COMPATIBILITY OF CERTAIN BIO-CONTROL AGENTS WITH COMMONLY USED AGROCHEMICALS

By

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B Sc (Ag.)

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SEPTEMBER, 2005

CERTIFICATE

Mr. M. ASHOK has satisfactorily prosecuted the course of research and that the thesis entitled, **"COMPATIBILITY OF CERTAIN BIO-CONTROL AGENTS WITH COMMONLY USED AGROCHEMICALS"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a deegree of any University.

Date : -09-2005

Place : Hyderabad

(Dr. D. RAJARAM REDDY)
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CERTIFICATE

This is to certify that the thesis entitled **"COMPATIBILITY OF CERTAIN BIO-CONTROL AGENTS WITH COMMONLY USED AGROCHEMICALS"** submitted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the Acharya N. G. Ranga Agricultural university, Hyderabad, is a record of the bonafide research work carried out by **Mr. M. ASHOK** under my guidance and supervision. The subject of the thesis has been approved by the Students Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. The published part has been fully acknowledged. All the assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.

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Date: -09-2005 **(M. ASHOK)**

Place: Hyderabad

C O N T E N T S

CHAPTER NUMBER	TITLE	PAGE NUMBER
I	INTRODUCTION	
II	REVIEW OF LITERATURE	
III	MATERIALS AND METHODS	
IV	RESULTS	
V	DISCUSSION	
VI	SUMMARY	
	LITERATURE CITED	

LIST OF TABLES

Table number	Title	Page number
1	Details of native and commercial biocontrol agents used in the present study	
2	Details of agrochemicals employed in the investigation	
3	*In vitro* effect of antagonistic fungi and bacteria against *P. aphanidermatum*	
4	*In vitro* effect of antagonistic fungi and bacteria against *M. phaseolina*	
5	*In vitro* effect of antagonistic fungi and bacteria against *S. rolfsii*	
6	Sensitivity of fungal antagonists against copper oxychloride (COC) at different concentrations	
7	Sensitivity of fungal antagonists against mancozeb at different concentrations	
8	Sensitivity of fungal antagonists against carbendazim at different concentrations	
9	Sensitivity of fungal antagonists against hexaconazole at different concentrations	
10	Sensitivity of fungal antagonists against imidacloprid at different concentrations	
11	Sensitivity of fungal antagonists against chlorpyriphos at different concentrations	
12	Sensitivity of fungal antagonists against carbosulfan at different concentrations	
13	Sensitivity of fungal antagonists against calcium ammonium nitrate (CAN) at different concentrations	
14	Sensitivity of fungal antagonists against diammonium phosphate (DAP) at different concentrations	
15	Sensitivity of fungal antagonists against single super phosphate (SSP) at different concentrations	

Table number	Title	Page number
16	Sensitivity of fungal antagonists against muriate of potash (MOP) at different concentrations	
17	Sensitivity of fungal antagonists against pendimethalin at different concentrations	
18	Sensitivity of fungal antagonists against fluchloralin at different concentrations	
19	*In vitro* compatibility of commercial isolate of *Pseudomonas fluorescens* (Vermigreen Pf) with fungicides	
20	*In vitro* compatibility of commercial isolate of *Pseudomonas fluorescens* (Sun Agro Monus Pf) with fungicides	
21	*In vitro* compatibility of commercial isolate of *Pseudomonas fluorescens* (Sun Agro Monus Pf) with insecticides	
22	*In vitro* compatibility of commercial isolate of *Pseudomonas fluorescens* (Vermigreen Pf) with insecticides	
23	*In vitro* compatibility of commercial isolate of *Pseudomonas fluorescens* (Sun Agro Monus Pf) with fertilizers	
24	*In vitro* compatibility of commercial isolate of *Pseudomonas fluorescens* (Vermigreen Pf) with fertilizers	
25	*In vitro* compatibility of commercial isolate of *Pseudomonas fluorescens* (Sun Agro Monus Pf) with herbicides	
26	*In vitro* compatibility of commercial isolate of *Pseudomonas fluorescens* (Vermigreen Pf) with herbicides	
27	Efficacy of the various fungicides on the radial growth of *P. aphanidermatum*	
28	Efficacy of the various fungicides on the radial growth of *M. phaseolina*	
29	Efficacy of the various fungicides on the radial growth of *S. rolfsii*	
30	Efficacy of the various insecticides on the radial growth of *P. aphanidermatum*	

Table number	Title	Page number
31	Efficacy of the various insecticides on the radial growth of *M. phaseolina*	
32	Efficacy of the various insecticides on the radial growth of *S. rolfsii*	
33	Efficacy of the various fertilizers on the radial growth of *P. aphanidermatum*	
34	Efficacy of the various fertilizers on the radial growth of *M. phaseolina*	
35	Efficacy of the various fertilizers on the radial growth of *S. rolfsii*	
36	Efficacy of the various herbicides on the radial growth of *P. aphanidermatum*	
37	Efficacy of the various herbicides on the radial growth of *M. phaseolina*	
38	Efficacy of the various herbicides on the radial growth of *S. rolfsii*	
39	Combined effect of fungal biocontrol agents with copper oxychloride (COC) against *P. aphanidermatum* at different concentrations	
40	Combined effect of fungal biocontrol agents with mncozeb against *P. aphanidermatum* at different concentrations	
41	Combined effect of fungal biocontrol agents with copper oxychloride (COC) against *M. phaseolina* at different concentrations	
42	Combined effect of fungal biocontrol agents with mancozeb against *M. phaseolina* at different concentrations	
43	Combined effect of fungal biocontrol agents with copper oxychloride (COC) against *S. rolfsii* at different concentrations	
44	Combined effect of fungal biocontrol agents with mancozeb against *S. rolfsii* at different concentrations	

Table number	Title	Page number
45	Combined effect of fungal biocontrol agents with imidacloprid against *P. aphanidermatum* at different concentrations	
46	Combined effect of fungal biocontrol agents with chlorpyriphos against *P. aphanidermatum* at different concentrations	
47	Combined effect of fungal biocontrol agents with carbosulfan against *P. aphanidermatum* at different concentrations	
48	Combined effect of fungal biocontrol agents with imidacloprid against *M. phaseolina* at different concentrations	
49	Combined effect of fungal biocontrol agents with chlorpyriphos against *M. phaseolina* at different concentrations	
50	Combined effect of fungal biocontrol agents with carbosulsfan against *M. phaseolina* at different concentrations	
51	Combined effect of fungal biocontrol agents with imidacloprid against *S. rolfsii* at different concentrations	
52	Combined effect of fungal biocontrol agents with chlorpyriphos against *S. rolfsii* at different concentrations	
53	Combined effect of fungal biocontrol agents with carbosulfan against *S. rolfsii* at different concentrations	
54	Combined effect of fungal biocontrol agents with calcium ammonium nitrate (CAN) against *P. aphanidermatum* at different concentrations	
55	Combined effect of fungal biocontrol agents with diammonium phosphate (DAP) against *P. aphanidermatum* at different concentrations	
56	Combined effect of fungal biocontrol agents with single super phosphate (SSP) against *P. aphanidermatum* at different concentrations	

Table number	Title	Page number
57	Combined effect of fungal biocontrol agents with muriate of potash (MOP) against *P. aphanidermatum* at different concentrations	
58	Combined effect of fungal biocontrol agents with Calcium ammonium nitrate (CAN) against *M. phaseolina* at different concentrations	
59	Combined effect of fungal biocontrol agents with diammonium phosphate (DAP) against *M. phaseolina* at different concentrations	
60	Combined effect of fungal biocontrol agents with single super phosphate (SSP) against *M. phaseolina* at different concentrations	
61	Combined effect of fungal biocontrol agents with muriate of potash (MOP) against *M. phaseolina* at different concentrations	
62	Combined effect of fungal biocontrol agents with calcium ammonium nitrate (CAN) against *S. rolfsii* at different concentrations	
63	Combined effect of fungal biocontrol agents with diammonium phosphate (DAP) against *S. rolfsii* at different concentrations	
64	Combined effect of fungal biocontrol agents with single super phosphate (SSP) against *S. rolfsii* at different concentrations	
65	Combined effect of fungal biocontrol agents with muriate of potash (MOP) against *S. rolfsii* at different concentrations	
66	Combined effect of fungal biocontrol agents with pendimethalin against *P. aphanidermatum* at different concentrations	
67	Combined effect of fungal biocontrol agents with fluchloralin against *P. aphanidermatum* at different concentrations	

Table number	Title	Page number
68	Combined effect of fungal biocontrol agents with pendimethalin against *M. phaseolina* at different concentrations	
69	Combined effect of fungal biocontrol agents with fluchloralin against *M. phaseolina* at different concentrations	
70	Combined effect of fungal biocontrol agents with pendimethalin against *S. rolfsii* at different concentrations	
71	Combined effect of fungal biocontrol agents with fluchloralin against *S. rolfsii* at different concentrations	
72	Combined effect of bacterial biocontrol agents with fungicides on radial growth of *P. aphanidermatum*	
73	Combined effect of bacterial biocontrol agents with fungicides on radial growth of *M. phaseolina*	
74	Combined effect of bacterial biocontrol agents with fungicides on radial growth of *S. rolfsii*	
75	Combined effect of bacterial biocontrol agents with insecticides on radial growth of *P. aphanidermatum*	
76	Combined effect of bacterial biocontrol agents with insecticides on radial growth of *M. phaseolina*	
77	Combined effect of bacterial biocontrol agents with insecticides on radial growth of *S. rolfsii*	
78	Combined effect of bacterial biocontrol agents with fertilizers on radial growth of *P. aphanidermatum*	
79	Combined effect of bacterial biocontrol agents with fertilizers on radial growth of *M. phaseolina*	
80	Combined effect of bacterial biocontrol agents with fertilizers on radial growth of *S. rolfsii*	
81	Combined effect of bacterial biocontrol agents with herbicides on radial growth of *P. aphanidermatum*	

Table number	Title	Page number
82	Combined effect of bacterial biocontrol agents with herbicides on radial growth of *M. phaseolina*	
83	Combined effect of bacterial biocontrol agents with herbicides on radial growth of *S. rolfsii*	
84	Combined effect of biocontrol agents and agrochemicals on *P. aphanidermatum* infection and seedling parameters of tomato cv. Pusa Ruby	
85	Combined effect of biocontrol agents and agrochemicals on *P. aphanidermatum* infection and seedling parameters of brinjal cv. Shyamala	
86	Combined effect of biocontrol agents and agrochemicals on *P. aphanidermatum* of bhendi cv. Parbhani Kranthi	
87	Combined effect of biocontrol agents and agrocheicals on *M. phaseolina* of tomato cv. Pusa Ruby	
88	Combined effect of biocontrol agents and agrochemicals on *M. phaseolina* of brinjal cv. Shyamala	
89	Combined effect of biocontrol agents and agrochemicals on *M. phaseolina* of bhendi cv. Parbhani Kranthi	
90	Combined effect of biocontrol agents and agrochemicals on *S. rolfsii* of tomato cv. Pusa Ruby	
91	Combined effect of biocontrol agents and agrochemicals on *S. rolfsii* of brinjal cv. Shyamala	
92	Combined effect of biocontrol agents and agrochemicals on *S. rolfsii* of bhendi cv. Parbhani Kranthi	

