *in vitro* conditions when compared to application of individual strains of the antagonists.

Varma *et al.* (2007) observed that among antagonists assayed *in vitro, Trichoderma viride*, *T. harzianum* and *Bacillus subtilis* were found inhibitory to *A. solani.* Among the plant extracts tested *in vitro* cold aqueous extracts of *Clerodendrum aculeatum* (45.67%) and *Azadirachta indica* (25.44%) showed maximum inhibition of mycelial growth of *A. solani.* Foliar spray of *Clerodendron* leaf extract (15%) immediately after appearance of symptoms or foliar spray of *T. viride* (HJ7 cfu/ml) 24 h before challenge inoculation with the test fungus was found effective in reducing the disease severity under green house conditions. Further, an *in vitro* experiment was conducted to study the compatibility of bioagents and plant extracts for their possible use in integrated disease management. The bioagents; *T. viride, T. harzianum* and *Glioctadium virens* were found to be compatible with *Clerodendron* leaf extract at a concentration of 15 per cent. Among the plant extracts tested, maximum mean inhibition of mycelial growth of was recorded in neem leaf extract (25.44%).

Lahkar *et al.* (2015) carried out the biocontrol efficacy of the biosurfactant produced by *Pseudomonas aeruginosa* JS29 on early blight of tomato. *In vitro* studies indicated that the biosurfactant produced by this bacterial strain inhibits the growth of *A. solani* by 73% at a concentration of 3.00 g/l. In field condition 1.50 g/l concentration of crude biosurfactant was sufficient for complete inhibition of *A. solani.*

Munde *et al.* (2013) found that the *Trichoderma viride* significantly reduced fungal growth and recorded 90.18 per cent inhibition over control. *Gliocladium virens* and *T. viride* were found statistically at par with each other recording 87.77 and 87.40 per cent inhibition respectively.

Rafai *et al.* (2003) study that biocontrol agents, namely *Trichoderma harzianum, T. hamatum, Bacillus subtilis* and *Pseudomonas fluorescens,* have been tested for their potential antagonism for controlling *fusarium* wilt, *verticillium* wilt and early blight diseases of tomato. *In vitro* studies showed that culture filtrates of all antagonistic organisms significantly decrease the spore germination (17.63, 4.76 and 20.80%) of the tested pathogens, *F. oxysporum* f. sp. *lycopersici, Verticillium dahliae and A. solani.* Soil inoculation and seed coating with *T. hamatum* spores completely controlled the concerned diseases and improved the yield.

Uddin *et al.* (2011) reported that cow dung, solarized and, *Trichoderma harzianum* and or with seed treatment by *T. harzianum* were evaluated against damping off disease complex of potato. All the treatments significantly reduced percent damping off over control. *T. harzianum* treated seed along with soil treatment with *T. harzianum* performed best in terms of seed germination, with *T. harzianum* formulations reduced the incidence of damping-off disease of tomato by up to (74%) damping off reduction and enhanced growth characters than soil application with *T. harzianum* alone.

Chethana *et al.* (2012) reported that purple blotch of onion caused by *Alternaria porri* (Ellis) is an economically important disease posing threat to onion cultivation in warm and humid regions. Bio efficacy of six plant products (*Clerodendron, cinnamon,* garlic oil, neem oil, pongamia oil and turmeric), five biocontrol agents *(Trichoderma harzianum, Chaetomium sp. Beauveria bassiana, Verticillium lecanii and Metarhizium anisopliae)* was evaluated under *in vitro* conditions and compared with commonly used fungicides viz., mancozeb, chlorothalonil, propineb and copper oxychloride. Among plant products evaluated, fresh aqueous extract of garlic (20%) was effective in causing 100 per cent inhibition of mycelial growth. Neem oil and pongamia oil (20%) caused 76.94 and 69.94 per cent inhibition. Among the biocontrol agents evaluated, maximum inhibition (79.5%) was recorded in *T. harzianum.*

Chowdappa *et al.* (2013) studied the efficacy of *Bacillus subtilis* and *Trichoderma harzianum* were evaluated for *in vitro* antibiosis to *A. solani* and *Phytophthora infestans* growth stimulation and induction of systemic resistance in tomato seedlings against early and late blight. Both inhibited mycelium growth of (15.3 mm) in *A. solani* and *P. infestans* (10.00 mm) under *in vitro* conditions and significantly increased root and shoot growth, leaf area and seedling vigour index in tomato crop.

Ganie *et al.* (2013) evaluated that three bioagents viz., *Trichoderma harzianum* Rifai, *Trichoderma viride* Pers. and *Trichoderm avirens* and five plant extracts viz., *Artimesia absinthium L., Datura stramonium L., Urtica dioica L., Juglans regia L.* and *Mentha arvensis L.* were evaluated *in vitro* against *A. solani* (Ellis and Martin) causing early blight of potato through dual culture and poisoned food technique, respectively. Among bioagents, significantly higher mycelial growth inhibition of *A. Solani* was recorded in the case of *T. harzianum* (71.85%), which was followed by *T. viride* (65.93%) and *T. virens* (58.65%) proved least effective in inhibiting the mycelial growth of *A. solani.* Among plant extracts, *D. stramonium* proved superior to all other botanicals, exhibiting (61.12%) mycelial growth inhibition of *A. solani.* This was followed by *A. absinthium* (58.54%). *Urtica dioica* (37.34%) proved least effective in inhibiting the mycelial growth of the test fungus.

Pandey and Chandel (2014) observed that *Pseudomonas* spp. were evaluated for antifungal activity against six fungal plant pathogens, i.e. *Pyricularia oryzae Fusarium oxysporum, Aspergillus niger, Aspergillus flavus, Alternaria alternata* and *Erysiphe cruciferarum.* All tested fungal strains showed significant reduction of radial growth after the treatment with *Pseudomonas* cultures, in comparison with the controls. The maximum inhibition in colony diameter was observed in *Pyricularia oryzae* (89%) followed by *Aspergillu sniger* (80%), *Alternaria alternata* (77%), *Fusarium oxysporum* (76%) and *Aspergillus flavus*, (71%) and *Erysiphe cruciferarum* (64%) over control.

Alagesaboopathi and Selvankumar (2011) evaluated that *Pseudomonas fluoruescens* has been found to show inhibition to the phytopathogens of *Rhizoctonia solani* (7.00 mm), *Bipolaris oryzae* (4.00 mm), *Cochliobo luslunatus* (30.00 mm), *Alternaria brassica* (43.00 mm), *Aspergillus niger* (6.00 mm), *Fusarium oxysporum* (38.00 mm) and *Trichothecium roseum* (33.00 mm). The antagonistic activity of the crude extract was studied by duel plate and poison plate assays. This results proved that the crude extract have antagonistic potential against fungal pathogens.

Zghair *et al.* (2014) evaluated that the effect of bio agents *Trichoderma harzianum* and *Pseudomonas fluorescens* and fungicides mancozeb against early blight of tomato caused by *A. solani* (Ell. and Mart.) minimum disease intensity was recorded in mancozeb with two foliar spray (15.43%, 17.90% and 20.47%, respectively) as compared to control. The bio agents *Trichoderma harzianum* and *Pseudomonas fluorescens* (seed treatment + two foliar spray) were also effective in reducing the disease intensity.

Bellishree *et al.* (2015) carried out to all the four bioagents inhibited the growth of *A. solani* after 7 days of inoculation. *B. subtilis* exhibited the maximum biocontrol activity with (0.53 cm) growth of pathogen, where as in control plate pathogen growth was recorded as (7.35cm). *B. subtilis* found to be the most potent bioagent by recording highest percent inhibition of the pathogen growth with (92.85%) and (12 mm) inhibition zone was observed at the periphery region where pathogen and bioagents colony meets. Fallowed by *(P. fluroscence)* with (78.12%) inhibition, (1.60cm) growth of pathogen and *T. harzianum* showed (71.40%) inhibition of the pathogen.

Ranaware *et al.* (2010) appraised the antifungal activity of aqueous extract of neem (*Azadiracta indica*) against safflower leaf spot causing fungus *Alternaria carthami* under *in vitro* condition and investigated linear growth reduction of pathogen 23.1 per cent. The observation indicated the efficacy of aqueous plant extract as potential inhibitors of *A. carthami.*

Naziha *et al.* (2010) evaluated that effect of neem (*Azadiracta indica*) leaf extract against *A. solani* the causal agents of early blight in tomato and found that different concentrations (5, 10 and 20 per cent) of aqueous neem extract suppressed mycelial growth of pathogenic fungi and the degree of suppression gradually increased with increasing concentration. A concentration of 20 per cent aqueous neem leaf extract sprayed on tomato plants lowered the incidence of early blight from 53.2 to 42.5 per cent after two weeks and from 79.20 to 100 per cent after 4 weeks as compare to control.

Hassanein *et al.* (2008) studied the efficacy of leaf extracts of neem (*Azadiracta indica*) and chinaberry (*Melia azedrach*) against two tomato pathogenic fungi *A. solani* and *Fusarium oxysporum*, the causal agents of early blight and wilt diseases of tomato plants, respectively and observed both ethanol and ethyl acetate extracts of neem leaves assayed at a concentration of 20 per cent, completely suppressed the growth of *F. oxysporum* and inhibited *A. solani* by ratio between 52.44 and 62.77 per cent.

Afroz *et al.* (2008) studied an eco-friendly management practices against major fungal diseases of tomato and revealed that Mustard oil cake + Karmacha + Mahogony, BAU - Biofungicide + Mustard oil cake + Neem + Mahogony, Mustard oil cake + Sanitation + Neem and BAU - Biofungicide + Mustard oil cake + Karmacha + Mahogony + Sanitation exhibited more or less equally effective against the disease. The lowest early blighted plants of 18.51 per cent were recorded in BAU - Biofungicide + Mustard oil cake + Neem + Mahogony.

Maya and Thippanna (2013) evaluated that ten locally available plants which are ethano-botanically important are selected viz., *Amaranthus caudatus, Anacardium occidentale, Azadirachta indica, Bambusa arundinacea, Capsicum annuum, Ecballium elaterium, Eucalyptus gobules, Ficus religiosa, Lantanacamara* and *Morusa lbaaquoes* and their extracts were evaluated against *A. solani* by poison food technique. The results revealed that leaf and seed extracts of 76.3, 78.2 and 82.0 per cent *A. indica* recorded maximum mycelial inhibition with 78.83% followed by *L. camara* with 59.9% and *E. globules* with 59.7% inhibition in mycelial growth and *B. Arundinacea* exhibited least mycelial inhibition with 3.7%.

Munde *et al.* (2013) observed that the leaf extract of *Azadirachta indica* (20%) was highly effective in controlling mycelial growth of *A. solani* which recorded 66.67 per cent inhibition over control.

Ravikumar and Garampalli (2013) showed that antifungal potential against *A. solani* causing early blight of tomato at 4% concentration in Potato Dextrose Agar by poison food technique. The plant extracts significantly reduced the mycelial growth of the pathogen. *Crotalaria trichotoma* (36.6%), *Citrus aurantifolia* (27.3%), *Azadirachta indica* (23.7%), *Polyalthia longifolia* (23.3%), *Daturametel* (21.3%), *Muntingia calabura* (20.09%) and *Oxalis latifolia* (20.09%).

Hassanein *et al.* (2010) studied the effect of neem *Azadiracta indica* leaf extract against *A. solani* and *Fusarium oxysporum* the causal agents of early blight and wilt of tomato plants respectively, was studied. Concentrations (5, 10 and 20%) of aqueous neem extract suppressed mycelial growth of both pathogenic fungi and the degree of suppression gradually increased with increasing concentration. A concentration of 20% aqueous neem leaf extract sprayed on tomato plants lowered the incidence of *Alternaria* early blight from 53.2 to 42.5% after two weeks and from 100 to 79.2% after 4 weeks.

Kamble *et al.* (2009) find out the efficacy of five fungitoxicants viz. bio-agent *(Trichoderma harzianum),* botanicals (Neemicide and Prabal), Vermiwash and fungicide (Mancozeb) against *A. solani* by poisoned food technique. It was revealed that Mancozeb (0.25%) and Vermiwash (30%) were more effective in inhibiting the growth and sporulation of the test fungus, subsequently followed by *Trichoderma harzianum* and Neemicide (0.3%), while Prabal (0.1%) was less effective.

Afzal *et al.* (2010) carried out to isolate fungi associated with seeds of seven cultivars of sunflower by using agar and blotter paper methods. A total of 13 phytopathogenic fungal species including *Alternaria alternata* and *A. helianthi, Aspergillus flavus, A. fumigatus* and *A. niger, Curvularia lunata, Drechslera tetramera, Fusarium solani* and *F. moniliforme, Macrophomina phaseolina, Mucor mucedo, Penicillium* and *Rhizopus* spp. were identified. The isolated fungi were found to reduce seed germination by (10-20%) and seedling mortality by (10-12%). Two systemic fungicides viz., Topsin and Bayleton were found to be significantly effective in the elimination of seed-borne fungi. Among the plant material, best antifungal activity was achieved by extracts of *Azadirachta indica,* and *Allium sativum* at the concentration of (0.015%).

Dheeba *et al.* (2014) present work is to compare and study the effect of plant extracts of Neem *(Azadirachta indica)* and Tulsi *(Ocimum sanctum)* against *A. solani* which causes early blight disease on tomato plants. Aqueous and ethylacetate leaf extracts of different concentrations were used. Foliar treatment of tomato plants with 30 % aqueous tulsi extract decreased the disease incidence to 40 %. Disease severity and control of pathogen after inoculation were also analyzed. The highest disease incidence was recorded as 82.1 % with test control whereas the lowest as 25.2 % with plants treated with pathogen and tulsi aqueous extract.

Singh *et al.* (2014) studied that *Alternaria alternata* has been responsible for causing leaf spot diseases in various host species. Methanolic extracts of six selected plant leaves viz *Parthenium hysterophorus, Vernonia amygdalina, Eucalyptus camaldulensis, Nerium oleander, Lantana camara* and *Ocimum sanctum* were *in vitro* screened for their antifungal activity against *A. alternata* at 5, 10 and 20% concentrations. Highest reduction in mycelial growth was achieved by *Oleander* followed by *Parthenium, Ocimum, Lantana, Vernonia* and *Eucalyptus* respectively.

Dellavalle *et al.* (2011) evaluated the antifungal activity of extracts of 10 plant species used in traditional Uruguayan medicine against the phytopathogenic fungus *Alternaria spp.* The plants were selected on the basis of their reported ethnobotanical uses. Aqueous, saline buffer and acid extracts of different plant species were screened *in vitro* for their antifungal activity against *Alternaria spp*. Minimal inhibitory concentration and minimum fungicidal concentration of the extracts were determined. The most pronounced antifungal activity were buffer extract of *C. scolymus,* acid extracts of *S. sclarea, S. officinalis* and buffer and acid extracts of *Lippia alba,* with 98% growth inhibition of *Alternaria* spp.

Ganie *et al.* (2013) studied that the extracts of five plants viz. *Azadirachta indica, Lantana camara, Ocimum sanctum, Eucalyptus globulus* and *Calotropis gigantea* were evaluated *in vitro* by poison food technique @ 3, 5, 7 and 9% concentrations against *Alternaria brassicae* and *Fusarium oxysporum* f. sp. *lycopersici* causing blight of mustard and wilt of tomato respectively. *In vitro* study on *A. brassicae* revealed that all five plant extracts at all four concentrations significantly inhibited the mycelial growth of this pathogen as compared to control. However *O. sanctum* was found most efficacious with growth inhibition of (31.85%) followed by *E. globulus* (28.97%) and *L. camara* (23.60%). While in *in vitro* study of *F. Oxysporum* f. sp. *lycopersici A. indica* extract was found most efficacious with growth inhibition of (29.33%) followed by *E. globulus* extract (28.72%). Therefore more evaluations in the green house of field experiments may validate their antifungal activity.

Moslem and El-Kholie (2009) evaluated that the study plant pathogenic fungi *A. solani, Fusarium oxysporum, Rhizoctonia solani* and *Sclerotinia sclerotiorum* were chosen to study the effect of ethanolic, hexane and methanolic extracts of neem seeds and leaves. Antifungal effects of neem leave and seed extracts obtained by ethanol, hexane and ptrolium ether were examined separately *in vitro* against *Fusarium oxysporum, Rhizoctonia solani, A. solani* and *Sclerotinia sclerotiorum*. Results indicated that *A. solani* exhibited the highest percent of inhibition (84.0%) followed by methanolic (78.3%) and hexane (73.1%) at 40% concentrations of leave extract. We can conclude that neem leave and seed extracts were effective as antifungal against all tested fungi but *F. oxysporum* and *A. solani* were the most sensitive fungi.

Hanif *et al.* (2013) carried out the antifungal activity of *Azadirachta indica* L. was investigated against *A. Solani* Sorauer responsible for early blight in potato. Different concentrations of leaf and fruit methanol extracts viz. 1%, 2%…5% were applied against *A. solani*. Results displayed by the methanolic extract of *A. indica* fruit against *A. solani* was showed that the highest concentration (5%) was highly effective against the target fungus as it retarded fungal growth (43.5%) as compared with control followed by the 2% concentration with a reduction of (39.2%). Fruit extracts other applied concentrations also significantly suppressed the *in vitro* growth of *A. solani* upto (37.5%).

Babu *et al.* (2000) evaluated that the effect of *Acacia concinna, Bassia latifolia* (*Madhuca longifolia var. longifolia), Ocimum sanctum (O. tenuiflorum) palmarosa (Cymbopogon martini)* and *Polyalthia longifolia* extracts and oils, and neem products (neem leaf, neem seed kernel and neem cake) on tomato leaf blight caused by *A. solani* was assessed in the field and in pot cultures using. The disease intensity was recorded 15 days after the last spray. Spraying with 10% *Acacia concinna* pod extract, 10% *B. latifolia* oil cake and 3% neem oil in tomato pot cultures resulted in (65, 59 and 53%) reductions in disease incidence, respectively over the control. Among the plant products, *Acacia concinna* pod extract resulted in the lowest percent disease index in the field (23.1%), followed by *B. latifolia* oil cake and neem oil (27.2 and 30.9%, respectively). *Acacia concinna* resulted in (3.67 kg/plot) fruit yield, which was higher than that in the control (1.22 kg/plot).