LIST OF PLATES

Plate number	Title	Page number
1	Pure culture of *Pythium aphanidermatum* on PDA medium	
2	Photomicrograph of *P. aphanidermatum* lobulate sporangia with protoplasmic center	
3	Pure culture of *Macrophomina phaseolina* on PDA medium	
4	Photomicrograph showing black irregular sclerotia of *M. phaseolina*	
5	Photomicrograph showing hyaline, broad septate and branched hyphae of *M. phaseolina*	
6	Pure culture of *Sclerotium rolfsii* on PDA medium	
7	Photomicrograph brown hard spherical sclerotia of *S. rolfsii*	
8	Photomicrograph showing hyaline, septate branched hyphae with clamp connections	
9	Pure culture of commercial isolate *T. viride* (BCL Tv) showing bluish green colonies on PDA medium	
10	Photomicrograph of *T. viride* (BCL Tv) showing phialospores borne on phialides	
11	Pure culture of native isolate *T. viride* (DOR 1 Tv) showing bluish green colonies on PDA medium	
12	Photomicrograph of *T. viride* (DOR 1 Tv) showing phialospores borne phialides	
13	Pure culture of commercial isolate *T. viride* (Sun Agro Derma Tv) showing bright colonies on PDA medium	
14	Photomicrograph of *T. viride* (Sun Agro Derma Tv) showing phialospores borne on phialides	
15	Pure culture of commercial isolate *T. viride* (NCC-58 Tv) showing light green colonies on PDA medium	

Plate number	Title	Page number
16	Photomicrograph of *T. viride* (NCC-58 Tv) phialospore borne on phialides	
17	Pure culture of commercial isolate *T. harzianum* (Sun gro Derma Th) bright greencolonies on PDA medium	
18	Photomicrograph of *T. harzianum* (Sun Agro Derma Th) showing phialospores borne on phialides	
19	Pure culture of native isolate *T. harzianum* (DOR 2 Th) showing light green colonies on PDA medium	
20	Photomicrograph of *T. harzianum* (DOR 2 Th) showing phialospore borne on phialides	
21	Pure culture of commercial isolate *T. harzianum* (NCC-57 Th) showing light greencolonies on PDA medium	
22	Photomicrograph of *T. harzianum* (NCC-57 Th) showing phialospore borne on phialide	
23	Pure culture of commercial isolate *T. harzianum* (Vermigreen Th) showing light greyish green colonies on PDA medium	
24	Photomicrograph of *T. harzianum* (Vermigreen Th) showing phialospore borne on phialide	
25	Pure culture of commercial isolate *Pseudomonas fluorescens* (Vermigreen Pf) on Pseudomonas Agar (for fluorescens) medium	
26	Pure culture of commercial isolate *Pseudomonas fluorescens* (SunAgro Monus Pf) pseudomonas agar (for fluorescens) medium	
27-28	Antagonistic effect of native and commercial isolates of *Trichoderma* spp. against *P. aphanidermatum* in dual culture tests. Plate 27: *T. viride* and *P. aphanidermatum* Plate 28: *T. harzianum* and *P. aphanidermatum*	

Plate number	Title	Page number
29-30	Antagonistic effect of native and commercial isolates of *Trichdoerma* spp. against *M. phaseolina* in dual culture tests Plate 29: *T. viride* and *M. phaseolina* Plate 30: *T. harzianum* and *M. phaseolina*	
31-32	Antagonistic effect of native and commercial isolates of *Trichoderma* spp. against *S. rolfsii* in dual culture tests. Plate 31: *T. viride* and *S. rolfsii* Plate 32: T. *harzianum* and *S. rolfsii*	
33	Antagonistic effect of commercial isolate of *Pseudomonas fluorescens* (Vermigreen Pf) against *P. aphanidermatum* in dual culture tests	
34	Antagonistic effect of commercial isolate of *P. fluorescens* (Sun Agro Monus Pf) against *P. aphanidermatum* in dual culture tests	
35	Antagonistic effect of commercial isolate of *P. fluorescens* (Vermigreen Pf) against *M. phaseolina* in dual culture tests	
36	Antagonistic effect of commercial isolate of *P. fluorescens* (Sun Agro Monus Pf) against *M. phaseolina* in dual culture tests	
37	Antagonistic effect of commercial isolate of *P. fluorescens* (Vermigreen Pf) against *Sclerotium rolfsii* in dual culture tests	
38	Antagonistic effect of commercial isolate of *P. fluorescens* (Sun Agro Monus Pf) against *S. rolfsii* in dual culture tests	
39	Sensitivity of native and commercial isolates of *Trichoderma* spp. against copper oxychloride (COC) at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique	
40	Sensitivity of native and commercial isolates of *Trichoderma* spp. against mancozeb at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique	

41 Sensitivity of native and commercial isolates of *Trichoderma* spp. against carbendazim at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

Plate number	Title	Page number

42 Sensitivity of native and commercial isolates of *Trichoderma* spp. against hexaconazole at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

43 Sensitivity of native and commercial isolates of *Trichoderma* spp. against imidacloprid at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

44 Sensitivity of native and commercial isolates of *Trichoderma* spp. against chlorpyriphos at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

45 Sensitivity of native and commercial isolates of *Trichoderma* spp. against carbosulfan at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

46 Sensitivity of native commercial isolates of *Trichoderma*spp against calcium ammonium nitrate (CAN) at 100, 500, and 2000 ppm concentrations Poisoned food technique.

47 Sensitivity of native and commercial isolates of *Trichoderma* spp. against calcium ammonium nitrate (CAN) at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

48 Sensitivity of native and commercial isolates of *Trichoderma* spp. against diammonium phosphate (DAP) at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

49 Sensitivity of native and commercial isolates of *Trichoderma* spp. against single superphosphate (SSP) at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

50 Sensitivity of native and commercial isolates of *Trichoderma* spp. against muriate of potash (MOP) at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique

Plate number	Title	Page number
51	Sensitivity of native and commercial isolates of *Trichoderma* spp. against pendimethalin at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique	
52	Sensitivity of native and commercial isolates of *Trichoderma* spp. against fluchloralin at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique	
53-55	Effect of copper oxychloride on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique Plate 53: *P. aphanidermatum* Plate 54: *M. phaseolina* Plate 55: *S. rolfsii*	
56-58	Effect of mancozeb on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique Plate 56: *P. aphanidermatum* Plate 57: *M. phaseolina* Plate 58: *S. rolfsii*	
59-61	Effect of carbendazim on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique Plate 59: *P. aphanidermatum* Plate 60: *M. phaseolina* Plate 61: *S. rolfsii*	
62-64	Effect of hexaconazole on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique Plate 62: *P. aphanidermatum* Plate 63: *M. phaseolina* Plate 64: *S. rolfsii*	
65-67	Effect o0f thiomethaxam on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique.	

Plate 65: *P. aphanidermatum*

Plate 66: *M. phaseolina*

Plate 67: *S. rolfsii*

Plate number	Title	Page number
68-70	Effect of chlorpyriphos on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique	
	Plate 68: *P. aphanidermatum*	
	Plate 69: *M. phaseolina*	
	Plate 70: *S. rolfsii*	
71-73	Effect of imidacloprid on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique	
	Plate 71: *P. aphanidermatum*	
	Plate 72: *M. phaseolina*	
	Plate 73: *S. rolfsii*	
74-76	Effect of carbosulfan on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations in poisoned food technique	
	Plate 74: *P. aphanidermatum*	
	Plate 75: *M. phaseolina*	
	Plate 76: *S. rolfsii*	
77-79	Effect of calcium ammonium nitrate on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 77: *P. aphanidermatum*	
	Plate 78: *M. phaseolina*	
	Plate 79: *S. rolfsii*	
80-82	Effect of diammonium phosphate on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 80: *P. aphanidermatum*	
	Plate 81: *M. phaseolina*	
	Plate 82: *S. rolfsii*	
83-85	Effect of single superphosphate (SSP) on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm	

	concentrations	
	Plate 83: *P. aphanidermatum*	
	Plate 84: *M. phaseolina*	
	Plate 85: *S. rolfsii*	
86-88	Effect of muriate of potash (MOP) on radial growth of test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 86: *P. aphanidermatum*	
	Plate 87: *M. phaseolina*	
	Plate 88: *S. rolfsii*	
89-91	Effect of pendimethalin on radial growth of test pathogens in poisoned food technique at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 89: *P. aphanidermatum*	
	Plate 90: *M. phaseolina*	
	Plate 91: *S. rolfsii*	
92-94	Effect of fluchloralin on radial growth of test pathogens in poisoned food technique at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 92: *P. aphanidermatum*	
	Plate 93: *M. phaseolina*	
	Plate 94: *S. rolfsii*	
95-97	Combined effect of native and commercial isolates of *Trichoderma* spp and copper oxychloride against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 95: *P. aphanidermatum*	
	Plate 96: *M. phaseolina*	
	Plate 97: *S. rolfsii*	
98-100	Combined effect of native and commercial isolates of *Trichoderma* spp and mancozeb against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 98: *P. aphanidermatum*	
	Plate 99: *M. phaseolina*	
	Plate 100: *S. rolfsii*	
101-103	Combined effect of native and commercial isolates of	

	Trichoderma spp and chlorpyriphos against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 101: *P. aphanidermatum*	
	Plate 102: *M. phaseolina*	
	Plate 103: *S. rolfsii*	
Plate number	Title	Page number
104-106	Combined effect of native and commercial isolates of *Trichoderma* spp and imidacloprid against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 104: *P. aphanidermatum*	
	Plate 105: *M. phaseolina*	
	Plate 106: *S. rolfsii*	
107-109	Combined effect of native and commercial isolates of *Trichoderma* spp and carbosulfan against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 107: *P. aphanidermatum*	
	Plate 108: *M. phaseolina*	
	Plate 109: *S. rolfsii*	
110-112	Combined effect of native and commercial isolates of *Trichoderma* spp and calcium ammonium nitrate (CAN) against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 110: *P. aphanidermatum*	
	Plate 111: *M. phaseolina*	
	Plate 112: *S. rolfsii*	
113-115	Combined effect of native and commercial isolates of *Trichoderma* spp and diammonium phosphate (DAP) against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 113: *P. aphanidermatum*	
	Plate 114: *M. phaseolina*	
	Plate 115: *S. rolfsii*	
116-118	Combined effect of native and commercial isolates of *Trichoderma* spp and single superphosphate (SSP) against three test pathogens at 100, 500, 1000 and 2000 ppm	

	concentrations	
	Plate 116: *P. aphanidermatum*	
	Plate 117: *M. phaseolina*	
	Plate 118: *S. rolfsii*	
119-121	Combined effect of native and commercial isolates of *Trichoderma* spp and muriate of potash (MOP) against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 119: *P. aphanidermatum*	
	Plate 120: *M. phaseolina*	
	Plate 121: *S. rolfsii*	
122-124	Combined effect of native and commercial isolates of *Trichoderma* spp and pendimethalin against three test pathogens at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 122: *P. aphanidermatum*	
	Plate 123: *M. phaseolina*	
	Plate 124: *S. rolfsii*	
125-128	Combined effect of commercial isolate of *P. fluorescens* (Sun Agro Monus Pf) and test fungicides against *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 125: Copper oxychloride (COC)	
	Plate 126: Mancozeb	
	Plate 127: Carbendazim	
	Plate 128: Hexaconazole	
129-132	Combined effect of commercial isolate of *P. fluorescens* (Vermigreen Pf) and test fungicides against *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 129: Copper oxychloride (COC)	
	Plate 130: Mancozeb	
	Plate 131: Carbendazim	

Plate 132: Hexaconazole

Plate number	Title	Page number
133-135	Combined effect of commercial isolate of *P. fluorescens* (Sun Agro Monus Pf) and test insecticides against *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 133: Imidacloprid	
	Plate 134: Chlorpyriphos	
	Plate 135: Carbosulfan	
136-138	Combined effect of commercial isolate of (Vermigreen Pf) and test insecticides against *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 136: Imidacloprid	
	Plate 137: Chlorpyriphos	
	Plate 138: Carbosulfan	
139-142	Combined effect of commercial isolate of *P. fluorescens* (Sun Agro Monus Pf) and test fertilizers against *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 139: Calcium ammonium nitrate (CAN)	
	Plate 140: Diammonium phosphate (DAP)	
	Plate 141: Single superphosphate (SSP)	
	Plate 142: Muriate of potash (MOP)	
143-146	Combined effect of commercial isolate of *P. fluorescens* (Vermigreen Pf) and test fertilizers against *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 143: Calcium ammonium nitrate (CAN)	
	Plate 144: Diammonium phosphate (DAP)	

Plate 145: Single superphosphate (SSP)

Plate 146: Muriate of potash (MOP)

Plate number	Title	Page number
147-148	Combined effect of commercial isolate of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) and test herbicides against *P. aphanidermatum, M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations	
	Plate 147: Pendimethalin	
	Plate 148: Fluchloralin	
149-150	Mass multiplication of *Trichoderma* spp. on sorghum seeds	
151	Mass multiplication of test pathogens viz, *P. aphanidermatum, M. phaseolina* and *S. rolfsii* on sorghum seeds	
152-154	Combined effect of potential biocontrol agents and agrochemicals on test tomato (cv. Pusa Ruby) crop in pot culture experiments under glasshouse conditions	
	Plate 152: *P. aphanidermatum*	
	Plate 153: *M. phaseolina*	
	Plate 154: *S. rolfsii*	
155-157	Combined effect of potential biocontrol agents and agrochemicals on test pathogens on brinjal (cv. Shyamala) crop in pot culture experiments under glasshouse conditions	
	Plate 155: *P. aphanidermatum*	
	Plate 156: *M. phaseolina*	
	Plate 157: *S. rolfsii*	
158-160	Combined effect of potential biocontrol agents and agrochemicals on test pathogens on test crop bhendi (cv. Parbhani Kranthi) in pot culture experiments under glasshouse conditions	
	Plate 158: *P. aphanidermatum*	

Plate 159: *M. phaseolina*

Plate 160: *S. rolfsii*

LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Percentage
@	:	At the rate of
a.i.	:	Active ingredient
a.m.u.	:	Atomic mass units
CD at 5%	:	Critical difference at 5% level of significance
cfu/g	:	Colony forming units per gram of soil
cm	:	Centimetre
CMI	:	Common Wealth Institute
cv	:	Cultivar
sec	:	Seconds
dia	:	diameter
EC	:	Emulsifiable concentration
et al.	:	co-workers
g	:	gram (s)
h	:	hour (s)
ha	:	Hectare (s)
i.e.,	:	that is
kg	:	kilogram
ml	:	millilitre
mm	:	millimetre
MW	:	molecular weight
No	:	Number
PDA	:	Potato dextrose agar
PDI	:	Per cent disease incidence
pH	:	Power of hydrogen in concentration
ppm	:	Parts per million
SEm	:	Standard error of mean
SL	:	Soluble liquid
SP (or) SPP	:	Species (singular or plural)
viz.,	:	namely
WP	:	Wettable powder
WS	:	Water soluble

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ABSTRACT

A detailed study on compatibility of both native and commercial formulations of biocontrol agents such as *Trichoderma viride, T. harzianum* and *Pseudomonas fluorescens* with commonly used agrochemicals which included certain fungicides (copper oxychloride, mancozeb, carbendazim and hexaconazole), insecticides (thiomethoxam, imidacloprid, chlorpyriphos and carbosulfan), fertilizers (calcium ammonium nitrate, diammonium phosphate, single superphosphate and muriate of potash) and herbicides (pendimethalin and fluchloralin)was carried out during the present investigation with three soil-borne plant pathogens viz., *Pythium aphanidermatum, Macrophomina phaseolina* and *Sclerotium rolfsii*.

The pathogens were isolated from infected host plants, purified and identified as *P.aphanidermatum, M.phaseolina* and *S.rolfsii* and pathogenicity was proved by soil inoculation method.

In vitro studies have established the superiority of commercial isolate of *T. viride* (NCC-58 Tv) as potential bioagent over other native and commercial formulations of *T. viride, T. harzianum* and *P. fluorescens* against *P. aphanidermatum*. While, maximum inhibition of growth of *M. phaseolina* was recorded with commercial isolate of *T. viride* (BCL Tv). Whereas, commercial isolate of *T. harzianum* (NCC-57 Th) significantly arrested the radial growth of *S. rolfsii*. However, all the isolates of *Trichoderma* spp. significantly inhibited the growth of test pathogens compared to the two commercial isolates of *P. fluorescens*.

Out of two systemic and two non-systemic fungicides tested *in vitro* for compatibility with bioagents, copper oxychloride (COC) and mancozeb at 100 ppm were found to be compatible with commercial and native isolates of *T. viride* and *T. harzianum*. While, carbendazim and hexaconazole were highly incompatible with all bioagents at all the concentrations tested. Whereas, the bacterial antagonistic

isolates of *P. fluorescens* were compatible with all the fungicides tested at 100 ppm concentration and incompatible at higher concentrations of the fungicides.

Among the insecticides, imidacloprid was highly compatible with all the commercial and native isolates of *Trichoderma* spp. at all test concentrations. While, these isolates were incompatible with the insecticides, chlorpyriphos and carbosulfan even at lower concentrations. Sensitivity of the two isolates of *P. fluorescens* against three insecticides was tested under *in vitro* conditions. Of these, chlorpyriphos found to be highly toxic to both the bacterial antagonists tested at higher concentrations. Carbosulfan and imidacloprid was found to be relatively less toxic to the commercial isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) even at higher concentrations.

All the fertilizers (calcium ammonium nitrate, diammonium phosphate, single superphosphate and muriate of potash) tested were found compatible with all the isolates of *Trichoderma* spp. and *P. fluorescens* at all the test concentrations.

Pendimethalin and fluchloralin were inhibitory to the growth of all the fungal antagonists tested. However, these herbicides were highly inhibitory at higher concentrations than at lower concentrations. Whereas, the commercial isolate of *P. fluorescens*(Sun Agro Monus Pf) showed tolerance to the test herbicides at 100 and 500 ppm concentrations. Of the two herbicides, fluchloralin was found superior in inhibiting the growth of the antagonistic isolates.

Complete inhibition of growth of *P. aphanidermatum* was observed with COC at 500, 1000 and 2000 ppm concentrations and with mancozeb and hexaconazole at 1000 and 2000 ppm concentrations. Whereas, mancozeb, carbendazim and hexaconazole completely inhibited *M. phaseolina* at all the test concentrations. While, mancozeb and hexaconazole completely inhibited the growth of *S. rolfsii* at all the test concentrations.

Efficacy of four insecticides was tested *in vitro* against three test pathogens, of which chlorpyriphos was found to be superior in inhibiting the growth of *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* compared to other insecticides at all the concentrations tested. While, imidacloprid was ineffective against *M. phaseolina* and *S. rolfsii* at all the test concentrations. Whereas, thiomethoxam and carbosulfan were found highly effective in inhibiting the growth of *M. phaseolina* at all the test concentrations.

Of the four fertilizers tested, calcium ammonium nitrate was found to be effective against *S. rolfsii*. However, no inhibition of the growth of the test pathogens was observed with all the fertilizers at all the test concentrations.

The growth of the test pathogens was completely inhibited at 1000 and 2000 ppm concentrations by pendimethalin and fluchloralin. Of the two, fluchloralin was highly effective in inhibiting the growth of the test pathogens at all the test concentrations.

All the compatible combinations of agrochemicals (fungicides, insecticides fertilizers and herbicides) with potential fungal antagonistic isolates reduced the radial growth of the test pathogens at lower concentrations to at higher concentrations. Of the eight fungal antagonistic isolates tested, native isolate of *T. harzianum* (DOR 2 Th) found superior than other isolates in inhibiting the growth of *P. aphanidermatum* in COC and mancozeb amended medium at 100 ppm

concentration. While, the commercial isolates of *T. harzianum* (Sun Agro Derma Th) and *T. viride* (Sun Agro Derma Tv) were highly inhibitory to *M. phaseolina* in COC and mancozeb amended medium respectively. Whereas, commercial isolate of *T. harzianum* (NCC-57 Th) was found superior in inhibiting the growth of *S. rolfsii* in COC amended medium. While, native isolate of *T. viride* (DOR 1 Tv) found superior than other isolates in inhibiting the growth of *S. rolfsii* in mancozeb amended medium.

In association with imidachloprid and chlorpyriphos (100 ppm), the commercial isolate of *T. harzianum* (Vermigreen Th) performed better in inhibiting the growth of *P. aphanidermatum*. While, the commercial isolate of *T. viride* (BCL Tv) found superior in inhibiting the growth of *P. aphanidermatum* in carbosulfan amended medium. Maximum inhibition of *M. phaseolina* was recorded with the commercial isolate of *T. viride* (NCC-58 Tv) in imidacloprid amended medium. In chlorpyriphos and carbosulfan amended medium the commercial isolate of *T. harzianum* (Vermigreen Th) was more effective in inhibiting the radial growth of *M. phaseolina* at 100 ppm. While, maximum growth reduction of *S. rolfsii* was recorded in chlorpyriphos amended medium with native and commercial isolates of *T. viride* (DOR 1 Tv and NCC-58 Tv) at 100 ppm concentration. In association with carbosulfan (100 ppm), the commercial isolate of *T. harzianum* (Sun Agro Derma Th) was most effective in inhibiting the growth of *S. rolfsii* compared to other isolates.

In contrast to the other agrochemicals combination with the biocontrol agents, the synergistic effect of the combination of fungal biocontrol agents with the fertilizers increased with the increase in concentrations against all the test pathogens. Fertilizer amended media inhibited the growth of all the three pathogens differently in the presence of different *Trichoderma* isolates. Highest inhibition of *P. aphanidermatum* was observed in CAN amended medium at 2000 ppm with *T. viride* (Sun Agro Derma Tv) and in DAP and SSP amended medium (2000 ppm) with *T. harzianum* (NCC-57 Th) and in MOP amended medium (2000 ppm) with *T. viride* (DOR 1 Tv). Nextly, *M. phaseolina* was inhibited in CAN, DAP and SSP amended media at all the concentrations with *T. viride* (DOR 1 Tv). But in MOP amended medium *T. viride* (NCC-58 Tv) was the best in inhibiting *M. phaseolina*. Whereas, *S. rolfsii* was inhibited to the maximum extent in CAN and DAP amended media with *T. viride* (Sun Agro Derma Tv). But in SSP and MOP amended medium at 2000 ppm it was *T. harzianum* (DOR 2 Th) which inhibited *S. rolfsi* to the maximum extent.

The combined effect of herbicides and antagonistic fungal isolates was studied at various concentrations against the test pathogens. The commercial and native isolates of *T. viride* (BCL Tv and DOR 1 Tv) was found to be superior in inhibiting the radial growth of *P. aphanidermatum* in pendimethalin and fluchloralin amended medium in respect of at 100 ppm concentration. Whereas, commercial isolates of *T. harzianum* (Sun Agro Derma Th) and *T. viride* (BCL Tv)were inhibitory to *M. phaseolina* in pendimethalin and fluchloralin amended medium respectively at 100 ppm concentration. While, the commercial isolates of *T. viride* (NCC-58 Tv and BCL Tv) were found to be superior in inhibiting the radial growth of *S. rolfsii* in pendimethalin and fluchloralin amended media at 100 ppm concentration.

The combined effect of two bacterial biocontrol isolates (Sun Agro Monus Pf and Vermigreen Pf) with various agrochemicals like fungicides, insecticides, fertilizers and herbicides was studied at 100, 500, 1000 and 2000 ppm concentrations against *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii*. The synergistic effect of the chemicals and the bacterial biocontrol agents was observed at 100 ppm concentration. With increase in the concentration of the chemicals, the synergistic effect of the chemicals and biocontrol agents was not observed. However, at higher concentrations (500, 1000 and 2000 ppm), the radial growth of the pathogens was inihibited only by the chemicals but not by the bacterial biocontrol agents. In contrast, at higher concentrations of the fertilizers, the three test pathogens overgrew the bacterial biocontrol agents.