Goussous *et al.* (2010) found that the antifungal activity for several medicinal plants against the early blight fungus *A. solani* has been investigated. These plants were Syrian marjoram *(Majorana syriaca)*, rosemary *(Rosmarinus officinalis)*, Greek sage *(Salvia fruticosa)*, roselle *(Hibiscus sabdariffa)* and cotton lavender *(Santolina chamaecyparissus)*. The inhibitory effect of these extracts on the radial mycelial growth as well as on spore germination was measured *in vitro* at various concentrations of crude extract (0.5 g dry plant powder/ml medium). Extracts of *M. syriaca* and *H. sabdariffa* were most effective causing total inhibition of mycelial growth and spore germination at 8–10% concentration. Extract of *R. officinalis* also caused total inhibition of the above two parameters but at double the concentration (20%). Extracts of *S. fructicosa* and *S. chamaecyparissus* produced relatively moderate antifungal activity. At 25% concentration, these extracts showed an incomplete inhibition in mycelial growth being around 75–85% and 70–90%, respectively. However, at this same concentration both plant extracts produced total inhibition of spore germination.

Zafar *et al.* (2014) carried out fifteen plant species were selected from local flora and gardens for evaluation of their antifungal potential using poison food technique against *A. solani* in aqueous extracts at 4% concentration in Potato Dextrose Agar (PDA). The 8 plants out of 15 significantly reduced the mycelial growth of *A. solani*. The following species inhibited the radial growth of *A. solani* by more than 60 percent. *Tephrosia purpurea* (72%), *Capsicum annum* (70%), *Gliricidia sepium* (stem) (70%), *Cleome viscose* (69%), *Caesalpinia bonduc* (67%), *Cassia fistula* (fruit) (63%), *Azadirachta indica* (62%) and *Cassia alata* (62%). Farming of these plants in local gardens should be practiced to obtain sufficient quantities of these non-hazardous and eco-friendly potent fungicides.

Nashwa and Abo-Elyousr (2012) carried out antimicrobial activity of six plant extracts from *Ocimum basilicum* (Sweat Basil), *Azadirachta indica* (Neem), *Eucalyptus chamadulonsis* (Eucalyptus), *Datura stramonium* (Jimsonweed), *Nerium oleander* (Oleander) and *Allium sativum* (Garlic) was tested for controlling *A. solani in vitro* and *in vivo* condition. In *in vitro* study the leaf extracts of *D. stramonium*, *A. indica*, and *A. sativum* at 5% concentration caused the highest reduction of mycelial growth of *A. solani* (44.4, 43.3 and 42.2%, respectively) while *O. basilicum* at 1% and 5% concentration and *N. oleander* at 5% concentration was lowest inhibition of mycelial growth of the pathogen. In greenhouse experiments the highest reduction of disease severity was achieved by the extracts of *A. sativum* at 5% concentration and *D. stramonium* at 1% and 5% concentration. The greatest reduction of disease severity was achieved by *A. sativum* at 5% concentration and the smallest reduction was obtained when tomato plants were treated with *O. basilicum* at 1% and 5% concentration (46.1 and 45.2 %, respectively).

Singh *et al.* (2014) evaluated that antifungal activity against predominant seed fungi viz. *Aspergillus niger, Alternaria alternata, Penicillium rubrum* and *Fusarium* *moniliformae* at 5% and 10% concentration by poisoned food techniques. The results revealed that all the plant extracts inhibited the percent growth inhibition against all test fungi with varying degree in comparison with control. Overall treatment Neem and Garlic showed the best antifungal property against all the fungi tested and thus represent useful substitutes for the control of hazardous fungicides and some extract such as onion and ginger showed moderate inhibition over control. Neem manifested maximum percent growth inhibition against *Alternaria alternata* and *Penicillium rubrum* (82.62% and 89.00%). Among all plant extract, Tulsi showed least inhibition over control against all tested fungi.

Yanar *et al.* (2011) antifungal activities of 27 plant extracts were tested against *A. solani*. Jones and Grout using radial growth technique. While all tested plant extracts produced some antifungal activities, the results revealed that *Circium arvense, Humulus lupulus, Lauris nobilis* and *Salvia officinalis* showed significant antifungal activities. The leaf extract of *L. nobilis* was most effective in inhibiting the mycelial growth of *A. solani* (79.35%) at 4% concentration, followed by *S. officinalis, H. lupulus* and *C. arvense* with 76.50, 61.50 and 55.83% inhibition, respectively.

Chaudhary *et al.* (2003) carried out *in vitro* tests by using different plant extracts including those from *Azadiracta indica*, against *A. alternata* causing early blight of potato, revealed that extracts of *A. indica* gave the second highest inhibition of *A. alternata* (54%).

Manasa *et al.* (2014) found that the antifungal effect of cow urine (10%) extracts of plants viz., *Anisomeles indica, Pimenta dioica, Alpinia galanga* and *Anacardium occidentale* against *Helminthosporium* sp. and *Alternaria* sp. isolated from sorghum seeds by standard blotter method. Poisoned food technique was employed to screen antifungal effect. *Anacardium occidentale* extracts showed (1.4 cm) and (1.5 cm) inhibitory activity test fungi to a varied extent.

Karande *et al.* (2014) reported that a field experiment to evaluate the efficacy of different bio organics for management of early blight of tomato caused by *A. solani* revealed that among all treatments of bio organics goat urine (10%) was effective with 43.20 per cent disease reduction over control.

Prashith *et al.* (2014) observed that inhibitory effect of cow urine (5%) extract of four plants namely *Anacardium occidentale L., Pimenta dioica (Linn.) Merill., Alpinia* *galanga Willd.* and *Anisomeles indica Linn.* against *Colletotrichum capsici* isolated from anthracnose of chilli *(Capsicum annuum L.)*. Poisoned food technique was performed to investigate antifungal effect of cow urine extracts. All extracts were found inhibitory against the fungus but to a varied extent. These cow urine based plant extract appears to be promising and can be used to control of (>60% inhibition) was shown against anthracnose disease in chilli.

Basak and Lee (2002) studied the efficacy and *in vitro* activities of cow urine and dung for controlling wilt caused by *F. oxysporum* f. sp. cucumerinum of cucumber and *F. Solani* f. sp. cucurbitae. Cow dung solution showed 80-84 per cent inhibition of wilt pathogens and cow urine showed 100 per cent inhibition of wilt pathogens. Fresh cow dung, urine, milk and cow dung based preparations namely cow dung slurry, dried powder and ash were evaluated against *R. solani* causing damping-off of okra and root rot of pea pathogens. Complete inhibition in mycelial growth was obtained by amending potato dextrose agar with cow dung and cow dung ash @ 5 g/100 ml medium followed by cow dung powder (0.5 mm radial mycelial growth).

Rakesh *et al.* (2013) reported that the inhibitory effect of cow urine extracts of nine plants against two fungi viz., *Fusarium oxysporum* f. sp. *zingiberi, Pythium aphanidermatum* and a bacterium *Ralstonia solanacearum* that are known to cause rhizome rot of ginger. Antifungal and antibacterial activity of cow urine extracts was investigated by poison food technique.

Sharma *et al.* (2010) found that there are five major substances obtained from cow. All these have medicinal properties against various diseases. Materials obtained from cow viz., cow urine and cow dung in non composted and composted form (vermicompost), respectively were used in varying concentration (0.5%, 2%, 3.5% and 5%) for observing the spore germination behaviour of four fungal species of phytopathogenic behavior. The conidia of *Alternaria alternate* (29.75 mm), *Fusarium oxysporium* (63.50 mm), *Colletotrichum capsici* (25.25 mm) and *Curvularia lunata* (32.50 mm) were used for their germination attributes. Both the cow products posed inhibitory impact towards germination, however, degree of inhibition increased with the improvement of concentration dose.

MATERIALS AND METHODS

Chapter 3

MATERIALS AND METHODS

The present investigation was carried out at the Vegetable Research and Demonstration Block department of Vegetable Science, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal. The site is located at an altitude of 1950 meters above mean sea level at a longitude of 78.99 ºE and latitude of 30.056 ºN. (IMD, 2014).

The climate of Bharsar is mild summer, higher precipitation and colder or severe cold prolonged winter. The South-east monsoon commences towards the end of June while the North-east monsoon causes occasional winter showers during November-February. During winter, snow fall is common in this region. The experimental site received average rainfall of 962.8 mm. During summer months, the valley has hot climate prevailing for few hours in a day, the maximum temperature during April-July is recorded between 25°C-35°C however and nights are cool. December and January are the coldest months; the minimum temperature reaches to 1°C to -4°C. Relative humidity is normally highest during rainy season (July - August), often recorded near to saturation point (92-97%) and it gradually decreases towards December.

3.1 OBSERVATION OF SYMPTOMS

Development of symptoms of the disease was studied in experimental plot at Vegetable Research and Demonstration Block.

3.2 SCORING METHOD

3.2.1 Early blight

Pandey & Pandey (2002) reported that rating scale for scoring disease intensity.

Disease intensity:

Category	Grade/numerical value	Leaf area infected
I	0	Disease free
II	1	1-10
III	2	11-25
IV	3	26-50

V	4	51-75
VI	5	>76

Per cent disease intensity were calculated as per the following formula.

$PDI = \sum (N \times V) \div N \times S \times 100$

Where, $\sum$=Summation

N= No. of leaves in each category

V= numerical value of leaves observed

S= maximum numerical value/grade

3.2.2 Isolation

Tomato plant showing symptoms of early blight were collected from the field and were washed thoroughly with water then after placed in between blotting paper to remove excess moisture it any. The infected parts were cut aseptically into small pieces and surface sterilized with mercuric chloride 0.1% for one minute followed by two to three washed with sterilized distilled water and then placed aseptically on solidified potato dextrose agar (PDA) in petriplates were incubated at 25±1 ^{0}C for 8 hours. Mycelial growth appeared on PDA. A single unit of mycelial growth transferred on PDA and was sub cultured to maintain pure culture. The pure culture was maintained in the refrigerator at 5 ^{0}C for future studies.

Composition of Culture Media

The investigation of the culture medium PDA used in present investigation in given below.

Potato Dextrose Agar (PDA)

Peeled potato= 200 gm

Dextrose= 20 gm

Agar= 20 gm

Distilled water= 1000 ml

3.2.3 Pathogenicity test

Pathogenicity test was carried out in laboratory. Different inoculation methods was applied on potted plants grown in sterilized soil.

T_1 Un-inoculated (control)

T_2 Soil inoculation

T_3 Foliar spray inoculation

T_4 Syringe inoculation

T_5 Wound inoculation of branch

T_6 Wound inoculation of stem

Pathogenicity test was conducted on healthy tomato plants in Plant Pathology Laboratory of Collage of Horticulture, VCSGUUHF Bharsar. Different inoculation methods namely Soil inoculation, Foliar spray inoculation, Syringe inoculation, Wound inoculation on branch, Wound inoculation on stem and Cotton swabbing were applied on potted plants grown in sterilized soil to prove the pathogenicity of isolated pathogen. Un-inoculated healthy tomato plants were kept as control. Observation on incubation periods in days and type of symptoms developed were recorded and data analysed statistically by using Randomized Complete Block Design (RCBD).

Observations recorded

Colony: Colour, shape, and fragmentation.

Mycelium: colour, shape, septation and branching.

Conidia: colour, shape.

Observations recorded:

1. Inoculation period in days

2. Type of symptoms development

Number of treatment - 6

Replication - 4

Design - CRD

3.3 DISEASE MANAGEMENT

Two different chemicals, biocontrol agents, oils and animal product *viz.* Carbendazim, Captan, *Pseudomonas fluorescens, Trichoderma harzianum,* Neem oil, Mustard oil, Cow dung and Cow urine were assessed against *A. solani* Sorauer with different concentration (1000, 2000, 3000, 4000, 5000, 6000 ppm) and radial growth of pathogen was calculated after 24, 48, 72 & 96 hours after incubation at 25± 1 ^{0}C.

Treatment - 9

Replication - 3

Design – Factorial CRD

3.3.1 Treatments with their Combinations

Seven different treatments with their combinations which are listed below were assessed their comparability by using food poison technique and effect against *A. solani* Sorauer with different concentration. (1000, 2000, 3000, 4000, 5000, 6000 ppm) and radial growth of pathogen were calculated after 24, 48, 72 & 96 hours after incubation at 25± 1 ^{0}C.

T_1 Carbendazim + Captan

T_2 Carbendazim + *Pseudomonas fluorescens*

T_3 Carbendazim + *Trichoderma harzianum*

T_4 Carbendazim + Neem oil

T_5 Carbendazim + Mustard oil

T_6 Carbendazim + Cow dung

T_7 Carbendazim + Cow urine

T_8 Check

Treatment– 8

Replication- 3

Design- Factorial (CRD)

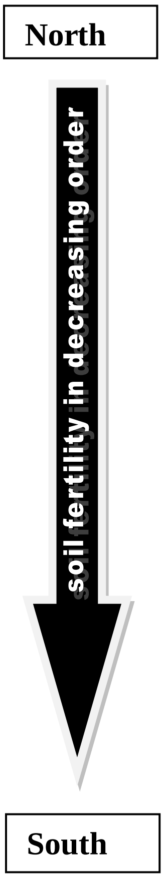
3.3.2 Field experiments *(In vivo)*:

Field experiments was conducted during Zaid session 2014 at Vegetable Research and Demonstration Block.

3.3.3 Layout and plan

The field experiment was conducted in Randomized Complete Block Design (RCBD) with three replication. The treatments was randomized with the help of random table.

Table 3.1 Allotment of treatments in experiment field under RCBD



Replication-1	Replication-2	Replication-3
T-4	T-5	T-8
T-2	T-9	T-6
T-3	T-1	T-5
T-7	T-7	T-9
T-1	T-8	T-2
T-6	T-3	T-1
T-5	T-4	T-3
T-8	T-2	T-7
T-9	T-6	T-4

3.4 Field preparation and showing

The experimental plot is clay loamy soil. Field preparation was done in the 1st week of March 2014. Field was prepared thoroughly by two ploughing with power tiller followed by two cross tilling and it was leveled with the help of 'Pata', then it was divided into 27 plots having irrigation channels, path and distance to mark different replications as well as plots as shown in layout. Recommendation dose of Farm Yard Manure @ 20 t/ha and fertilizers were applied as per the recommended of package of practices *i.e.* 100 kg N, 75 kg P_2O_5 and 50 kg K_2O/ha. One third dose of N and full doses of P_2O5 and K_2O were applied at the time of field preparations. Remaining two-third dose of N was top dressed in equal amounts after 30 and 45 days of transplanting. A highly early blight susceptible tomato variety Arka vikas was selected for transplanting. The remaining intercultural operations were carried out in accordance with the recommended package of practices.

3.5 Statistical analysis

The data obtained for different season during the investigation were analysed by using standard statistical procedure in the Factorial Completely Randomized Design (FCRD). Standard errors of mean's (S.EM.±) were computed in each case and the critical differences (C.D.) at 5 percent level of significance were calculated only for significance results Gomez and Gomez (1984) The experimental results are presented with the help of tables, graph and photographs wherever found necessary.

The statistical analysis was carried out for each observed character under the study using MS-Excel, OPSTAT and SPAR 1.0 packages. The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1983) for Randomized Complete Block Design (RCBD). For estimation of different statistical parameters, following procedure and formulae were adopted.

3.5.1 Analysis of variance

Source of variance	Degree of freedom	Sum of squares	Mean sum of squares	Variance ratio (V.R.)
Replication (r)	r-1	Sr	Sr/(r-1) = Mr	Mr/Me
Treatments (t)	t-1	St	St/(t-1) = Mt	Mt/Me
Error (e)	(r-1) (t-1)	Se	Se/(r-1) (t-1) = Me	

Where,

r = Number of replications

t = Number of treatments

Sr = Sum of squares due to replications

St = Sum of squares due to treatments

Se = Sum of squares due to error

Mr = Mean sum of squares due to replications

Mt = Mean sum of squares due to treatments

Me = Mean sum of squares due to error

The calculated F-value was compared with tabulated F-value. When F-test was found significant, critical difference was calculated to find out the superiority of one entry over the others.

The standard error and critical differences were calculated as follows:

SE (m) ± = $\sqrt{Me/r}$

SE (d) ± = $\sqrt{2\,Me/r}$

$CD_{0.05}$ = S.E. (d) x $t_{(0.05)}$ (r-1) (t-1) df

Where,

SE (m) ± = Standard error of mean

SE (d) ± = Standard error of difference

$CD_{0.05}$ = Critical difference at 5 per cent level of significance

All the traits, which differed significantly, were utilized further for estimation of following parameters.

3.6 OBSERVATION OF GROWTH AND YIELD COMPONENTS

Plant growth and yield attributes studied as per procedure given below.

1. Number of fruits /plant
2. Average fruit weight (g/plant)
3. *Alternaria* infected average fruit weight (g/plant)
4. Percent disease index at 75, 90 and 105 DAT
5. Percent fruit infection /plot
6. Fruit yield (kg/plot) and (t/ha)
7. Per cent yield increase over control

i. The observations were recorded on randomly selected five plants in crop from each replication. The data on following characters were recorded.

3.6.1 Number of fruits /plant

The marketable fruits harvested from randomly taken plants and calculated sum up each harvest and obtained per plant.

3.6.2 Total fruit weight (g/plant)

Total weight of fruits from five randomly selected plants at every picking was recorded and divided by total number of fruits of all the harvests to compute the mean fruit weight in grams.

3.6.3 *Alternaria* infected fruit (g/plot)

Total no. of infected fruits selected from plants at every picking was recorded and calculate average infected fruit.

3.6.4 Percent fruit infection /plot

The Percent fruit infection of *A. solani* in each treatment was calculated.

3.6.5 Fruit yield (kg/plot) and t/ha

The pickings were made at mature stage for recording fruit yield per plant. Fruit yield was recorded at every picking in grams and added up for all the pickings to arrive at the total yield per plant. The total yield per plant was multiplied with total number of plants per plot to obtain yield per plot in kilograms. The total yield per plot was multiplied with total number of plants accommodated per hectare to obtain yield per hectare.

3.6.6 Per cent yield increase over control

The total no. of yield increase per treatment was calculated by comparing it to over control.

Chapter-4

EXPERIMENTAL RESULTS

Chapter 4
EXPERIMENTAL RESULTS

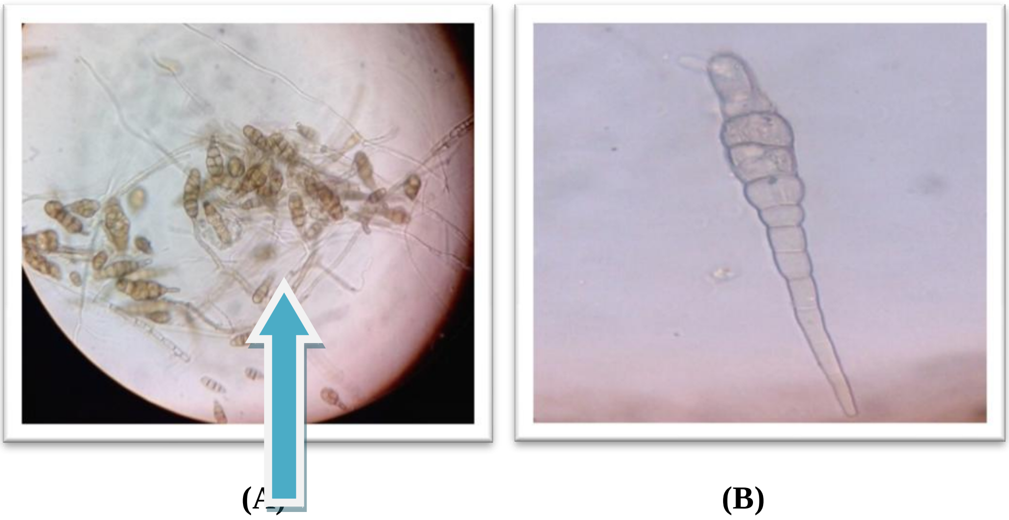
Tomato (*Solanum lycopersicum* L.) is an important vegetable crop grown worldwide for fresh and processing due to its wider adaptability in various agro-climatic conditions. There are many factors involved in such low yield of tomato in India among them fungi, bacteria, nematodes, viruses and the competing weeds are predominant (Villaral, 1980). Early blight is one of the most important foliar disease of tomato it is caused by *A. solani* Sorauer. The disease appears every year in Uttarakhand and causes huge losses to the growers. Early blight is one of the important fungal diseases among the foliar disease affecting tomato, potato and other solanaceous crop.

Tomato leaflet shows target-ring lesions characteristic of early blight early in the season, but the greatest damage usually appears after fruit set. Under favourable environmental conditions for disease development, the fungus may also cause spotting of the fruit stems and blossoms and drop of young fruit. Early blight is most important problems of tomato in Varanasi region and average disease intensity vary from 35-40 and 80-86 per cent losses caused by early blight in every year (Pandey and Pandey 2003).

4.1 SYMPTOMATOLOGY

During the study, typical symptoms of the disease were observed in tomato plant. The initial symptoms were small necrotic lesion at leaf margins and brown streak may occur on stems and petioles. A few small, irregular, discolored areas at the blossom end on the green fruit were produced which increased to form a superficial angular brownish patch on ripe fruit. The first symptoms usually appeared on leaves as water soaked oily, pale or dark-green or brown or black, circular or irregular lesions. Typically, younger, more succulent tissue was affected first. During periods of abundant moisture, sporulation of the pathogen could be seen by the naked eye as a white, cottony growth on the underside of affected leaves or on fruit lesions oily.

PLATE 1



(A) **(B)**

(A) and (B) Conidia of *Alternaria solani*.

Microscopic study of *Alternaria solani*

PLATE-2

(A)

(B)

(C)

Alternaria **infected (A) leaves (B) branches and (C) fruits**

4.2 PATHOGENICITY TEST

Table 4.1 Mean performance of different inoculation method for average lesion size, incubation period and type of symptom

	Inoculation methods	Average lesion size after 9 days (mm)	Incubation period (days)	Types of symptom
T_1	Soil inoculation	4.64 ± 0.24	5.6 ± 0.25	Brown lesion
T_2	Foliar spray inoculation	8.74 ± 0.13	2.2 ± 0.37	Brown lesion
T_3	Syringe inoculation	5.62 ± 0.14	4.0 ± 0.32	Brown lesion
T_4	Wound in branch inoculation	5.82 ± 0.24	3.4 ± 0.25	Brown lesion
T_5	Wound in stem inoculation	4.52 ± 0.35	4.8 ± 0.37	Brown lesion
T_6	Cotton swabbing inoculation	5.28 ± 0.34	2.8 ± 0.58	Brown lesion
T_7	Un-inoculated (control)	0.00 ± 0.00	0.00 ±0.00	No lesion
	Mean	**4.94**	**3.25**	
	S.E.(d)	**0.32**	**0.49**	
	C.D$_{(0.05)}$	**0.67**	**1.00**	

4.2.1 Average lesion size

Significant variations among all the treatments were observed for average lesion size after nine days. It ranged from 0.00-8.74 and general mean for the character was 4.94. The maximum average lesion size was observed in foliar spray inoculation method (8.74 mm) and which was followed by wound of branch (5.82 mm), syringe inoculation method (5.62 mm), cotton swabbing inoculation method (5.28 mm), soil inoculation method (4.64 mm), wound in stem inoculation method (4.52 mm) and un-inoculated plant remain healthy.

4.2.3 Incubation period

Significant variations among all the inoculation methods were observed for incubation period. It ranged from 0.00-5.6 and population mean for the character was 3.25. The maximum incubation period was observed in soil inoculation method (5.6 days) and which was followed by wound in stem inoculation (4.8), syringe inoculation method (4.0 days), wound of branch (3.4), cotton swabbing Inoculation method (2.8 day), foliar spray inoculation method (2.2 days and minimum in un- inoculated plants (0.00 days).

4.3 Climatic condition 2014-2015 crop seasons

Climatic condition play very important role in disease development during Zaid season 2014-2015 on tomato crop maximum temperature (28.16 ^{0}C),relative humidity (99 %) and average rain fall recorded (179.62 mm)during 6 March– 4 September, this climatic conditions favour the development of early blight disease of tomato crop.

4.4 *In vitro* Study of Different Treatments

4.4.1 Effect of different treatments on radial growth of *Alternaria solani* at 1000 ppm concentration

Data presented in Table No. 2 illustrated that, different treatments were tested against *Alternaria solani in vitro* the results revealed that minimum radial growth was found in carbendazim (4.92 mm) followed by captan (6.63 mm) and *Trichoderma harzianum* (7.21 mm) while cow dung gave maximum redial growth (10.05 mm).

4.4.2 Effect of different treatments on radial growth of *A. solani* at 2000 ppm concentration

Data showed in Table 3 revealed that minimum radial growth (4.51 mm) was recorded in carbendazim followed by captan (5.98 mm) and *Trichoderma harzianum* (6.35 mm) while maximum radial growth was observed in cow dung (9.26 mm) at 2000 ppm concentration.

4.4.3 Effect of different treatments on radial growth of *A. solani* at 3000 ppm concentration

Data presented in Table 4showed that carbendazim (4.20 mm) showed lowest radial growth followed by captan (5.61 mm) and *Trichoderma harzianum* (5.91 mm) while maximum radial growth was observed in cow dung (8.75 mm).

4.4.4 Effect of different treatments on radial growth of *A. solani* at 4000 ppm concentration

Data obtainable in Table 5 revealed that different treatment at 4000 ppm inhibits radial growth of pathogen over control. Minimum radial growth was carbendazim (3.78 mm) followed by captan (5.13 mm) and *Trichoderma harzianum* (5.32 mm) while maximum radial growth was observed in cow dung (8.04 mm).

4.4.5 Effect of different treatment on radial growth of *A. solani* at 5000 ppm concentration

Data symbolized in Table 6 pertinent that different treatment at 5000 ppm concentration minimum radial growth was observed in carbendazim (3.25 mm) followed by captan (4.55 mm) and *Trichoderma harzianum* (4.88 mm) while maximum radial growth was observed in cow dung (7.39 mm).

4.4.6 Effect of different treatment on radial growth of *A. solani* at 6000 ppm concentration

Data showed in Table 7 pertinent that, different treatments were tested at 6000 ppm concentration inhibit radial growth of pathogen, minimum radial growth was found in carbendazim (2.56 mm) followed by captan (3.75 mm) and *Trichoderma harzianum* (4.34 mm) while maximum radial growth was observed in cow dung (6.99 mm).

4.4.7 Evaluation of different treatments against early blight pathogen of tomato *in vitro* condition.

The observations recorded in the experiment is shown in (Table No. 1, 2, 3, 4, 5 and 6 plate. 3, 4, 5, 6, 7, 8, 9 and 10 which revealed that all the treatments were found significantly superior over check and inhibiting the growth of test pathogen. Carbendazim proved the best treatment which significantly gave growth 4.92, 4.51, 4.20, 3.78, 3.25 and 2.56 mm) at 1000, 2000, 3000, 4000, 5000 and 6000 ppm concentration respectively where as cow dung was found least effective at 1000, 2000, 3000, 4000, 5000 and 6000 ppm which showed radial growth (10.05, 9.26, 8.75, 8.04, 7.39 and 6.99 mm).

Table 4.2 Effect of different treatments on radial growth of *A. solani* at 1000 ppm concentration

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim	3.33±0.16	4.50±0.28	5.67±0.33	6.17±0.33	4.92
T_2	Captan	3.50±0.28	5.67±0.66	8.00±0.57	9.33±0.60	6.63
T_3	*Pseudomonas fluorescens*	4.17±0.16	7.50±0.01	10.33±0.66	12.33±0.16	8.58
T_4	*Trichoderma harzianum*	3.83±0.28	6.67±0.44	8.17±0.44	10.17±0.44	7.21
T_5	Neem oil	4.00±0.44	6.83±0.44	9.67±0.88	10.67±0.44	7.79
T_6	Mustard oil	4.67±0.16	8.17±0.31	11.17±0.88	13.50±0.28	9.38
T_7	Cow dung	4.83±0.33	8.85±0.16	11.67±0.44	14.83±0.92	10.05
T_8	Cow urine	4.33±0.16	7.67±0.16	11.00±0.28	13.33±0.92	9.08
T_9	Check	5.33±0.33	10.5±0.7	15.17±0.60	16.33±0.16	11.83
	Mean	4.22	7.37	10.09	11.85	

	S.E.(d)	$C.D_{(0.05)}$
Interval	0.22	0.43
Treatment	0.33	0.65
Interval × Treatment	0.66	1.31

Table 4.3 Effect of different treatments on radial growth of *A. solani* at 2000 ppm concentration

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim	3.06±0.05	4.10±0.10	5.30±0.20	5.57±0.23	4.51
T_2	Captan	3.17±0.16	5.42±0.50	7.05±0.45	8.27±0.23	5.98
T_3	*Pseudomonas fluorescens*	4.00±0.26	7.42±0.30	7.93±0.06	8.97±0.29	7.08
T_4	*Trichoderma harzianum*	3.80±0.26	5.58±0.30	7.50±0.25	8.50±0.20	6.35
T_5	Neem oil	3.97±0.15	6.42±0.65	7.75±0.57	8.90±0.28	6.76
T_6	Mustard oil	4.60±0.45	7.75±0.14	9.97±0.40	12.33±0.16	8.66
T_7	Cow dung	4.75±0.25	8.33±0.33	10.07±0.43	13.90±0.20	9.26
T_8	Cow urine	4.07±0.06	7.57±0.34	9.63±0.08	10.37±0.08	7.91
T_9	Check	5.03±0.54	10.18±0.45	15.17±0.60	16.40±0.37	11.70
	Mean	4.05	6.97	8.93	10.36	

	S.E.(d)	$C.D_{(0.05)}$
Interval	0.15	0.31
Treatment	0.23	0.47
Interval × Treatment	0.47	0.94

Table 4.4 Effect of different treatments on radial growth of *A. solani* at 3000 ppm concentration

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim	2.93±0.06	3.87±0.13	4.83±0.24	5.17±0.20	4.20
T_2	Captan	3.10±0.10	4.83±0.37	6.63±0.31	7.87±0.06	5.61
T_3	*Pseudomonas fluorescens*	3.60±0.30	6.63±0.18	7.67±0.12	8.70±0.15	6.65
T_4	*Trichoderma harzianum*	3.47±0.23	5.03±0.32	7.00±0.17	8.13±0.26	5.91
T_5	Neem oil	3.57±0.29	5.70±0.46	7.20±0.57	8.47±0.06	6.23
T_6	Mustard oil	4.30±0.16	7.13±0.31	9.07±0.28	11.97±0.16	8.12
T_7	Cow dung	4.33±0.35	7.83±0.06	9.50±0.06	13.33±0.08	8.75
T_8	Cow urine	4.00±0.28	7.03±0.40	8.17±1.00	9.70±0.05	7.23
T_9	Check	5.40±0.30	10.16±0.46	15.20±0.60	16.07±0.29	11.70
	Mean	3.86	6.47	8.36	9.93	

	S.E.(d)	$C.D_{(0.05)}$
Interval	0.12	0.30
Treatment	0.25	0.46
Interval × Treatment	0.41	0.92

Table 4.5 Effect of different treatments on radial growth of *A. solani* at 4000 ppm concentration

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim	2.57±0.06	3.63±0.12	4.40±0.25	4.53±0.14	3.78
T_2	Captan	2.83±0.08	4.57±0.29	6.13±0.23	6.97±0.12	5.13
T_3	*Pseudomonas fluorescens*	3.37±0.18	6.23±0.14	6.87±0.18	7.83±0.16	6.08
T_4	*Trichoderma harzianum*	3.23±0.14	4.73±0.27	6.30±0.49	7.00±0.10	5.32
T_5	Neem oil	3.33±0.16	5.23±0.29	6.57±0.12	7.63±0.17	5.69
T_6	Mustard oil	3.97±0.35	6.63±0.05	8.20±0.20	11.17±0.06	7.49
T_7	Cow dung	4.03±0.18	6.90±0.12	8.60±0.11	12.63±0.08	8.04
T_8	Cow urine	3.60±0.11	6.43±0.29	8.00±0.05	8.80±0.05	6.71
T_9	Check	5.27±0.26	10.37±0.63	15.50±0.28	16.30±0.47	11.86
	Mean	3.58	6.08	7.84	9.21	

	S.E.(d)	$C.D_{(0.05)}$
Interval	0.11	0.22
Treatment	0.16	0.33
Interval × Treatment	0.33	0.66

Table 4.6 Effect of different treatments on radial growth of *A. solani* at 5000 ppm concentration

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim	2.10±0.10	3.07±0.06	3.83±0.60	4.00±0.05	3.25
T_2	Captan	2.47±0.03	4.23±0.14	5.73±0.26	5.77±0.08	4.55
T_3	*Pseudomonas fluorescens*	3.23±0.14	5.17±0.16	6.67±0.16	7.33±0.16	5.60
T_4	*Trichoderma harzianum*	2.90±0.15	4.37±0.18	5.93±0.06	6.33±0.16	4.88
T_5	Neem oil	2.97±0.03	4.70±0.25	6.20±0.40	7.20±0.20	5.27
T_6	Mustard oil	3.67±0.24	6.10±0.05	7.83±0.12	10.83±0.03	7.11
T_7	Cow dung	3.90±0.05	6.33±0.16	8.00±0.11	11.33±0.16	7.39
T_8	Cow urine	3.57±0.18	5.40±0.23	7.33±0.16	10.67±0.16	6.74
T_9	Check	5.37±0.31	10.17±0.44	15.03±0.51	16.33±0.40	11.73
	Mean	3.35	5.50	7.40	8.87	

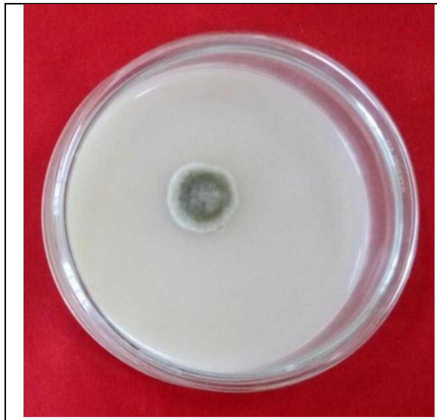
	S.E.(d)	$C.D_{(0.05)}$
Interval	0.11	0.22
Treatment	0.16	0.33
Interval × Treatment	0.38	0.66

Table 4.7 Effect of different treatments on radial growth of *A. solani* at 6000 ppm concentration

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim	1.60±0.2	2.50±0.50	3.00±0.28	3.13±0.00	2.56
T_2	Captan	2.10±0.10	3.57±0.20	4.83±0.16	4.50±0.05	3.75
T_3	*Pseudomonas fluorescens*	2.97±0.49	4.67±0.44	6.30±0.30	6.47±0.03	5.10
T_4	*Trichoderma harzianum*	2.43±0.29	3.83±0.33	5.57±0.23	5.53±0.03	4.34
T_5	Neem oil	2.57±0.08	4.03±0.08	5.70±0.25	6.07±0.06	4.59
T_6	Mustard oil	3.60±0.11	5.50±0.00	7.57±0.20	8.83±0.88	6.38
T_7	Cow dung	3.80±0.05	5.97±0.06	7.67±0.33	10.53±0.03	6.99
T_8	Cow urine	3.27±0.17	5.00±0.28	7.23±0.14	8.53±0.08	6.01
T_9	Check	5.33±0.33	10.57±0.7	15.10±0.55	16.43±0.47	11.86
	Mean	3.07	5.07	7.00	7.78	