Out of 13 treatment combinations, maximum disease reduction (per cent mortality) was achieved by integrated use of seed treatment with the native isolate of *T. harzianum* (DOR 2 Th) plus soil drenching with COC (100 ppm) in tomato, brinjal and bhendi cultivars in respect of *P. aphanidermatum*. This treatment not only reduced the seedling mortality, but also promoted highest population stand, root and shoot lengths and dry weight of seedlings of tomato (cv. Pusa Ruby), brinjal (cv. Shyamala) and bhendi (cv. Parbhani Kranthi).

Among all the treatments, a combination of seed treatment with *T .harzianum* (Sun Agro Derma Th) and soil drenching with COC (100 ppm) was found to be best in reducing seedling mortality caused by *M. phaseolina*. This treatment not only reduced the disease, but also increased the growth parameters of the seedlings of tomato, brinjal and bhendi. Least seedling mortality caused by *S. rolfsii* was recorded with seed treatment by *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb (100 ppm) in all the test crops. While, combination of biocontrol agents with fertilizers (CAN and DAP) and insecticide (imidacloprid) recorded highest seed germination, root and shoot lengths and dry weight of seedlings of tomato, brinjal and bhendi crops. Whereas minimum seed germination was recorded in the treatments involving the herbicides (pendimethalin and fluchloralin).

CHAPTER – I

INTRODUCTION

In the present day agriculture, Integrated Pest Management (IPM) and Integrated Nutrient Management (INM) concepts are gaining importance with an ultimate aim of total crop care through the use of various inputs. Integrated plant disease management (IPDM) is an approach that attempts to make complementary use of cultural, chemical, biological and also other methods of disease management for achieving best possible results. One of the important components of IPDM is use of antagonistic microorganisms, which include several species of *Trichoderma* and fluorescent pseudomonads. It is needless to point out that biocontrol agents play a key role in this approach and hence getting popularized.

Biological control of soil borne plant pathogens by species of *Trichoderma* is a vital area of plant pathological research all over the world these days (Mukhopadyay, 1987). Most of the soil borne diseases are not amenable for management through chemicals. The need for devising cultural and biological control is obvious and a distinct possibility in the framework of IPDM.

Use of several antagonistic species of *Trichoderma* (*T. viride, T. harzianum* and *T. virens*) against a range of economically important soil borne plant pathogens has been well documented (Cook and Baker, 1983; Chet, 1987; Mukhopadhyay, 1987; Hornby, 1990; Raghuchander *et al*., 1997; Anitha and Tripathi, 2000; Mukerjee *et al*., 2001; Pamak *et al*., 2001; Patibanda *et al*., 2002; Pranab Dutta and Das, 2002; Rettinassababady *et al*., 2002; Champawat and Sharma, 2003; Gaikwad and Nimbalkar, 2003; Gnanavel and Jeyarajan, 2003;

Gopalakrishnan *et al*., 2003). Heterotrophic rhizobacteria of *Pseudomonas fluorescens* types have been successfully used for biological control of several plant pathogens (Howell Stipanovic, 1979; Weller and Cook, 1983; Vidyashekharan and Muthamilan, 1995; Ganeshan and Gnanamanickam, 1997; Robert Karkins and Deborah Frahel, 1998; Jayasree *et al*., 2000; Chatterson, 2002; Khan *et al*., 2003; Chatterson *et al*., 2004).

Search for effective biocontrol agents for the management of plant diseases has been intensified in recent years to reduce the dependence on ecologically hazardous chemicals. Biocontrol agents must be effective and compatible with latest crop production practices so that they can be integrated into the production system. In such an approach biocontrol agents have to be used with other agrochemicals such as fungicides, insecticides, fertilizers and weedicides without any toxic effect on antagonists. Use of some strains of *Trichoderma harzianum* and *T. viride* tolerant to fungicides have been reported for integrated control of plant diseases (Henis *et al*., 1978; Papavizas and Lewis, 1981; Papavizas *et al*., 1982; Mukhopadyay, 1986; Sawant and Mukhopadyay, 1990; Mahadevamurthy *et al*., 1990; Chattopadyay and Bineeta Sen, 1996; Muthamilan and Jeyarajan, 1996; Jayaraj and Ramabhadran, 1998; Uma Singh *et al*., 1998; Anitha *et al*., 2000; Ramarethinam *et al*., 2001; Mukerjee *et al*., 2001; Dharam Singh *et al*., 2001; Deepa *et al*., 2002; Suriachandraselvan, 2002; Rama Yalla Reddy *et al*., 2002; Prasanna *et al*., 2002; Manisha Tripathi *et al*., 2002; Prathibha Sharma *et al*., 2004). The inhibitory effects of insecticides, weedicides and fertilizers to various *Trichoderma* spp. in general has not been studied widely.

Soil application of manures and fertilizers is a basic necessity for sustained crop growth and yield. Biocontrol agents especially various species of

Trichoderma are known to utilize a wide variety of carbon and nitrogen sources for their growth and activity in soil.

The activity of the biocontrol agents is highly influenced by several factors. In the present day agriculture, the usage of herbicides has become an indispensable component. Application of herbicides generally disturbs and alters the biological equilibrium in soil. The effect of herbicides on the growth and activity of the antagonistic fungi and bacteria has not been clearly studied yet.

In recent years, the search of biological control agents for the management of dreaded soil borne diseases has been advocated widely. Since, the biocontrol agents are applied either to seed or soil or both, there is every possibility of interaction and interference that would arise with the commonly used agrochemicals applied to seed, soil or both. The full expression of potential biocontrol is considered in terms of rhizosphere competence, suppression of pathogens, tolerance to pesticides, competitive saprophytic ability, adaptability to environment etc. Combined application of biocontrol agents with commonly used agrochemicals may result either in synergism / antagonism between the two.

Though few studies about the sensitivity of biocontrol agents with certain fungicides and insecticides are available, studies / reports with special reference to commercially available biocontrol agents of *Trichoderma* and *Pseudomonads* are meagre. Compatibility of living organisms with modern inputs in plant protection like fungicides, insecticides and weedicides is a pre-requisite for developing integrated disease management strategies. Hence, the present investigation was undertaken to study the compatibility of biocontrol agents with commonly used agrochemicals with the following objectives.

1. To test the efficacy of commercial formulations of biocontrol agents against soil-borne plant pathogens viz., *Pythium aphanidermatum* (Edson) Fitz, *Rhizoctonia solani* Khun, *Sclerotium rolfsii* Sacc *in vitro*.
2. To test the sensitivity of biocontrol agents against commonly used agrochemicals like fungicides, insecticides, herbicides, fertilizers *in vitro*.
3. To test the efficacy of agrochemicals against the soil-borne test pathogens.
4. To test the synergistic effect of biocontrol agents and agrochemicals on the soil borne test pathogens *in vitro*.
5. To test the combined effect of biocontrol agents and agrochemicals on the soil borne test pathogens *in vivo*.

CHAPTER II

REVIEW OF LITERATURE

The literature pertaining to the use of various antagonistic fungi and bacteria for the control of soil borne plant pathogens viz., *Pythium aphanidermatum, Macrophomina phaseolina*, *Sclerotium rolfsii* with special reference to *in vitro* and *in vivo* efficacy of these antagonists, their sensitivity against various agrochemicals and the combined effect of biocontrol agents with agrochemicals on the management of diseases caused by the test pathogens is reviewed in this chapter under the following headings.

2.1 *In vitro* efficacy of biocontrol agents against *P. aphanidermatum*

2.2 *In vivo* efficacy of biocontrol agents against *P. aphanidermatum*

2.3 *In vitro* efficacy of biocontrol agents against *M. phaseolina*

2.4 *In vivo* efficacy of biocontrol agents against *M. phaseolina*

2.5 *In vitro* efficacy of biocontrol agents against *S. rolfsii*

2.6 *In vivo* efficacy of biocontrol agents against *S. rolfsii*

2.7 Sensitivity of biocontrol agents against agrochemicals

2.7.1 Fungicides

2.7.2 Insecticides

2.7.3 Fertilizers

2.7.4 Herbicides

2.8 Efficacy of agrochemicals against *P. aphanidermatum*

2.8.1 Fungicides

2.8.2 Insecticides

2.8.3 Fertilizers

2.8.4 Herbicides

2.9 Efficacy of agrochemicals against *M. phaseolina*

2.9.1 Fungicides

2.9.2 Insecticides

2.9.3 Fertilizers

2.9.4 Herbicides

2.10 Effect of agrochemicals against *S. rolfsii*

2.10.1 Fungicides

2.10.2 Insecticides

2.10.3 Fertilizers

2.10.4 Herbicides

2.11 Synergistic/antagonistic effect of biocontrol agents and agro chemicals against test pathogens *in vitro*

2.12 Combined effect of biocontrol agents with agrochemicals against test pathogens *in vivo*

2.12.1 *P. aphanidermatum*

2.12.2 *M. phaseolina*

2.12.3 *S. rolfsii*

2.1 *IN VITRO* EFFICACY OF BIOCONTROL AGENTS AGAINST *P. APHANIDERMATUM*

Bell *et al*. (1982) while studying the *in vitro* antagonism of *Trichoderma harzianum* against six fungal plant pathogens namely *viz., Sclerotium rolfsii, Certatobasidium cornigerum, Phytophthora parasitica* f. sp. *nicotianae, Pythium aphanidermatum, P. myriotylum* and *R. solani* observed that a single isolate of *Trichoderma* can be highly effective against an isolate of a pathogen species but may have only minimal effects on other isolates of the same species.

Trichoderma, a biocontrol agent of several soil borne plant pathogens was shown to actively invade the *R. solani* and *Pythium* spp. (Chet *et al*., 1981) and to produce the lytic extra cellular enzymes chitinase and β-1,3 glucanase *in vitro* (Elad *et al*., 1982a).

Lifshitz *et al*. (1984 b) reported a newly described mycoparasitic species of *Pythium* induced early lysis of germinating sporangia of plant pathogenic *Pythium* spp. *in vitro* and which also suppressed its capacity to induce damping-off of cucumber Lifshitz *et al*. (1984a).

Mukerjee *et al*. (1989) reported various mechanisms of biocontrol agent *T. harzianum* in suppressing the growth of *P. aphanidermatum* which include coiling of hypha, formation of septa and lysis of hyphae.

T. harzianum is a destructive mycoparasite on *P. aphanidermatum*. There are reported regarding coiling of *Trichoderma* around *Pythium* hyphae (Bell *et al*., 1982, Hadar *et al*., 1984; Fajola and Alasoudura, 1975). Formation of septa in *Pythium* hypha may be attributed to an attempt to prevent the draining out of the cell contents due to lysis (Mukhopadyay *et al*., 1986).

G. virens produced certain metabolites in culture filtrate which are pernicious to *P. aphanidermatum*. This provides a superfluous chemical weapon to *G. virens* to suppress the pathogen. Gliovirin is a diketopiperazine was isolated from the culture filtrate of *G.virens* (Howell and Stipanovic, 1983). Formation of septa in the host hyphae at a point away from zone of contact between the two fungi may probably be a defence mechanism (Mukhopadyay *et al*., 1986).

P. aphanidermatum colony was completely overgrown by *T. harzianum* within 4 days of contact. The mechanism of mycoparasitism was by close contact, coiling and penetration and disintegration of the protoplasm (Sawant and Mukhopadyay, 1990).

Vijay Krishna Kumar *et al*. (1997) evaluated that the efficacy of native isolates of biocontrol agents against *P. aphanidermatum* in dual culture reported that the per cent growth reduction of test fungus was maximum in case of studies with *Gliocladium virens* (75.00) followed by *T. harzianum* (native) (71.21), *T. harzianum* Alien (69.04) and *T. viride* (64.39).

Shanmugam and Verma (1998) reported that antagonistic properties of the isolated microorganisms against *P. aphanidermatum* incitant of ginger rhizome rot were determined by dual culture method. *A. niger* caused inhibition at distance and disintegration of pathogen while *A. fumigatus, A. flavus* and *T. viride* was found disintegration of pathogen. Of these, *T. viride* was found as an efficient antagonist of *P. aphanidermatum*.

Sanjay and Kaushik (2001) investigated *in vitro* efficacy of six species of *Trichoderma*, *Gliocladium virens* and *Chaetomium globosum* against the forest tree-nursery damping-off fungi, namely, *Fusarium oxysporum*, *Pythium*

aphanidermatum and *Rhizoctonia solani* maximum antagonistic activity against *F. oxysporum, P. aphanidermatum* and *R. solani* with 74.7, 75.8 and 75.2 per cent mycelial growth inhibitions respectively.

An isolate of *Streptomyces diaticus* (MM-196) suppressed the growth of *P. aphanidermatum* and reduced the post-emergence damping off in first crop of tomato and in the subsequent planting completely reduced both the pre as well as post-emergence damping off (Singh and Reddy, 1979).

Fluorescent Pseudomonads also have potential as biocontrol agents of *Pythium* and *Rhizoctonia* in cotton seedlings (Howell and Stipanovic, 1979 & 1980).

The bacterial biocontrol agent *Enterobacter cloacae* reduced *Pythium* induced rot of peas, beat and cucumber (Hadar *et al*., 1983). The bacteria were believed to attach to the hyphae through a lectin interaction (Nelson *et al*., 1984) and formed sheaths around hyphae of *P. ultimum*, resulting in lysis of the enclosed hyphae (Hadar *et al*., 1983).

Atleast 10 species or varieties of *Pythium* attack wheat roots in Washington (Charmswamy and Cook, 1985) and also were subject to control by *Pseudomonas* species (Weller and Graham, 1984).

Elad and Chet (1987) observed competition for nutrients between germinating oospores of *P. aphanidermatum* and bacterial isolates *Pseudomonas putida* and *P. cepacia* and correlated this with the suppression of *Pythium* damping off disease in tomato, cucumber, melon, bean and cotton plants.

The principle of bacterization of plant materials with rhizobacteria for the control of damping off of sugarbeet caused by *Pythium* spp. was explored by Homma (1991).

2.2 *IN VIVO* EFFICACY OF BIOCONTROL AGENTS AGAINST *P. APHANIDERMATUM*

Wright (1956) reported that seed treatment with spores of *T. viride, Penicillium nigricans, P. frequentans* and *P. goldiwski* controlled the disease symptoms caused by *Pythium* to some extent in case of white mustard.

In recent years, *Trichoderma* spp. have proved to be potential bio-agents for controlling several soil borne diseases under both greenhouse and field conditions (Elad *et al*., 1981; Cook and Baker, 1983; Papavizas, 1988; Mukerjee *et al*., 1989).

Howell and Stipanovic (1983) produced mutants of *Gliocladium virens* by UV radiation that differed from the wild type strain in their ability to produce the diketopiperazine antibiotic gliovirin. Which is highly toxic to *P. ultimum* causing damping off of cotton.

Sivan *et al*. (1984) reported that wheat bran plus peat mixture (1:1 v/v) was the most efficient of the raw plant material substrates for growing a new isolate of *Trichoderma harzianum* (T-135), the bran/peat preparation of *T. harzianum* applied to either soil or rooting mixture, effectively controlled damping off induced by *P. aphanidermatum* in peas, cucumbers, tomatoes, peppers and gypsophila. Disease reduction up to 85 per cent was obtained in tomatoes. *T. harzianum* applied in a seed coating mixture containing 5×10^9 conidia/ml was as effective in sandy soil as the broadcast application of wheat bran peat preparation.

Lifshitz *et al*. (1986) studied the mechanism of biocontrol of pre-emergence damping off pea by seed tratment with *Trichoderma* spp. and reported that T-95 and T-12 strains of *T. harzianum* and T-8 strain of *T. koningii* significantly

reduced the seedling damping off. Windham *et al*. (1986) observed an increased growth of tomato and tobacco seedlings over that of controls when the soil was amended with *T. harzianum* and *T. koningii* and attributed the growth enhancement to a direct effect of these *Trichoderma* spp. on the plant or a secondary effect due to control of minor plant pathogens.

Of all the eight antagonist isolates screened *in vitro* against *P.aphanidermatum* the incitant of cauliflower damping-off, Mukerjee and Upadhyay (1988) concluded that *T. harzianum*-2 showed potential antagonism against the pathogen. The wheat bran saw dust preparation of the antagonistic isolate (alive or dead) when added to soil, enhanced the growth of cauliflower seedlings.

Chang *et al*. (1986) observed an increase in dry weights of tomato, pepper and cucumber seedlings over control when *T. harzianum* was applied to soil at the rate of 10^5 conidia/g of soil.

Mukhopadyay *et al*. (1986) studied the antagonistic activities of an isolate of *T. harzianum* Rifai against tobacco isolate of *P. aphanidermatum in vitro*. *T. harzianum* directly attacked the hyphae of *P. aphanidermatum* causing lysis. Under glasshouse conditions, incorporation of inoculum of *T. harzianum* (prepared on wheat bran saw dust medium) in artificially infested soil significantly reduced damping-off.

The efficacy and consistency of *Gliocladium virens* in controlling damping-off disease on zinnia, cotton and cabbage caused by *P. ultimum* and *Rhizoctonia solani* in non sterile soil less mix was reported by Lumsden and Locke (1989).

Windham *et al*. (1986) reported that addition of *Trichoderma* spp. to autoclaved soil increased rate of emergence of tomato and tobacco seedlings over that of controls. Eight weeks after planting, root and shoot dry weights of tomato and tobacco were increased 213 to 275 and 259 to 318 per cent, respectively, over the controls.

Among the compounds evaluated for increasing the biological control activity, Nelson *et al*. (1988) reported that organic acids were most promotive to *T. koningii* whereas polysaccharides and polyhydroxy alcohols were most promotive to *T. harzianum* in controlling *Pythium* seed rot and pre-emergence damping-off of peas.

Sharif *et al*. (1988) used *T. harzianum*, *Penicillium sptipitatum* as bio-control agents and found that these antagonistic agents were equivalent to that of metalaxyl (Ridomil) in controlling *P. aphanidermatum* in cucumber.

Mukerjee *et al*. (1989) studied the mycoparasitism and bio-control potential of *T. harzianum* either alone or in conjunction with fungicidal seed treatment to control *Pythium* damping-off of cauliflower and reported that integration of fungicidal seed treatment with application of *T. harzianum* improved the degree of disease control than individual applications.

Krishnamoorthy and Bhaskaran (1990) conducted a pot culture experiment to find out the efficacy of antagonist in the control of damping-off disease of tomato caused by *P. indicum*. Soil inoculation with *T. viride* Pers, *T. harzianum* Rifai and *Laetisaria arvalis* gave good control of the pathogen and the treated pots recorded 78.2, 70.9 and 72.2 per cent seed germination, respectively, as

against 19.3 per cent in the control. Seed treatment with the above bio-agents was also found to be equally good and improved seedling vigour was noticed.

Sreenivasa Prasad and Manibhushan Rao (1990) evaluated the biocontrol potential of *G. virens* and *T. longibrachiatum* against tomato damping-off agent *P. aphanidermatum* and proved that soil application of the antagonists conferred greater protection than did seed dressing.

Wolfhechel and Funck Jensen (1992) while working on the biological control of damping-off and root rot of cucumber caused by *P. ultimum* studied the antagonistic activity of *G. virens* (G2) and *T. harzianum* (T3, T12B and T95) and proved that all strains were equally effective when applied as one of the wheat bran preparation, whereas the effectiveness of disease control was reduced at higher concentrations of antagonists.

Theradi *et al*. (1992) reported that the effect of decomposed coirpith, fungicides and biocontrol agents on damping off of chillies and dry root rot of blackgram. Among these decomposed coirpith was comparable with *T. hamatum* and *T. viride*-2 which recorded 16.3 and 11.5 per cent post emergence damping off in the treatments with antagonists than with fungicides and results obtained were comparable to soil drenching with fungicides like fenaminosulf (0.060 g a.i. litre^{-1}), copper oxychloride (1.125 g a.i. litre^{-1}) and seed treatment with captan or thiram (0.075 g a.i. litre^{-1}).

Ercole *et al*. (1993) carried out *in vivo* assays to determine the activity of *Trichoderma* isolates towards *Rhizoctonia solani* and *Pythium ultimum*; the causal agents of rot in tomato and capsicum seeds and reported that isolates producing ethylene and formic aldehyde in *in vitro* tests gave the best control of rot .

Devaki *et al*. (1992) reported that *T. harzianum* rendered *P. aphanidermatum* and *P. myriotylum* non-viable in petri dish dual culture. The *Pythium* mycelia from such cultures showed natural fluorescence in the regions of interactions, indicating their death. Non-volatile and volatile fungicidal activities were detected in *T. harzianum* culture. Lytic activity of β (1.3) glucanase was detected on the cell walls of the *Pythium* spp. There was a significant decrease in the disease incidence when *T. harzianum* was incorporated into sterile soil, whereas the effect was insignificant in natural soil.

Rajibkumar De and Mukhopadyay (1994) reported that *Gliocladium virens* strongly antagonized. *P. aphanidermatum*, incitant of tomato damping-off by seed coating and soil amendment with *G. virens* separately resulted on 128.94, 162.38 and 107.89, 108.92 per cent increase in seedling stand over check in pre and post-emergence phases, respectively in the nursery.

Mani and Marimuthu (1994) reported that the decomposed coirpith gave comparable results with *T. hamatum* and *T. viride* Strain 2 giving 16.3 and 11.5% post-emergence damping-off in *Capsicum annum* caused by *P. aphanidermatum* compared with 75% in untreated inoculated controls in a series of pot experiments. Decomoposed coirpith alone and in combination with *T. harzianum* Strain 2 gave the best survival of plants up to 60 days after sowing.

Mehta *et al*. (1995) reported the potential use of *T. harzianum* as bio-control agent against various members of soil borne plant pathogens such as *Fusarium udum, P. aphanidermatum, R. solani* and *S. rolfsii*.

Dinakaran and Ramakrishnan (1996) conducted studies on the control of tomato damping-off with *T. viride* and reported that seed treatment with *T. viride*

at 4 g kg^{-1} seed significantly reduced disease incidence of *P. indicum* and increased seedling emergence of tomato.

Sreeramulu *et al*. (1998) conducted an experiment on the efficiency of VA-mycorrhiza, *Glomus fasciculatum* and *T. harzianum* in damping-off and black shank disease of tobacco seedlings under nursery conditions in comparison with the recommended fungicides viz., copper oxychloride (blitox 50% WP) (0.2%) and metalaxyl (ridomil MZ-72 WP 0.2%). Results showed that the dual inoculation of *G. fasciculatum* and *T. harzianum* was more effective in controlling both the diseases than the individual inoculation, and resulted in better germination count and improved the plant growth parameters.

Manoranjitham *et al*. (1999) reported that the *T. viride* and *P. fluorescens* Migula effectively inhibited the growth of *P. aphanidermatum*. Seed treatment with talc based formulation of *T. viride* (4 g kg^{-1}) + *P. fluorescens* (5 g kg^{-1}) recorded the maximum germination (92.3%), shoot length (4.45 cm), root length (13.50 cm), dry matter production (6.77 mg) and vigour index (1655.67) compared to the minimum in control.

Beena and Sharma (2000) tested combined activity of five species of *Trichoderma* and five isolates of fluorescent Pseudomonads in various combinations on rhizome rot of ginger caused by *P. aphanidermatum*. The data obtained revealed that a reduced disease incidence of 0 to 35 per cent was obtained in all the treated plants when compared to 50 per cent in control.