	S.E.(d)	$C.D_{(0.05)}$
Interval	0.15	0.30
Treatment	0.22	0.45
Interval × Treatment	0.45	0.90

PLATE-3



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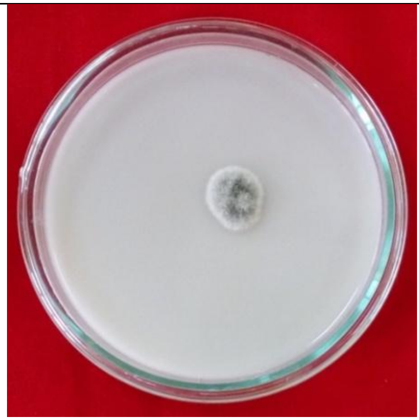


2000 ppm

3000 ppm

4000 ppm

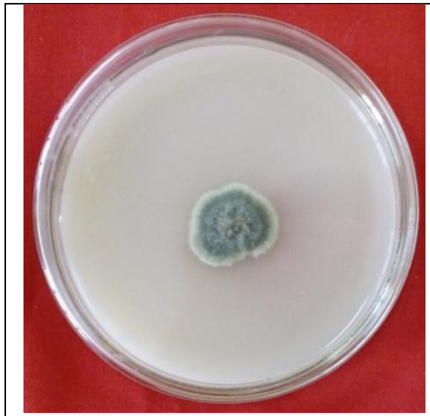
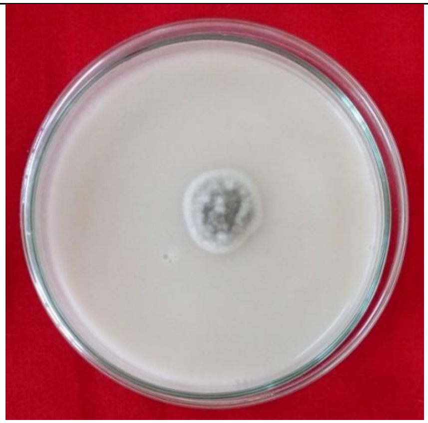
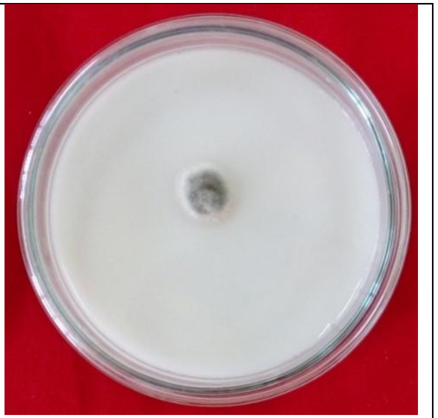
5000 ppm

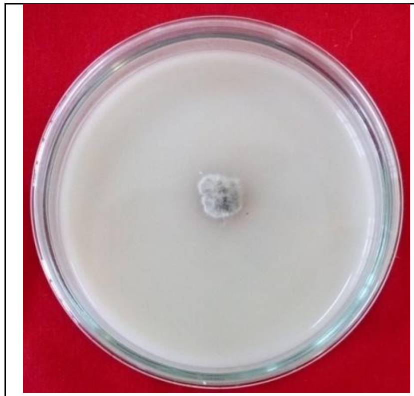
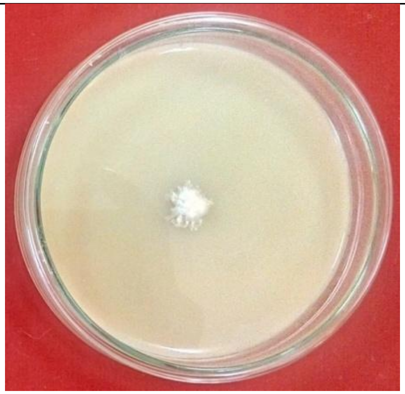
6000 ppm

Check

Effect of carbendazim on the radial growth of *Alternaria solani* at different ppm concentrations

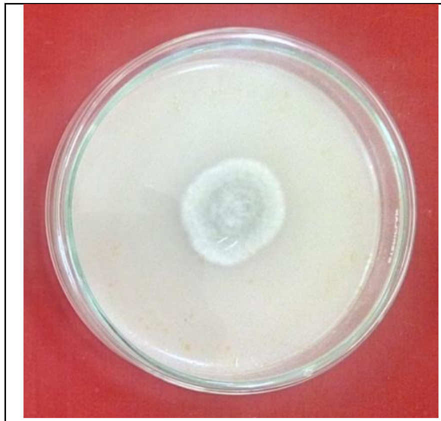
PLATE-4

 1000 ppm	 2000 ppm	 3000 ppm	 4000 ppm

 5000 ppm	 6000 ppm	 Check

Effect of captan on the radial growth of *A. solani* at different ppm concentrations

PLATE-5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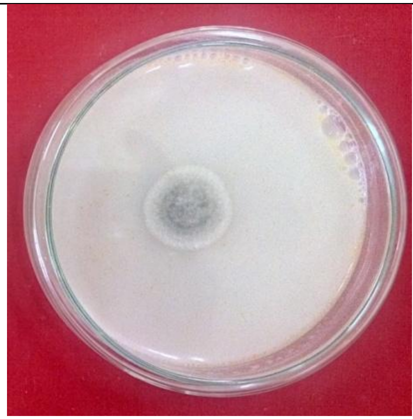
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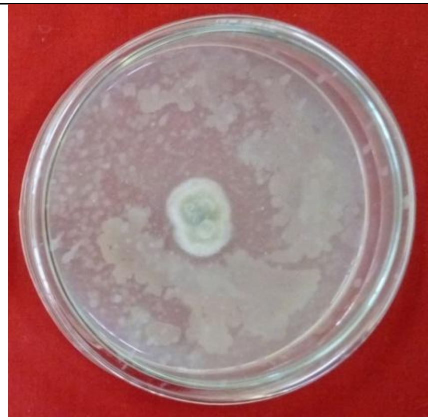
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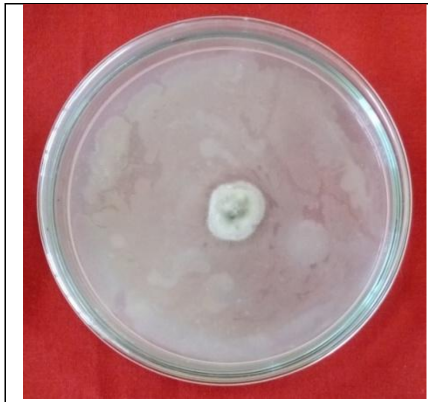
4000 ppm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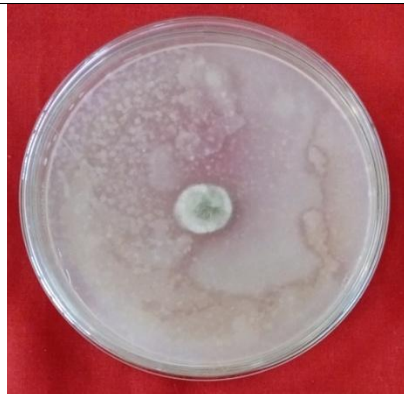
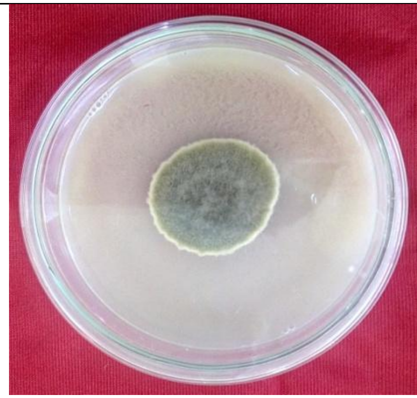

6000 ppm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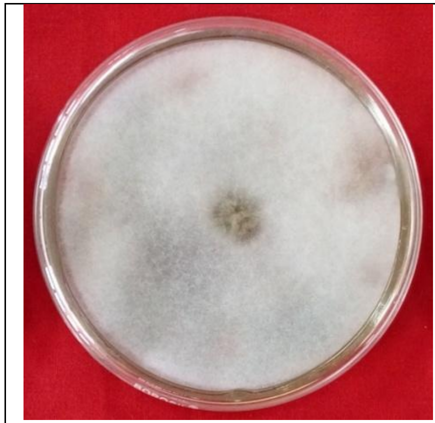
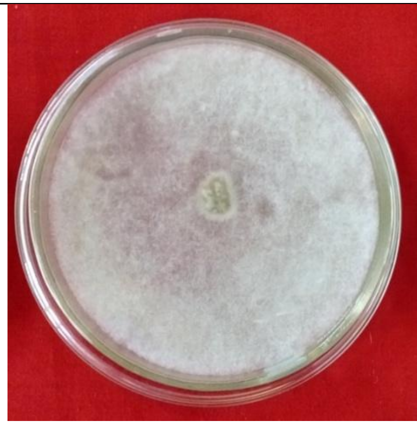
Effect of *Pseudomonas fluorescens* on the radial growth of *A. solani* at different ppm concentrations

PLATE-6



1000 ppm

2000 ppm



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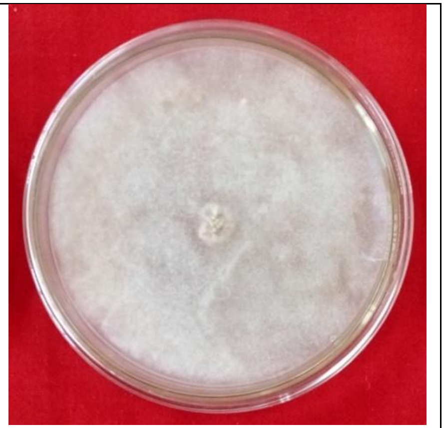


4000 ppm

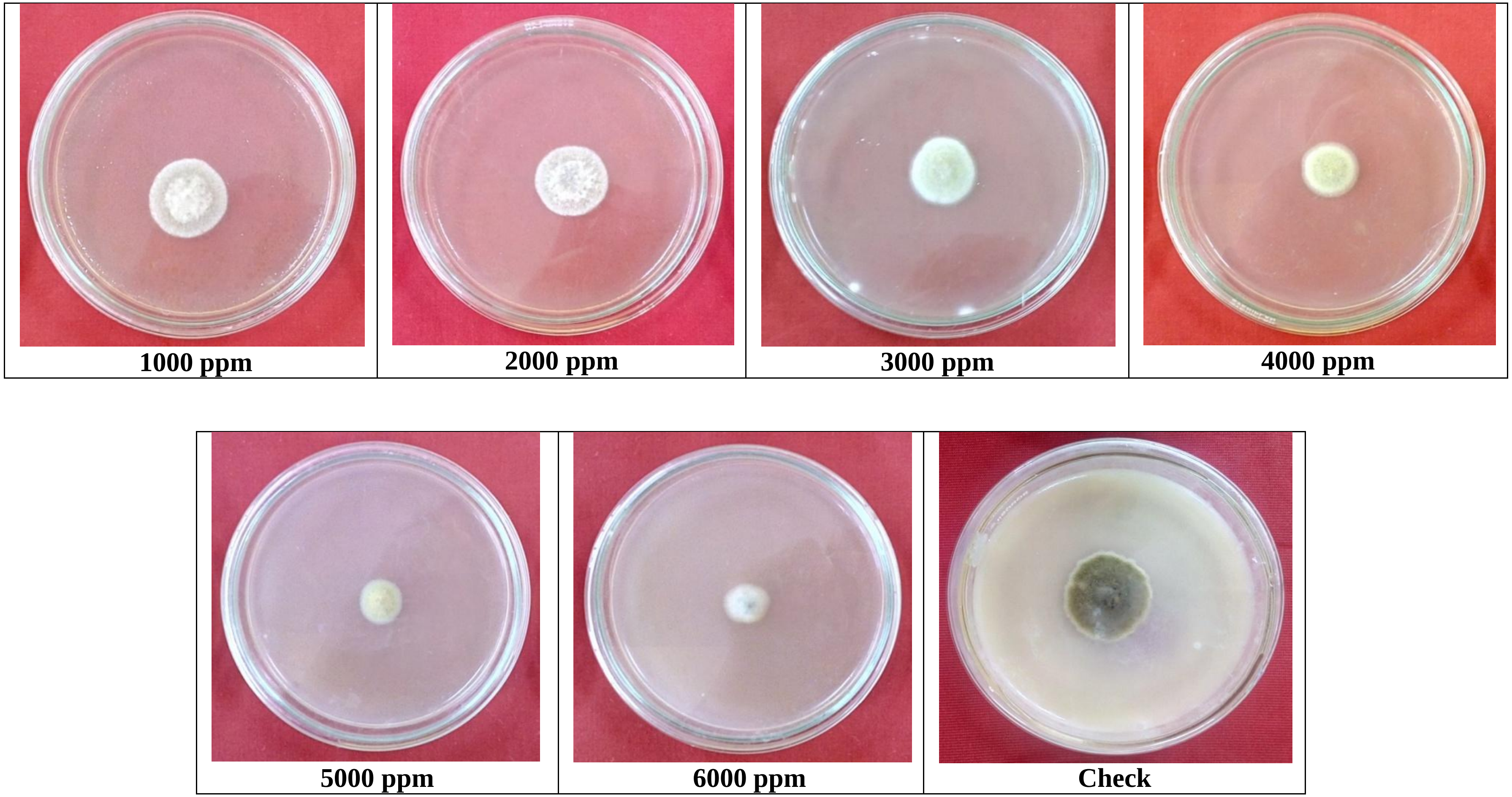
5000 ppm

6000 ppm

Check

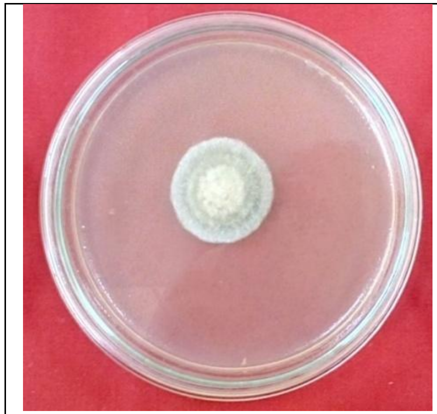
Effect of *Tcichoderma harzianum* on the radial growth of *A. solani* at different ppm concentrations

PLATE-7



Effect of neem oil on the radial growth of *A. solani* at different ppm concentrations

PLATE-8



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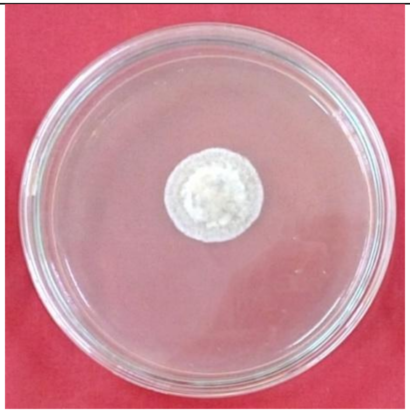

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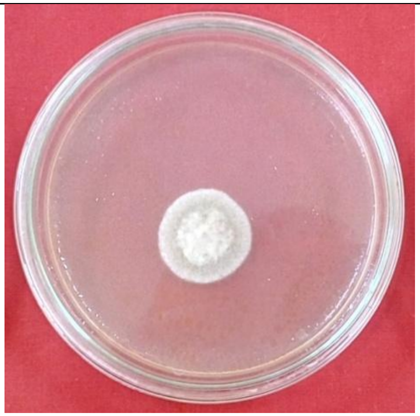

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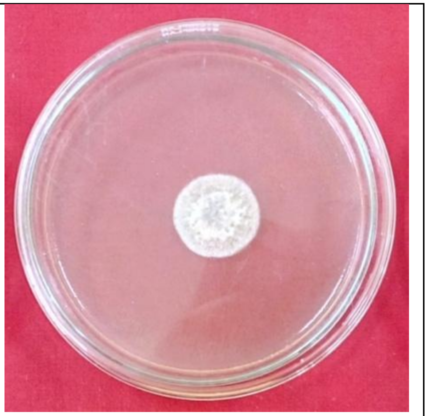

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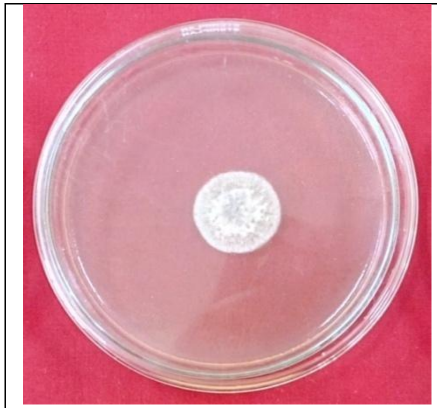

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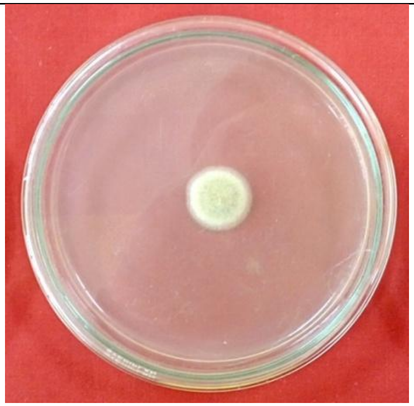