Manoranjitham *et al*. (2000) reported that seed treatment with *T. viride* (4 g kg^{-1}) + *P. fluorescens* (5 g kg^{-1}) showed 7.00 and 12.50 per cent pre and post-emergence damping-off, respectively, against 27.50 and 54.75 per cent in

control. This treatment also increased the shoot length, root length and dry matter production of chilli seedlings and reduced the population of *P. aphanidermatum* from 16.75 x 10^2 cfu g^{-1} at the time of sowing to 13.41 x 10^2 cfu g^{-1} at 20 days after sowing compared to 17.50 x 10^2 cfu g^{-1} and 17.08 x 10^2 cfu g^{-1} in control.

Karthikeyan *et al*. (2000) reported that the biological control of *P. aphanidermatum* (Edson) Fitz, *Meloidogyne incognita* (Chitwood) disease complex in chilli (*Capsicum annum* L.) and brinjal (*Solanum melongena* L.) were evaluated in field. Among the biocontrol agents, *T. viride* recorded lower incidence of damping-off followed by *T. harzianum* and *P. lilacinus*. In *T. viride* treatment the per cent incidence of pre- and post-emergence damping off chilli was reduced to 1.89 and 16.26, whereas in brinjal it was reduced to 22.75 and 25.96 per cent respectively.

Manoranjitham *et al*. (2001) reported that the damping-off of tomato caused by *P. aphanidermatum* was reduced by the application of talc based formulation of *T. viride* and *Pseudomonas fluorescens* in nursery beds before sowing. Pre- and post-emergence damping-off of 5.50 and 7.50 per cent was registered by soil application of *T. viride* (2.5 g) + *P. fluorescens* (2.5 g) compared to 24.75 and 26.60 per cent in control. *P. fluorescens* (5 g) + *T. viride* (1.25 g) caused 67.60 and 64.15 per cent reduction in pre- and post-emergence damping-off, respectively, over control. The effect of *T. viride* (1.25 g) + *P. fluorescens* (2.5 g) in reducing the damping-off of tomato was at par with rest of the treatments.

Trichoderma harzianum and *T. viride* antagonistic to *Pythium aphanidermatum* produced cellulolytic enzymes (C1 and Cx) in fungicide amended medium and showed profound influence on the damping-off incidence, shoot, and

root length and dry matter production of tomato seedlings. Fytolan application along with antagonists reduced the damping-off (11.66%) and increased the root and shoot length considerably recording maximum of 3.10 and 8.10 cm in *T. harzianum* and 3.20 and 8.20 in *T. viride*. Next best was bavistin (13.00%) recording 5.90 and 2.50 cm of shoot and root in *T. harzianum* and 6.60 and 3.00 cm in *T. viride* (Karpagavalli *et al*., 2001).

Sanjay and Kaushik (2001) evaluated the efficacy of six species of *Trichoderma*, *Gliocladium virens* and *Chaetomium globosum* against the forest tree nursery damping-off fungi, viz., *Fusarium oxysporum, Pythium aphanidermatum* and *Rhizoctonia solani in vivo*. The highest seed germination (86.6%) and seedling survival (83.4%) were recorded in *A. nilotica* on treatment with *T. viride*, followed by *T. longibrachiatum. Dulbergia sisso* seeds on treatment with *T. viride* and *T. longibrachiatum* showed significantly higher seed germination and seedling survival compared to control.

Manoranjitham and Prakasam (2002) reported that in tomato the least pre-emergence damping-off (6.5%) and post-emergence damping-off (11.7%) were recorded in the treatment with *T. viride* (4 g kg^{-1}) + *P. fluorescens* (5 g kg^{-1}) in pot culture studies. In field trial, the maximum reduction of 73.07 per cent in pre-emergence damping-off and 69.10 per cent in post-emergence damping-off was recorded in the combined seed treatment with *T. viride* (4 g kg^{-1}) + *P. fluorescens* (5 g kg^{-1}). This treatment showed an increase in shoot length by 28.11% root length by 28.88% and dry matter production by 34.17% over control.

Neelamegam and Govindarajalu (2002) conducted experiments to control damping-off of tomato caused by *P. indicum* by using *Trichoderma viride*

alone (or) in combination with farmyard manure (FYM). Addition of FYM in *P. indicum* inoculated unsterilized soil resulted in low seed germination (41%) in comparison to sterilized soil (53%). However, the integrated application of *T. viride* and FYM still increased the seed germination in unsterilized soil to 100 per cent as against 84 per cent in sterilized soil.

Gnanavel and Jayaraj (2003) reported the control of damping-off of tomato caused by *Pythium aphanidermatum* by using *Trichoderma viride* alone or in combination with soil solarization. *T. viride* along with soil solarization effectively reduced the pre and post-emergence damping-off by 75.23 per cent and 88.34 per cent, respectively over control with concomitant increase in seedling vigour index (1182.0) and biomass of tomato (656 mg/m^2).

2.3 *IN VITRO* EFFICACY OF BIOCONTROL AGENTS AGAINST *M. PHASEOLINA*

Weindling (1932) reported that the culture of virulent fast growing strains of *Rhizoctonia* and *Armillaria mellea* pathogens were parasitised by *Trichoderma lignorum.*

Norton (1954) reported that *T. lignorum* and *T. terricola* were the only two fungi which invaded the charcoal rot fungus colony extensively among *A. flavus, A. rugulosus, A. terreus, Thielavia ferricola* and *Bacillus cereus.*

Gaffar (1968) reported that the fungal antagonist *T. viride* inhibited the growth of *M. phaseolina*, the root rot pathogen of cotton. The hyphae of *T. viride* were found to coil around hyphae of *M. phaseolina* and parasitise it.

Sarwar (1974) isolated and screened eight antagonistic fungi against *M. phaseolina*, the causal agent of root rot of castor and found that *Myrothecium* and *Trichoderma* spp. were found to be effective in inhibiting the test pathogen.

Paramjit Sing and Mehrotra (1980) isolated the antagonistic bacteria and actinomycetes from a loam soil and screened them against *R. bataticola* on PDA. Four bacterial isolates and six actinomycetes isolates were proved as effective antagonists to *R. bataticola in vitro*.

Punja and Grogan (1981) reported that the most frequently studied fungi in relation to biological control were the species of *Trichoderma*. Which were antagonistic to *M. phaseolina* because of rapid growth and ability to degrade sclerotia.

Association of fluorescent Pseudomonads with reduction in survival and activity of *M. phaseolina* has been reported by Arora *et al*. (1983). Biological control of *Rhizoctonia solani* and *Sclerotium rolfsii* causing stem rot of peanut was achieved through seed treatment with *P. fluorescens* (Ganeshan and Gnanamanickam, 1987). *Pseudomonas fluorescens* was shown to inhibit the growth of *M. phaseolina* (Ray *et al.*, 1990).

Elad *et al*. (1986) found that four isolates of *T. harzianum* inhibited linear growth and micro sclerotial production in *M. phaseolina in vitro*.

Parakhia and Vaishnav (1986) reported that the growth of *R. bataticola*, causal agent of root rot of chickpea was inhibited by *T. harzianum* in culture and the antagonist overgrew the pathogen.

The growth of *M. phaseolina* was significantly inhibited by *Bacillus subtilis* under *in vitro* conditions (Jharia and Khare, 1986).

Alagaraswamy and Sivaprakasam (1988) reported *in vitro* antagonistic activity of *Trichoderma* spp. against *M. phaseolina* infection in cowpea and observed that the antagonist inhibited the growth of test pathogen by 58.5 per cent.

Jacob (1989) reported that *B. subtilis* produced a wide inhibition zone of 5-6 mm against *M. phaseolina*.

Antagonistic effect of *T. harzianum* against *M. phaseolina* has been reported by Dubey and Dwivedi (1988). Ikotun and Adenkunle (1990) reported that *T. harzianum* was effective antagonist against the mycelia of *M. phaseolina* and prevented further growth *in vitro*.

Ramamoorthy and Muthusamy (1991) demonstrated that all antagonistic fungi viz., *Trichoderma harzianum, T. viride, T. reesi, T. hamatum* and *T. pseudokoningii* were tested effectively inhibited the mycelial growth of *R. bataticola* (*M. phaseolina*) and *Fusarium semitectum*. The biocontrol agents were as effective as seed treatment with mancozeb and carbendazim in controlling the seed borne pathogens of groundnut.

Bikkar Singh *et al*. (1991) reported the antagonistic ability of *T. viride*, isolated from the rhizosphere of healthy okra plants against *Macrophomina phaseolina*.

Angappan (1992) reported that the volatile substances from *T. viride, T. harzianum* and *T. longibrachiatum* inhibited the mycelial growth of *M. phaseolina.* *T. harzianum* and *T. viride* were also effective in inhibiting the mycelial growth, production and size of sclerotia of *M. phaseolina* (Sankar, 1994).

Ghisalboti and Sivasithapuram (1991) grouped the antifungal metabolites of *Trichoderma* into pentaketiles, terpenoids, octaketides and peptaibols. Bioefficacy of *T. harzianum* to *M. phaseolina* and its hyperparasitic nature were reported earlier by Papavizas (1988) and Ramesh Sunder *et al*. (1995).

Lazaretti *et al*. (1994) tested three strains of *B.* subtilis under *in vitro* conditions against *Alternaria tenuis, M. phaseolina, Septoria nodorum, S. rolfsii, F. solani, F. graminearum* and *Colletotrichum lindemuthianum* and found that the three strains inhibited the mycelial growth by more than 83 per cent in all the test pathogens.

Sanhez *et al*. (1994) demonstrated that a strain UPR 5C of *P. cepacia* strongly inhibited the mycelial growth of *M. phaseolina, S. rolfsii, R. solani, Pythium aphanidermatum* and to a lesser extent, *Fusarium solani,* the mechanism of biocontrol is both antibiosis and nutrient competition.

Mahabeer Singh (1995) studied the effects of *T. harzianum* and *T. viride* on cowpea stem and root rot fungus *M. phaseolina in vitro*. *T. harzianum* and *T. viride* both inhibited *M. phaseolina* growth on PDA, but *T. viride* caused greater inhibition.

Alice (1996) found that among eleven antagonists, *T. harzianum*-2, *T. viride*-native and *T. viride*-commercial formulation were effective against *M. phaseolina in vitro.*

Srivastava *et al*. (1996) recorded the potential sclerotial antagonists viz., *T. harzianum* isolate 25-92 and *Pseudomonas fluorescens* isolate 4-92 against *M. phaseolina* and observed that the antagonists significantly reduced the germination of sclerotia by 60 and 63 per cent respectively.

Majumdar *et al*. (1996) reported that both *T. harzianum* and *T. viride* inhibited the growth of the moth bean blight pathogen, *Macrophomina phaseolina*, *T. harzianum* caused more growth inhibition (51.5 mm inhibition zone) of *M. phaseolina* than *T. viride* (48.05 mm inhibition zone).

The antagonist *T. harzianum* induced the maximum inhibition zone (5.7 mm) and was significantly superior to other fungal antagonists against *M. phaseolina* (Selvarajan and Jeyarajan, 1996).

Rabindran and Vidhyasekaran (1996) reported that the isolates of *Pseudomonas fluorescens* viz., PfALR1, PfALR2, PfK1 and PfK2 were effective in restricting growth of *Rhizoctonia solani* under *in vitro* conditions.

Among nine mutants of *T. viride,* M1 showed the highest *in vitro* inhibition of mycelial growth (54.4%) and sclerotial germination (75.8%) of *M. phaseolina* followed by M3 mutant and they were on par with each other (Dinakaran and Marimuthu, 1997).

Calistru *et al*. (1997) observed the antagonistic nature of *Trichoderma* spp. against *Aspergillus flavus* and concluded that the activity was due to production of extracellular amylolytic, proteolytic and cellulolytic enzymes. Antibiosis is an activity expressed phenomenon of antagonism in biological control and biocontrol agents produce volatile and non-volatile compounds toxic to pathogen (Pandey and Upadyay, 1997). The growth of *M. phaseolina* was significantly inhibited by *T. harzianum* under *in vitro* conditions (Kajal Kumar and Chitraswaran, 2000).