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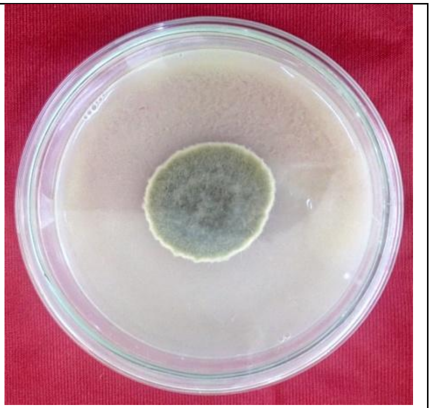
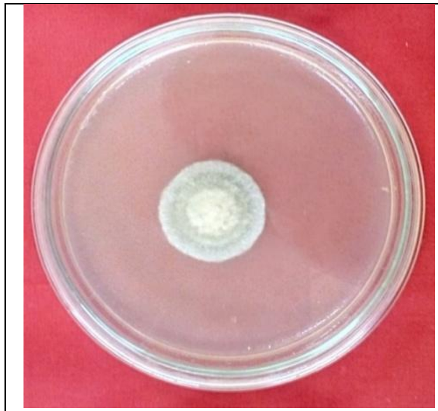


Check

Effect of mustard oil on the radial growth of *A. solani* at different ppm concentrations

PLATE-9



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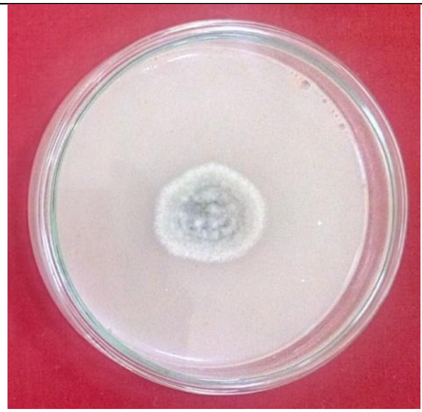

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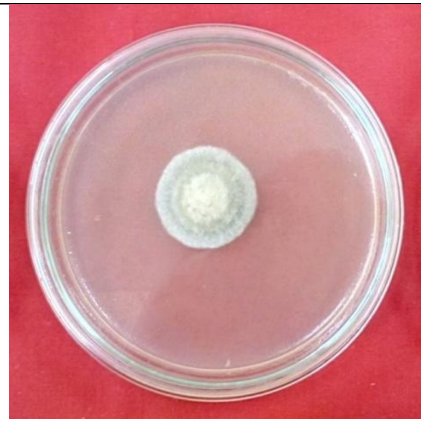
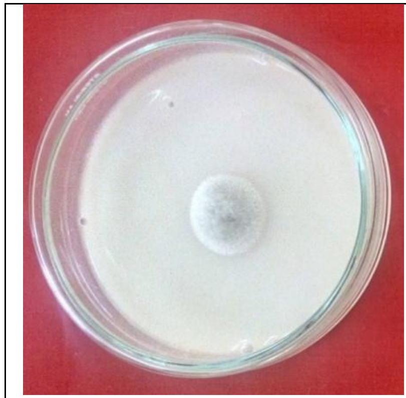
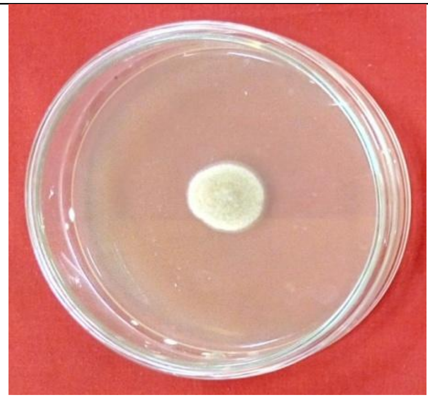


3000 ppm

4000 ppm



5000 ppm

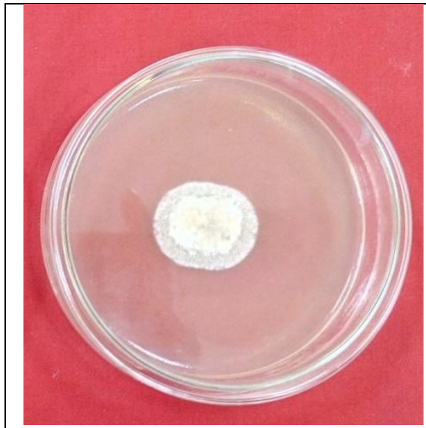


6000 ppm

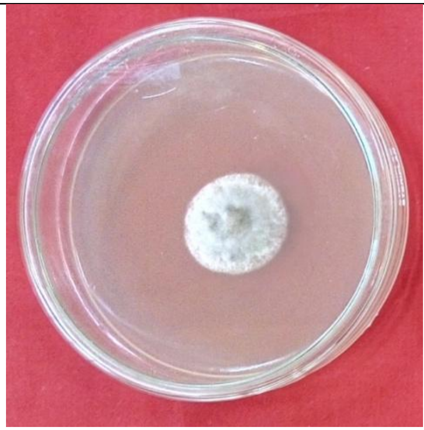
Check

Effect of cow dung on the radial growth of *A. solani* at different ppm concentrations

PLATE-10



1000 ppm



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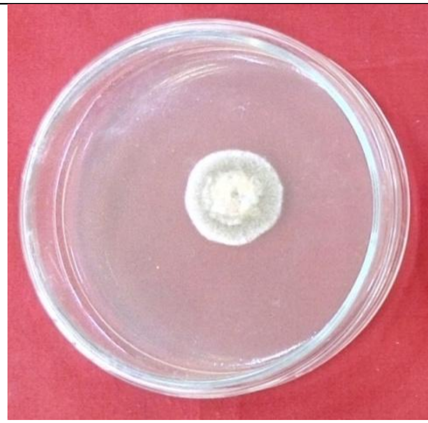
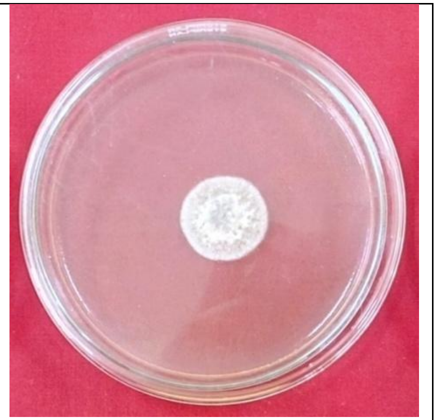
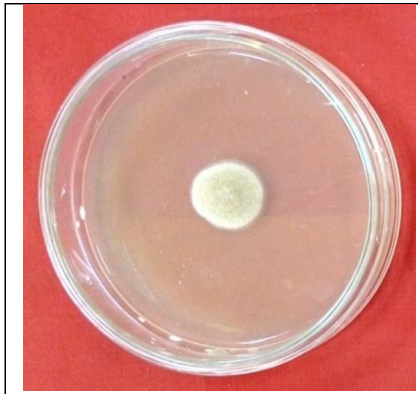


3000 ppm



4000 ppm



5000 ppm

6000 ppm

Check

Effect of cow urine on the radial growth of *A. solani* at different ppm concentrations

4.5 *In vitro* Study of Different Treatments with Combination

4.5.1 Effect of different treatments with integration at 1000 ppm concentration.

Data presented in Table 8 illustrated that, different treatment at 1000 ppm indicated minimum radial growth was recorded in carbendazim + captan (4.85 mm) followed by carbendazim + neem oil (6.06 mm) and carbendazim + *T. harzianum* (6.29 mm) while maximum radial growth was observed in carbendazim + cow dung (8.29 mm).

4.5.2 Effect of different treatments with integration at 2000 ppm concentration.

Data showed in Table 9 demonstrated that minimum radial growth of test pathogen in carbendazim + captan (4.00 mm) followed by carbendazim + *T. harzianum* (5.03 mm) and carbendazim + neem oil (5.95 mm) while maximum radial growth was observed in carbendazim + cow dung (7.83 mm).

4.5.3 Effect of different treatments with combination at 3000 ppm concentration.

Data presented in Table 10 pertinent that, different treatment at 3000 ppm indicated the minimum radial growth carbendazim + captan (3.40 mm) followed by carbendazim + *T. harzianum* (4.53 mm) and carbendazim + neem oil (5.40 mm) while maximum radial growth was observed in carbendazim + cow dung (7.38 mm).

4.5.4 Effect of different treatments with combination at 4000 ppm concentration.

Data obtainable in Table 11 minimum radial growth was recorded in carbendazim + captan (3.08 mm) followed by carbendazim + *T. harzianum* (4.36 mm) and carbendazim + neem oil (5.22 mm) while maximum radial growth was observed in carbendazim + cow dung (7.07 mm).

4.5.5 Effect of different treatments with integration at 5000 ppm concentration.

Data symbolized in Table 12 demonstrated that, different treatment at 5000 ppm concentration indicated that minimum radial growth carbendazim + captan (2.50 mm) followed by carbendazim + *T. harzianum*(4.01 mm) and carbendazim + neem oil (4.87 mm) while maximum radial growth was observed in carbendazim + cow dung (6.67 mm).

4.5.6 Effect of different treatment with integration at 6000 ppm concentration.

Data showed in Table 13 pertinent that, different treatment at 6000 ppm indicated that minimum radial growth carbendazim + captan (2.04 mm) followed by carbendazim +

T. harzianum (3.74 mm) and carbendazim + neem oil (4.31 mm) while maximum radial growth was observed in carbendazim + cow dung (6.28 mm).

4.5.7 Evaluation of different treatments against early blight pathogen of tomato *in vitro* condition.

The observations recorded in the experiment is shown in Table No. 7, 8, 9, 10, 11 and 12 plate 11, 12, 13, 14 and 15 which revealed that all the treatments were found significantly superior over check of inhibiting the growth of test pathogen. Carbendazim + captan proved the best treatment which significantly gave radial growth 4.85, 4.00, 3.40, 3.08, 2.50 and 2.04 mm) at 1000, 2000, 3000, 4000, 5000 and 6000 ppm concentration respectively where as carbendazim + cow dung was found least effective at 1000, 2000, 3000, 4000, 5000 and 6000 ppm which showed minimum radial growth (8.29, 7.83, 7.38, 7.07, 6.67 and 6.28 mm).

Table 4.8 Effect of different treatments with combination on radial growth of *A. solani* at 1000 ppm concentration.

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim + Captan	2.30±0.15	4.50±0.28	5.43±0.06	7.17±0.33	4.85
T_2	Carbendazim+ *P. fluorescens*	4.87±0.16	6.43±0.29	8.63±0.23	10.47±0.43	7.60
T_3	Carbendazim + *T. harzianum*	4.17±0.16	5.99±0.23	7.23±0.28	7.77±0.14	6.29
T_4	Carbendazim + Neem oil	3.47±0.03	5.27±0.22	6.67±0.24	8.83±0.68	6.06
T_5	Carbendazim + Mustard oil	4.57±0.20	6.67±0.24	8.73±0.37	10.50±0.28	7.62
T_6	Carbendazim + Cow dung	5.03±0.14	7.37±0.31	9.40±0.05	11.37±0.34	8.29
T_7	Carbendazim + Cow urine	4.67±0.33	6.23±0.14	7.87±0.23	9.07±0.29	6.96
T_8	Check	5.50±0.28	10.27±0.26	13.67±0.33	16.67±0.16	11.53
	Mean	4.32	6.59	8.45	10.23	

	S.E.(d)	C.D $_{(0.05)}$
Interval	0.13	0.27
Treatment	0.19	0.39
Interval × Treatment	0.39	0.78

Table 4.9 Effect of different treatments with combination on radial growth of *A. solani* at 2000 ppm concentration.

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim + Captan	2.17±0.16	3.67±0.16	4.17±0.16	6.00±0.28	4.00
T_2	Carbendazim+ *P. fluorescens*	4.77±0.18	5.90±0.26	8.00±0.47	9.17±0.14	6.96
T_3	Carbendazim + *T. harzianum*	3.27±0.14	4.43±0.2	5.27±0.15	7.17±3.02	5.03
T_4	Carbendazim + Neem oil	3.93±0.03	5.30±0.15	6.90±0.23	7.67±0.29	5.95
T_5	Carbendazim + Mustard oil	4.83±0.16	6.37±0.38	8.07±0.12	10.27±0.12	7.38
T_6	Carbendazim + Cow dung	4.53±0.17	6.53±0.14	9.27±0.37	10.97±0.24	7.83
T_7	Carbendazim + Cow urine	4.23±0.23	5.63±0.28	7.83±0.32	8.73±0.33	6.61
T_8	Check	5.43±0.29	10.40±0.23	13.50±0.28	16.60±0.20	11.48
	Mean	4.15	6.03	7.88	9.57	

	S.E.(d)	C.D $_{(0.05)}$
Interval	0.29	0.58
Treatment	0.41	0.82
Interval × Treatment	0.82	1.65

Table 4.10 Effect of different treatmentswith combination on radial growth of *A. solani* at 3000 ppm concentration.

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim + Captan	2.10±0.05	3.00±0.28	3.50±0.28	5.00±0.00	3.40
T_2	Carbendazim+ *P. fluorescens*	4.40±0.15	5.40±0.30	7.30±0.28	8.87±0.46	6.49
T_3	Carbendazim + *T. harzianum*	3.00±0.00	4.33±0.28	5.00±0.29	5.80±0.32	4.53
T_4	Carbendazim + Neem oil	3.73±0.23	5.13±0.61	5.23±0.11	7.50±0.32	5.40
T_5	Carbendazim + Mustard oil	4.37±0.24	5.60±0.11	7.67±0.13	10.03±0.24	6.92
T_6	Carbendazim + Cow dung	4.47±0.37	5.90±0.15	8.47±0.26	10.67±0.57	7.38
T_7	Carbendazim + Cow urine	4.07±0.29	5.17±0.17	6.23±0.14	8.30±0.11	5.94
T_8	Check	5.33±0.33	10.67±0.33	13.57±0.29	16.50±0.28	11.52
	Mean	3.93	5.65	7.12	9.08	

	S.E.(d)	C.D $_{(0.05)}$
Interval	0.14	0.28
Treatment	0.20	0.40
Interval × Treatment	0.40	0.81

Table 4.11 Effect of different treatments withcombination on radial growth of *A.solani* at 4000 ppm concentration.

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim + Captan	1.80±0.15	2.83±0.33	3.33±0.16	4.35±0.15	3.08
T_2	Carbendazim+ *P. fluorescens*	4.33±0.08	5.23±0.28	6.67±0.40	8.03±0.61	6.07
T_3	Carbendazim + *T. harzianum*	2.83±0.06	4.10±0.32	4.87±0.33	5.63±0.31	4.36
T_4	Carbendazim + Neem oil	3.67±0.16	4.67±0.12	5.10±0.17	7.43±0.29	5.22
T_5	Carbendazim + Mustard oil	4.33±0.34	5.50±0.56	6.87±0.48	9.17±0.22	6.47
T_6	Carbendazim + Cow dung	4.43±0.33	5.73±0.40	7.53±0.44	10.57±0.14	7.07
T_7	Carbendazim + Cow urine	3.83±0.33	4.87±0.17	6.21±0.01	7.58±0.37	5.62
T_8	Check	5.40±0.20	10.63±0.32	13.53±0.26	16.33±0.33	11.48
	Mean	3.83	5.45	6.76	8.64	

	S.E.(d)	C.D $_{(0.05)}$
Interval	0.15	0.31
Treatment	0.22	0.44
Interval × Treatment	0.44	0.88

Table 4.12 Effect of different treatmentswith combination on radial growth of *A. solani* at 5000 ppm concentration.

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim + Captan	1.33±0.16	2.17±0.16	2.50±0.00	4.00±0.28	2.50
T_2	Carbendazim+ *P. fluorescens*	4.07±0.06	4.96±0.18	6.63±0.28	7.90±0.51	5.89
T_3	Carbendazim + *T. harzianum*	2.63±0.14	3.70±0.28	4.70±0.25	5.00±0.10	4.01
T_4	Carbendazim + Neem oil	3.17±0.16	4.39±0.24	4.97±0.13	6.93±0.18	4.87
T_5	Carbendazim + Mustard oil	4.19±0.15	5.05±0.38	6.80±0.37	9.06±0.10	6.27
T_6	Carbendazim + Cow dung	4.37±0.34	5.26±0.07	7.20±0.23	9.83±0.32	6.67
T_7	Carbendazim + Cow urine	3.61±0.32	4.40±0.45	5.73±0.23	7.08±0.11	5.21
T_8	Check	5.23±0.14	10.40±0.23	13.40±0.30	16.50±0.28	11.38
	Mean	3.57	5.04	6.49	8.29	

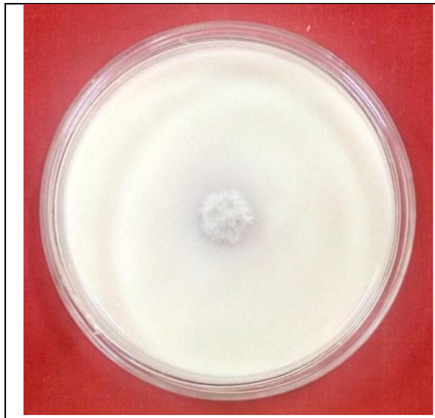
	S.E.(d)	C.D $_{(0.05)}$
Interval	0.12	0.25
Treatment	0.18	0.36
Interval × Treatment	0.36	0.72

Table 4.13 Effect of different treatmentswith combination on radial growth of *A. solani* at 6000 ppm concentration.