Dubey (1998) investigated that the three fungal antagonists, *Trichoderma viride, T. harzianum* and *Gliocladium virens* significantly inhibited the

mycelial growth and sclerotial production of *Thanetophorus cucumeris (Rhizoctonia solani*). Among the three, *G. virens* was more effective. Complete mycelial inhibition and 92% inhibition of sclerotial formation were recorded in 4:1 ratio of *G. virens* and *T. cucumeris*.

Rajeswari *et al*. (1998) tested antagonistic nature of different isolates of *Trichoderma* and *Gliocladium* spp., viz., one native *T. harzianum* (H5), other exotic isolates of *T. harzianum* (H1, H2, H3, and H4), *T. viride* (V1, V2), *G. virens* (G1, G2), *T. koningii* (K), *T. pseudokoningii* (TPK), *T. longibrachiatum* (TL) and *T. hamatum* (T4) against the mungbean dry root rot pathogen *M. phaseolina* in dual culture technique. They reported maximum inhibition of pathogen growth with native isolate of *T. harzianum* (H5) (69.28%) followed by *T. viride* (V2) (64.94%), *G. virens* (G2) (64.84%) and least with *T. koningii* (K) (49.06%).

Kanakamahalaxmi *et al*. (1998) reported antagonistic activity of *T. viride*, *T. harzianum* and *G. virens* against castor root rot pathogen *M. phaseolina* by employing dual culture technique. Of the three antagonists studied *T. harzianum* was superior in suppressing growth of castor root rot fungus followed by *T viride* and *G. virens*.

The growth of *Rhizoctonia solani* was significantly inhibited by *P. fluorescens* under *in vitro* conditions (Laha and Verma, 1998).

Jayasree *et al*. (2000) obtained ten fluorescent pseudomonad strains were obtained from rhizospheres of blackgram (Pf1), carrot (Pf RA1), banana (Pf NA1), tapioca (Pf ATR1), pepper (Pf KO2), rice (Pf BS1), and forest trees (Pf NL1) and studied their efficacy against *M. Phaseolina* under *in vitro* conditions. All the strains were identified as *P. fluorescens*. Among these strains, Pf1 was found to be

more effective in inhibiting the mycelial growth of *M. phaseolina* of blackgram (82.6 mm) and sesame (84.5 mm).

Bunker *et al*. (2001) isolated five isolates of biocontrol agent *Trichoderma* spp. from rhizosphere and evaluated *in vitro* against *R. solani*. *T. harzianum* was the most effective in causing significant suppression of both growth and sclerotial formation of *R. solani*. It caused above 60 per cent inhibition of growth and sclerotial formation after 7 days of incubation followed by *T. viride* (ITCC-1433) which caused about 50 per cent inhibition of growth after 3 days of incubation, but about 60 per cent inhibition of growth and above 50 per cent of sclerotial formation after 7 days. On further incubation upto 12 days it caused 6 per cent inhibition of sclerotial formation.

Hazarika and Das (1998) studied the potential of Assam and Tamil Nadu isolates of *Trichoderma harzianum, T. viride* and *T. virens* against *Rhizoctonia solani* the French bean root rot pathogen under *in vitro* conditions. Assam isolates of *T. harzianum* (78.4 per cent) and *T. viride* (75.8 per cent) were found to be more effective than isolates from Tamil nadu in inhibiting mycelial growth of *R. solani* in dual culture.

Dubey (2000) evaluated different biocontrol agents viz., *Trichoderma viride, T. harzianum* and *G. virens* evaluated against *Rhizoctonia solani in vitro* by dual culture technique. *Gliocladium virens* was most effective, which inhibited maximum mycelial growth (59.8%) and sclerotial production (70.0%) followed by *T. viride*.

Biswas and Sen (2000a) reported that all the eleven isolates of *Trichoderma harzianum* showed the antagonistic ability against *M. phaseolina*, the

incitant of stem and root rot of jute. Among the eleven isolates, T2, T6, T8 and T10 completely overgrew the pathogen within two days after contact and closely followed by T4, T1, T3, T5 and T11 that elicited moderate antagonism, while least antagonism was observed with T7 and T9.

T. harzianum was the most effective in causing significant suppression of growth and sclerotial formation of *R. solani in vitro* through production of volatile and non-volatile antibiotics, followed by *Gliocladium virens* and *T. aureoviride* (Bunker and Kusum Mathur, 2001). *Trichoderma harzianum* suppressed the growth of *M. phaseolina* by over growth which showed its mycoparasitism (Patel and Anahosur, 2001).

The principal mechanism observed was coiling of antagonistic hyphae around the hyphae of pathogen and lysing. The mechanism of inhibition may be competition for food and space, production of antibiotics and mycoparasitism (Deepak Kumar and Dubey, 2001).

Indra and Thirubuvanamala (2002) tested antagonism on *Trichoderma* species and *Gliocladium virens* against *M. phaseolina* by dual culture method and found that the broader inhibition zone in *T. viride* and *T. harzianum* might be due to the production of fungistatic metabolites.

Indra *et al*. (2002) studied the efficacy of different antagonists on the growth of *M. phaseolina in vitro* in blackgram. The radial growth of the pathogen was effectively inhibited by *T. viride*, *T. harzianum* and *T. longibrachiatum* recording 39.17, 39.83 and 42.03 mm linear growth of mycelium respectively after 120 h of incubation. Similar results were obtained with the volatile metabolites of

T. viride, T. pseudokoningii, T. longibrachiatum, T. harzianum recording 51, 52, 53 and 53 mm diameter of the pathogen.

Padmalatha (2002) tested with the efficacy of biocontrol agents in dual culture technique. *T. harzianum* recorded maximum inhibition (82.9%) of *M. phaseolina* growth compared to *Gliocladium virens* (25%), *Bacillus subtilis* (57.9%) and *P. fluorescens* (53.4%).

The efficacy of exotic isolates of bioagents *viz., T. viride, T. harzianum, G. virens, P. fluorescens* (D) and *P. fluorecens* (T) was assessed against three test pathogens, *F.o*. f.sp. *ricini, M. phaseolina* and *S. rolfsii* by dual culture technique. The per cent growth reduction of the pathogen was maximum (45.33) with *T. viride* against *F.o*. f.sp. *ricini* and maximum per cent reduction (47.56, (46.89) with the *T. harzianum* and *T. viride* against *M. phaseolina* and *S. rolfsii* respectively (Humayun, 2002).

Gopalakrishnan *et al*. (2003) tested twelve *Trichoderma* isolates against damping-off of cotton caused by *Rhizoctonia solani*. The native cotton isolate *T. viride* exhibited the fastest growth rate and strong antagonism against *R. solani* recording 56.2 per cent inhibition in dual culture.

Durai (2004) evaluated eleven antagonistic mycoflora against *M. phaseolina* in *in vitro. Trichoderma* isolate-6 (T6) reduced mycelial growth by 74.70 per cent.

2.4 *IN VIVO* EFFICACY OF BIOCONTROL AGENTS AGAINST *M. PHASEOLINA*

Peanut seed coated with *B. subtilis* improved germination, plant growth, nodulation and plant nutrition (Turner and Backman, 1991).

Urd bean plant survival was increased in soil infested with *M. phaseolina* when seeds were treated with *B. subtilis* (Sridhar *et al*., 1991).

Bacterization of chickpea and soybean seeds with siderophore producing fluorescent Pseudomonads RBT B resulted in increased seed germination, growth and yield of the plants (Dileep Kumar and Dubey, 1992). Population of *P. fluorescens* was found to increase in the rhizosphere of rice and chickpea with reduced disease incidence (Muthamilan, 1994).

Application of *T. harzianum* to *M. phaseolina* in infested soil gave 85 per cent germination in blackgram against 67 per cent in control soil infested with *M. pahseolina* (Kousalya and Jeyarajan, 1988). Soil treatment with *T. harzianum* and *T. viride* reduced *M. phaseolina* in urd bean (Kousalya and Jeyarajan, 1991). Dry root rot in mung bean caused by *M. phaseolina* was reduced by the application of biocontrol agent *T. viride* multiplied in organic substrates, such as coir pith, groundnut shells and pressmud as row application in acid soil condition (Raghuchander *et al*., 1993).

Effect of fungicides and *T. harzianum* on *Rhizoctonia* collar rot of passion fruit under inoculated conditions was studied. In disease control studies, collar rot symptoms were not observed in rizolex, bavistin and *T. harzianum* treatments, while in the other treatments, incidence of collar rot was 50-100 per cent after 60 days of inoculation with *R. solani*. Specific rizolex treatment (44.0%), while in other treatments, it was at par with control. Lesion length was significantly less in bavistin (3.13 cm), foltaf (3.38 cm), rizolex (3.75 cm) and *T. harzianum* (4.13 cm) treatments than control (6.63 cm) (Sawant *et al*., 1994).

Jeyarajan *et al*. (1994) developed a talc based formulation of *T. harzianum* which reduced the root rot incidence in urd bean, chickpea, peanut and gingelly by 66, 50, 77 and 67 per cent and increased the yield of 20, 13, 12 and 12 per cent, respectively.

Seed coating with *Bacillus subtilis* checked dry root rot incidence by 52 per cent in chickpea (Saxena and Saxena, 1995).

In sesamum seed treatment with *T. harzianum* and *T. viride* significantly reduced root rot incidence to 10.1 and 12.8 per cent, respectively and these were followed by *Gliocladium virens* (13.5%) as against 60 per cent in control (Sanker and Jeyarajan, 1995).

Ramakrishnan *et al*. (1994) developed a talc-based formulation of *T. viride* for bio-control of *Macrophomina phaseolina*, by mixing talc powder with *Trichoderma* bio-mass obtained by growing the fungus in molasses yeast medium for 15 days and drying. This formulation packed in polythene bags yielded 8 x 10^7 colonies / gram after 120 days. Seed treatment with this product effectively reduced the root rot diseases of urdbean caused by *M. phaseolina*, both in the artificially infected soil and natural soil in farmers fields.

Ushamalini *et al*. (1997) reported that the efficacy of biocontrol agents, farmyard manure (FYM) and plant products against cowpea wilt caused by *Fusarium oxysporum* f.sp. *tracheiphilum*. Seed treatment with *Trichoderma harzianum* registered 98.8 per cent seed germination and was on par with the standard treatment of fungicide carbendazim compared to the lower germination per cent of 93.2 in control. The rhizosphere and non-rhizosphere population of fungi, bacteria and actinomycetes was more in neem cake applied plots whereas the

population of *Trichoderma* was more in pots sown with seeds treated with talc based product of *T. viride* and *T. harzianum* with respect to *Trichoderma* the minimum root to shoot (R/S) ratio of 1-55 was recorded by neem cake at 20 days after sowing (DAS), while at 40 and 60 DAS, farmyard manure and *Delonix regia* recorded the minimum R/S ratio of 1/30 and 1-33 respectively.

Rathore (1997) reported the efficacy of fungicidal seed dressers against *M. phaseolina* (seedling blight of moth bean). The per cent disease incidence, seed yield, fodder yield and net return in bavistin 50% WP (2 g kg^{-1}) treated plots were 13.3%, 244 kg ha^{-1}, 28.52 q ha^{-1} and Rs.1612 ha^{-1}, captan 75 SD (3 g kg^{-1}), Topsin-M 70% WP (2 g kg^{-1}), 15.0% 233 kg ha^{-1}, 26.85 g ha^{-1} and Rs.1311 ha^{-1} respectively. The maximum disease incidence, minimum seed and fodder yield recorded in control, treatment were 23.3 per cent, 169 kg ha^{-1} and 20.83 kg ha^{-1}, respectively.