	Radial growth (mm)					Mean
	Treatments	**24 hrs**	**48 hrs**	**72 hrs**	**96 hrs**	
T_1	Carbendazim + Captan	1.17±0.16	1.67±0.16	2.00±0.00	3.33±0.16	2.04
T_2	Carbendazim+ *P. fluorescens*	3.83±0.03	4.79±0.00	5.57±0.14	7.62±0.23	5.45
T_3	Carbendazim + *T. harzianum*	2.23±0.03	3.53±0.24	4.41±0.20	4.80±0.30	3.74
T_4	Carbendazim + Neem oil	2.50±0.00	4.01±0.15	4.50±0.11	6.23±0.14	4.31
T_5	Carbendazim + Mustard oil	3.17±0.16	4.93±0.24	6.07±0.28	8.94±0.42	5.78
T_6	Carbendazim + Cow dung	4.00±0.28	5.17±0.34	6.85±0.27	9.12±0.35	6.28
T_7	Carbendazim + Cow urine	3.50±0.28	4.20±0.10	5.27±0.08	6.75±0.14	4.93
T_8	Check	5.37±0.20	10.73±0.17	13.60±0.26	16.67±0.23	11.59
	Mean	3.22	4.88	6.03	7.93	

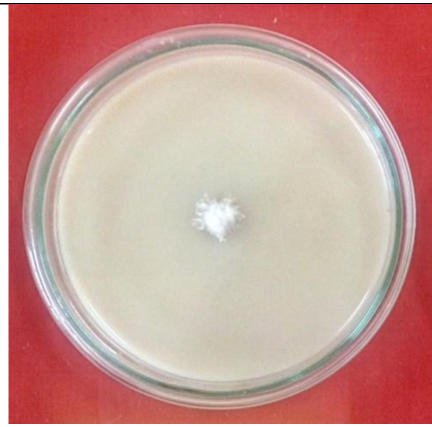
	S.E.(d)	C.D $_{(0.05)}$
Interval	0.11	0.21
Treatment	0.15	0.31
Interval × Treatment	0.31	0.62

PLATE-11



1000 ppm

2000 ppm



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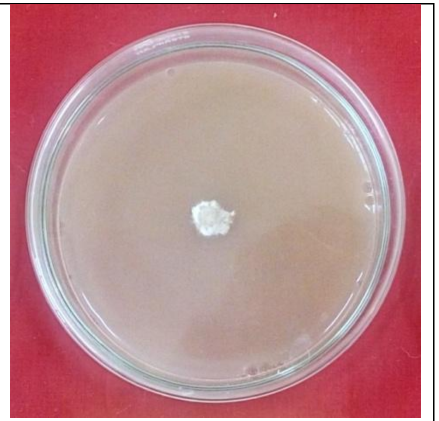

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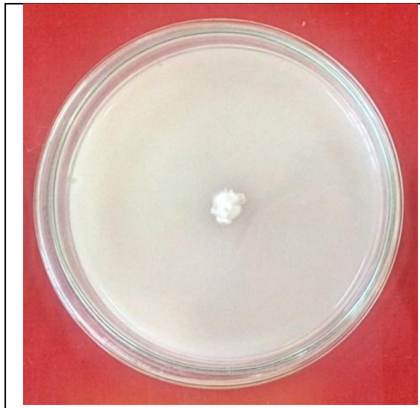

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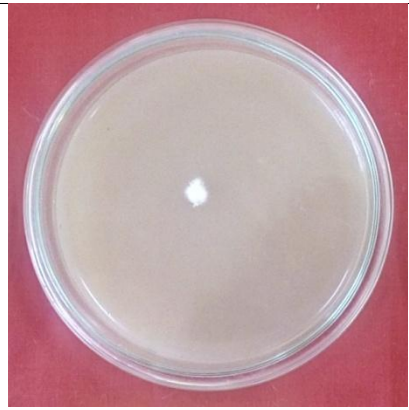

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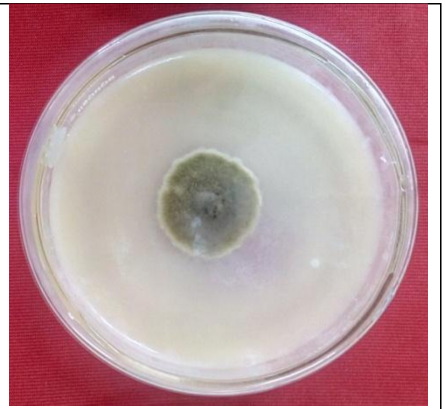
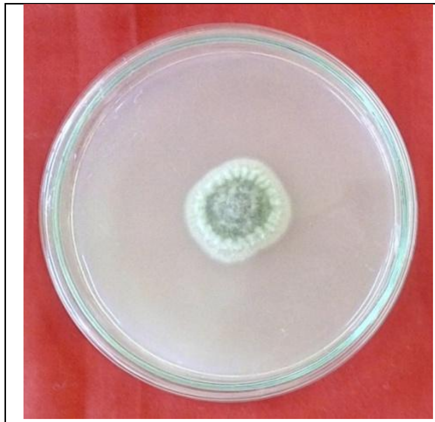


Check

Effect of carbendazim + captan on the radial growth of *A. solani* at different ppm concentration

PLATE-12



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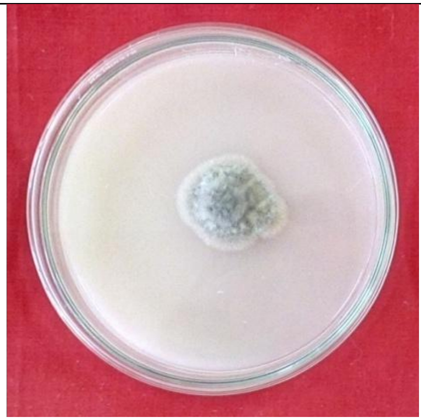

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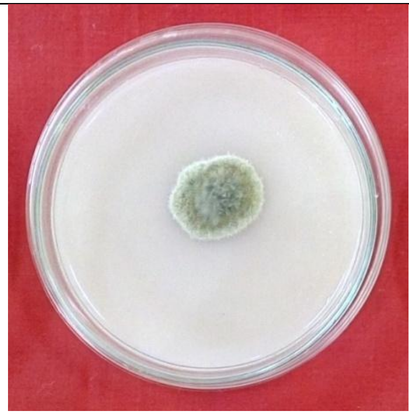
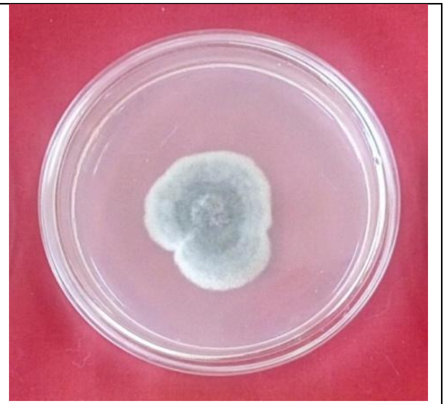


3000 ppm

4000 ppm

5000 ppm

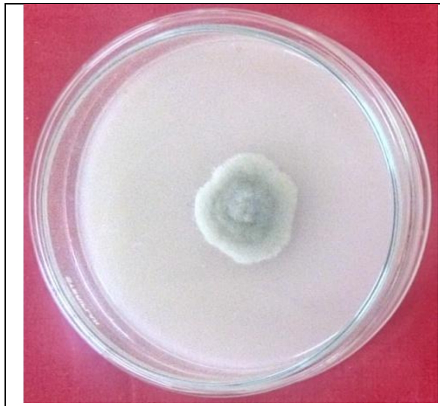
6000 ppm



Check

Effect of carbendazim + neem oil on the radial growth of test pathogen at different concentration

PLATE-13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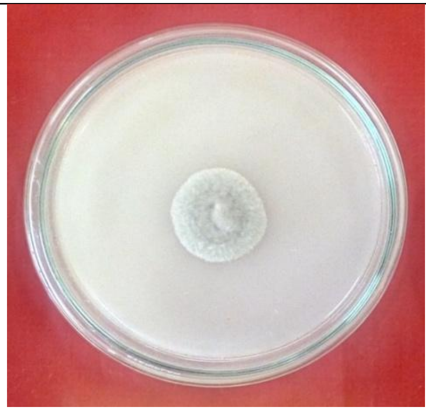
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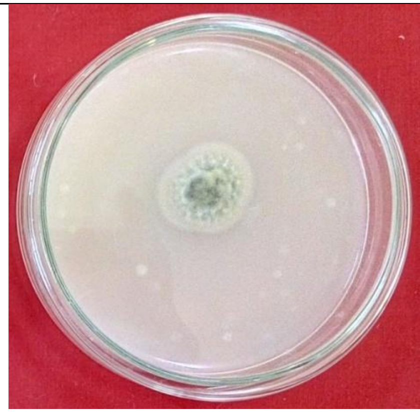
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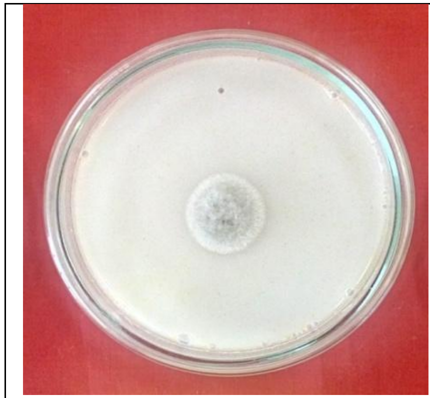
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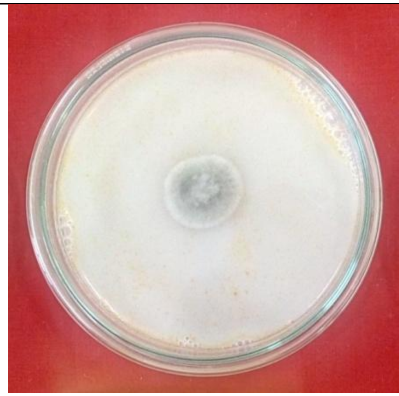
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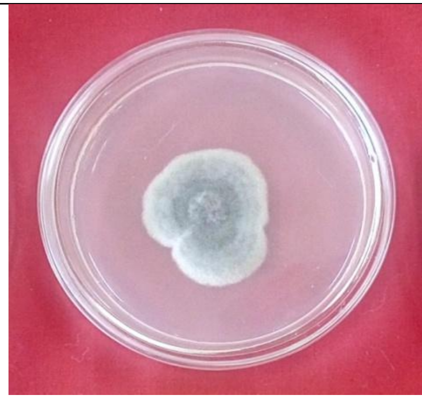
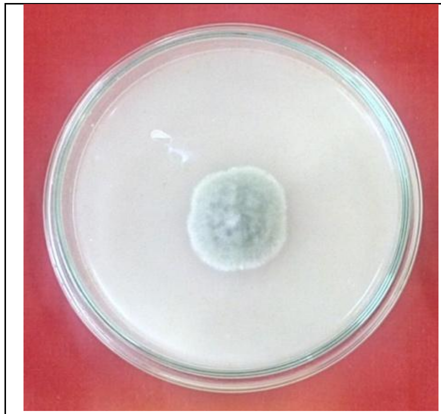

Check

Effect of carbendazim + mustard oil on the radial growth of test pathogen at different concentration

PLATE-14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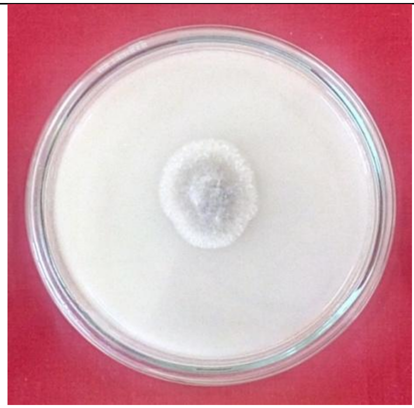
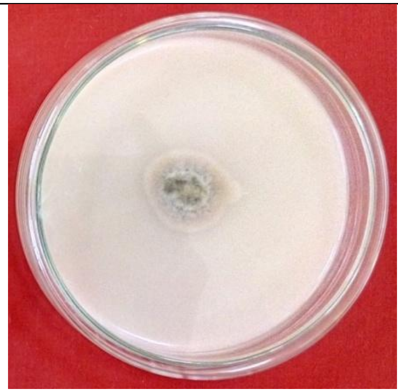

2000 ppm


3000 ppm


4000 ppm


5000 ppm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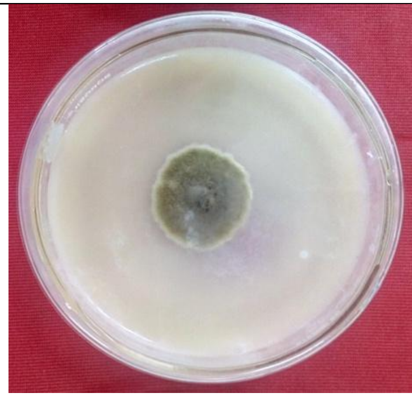
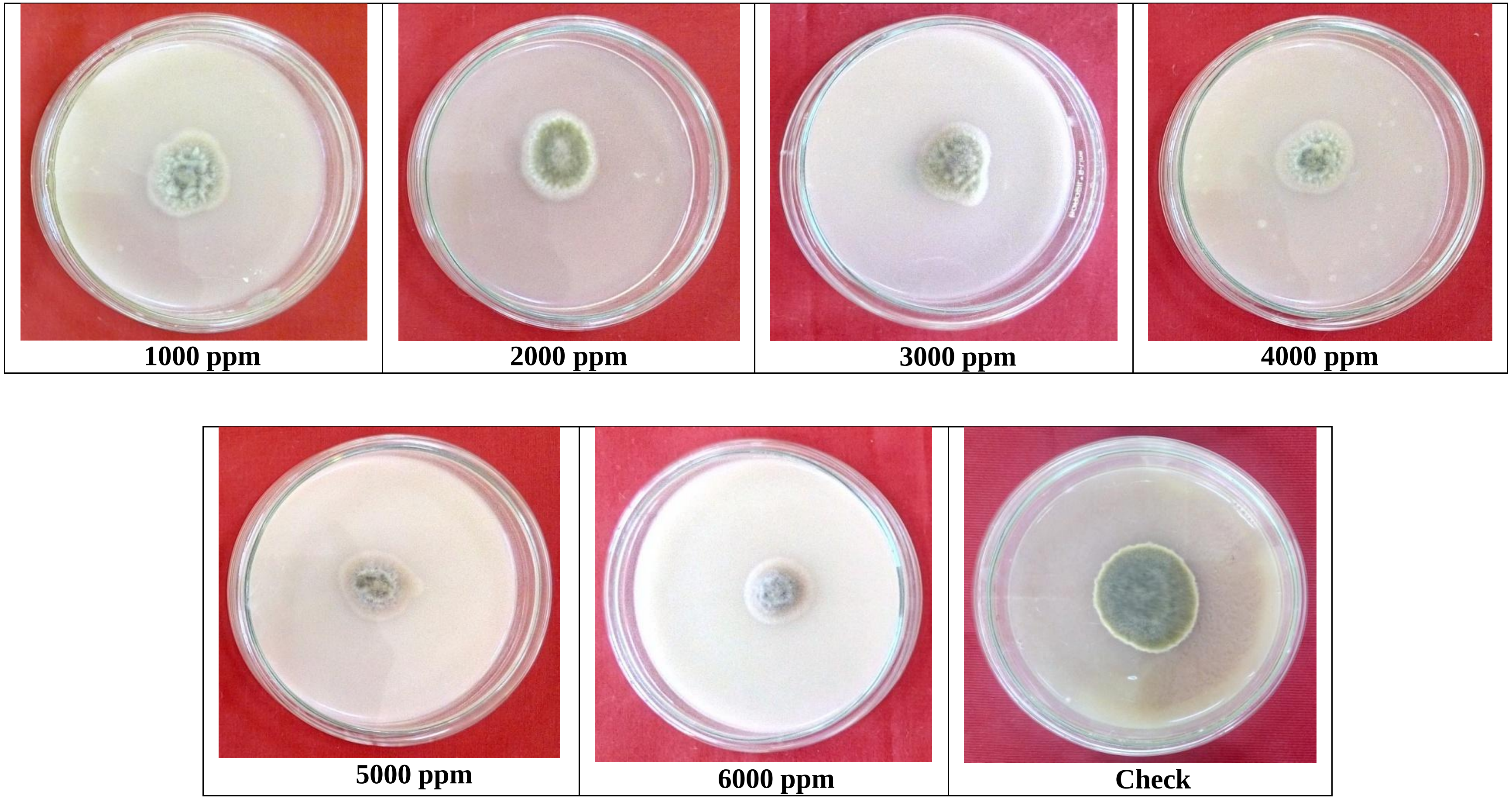

Check

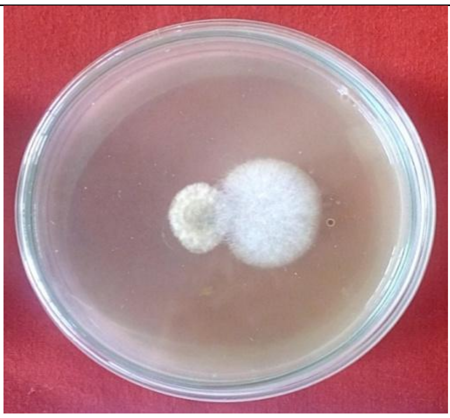
Effect of carbendazim + cow dung on the radial growth of test pathogen at different concentration

PLATE-15



Effect of carbendazim + cow urine on the radial growth of test pathogen at different concentration

PLATE-16

	
A. solani* + *T. harzianum	**Check**

(A)

	
A. solani* + *P. fluorescens	**Check**

(B)

(A) *A. solani* + *T. harzianum* (B) *A. solani* + *P. fluorescens*

Table 4.14 Antagonistic of *Trichoderma harzianum* and *Pseudomonas fluorescens* on mycelial growth of *Alternaria solani*

S. No.	Treatments	(%) inhibition of mycelial growth
1.	*Trichoderma harzianum*	74.75%
2.	*Pseudomonas fluorescens*	62.87%

The two fungal cultures were found to have inhibitory effect on the mycelial growth of the pathogen in (Table 13) and data showed that degree of inhibition was maximum with *Trichoderma harzianum* (74.75%) followed by *Pseudomonas fluorescens* (62.87%) after 96 hours of incubation. *T. harzianum* was found effective with compare to *P. fluorescens.*

4.6 FOLIAR SPRAY OF TREATMENTS

Treatments applications were done by Knapsack sprayer. Two sprays of each treatment was applied at ten days intervals and recorded disease intensity after 75, 90 and 105 days after transplanting.

4.7 Effect of Different Treatments on No. of Fruits Per Plant, Fruit Weight (g/ plant), *Alternaria* Infected Fruit Weight (g/plant), Percent Fruit Infection/Plot and Fruit Yield t/hectare.

4.7.1 Number of fruits per plant

The data presented in Table 15 showed that maximum number of fruit per plant was recorded in carbendazim (19.56) is followed by captan (17.23) and neem oil (14.21)while minimum numbers of fruits per plant were recorded in the treatment with cow dung (8.77). It revealed that the treatment T_7(8.77) at par with compared to T_9(7.21) and all the data are significantly superior over check.

4.7.2 Average fruit weight (g/plant)

Maximum fruit weight was recorded in carbendazim (57.10 g) followed by captan (55.97 g) and *Trichoderma harzianum* (51.70 g), whereas minimum fruit weight was observed in mustard oil (42.92 g). It is found from the data all treatments are significantly better than the treatment check.

4.7.3 *Alternaria* infected average fruit weight (g/plant)

The data on *Alternaria* infected fruit weight (g/plot) during 2014-2015 crop season all treatments resulted significant decrease *Alternaria* infected fruit as compare to Check. Minimum *Alternaria* infected fruit was recorded in carbendazim (54.02 g) followed by captan (50.43 g) and neem oil (47.69 g) while maximum *Alternaria* infected fruit was observed in cow dung (40.99 g). All the treatments are significantly better compared with treatments check (T_9).

4.7.4 Percent fruit infection/plot

The data indicate that the Effect of different treatments on percent fruit infection per plot of tomato was found significant during the 2014-2015 crop season. Minimum percent fruit infection per plot was recorded in carbendazim (23.83%) followed by captan (27.66%) and neem oil (28.14%). While cow dung was observed maximum percent fruit infection per plot (45.74%).

4.7.5 Fruit yield t/ha

The data revealed to the fruit yield (t/ha) as affected by different treatments resulted significant increase in fruit yield as compare to the control. Maximum fruit yield per hectare was recorded in the carbendazim (37.22 t/ha) followed by captan (32.14 t/ha) and *T. harzianum* (24.48 t/ha). While minimum fruit yield per hectare was observed in mustard oil (12.54 t/ha). It is found that all data are significantly superior than check.

4.7.6 Per cent yield increase over check

Maximum Per cent yield increase was observed in carbendazim (29.57%) followed by captan (24.17%) and *T. harzianum* (16.03%), while minimum per cent yield increase over check was recorded in mustard oil (3.33%).

4.8 Disease intensity on leaves and fruits of tomato

All the treatments were found significantly effective in reducing the disease intensity when compared to Check. Minimum disease intensity was observed in carbendazim (46.40, 51.10 & 56.97%) with maximum fruit yield (13.40 kg/plot) at 75, 90 and 105 DAT, respectively. It was found to be most effective followed by captan (11.57 kg/plot) and neem oil (8.77 kg/plot) which were next best treatments. It can be concluded that carbendazim was highly effective against early blight of tomato. It showed significant decrease in disease intensity compared to all other treatments including check. Among the treatments, non-significant results were found in the treatments cow dung and mustard oil to over check.

Table 4.15 Effect on different treatments on No. of fruits per plant, fruit weight (g/plant), *Alternaria* infected fruit weight (g/plant), percent fruit infection/plot and fruit yield t/hectare during 2014-2015 crop season

Treatment		Dose (%)	No. of fruit/plant	Average fruit weight (g/plant)	*Alternaria* infected average fruit weight (g/plant)	Percent fruit infection /plot	Fruit yield (t/hectare)	Per cent Yield increase over Check
T_1	Carbendazim	0.2	17.56 ± 1.23	57.10 ± 0.70	54.02± 1.95	23.83± 1.32	37.22 ± 1.24	29.57
T_2	Captan	0.2	15.23 ± 0.81	55.97 ± 0.60	50.43± 0.84	27.66± 1.31	32.14 ± 1.21	24.17
T_3	*Pseudomonas fluorescens*	0.5	9.80 ± 0.40	49.30 ± 0.46	44.17± 1.10	37.19± 0.10	19.39 ± 1.76	10.61
T_4	*Trichoderma harzianum*	0.5	10.37 ± 1.23	51.70 ± 0.50	47.69± 1.64	36.31± 0.48	24.48 ± 1.43	16.03
T_5	Neem oil	0.6	12.21±0.87	50.01 ± 1.15	45.29± 1.49	28.14± 2.32	20.65 ± 0.69	11.95
T_6	Mustard oil	0.6	7.18 ± 0.70	42.92 ± 0.81	40.99± 1.44	41.77± 0.65	12.54 ± 0.03	3.33
T_7	Cow dung	0.6	6.77 ± 0.57	45.70 ±1.07	41.64± 1.36	45.74± 0.44	13.98 ± 0.09	4.86
T_8	Cow urine	0.6	9.09 ± 0.93	47.87 ±1.42	42.84± 0.85	41.51± 0.40	17.69 ± 0.23	8.81
T_9	Check	00	7.21 ± 0.71	39.56 ± 0.51	38.44± 1.51	58.24± 2.32	9.40 ± 1.19	00
	Mean		**12.38**	**48.90**	**45.06**	**37.82**	**20.84**	
	S.E.(d)		**0.87**	**1.12**	**0.67**	**1.88**	**0.12**	
	C.D. $_{(0.05)}$		**1.84**	**2.37**	**1.42**	**3.99**	**0.26**	

Table 4.16 Effect of different treatments on disease intensity of tomato crop

Treatments (kg/plot)		Dose (%)	Disease intensity			Yield
			75 DAT	90 DAT	105 DAT	
T_1	Carbendazim	0.2	46.40±2.30	51.10±1.99	56.97±2.12	13.40±0.55
T_2	Captan	0.2	48.80±3.78	53.80±2.66	59.40±2.57	11.57±0.29
T_3	*P. fluorescens*	0.5	54.32±2.86	62.15±0.85	66.30±1.76	6.98±0.57
T_4	*T. harzianum*	0.5	50.13±5.86	54.50±2.92	60.90±3.27	7.41±0.63
T_5	Neem oil	0.6	52.53±3.34	56.90±3.32	65.10±1.53	8.77±0.46
T_6	Mustard oil	0.6	66.40±0.47	69.30±0.52	76.90±1.38	5.00±0.19
T_7	Cow dung	0.6	61.87±0.53	65.60±0.60	76.57±1.15	4.52±0.29
T_8	Cow urine	0.6	57.20±1.40	64.07±0.13	71.43±1.13	6.37±0.57
T_9	Check	00	72.00±1.38	78.80±0.76	85.40±2.08	3.42±0.08
	Mean		**56.63**	**61.80**	**68.77**	**7.49**
	S.E.(d)		**4.36**	**2.72**	**2.82**	**0.66**
	C.D. $_{(0.05)}$		**9.24**	**5.78**	**5.99**	**1.40**

4.9 Integration of Different Treatments on No. of Fruits Per Plant, Fruit Weight (g/plant), *Alternaria* Infected Fruit Weight (g/plant), Percent Fruit Infection/Plot and Fruit Yield t/hectare.

4.9.1 Number of fruits per plant

Effect of treatments on number of fruits per plant Table 17. The data revealed that carbendazim + captan showed the maximum numbers of fruits per plant (20.10) followed by carbendazim + Neem oil (16.78) and carbendazim + *T. harzianum* (13.65). Whereas lowest number of fruits per plant was recorded in carbendazim + cow dung (8.37). It is evident from the data that treatments T_6 (8.37) is at par with the check T_9 (7.56) and all the treatments are significantly better when compared with the treatments check.

4.9.2 Average fruit weight (g/ per plant)

During 2014-2015 crop season the observation recorded that maximum fruit weight was recorded in carbendazim + captan (58.10 g) followed by carbendazim + *T. harzianum* (55.91 g) and carbendazim + neem oil (54.89 g). While minimum fruit weight was recorded in carbendazim + mustard oil (44.72 g).

4.9.3 *Alternaria* infected average fruit weight (g/plant)

The Effect of foliar spray of different treatments with combination on *Alternaria* infected fruit weight g/plot was found significant during crop season 2014-2015. Minimum infected fruit weight was observed in the treatment carbendazim + captan(50.79 g) which are followed by carbendazim + *T. harzianum* (47.09 g) and carbendazim + cow urine (46.32 g). While maximum infected average fruit weight was recorded in the carbendazim + cow dung (47.09 g).

4.9.4 Percent fruit infection/plot

The observations recorded for this trail showed significant differences among all the treatment. Minimum percent fruit infection per plot was observed in carbendazim + captan (17.26%) followed with carbendazim + *T. harzianum* (25.27%) and carbendazim + cow urine(25.33%). Whereas maximum percent fruit infection/plot was recorded in carbendazim + cow dung (38.84%).

4.9.5 Fruit yield t/ha)

Maximum fruit yield per hectare was recorded in the carbendazim + captan(38.92 t/ha) and carbendazim + *T. harzianum* (31.27 t/ha) and carbendazim + neem oil(24.97 t/ha) minimum fruit yield per hectare was observed in carbendazim + mustard oil (13.96 t/ha).

4.9.6 Per cent yield increase over check

Maximum per cent yield increase was observed in carbendazim + captan (30.18%) followed by carbendazim + *T. harzianum* (22.28%) and carbendazim + neem oil (15.78%), while minimum per cent yield increase over Check was recorded in carbendazim + cow dung (8.00%).

4.9.7 Disease intensity on leaves and fruits of tomato

Different treatments with combination were observed significantly effective in decreasing the disease intensity when compared to Check. Lowest disease intensity was observed in carbendazim + captan (39.97, 47.07 & 51.83%) maximum fruit yield (14.02 kg/plot)at 75, 90 and 105 DAT, respectively followed by carbendazim + *T. harzianum* (11.26 kg/plot) and carbendazim + neem oil (8.99 kg/plot). carbendazim + mustard oil was found least Effective (5.02 kg/plot).

Table 4.17 **Effect on different treatments with integration on No. of fruits per plant, Fruit weight (g/plant), *Alternaria* infected fruit weight (g/plant), Percent fruit infection/plot and fruit yield t/hectare) during 2014-2015 crop season**

Treatment		Dose (%)	No. of fruit/plant	Average fruit weight (g/plant)	*Alternaria* infected average fruit weight (g/plant)	Percent fruit infection /plot	Fruit yield (t/hectare)	Per cent Yield increase over Check
T_1	Carbendazim + Captan	0.10+0.10	20.10±0.57	58.10±0.65	50.79±1.43	17.26±0.60	38.92±2.43	30.18
T_2	Carbendazim+ *P. fluorescens*	0.10+0.25	11.56±0.44	50.10±1.78	41.66±0.86	27.21±1.24	19.70±0.77	10.34
T_3	Carbendazim + *T. harzianum*	0.10+ 0.25	13.65±0.55	55.91±1.20	46.32±0.45	25.27±0.71	31.27±1.52	22.28
T_4	Carbendazim + Neem oil	0.10+0.30	16.78±0.84	54.89±0.95	47.09±0.56	33.90±1.24	24.97±0.57	15.78
T_5	Carbendazim + Mustard oil	0.10+0.30	10.98±0.65	44.72±0.11	40.91±1.00	37.50±3.38	13.96±0.51	4.41
T_6	Carbendazim + Cow dung	0.10+0.30	8.37±1.25	47.65±0.57	38.47±1.02	38.84±0.58	17.44±0.39	8.00
T_7	Carbendazim + Cow urine	0.10+0.30	11.80±0.52	51.89±0.98	44.59±0.47	25.33±1.27	19.99±0.26	10.64
T_8	Check	00	7.56±0.37	38.44±0.45	36.00±0.38	57.52±1.46	9.68±0.68	00
	Mean		**12.59**	**50.21**	**43.23**	**32.85**	**21.99**	
	S.E.(d)		**0.58**	**1.01**	**0.61**	**2.17**	**0.15**	
	C.D. $_{(0.05)}$		**1.24**	**2.17**	**1.31**	**4.67**	**0.33**	

Table 4.18 Effect of different treatments with combination on disease intensity of tomato crop

Treatments	Dose (%)	Disease intensity 75 DAT	90 DAT	105 DAT	Yield (kg/plot)
T_1Carbendazim + Captan	0.1+0.1	39.97±0.91	47.07±2.48	51.83±1.74	14.02±0.34
T_2 Carbendazim+ *P. fluorescens*	0.1+0.25	57.36±2.92	58.64±1.48	65.51±1.79	7.11±0.46
T_3 Carbendazim + *T. harzianum*	0.1+0.25	48.64±2.92	52.15±0.05	55.47±1.71	11.26±1.13
T_4Carbendazim + Neem oil	0.1+0.30	51.45±1.87	54.78±2.00	57.02±1.37	8.99±0.63
T_5 Carbendazim + Mustard oil	0.1+0.30	61.26±0.40	60.77±0.66	67.31±1.81	5.02±0.65
T_6 Carbendazim + cow dung	0.1+0.30	57.73±1.88	65.45±1.50	70.36±0.27	6.28±0.45
T_7 Carbendazim + cow urine	0.1+0.30	56.62±2.95	58.02±2.82	63.43±0.55	7.20±0.85
T_8 Check	00	65.69±2.84	74.93±1.06	79.35±0.75	3.48±0.50
Mean		**54.84**	**58.98**	**63.79**	**7.92**
S.E.(d)		**3.19**	**2.82**	**1.99**	**0.86**
C.D. $_{(0.05)}$		**6.84**	**6.06**	**4.27**	**1.85**

DISCUSSION

Chapter 5
DISCUSSION

Tomato *(Lycoperiscum esculantum* L.*)* is an herbaceous plant. Tomato is important crop on the basis of its high nutritional and consumption values all over the world. Tomato is considered as highly nutritious because of its high contents of vitamin A and C as well as lycopene natural antioxidant, which is not found in the other solanaceous crops. It is considered as an important cash and industrial crop in many parts of the world. *Alternaria solani* Sorauer is a soil inhabiting air-borne pathogen responsible for leaf blight, collar and fruit rot of tomato disseminated by fungal spores. The disease affects on all parts of the plant and causes great reduction in quantity and quality of fruit yield. Under humid conditions followed by warm and wet weather tomato plants are susceptible to the early blight disease caused by *A. solani*.

Limited information is available particularly on Integrated disease management of early blight of tomato. Keeping this fact in the mind, the present investigation was undertaken to develop suitable disease management strategy using chemical, biological agent, botanical oils and animal product, formulate an integrated approach against the early blight of disease. Under present investigation are discussed in the following paragraphs.

5.1 SYMPTOMLOGY

Alternaria solani is a fungal pathogenthat produces a disease in tomato plants. The pathogen produces distinctive "bullseye" patterned leaf spots and can also cause stem lesions and fruit rot on tomato. Foliar symptoms usually occur on older leaves.

On tomato, foliar symptoms of *A. solani* generally occur on the oldest leaves and start as small lesions that are brown to black in color. These leaf spots resemble concentric rings - a distinguishing characteristic of the pathogenand measure up to 1.3 cm in diameter. Under favorable conditions (e.g., warm weather with short or abundant dews), significant defoliation of lower leaves may occur, leading to sunscald of the fruit. As the disease progresses, symptoms may migrate to the plant stem and fruit. Stem lesions are dark, slightly sunken and concentric in shape. Basal girdling and death of seedlings may occur, a symptom known as collar rot.In fruit, *A. solani* invades at the point of attachment to the stem as well as through growth cracks and wounds made by insects, infecting large areas of the fruit. Fruit spots are similar in appearance to those on leaves brown with dark concentric circles. Mature lesions are typically covered by a black, velvety mass of fungal spores that may be visible under proper light conditions.

5.2 ISOLATION AND IDENTIFICATION

The identification of the *Alternaria solani* associated with early blight disease of tomato was carried out on the basis of morphological and microscopic characters of the isolated pathogen. Microscopic studies of the pathogen revealed that the conidia of pathogen were club and rod shaped with a beak structure and 8-9 septets brownish colour. On the basis of presence of rod shaped conidia the pathogenic fungi was identified as *A. solani* (Plate-1).

5.3 DISEASE MANAGEMENT

5.3.1 Nine different treatments were tested against early blight of pathogen *in vitro* condition @ 1000, 2000, 3000, 4000, 5000 and 6000 ppm concentration of carbendazim proved the best treatment which gave (4.92, 4.51, 4.20, 3.78, 3.25 and 2.56 mm) radial growth followed by captan and *Trichoderma harzianum*.

Carbendazim as best treatment against early blight of tomato was also reported by Tetarwal and Rai (2007) in management of *Alternaria* blight of senna *(Cassia angustifolia),* Sudarshana *et al.* (2012) and Sadana and Didwania (2015).

5.3.2 Eight different treatments with combination were testedagainst the test pathogen@ 1000, 2000, 3000, 4000, 5000 and 6000 ppm. The results revealed that carbendazim + captan @ 6000 ppm concentration showed lowest radial growth (2.04 mm) followed by carbendazim + *T. harzianum* (3.74 mm) and carbendazim + neem oil (4.31 mm) while maximum radial growth was found in carbendazim + cow dung (6.28 mm).

Carbendazim + mancozeb were most inhibitory for mycelial growth of *A. solani* according to Dushyant *et al.* (2014) and Sail *et al*. (2010) was also observed carbendazim + mancozeb was significantly superior over all the treatments inhibiting the radial mycelial growth of *Altemaria solani*.

5.3.3 Nine treatments namely carbendazim, captan, *Pseudomonas fluorescens, Trichoderma harzianum,* neem oil, mustard oil, cow dung and cow urinetested against early blight of pathogen *in vivo* condition carbendazim as best treatment which gave highest no. of fruit per plant (19.56), fruit weight (57.10 g/plant), *Alternaria* infected average fruit weight (54.02

g/plant), percent fruit infection per plot (23.83) and fruit yield (37.22t/ha) followed by captan and *Trichoderma harzianum.*

5.3.4 *In vivo* condition all the nine treatments were found significantly effective in reducing the disease intensity with compared to control. Minimum disease intensity was observed in carbendazim (46.40, 51.10 & 56.97%) with maximum fruit yield (13.40 kg/plot) at 75, 90 and 105 DAT, followed by captan and *T. harzianum*.

Minimum disease intensity was also observed in carbendazim with maximum plant height and Yield (kg/plot) Sudarshana *et al.* (2012) and carbendazim also effective against early blight of tomato and reducing of disease intensity with increase yield of tomato (t/ha) Patel and Chaudhary (2010).

5.3.5 All the treatment with combination were tested against early blight of pathogen in field condition carbendazim + captan as best treatment which revealed highest no. of fruit per plant (20.10), fruit weight (58.10 g/plant), average *Alternaria* infected fruit weight (50.79 g/plant), percent fruit infection per plot (17.26), fruit yield (38.92 t/ha) followed by carbendazim + *T. harzianum* and carbendazim + neem oil.

Carbendaizm + mancozeb was also gave better yield (16.91 t/ha) Dushyant *et al.* (2014).

5.3.6 Treatments with combination were observed significantly effective in decreasing the disease intensity. Lowest disease intensity was observed in carbendazim + captan at 75, 90 and 105 DAT, respectively followed by carbendazim + *T. harzianum* and carbendazim + neem oil.

Carbendazim + mancozeb were found also effective in reducing the fruit rot intensity Chavan and Tawade (2012), *T. harzianum* + hexaconazole were also showed statistically at par with other treatment of disease intensity respectively according to Ganie *et al.* (2013) and carbendazim + mancozeb have been proved effective in respect to disease control with maximum yield in tomato (Khade and Joi. 1980).

SUMMARY AND CONCLUSION

Chapter 6
SUMMARY AND CONCLUSION

Early blightof tomato caused by *Alternaria solani* Sorauer. It is a distractive soil borne and seed borne disease of tomato resulting into heavy yield losses. This diseaseis one of the major production constraints in India and has a damaging effect on tomato in the all over region of India, particularly plane areas of Uttarakhand. Efforts were made to develop suitable management strategy incorporating chemicals, bioagents, botanical oils and animal products.Integrated approach against the early blight disease under lab and field conditions. The findings of the present investigation entitled "Integrated management of early blight disease of tomato" are summarized in the following paragraph.

6.1) Characteristic symptoms of early blight was on the foliage exclusively on the leaves and stem werewater soakeddark-green, brown or black, depressed and usually with distinct rings.

6.2) Average temperature, relative humidity, rainfalland wind have been played very important role in disease development.

6.3) Nine treatments tested against the test pathogen under *in vitro* conditions, carbendazim proved to be the best treatment followed by captan and *T. harzianum*.

6.4) Eight different treatments with combination were testedagainst the pathogen.The result revealed that carbendazim + captan @ 2000 ppm concentration observed minimum radial growth followed by carbendazim + *T. harzianum* and carbendazim + neem oil while maximum radial growth was found in carbendazim + cow dung.

6.5) Carbendazim as best treatment in field condition which proved highest no. of fruit per plant, fruit weight g/plant, *Alternaria* infected fruit weight g/plant, percent fruit infection per plot, fruit yield t/hectare compare to other treatments like captan and *Trichoderma harzianum.*

6.6) All the treatment was tested *in vivo* condition and found to be effective and reducing the disease intensity with compared to control. Minimum disease intensity was found in carbendazim with maximum fruit yield followed by captan and *T. harzianum*.

6.7) All the treatments with combination were tested against early blight of pathogen in field condition carbendazim + captan as best treatment which gave highest no. of fruit per plant, fruit weight g/plant, *Alternaria* infected fruit weight g/plant, percent fruit infection per plot, fruit yield t/ ha. followed by carbendazim + *T. harzianum* and carbendazim + neem oil.

6.8) Out of eight treatments with combination on the intensity of early blight carbendazim + captan indicated that minimum disease intensity and maximum fruit yield 14.02 (kg/plot) was recorded followed by carbendazim + *T. harzianum* and carbendazim + neem oil.

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Chapter 7

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APPENDICES

APPENDIX- I

Appendix 1: Analysis of variance of radial growyh of *Alternaria solani* at 1000, 2000, 3000, 4000, 5000 and 6000 ppm concentration

SV	d.f	Mean sum of squares					
		A	B	C	D	E	F
Factor A	3	299.60	201.25	184.72	159.45	154.02	119.71
Factor B	8	49.53	53.27	56.84	65.00	71.09	85.86
Factor A × Factor B	24	3.88	4.80	4.48	5.40	5.28	5.14
Error	72	0.65	0.33	0.32	0.16	0.16	0.31

*Significant at 5% level of significance

Where,

A=1000 ppm concentration, B=2000 ppm concentration, C=3000 concetration, D=4000 ppm, E=5000 ppm concentration and F=6000 ppm concentration.

APPENDIX- II

Appendix 2: Showing analysis of variance for radial growth of test pathogen at different treatments with their combination

SV	d.f	Mean sum of squares					
		A	B	C	D	E	F
Factor A	3	153.97	131.42	114.88	99.56	97.50	94.23
Factor B	7	47.36	59.96	70.43	73.88	81.37	93.57
Factor A × Factor B	21	3.05	3.68	4.55	4.45	4.76	4.97
Error	64	0.23	1.02	0.25	0.29	0.19	0.14

*Significant at 5% level of significance

Where,

A=1000 ppm concentration, B=2000 ppm concentration, C=3000 concetration, D=4000 ppm, E=5000 ppm concentration and F=6000 ppm concentration.

APPENDIX- III

Appendix 3: ANALYSIS OF VARIANCE FOR DIFFERENT CHARACTERS UNDER STUDY

Source of variation	Degree of freedom	Mean sum of squares						
		X1	X2	X3	X4	X5	X6	X7
Replication	2.00	11.41187	5.161458	47.54731	3.715929	14.48611	0.1496107	334.3841
Treatment	8.00	48.903	97.801	72.708	339.085	25,058.844	32.383	238.167
Error	16.00	1.142	1.887	0.680	5.330	2.347	0.657	1.523

*Significant at 5% level of significance

X1= No. of fruits per plant X2= Average fruit weight (g/plant) X3= *Alternaria* infected average fruit weight (g/plant) X4= Percent fruit infection/plot X5= Fruit yield t/hectare X6= Fruit yield (kg/plot) X7= Disease intensity separately.

APPENDIX- IV

Appendix 4: ANALYSIS OF VARIANCE FOR DIFFERENT CHARACTERS UNDER STUDY WITH TREATMENT COMBINATION

Source of variation	Degree of freedom	Mean sum of squares						
		X1	X2	X3	X4	X5	X6	X7
Replication	2	8.34	11.64	13.17773	8.893555	5.375	3.099	160.3203
Treatment	7	52.502	126.272	71.206	452.490	26,896.239	34.889	207.807
Error	14	0.508	1.549	0.562	7.121	3.529	1.121	4.193

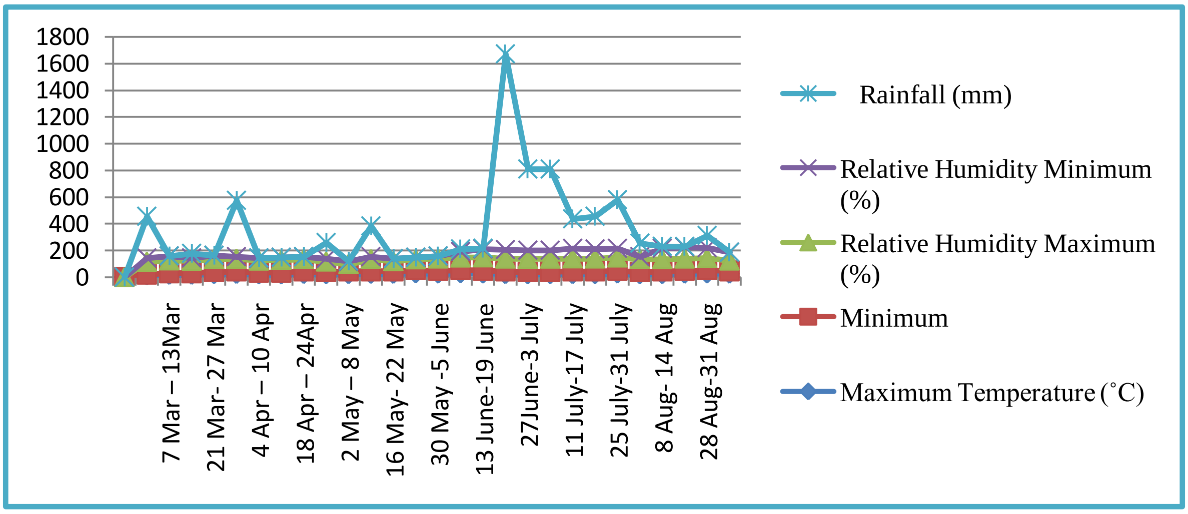
*Significant at 5% level of significance

X1= No. of fruits per plant X2= Average fruit weight (g/plant) X3= *Alternaria* infected average fruit weight (g/plant) X4= Percent fruit infection/plot X5= Fruit yield t/hectare X6= Yield (kg/plot) X7= Disease intensity separately.

APPENDIX- V

Appendix 5: Meteorological weather data from April to September (2015) in Bharsar

Month	Maximum Temperature (^{0}C)	Minimum Temperature (^{0}C)	Relative Humidity Maximum (%)	Relative Humidity Minimum (%)	Rainfall (mm)
1 Mar – 6 Mar	12.25	9.25	94	30.00	310.00
7 Mar – 13Mar	16.60	13.30	96	31	0.00
14 Mar – 20 Mar	16.75	14.08	93	22	30.00
21 Mar – 27 Mar	21.75	18.33	95	27	0.00
28 Mar – 3 Apr	22.87	19.50	96	16	420.00
4 Apr – 10 Apr	19.75	14.75	90	17	0.00
11 Apr – 17Apr	19.10	16.70	92	21	0.00
18 Apr – 24Apr	22.75	18.88	94	16	0.00
25 Apr – 1 May	21.00	18.50	78	21	120.00
2 May – 8 May	21.55	19.75	57	19	0.00
9 May – 15 May	23.75	21.67	90	16	230.00
16 May – 22 May	23.58	21.25	75	17	0.00
23 May – 29 May	27.42	24.67	82	15	0.00
30 May –5 June	25.50	22.67	92	17	0.00
6 June – 12 June	28.16	22.69	97	43	20.00
13 June – 19 June	26.00	23.75	99	60	5.40
20 June – 26 June	21.75	19.08	99	65	1464.78
27June – 3 July	20.25	19.33	98	64	608.34
4 July –10 July	21.16	19.41	99	63	604.00
11 July – 17 July	21.75	20.50	99	72	220.00
18 July – 24 July	21.12	20.27	99	70	244.00
25 July – 31 July	25.54	23.41	99	66	365.00
1 Aug – 7 Aug	20.50	18.50	97	18.5	97.00
8 Aug – 14Aug	21.50	20.50	93	80	15.50
21 Aug – 27Aug	24.50	21.50	94	85	5.50
28 Aug – 31 Aug	26.50	25.00	91	79	90.30
1 Sep – 7 Sep	24.50	20.50	80	60	0.00
	22.14	**19.55**	**91.41**	**41.13**	**179.62**



ABSTRACT

ABSTRACT

Name of the student: Suraj Biswas I.D Number: 14176

Semester and year of admission: Ist sem 2014 Degree: M.Sc. Agriculture (Plant Pathology)

Major: Plant Pathology Department: Plant Pathology

Thesis title: **"Integrated disease management of early blight in tomato caused by *Alternaria solani* Sorauer"**

Advisor: Prof. B. P. Nautiyal

Early blight caused by *Alternaria solani* Sorauer is an important soil borne and seed borne disease of tomato. This disease is very destructive disease resulting heavy yield losses. The present investigation was undertaken to develop suitable management strategy through chemical, bioagents, oils and animal products with a view to formulate an integrated approach against early blight of tomato under field condition.

In vitro and *in vivo* studies of different nine treatments were tested against early blight among them carbendazim gave minimum radial growth (2.56 mm) followed by captan (3.75 mm) and *Trichoderma harzianum* (4.34 mm) similarly same result was found *in vivo* two foliar spray of carbendazim (0.2%) was found most effective significantly reduced disease intensity (46.40, 51.10 and 56.97%) respectively after 75, 90, and 105 DAT significantly increased yield (37.22 t/ha) followed by captan (48.80, 53.80 and 59.40%) disease intensity and increase the yield (32.14 t/ha) and *Trichoderma hazianum* (50.13, 54.50 and 60.90%) as increased yield (24.48 t/ha) while maximum disease intensity (66.40, 69.30 and 76.90%) and lowest yield (4.52 t/ha) was found in mustard oil. Eight treatments tested with combination *in vitro* condition and minimum radial growth was found in carbendazim + captan (2.04 mm) followed by carbendazim + *T. harzianum* (3.74 mm) and carbendazim + neem oil (4.31 mm) where as *in vivo* condition carbendazim + captan was found most effective and reduced disease intensity (39.97, 47.07and 51.83%) with increased yield 38.92 t/ha) followed by carbendazim + *T. harzianum* (48.64, 52.15 and 55.47%) with yield 31.27 t/ha, carbendazim + neem oil (51.45, 54.78 and 57.02%) with 24.97 t/ha respectively.

Hence, it is concluded that the combined Integrated Disease Management package was reduced the disease intensity and significantly increase the tomato yield.

Prof. B. P. Nautiyal	Dr. Vijay Kumar	Suraj Biswas
Name and signature of Advisor	Co - Advisor	Name and Signature of Author

सारांश

नाम : सूरज विश्वास | पहचान संख्या : 14176

सत्र एवं प्रवेष का वर्ष : प्रथम षटमास, 2014 | उपाधि का नामः स्नात्तकोतर कृषि (पादप रोग विज्ञान)

मुख्य विषय : पादप रोग विज्ञान | विभाग : पादप रोग विज्ञान

शोध का शीर्षक : ''टमाटर में *अल्टरनेरिया सोलेनाई* सोर्र के कारण अगेती झुलसा का एकीकृत रोग प्रबंधन''

सलाहकार : प्रो.बी.पी.नौटियाल

अगेती झुलसा रोग *अल्टरनेरिया सोलेनाई* सोर्र की वजह से टमाटर का मृदा जनित और बीज जनित रोग है। यह रोग बहुत हानिकारक रोग है, जिसके फलस्वरूप उत्पादन में अधिक हानि होती है। वर्तमान जाँच, उपयुक्त प्रबंधन रणनीति के विकास के लिए विभिन्न माध्यमों रसायन, जैव घटक, वानस्पतिक तेल एवं पशु उत्पादकों के द्वारा टमाटर के अगेती झुलसा रोग के विरूद्ध एकीकृत दृष्टिकोण तैयार की गयी है।

इन विट्रो एवं इन विवो अध्ययन के तहत विभिन्न उपचारों के अगेती झुलसा रोग के विरूद्ध जाँच की गयी जिसमें कार्बेन्डाज़िम में न्यूनतम दीप्तिमान वृद्धि (2.56 मिमी.), केप्टान (3.75 मिमी.) एवं *ट्राईकोर्डमा हारज़िएनम* (4.34 मिमी.) दर्ज की गयी। इसी प्रकार इन विवो में एक ही परिणाम पाये गये, जिसमें कार्बेन्डाज़िम (0.2%) का दो बार पत्तियों पर छिड़काव प्रभावशाली पाया गया। जिसने काफी मात्रा में रोग गहनता को कम किया (46.40, 51.10 एवं 56. 97%) क्रमशः 75, 90 एवं 105 (दिन रोपाई के बाद) एवं काफी मात्रा में फसल उपज में वृद्धि (37.22 टन/है.) की उसके उपरांत केप्टान में (48.80, 53.80 एवं 59.40%) रोग गहनता में कमी व उपज में वृद्धि (32.14 टन/है.) एवं *ट्राईकोर्डमा हारज़िएनम* (50.13, 54.50 एवं 60.90%) रोग गहनता में कमी व उपज में वृद्धि (24.48 टन/है) क्रमशः 75, 90 एवं 105 (दिन रोपाई के बाद) दर्ज की गयी जबकि अधिकतम रोग गहनता (66.40, 69.30 एवं 76.90%) एवं न्यूनतम उपज (4.52 टन/है) सरसों के तेल में दर्ज की गयी। इन विट्रो स्थिति में आठ उपचारों की संयुक्त जाँच की गयी जिसमें न्यूनतम कवक वृद्धि कार्बेंडाज़िम + केप्टान (2.04 मिमी.) में पायी गयी इसके उपरांत कार्बेन्डाज़िम + *ट्राईकोर्डमा हाऱज़िएनम* (3.74 मिमी.) एवं कार्बेन्डाज़िम + नीम तेल (4.31 मिमी.) में दर्ज की गयी, जबकि इन विवो स्थिति में कार्बेंडाज़िम + केप्टान को बहुत प्रभावशाली पाया गया, जिसमें रोग गहनता को क्रमशः (39.97, 47.07 एवं 51.83%) कम किया एवं उपज में (38.92 टन/है.) वृद्धि दर्ज की गयी। इसके उपरांत कार्बेन्डाज़िम + *ट्राईकोर्डमा हाऱज़िएनम* रोग गहनता में कमी (48.64, 52.15 एवं 55.47%) एवं उपज में वृद्धि (31.27 टन/है.) दर्ज की गयी। कार्बेन्डाज़िम + नीम तेल में रोग गहनता में कमी (51.45, 54.78 एवं 57.02%) एवं उपज वृद्धि (24.97 टन/है.) दर्ज की गयी।

इस प्रकार प्रयोग से यह निष्कर्ष निकाला गया कि संयुक्त एकीकृत रोग प्रबंधन पैकेज से टमाटर में रोग गहनता में कमी एवं उपज में वृद्धि मिलेगी।

प्रो.बी.पी. नौटियाल	डॉ विजय कुमार	सूरज विश्वास
सलाहकार का नाम व हस्ताक्षर	सह - सलाहकार	लेखक का नाम व हस्ताक्षर

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