Latha *et al*. (2000) conducted a field trial to study the effect of antagonists and chemicals on root rot disease complex caused by root rot fungus *Macrophomina phaseolina* and cyst nematode *Heterodera cajani* in blackgram crop *Vigna mungo* (L.) hepper. Among the nine treatments tested, combination of fungicide carbendazim as seed treatment @ 2 g kg^{-1} of seed with a nematicide carbofuran as soil application (3.3 kg a.i. ha^{-1}) was found to be most effective in reducing the root rot incidence (13.9%) nematode population and increasing the pod yield (523.7 kg ha^{-1}) significantly.

Prasad and Rangeswaran (2000) conducted a microplot test under field conditions to evaluate a modified wheat bran-kaolin formulation of *Trichoderma harzianum* in controlling seed rot and damping-off of chickpea incited

by *Rhizoctonia solani*. Significant ($P < 0.01$) control of the disease was achieved in the plots treated with two doses (100 and 200 g/m^2) of the granular formulation when compared to bioagent treated seed plots or fungicide-treated plots. The disease incidence ranged between 10 and 15 per cent in granule treated plots where in other treatments, 51 to 57 per cent damping-off was observed.

Chandrasekhar *et al*. (2000) investigated the efficacy of native fungal antagonist, *Trichoderma viride* against root rot pathogen of brinjal as a talc based product under field conditions. The lowest root rot disease incidence of 9.4% was recorded in the plots treated with *T. viride* @ 4 g kg^{-1} of seed and 3 g/20 m^2 followed by the application of *T. viride* @ 2 g kg^{-1} of seed and 3 kg/20 m^2 (11.6%). The maximum per cent disease incidence (22.6%) was observed in the untreated control plots.

Sivakumar *et al*. (2000) reported that the *Pseudomonas fluorescens* Pf-1, isolated from the crop rhizosphere, exhibited inhibitory action against *Rhizoctonia solani* f.sp. *sasaki* Exur. causing banded leaf and sheath blight of maize.

Rangeswaran *et al*. (2001) studied the effect of seed treatment with two bacterial antagonists viz., *Pseudomonas putida* and *P. fluorescens* in control of root rot of chickpea caused by *Rhizoctonia* spp. and the results indicated that seed treatment with both the antagonists significantly reduced root rot incidence of chickpea when compared to control. Among the two bacterial antagonists *Pseudomonas fluorescens* was found to be highly effective in reducing the incidence by 6.4 per cent compared to *P. putida* seed treatment with these two bio-control agents also resulted in significant increase in seed yield.

Rangeswaran *et al*. (2001) evaluated that the talc based formulations of two antagonistic bacteria viz., *Pseudomonas putida* (PDBCAB 19) and *P. fluorescens* (PDBCAB2) against natural incidence of wilt (*Fusarium oxysporum* f.sp. *ciceri*) and wet root rot (*Rhizotonia solani* Kuhn.) in chickpea. At 30th day, highest root rot incidence (10.8%) was observed in pathogen control plots of minimum was fungicide treated plots (3.1%). *P. fluorescens* (PDBCAB2) treated plots also exhibited low root rot (4.4%). However, at 60 day (fusarial wilt) lowest root rot incidence (5%) was recorded in *P. fluorescens* (PDBCAB2) treated plots and highest root rot incidence 13.9% was observed in pathogen control. Low root rot incidence (5.8%) was also noticed in *P. putida* (PDBCAB19) treated plots. *Fusarium* wilt was lowest (3.3%) in *P. putida* (PDBCAB19) treated and highest (13.3%) on control plots at day 90.

Desai and Srikant Kulkarni (2002) reported that the effect of non volatiles produced by nine biocontrol agents on the hyphal growth and sclertial formation of *Macrophomina phaseolina* (Tassi) Goid isolated from M-35-1 sorghum variety. Cent per cent hyphal inhibition by sterilized (ST) non-volatile was recorded in (T2) *Aspergillus niger* and (T3) *A. niger* (K). Further *Gliocladium virens* (44.22) and (T8) *T. viride* II (43.32) which were on par with each other. Significantly higher hyphal inhibition was recorded in (T3) *A. niger* K (79.29) which was on par with (T1) was on par with (T6). *T. harzianum* and (T6) *T. viride* II cent per cent sclerotial inhibition was recorded in *A. flavus* (T1), *A. niger* (T2), *A. niver* (K) (T3) and *G. virens*.

Nagaraju *et al*. (2002) reported that the commercial formulation of *P. fluorescens*, *T. viride* and *T. harzianum* were used as seed treatment, root dip and foliar spray. The mean performance showed that application of *P. fluorescens* as

root dip and 1 foliar spry to be effective in reducing the severity of *R. solani* up to 62.13% and resulting in 47.68% higher grain yield compared with untreated check.

Srivastava *et al*. (2002) reported that eight *Trichoderma* isolates tested for their bioefficacy against seed, root and seedling rot incited by *Rhizoctonia solani* by adopting an *in vivo* test method (Blotter test). Vigour index ranging from 169.5 to 2239.4 and disease incidence ranging between 10 to 86 per cent were recorded in various treatments.

Padmalatha (2002) repoeted that the application of *T. harzianum* to both soil and seed was proved to be more effective in reducing the disease incidence (17.2%) seed treatment (31.0%) and soil application (25.4%) against *M. phaseolina* of sunflower (cv. morden) in pot culture experiments.

Sindhan *et al*. (2002) reported the antagonistic activity of *Trichoderma viride, T. harzianum, Aspergillus flavus, A. niger, A. ochraceous, Penicillium citrinum, Bacillus subtilis* and *Pseudomonas fluorescens* against *R. bataticola in vitro* separately using dual culture method. All the antagonists inhibited the mycelial growth and sclerotial production in comparison to control. Carbendazim was most effective causing 94.2 and 100% inhibition in mycelial growth and sclerotia production respectively. Among the antagonists, *P. fluorescens* exhibited maximum antagonistic activity causing 65.0 and 90.5% inhibition in mycelial growth and sclerotia production respectively. Among the antagonists, *P. fluorescens* exhibited maximum antagonistic activity causing 65.0 and 90.5% inhibition in mycelial growth and sclerotial production respectively. *T.viride*, the next best antagonist caused 62.3 and 87.0% inhibition in mycelial growth and sclerotial production followed by *T. harzianum, A. ochraceous, B. subtilis* and *P. citrinum.*

Jayalakshmi *et al*. (2003) reported that seed treatment with native isolate of *P. fluorescens* and *P. fluorescens* strains of Pf1 (4 x 109 cfu ml^{-1}) recorded the maximum germination (98.6% and 86.66%), shoot length (20 and 18 cm), root length (15 and 13 cm), dry matter production (60 and 57 mg) and vigour index (1973.2 and 1618) compared to control while testing against rice sheath blight caused by *Rhizoctonia solani*.

2.5 *IN VITRO* EFFICACY OF BIOCONTROL AGENTS AGAINST *S. ROLFSII*

The efficacy of *Trichoderma* spp. for control of *S. rolfsii* has been well documented in various studies under laboratory conditions (Morton and Strouble, 1955; Elad *et al*., 1980 and Almedia and Landin, 1981).

Weindling (1932) was the first person to demonstrate that *Trichoderma* spp. parasitized as well as inhibited the development of *S. rolfsii*, indicating the potential of these fungi as bio-control agents.

Agarwal *et al*. (1977) reported that *T. harzianum* arrested the growth of *S. rolfsii* by forming a brown coloured zone at the point of contact, whereas, in case of *T. viride* no such zone was observed and *S. rolfsii* colony was overgrown by *T. viride* after the point of contact.

Different isolates of *Trichoderma* sp. showed differential antagonistic potentiality on *S. rolfsii*. This type of variation in hyperparasitic potential within different isolates of *Trichoderma* spp. has already been well established (Morton and Stroube, 1955; Dennis and Webster, 1971; Elad *et al*.,1980 and Almedia and Landin, 1981).

Agarwal *et al*. (1978) reported the antagonistic activity of , *Trichoderma harzianum* and *Bacillus subtilis* against *S. rolfsii* causing collar rot of lentil. Culture filterates of both organisms inhibited growth of the pathogen on potato dextrose agar and their effectiveness being reduced with dilution.

Mathur and Sarbhoy (1978) demonstrated that *T. viride* and *T. harzianum* inhibited the mycelial growth of *S. rolfsii* by 88 and 86 per cent, respectively on dual culture.

Elad *et al*. (1983) reported by scanning electron microscopic studies that the *Trichoderma* spp. attached to the *S. rolfsii* either by hyphal coils, hooks or appressoria. They also found that high β-(1,3) glucanase and chitinase activities were detected on dual agar cultures when *T. harzianum* parasitized *S. rolfsii* compared with low levels found with either fungus alone.

Henis *et al*. (1983 a) reported that the sclerotia immersed in aqueous suspension of *Trichoderma* conidia (1.5×10^7 ml^{-1}) were degraded by the penetration of hyphae of *Trichoderma*. Due to this penetration the rind and cortex lysed the medullar tissue produced chlamydospores inside and conidia outside the sclerotia.

Pyke and Dietz (1966) found dermadine, while Dennis and Webster (1971) reported acetaldehyde as major volatile antibiotic produced by *Trichoderma. T. harzianum* excreted β-1,3 glucanase and chitinase which affects the growth of *S. rolfsii* (Davet, 1987).

Upadyay and Mukhopadyay (1986) reported that, an isolate of *Trichoderma harzianum* directly attacked and lysed the mycelium and sclerotia of

the pathogen in dual culture. Hyphal coiling, entry through haustoria like structures and direct entry into the hyphae and sclerotia of *S. rolfsii* were observed.

Wokocha *et al*. (1986) screened sixteen fungi against *S. rolfsii* on PDA under laboratory conditions and showed that only two out of sixteen fungi viz., *T. viride* and *T. harzianum*, invaded the colonies of *S. rolfsii* and completely inactivated the pathogen in culture.

Trichoderma spp. were known to produce enzymes necessary for the degradation of fungal walls composed of chitin, cellulose, glucan and xylan polymers that are necessary enough to cause lysis (Sundheim and Tronsmo, 1988).

Isolates of *T. harzianum* and *T. polisporus* inhibited *in vitro* mycelial growth of *S. rolfsii* by 32 and 30 per cent respectively and *T. harzianum* also colonized the degraded mycelium and sclerotia of *S. rolfsii* (Montealagre and Henriquez, 1990).

Kwee and Keng (1990) suggested that multiple mechanisms involving mycoparasitism, antibiosis, lysis and hyphal interference may be implicated in the interaction between *T. harzianum* and *S. rolfsii*.

T. harzianum an important antagonist is known produce several fungistatic substances in addition to parasitising mycelia of *S. rolfsii* (Kulkarni,1992).

Corpuz and Paderes (1993) isolated *Trichoderma* spp. from soil by using sclerotia of *S. rolfsii* as baiting material and *in vitro* study showed that this *Trichoderma* isolate was able to suppress sclerotial germination and mycelial growth of *S. rolfsii*.

Higher mycoparasitic activity of *T. harzianum* against *S. rolfsii* was due to utilization of sclerotial cell contents for its nutrients (Bhuyan *et al*., 1994; Elad *et al*., 1981; Roy, 1991).

Silveira *et al*. (1994) tested fourteen isolates of *Trichoderma* spp. collected from bean and cowpea growing areas, against *S. rolfsii*. Isolates TN-50, TN-21 and TN-52 gave the best inhibition of mycelial growth (76.8 and 71.6 per cent, respectively). TN-21, TN-50 and TR-1 isolates gave the best control of sclerotia production 93.4, 83.6, and 82.6 per cent, respectively) and isolates TN-21 and TN-16 showed the greatest hyperparasitic activity towards sclerotia of the pathogen.

Amar Singh *et al*. (1994) reported that out of 54 isolates of fungi and bacteria isolated from soil, three isolates of *Trichoderma harzianum* Rifai (Th-1, Th-2 and Th-3), two of *T. viride* Fers. Fr. (Tv-1 and Tv-2) and one each of *Penicillium* sp., *P. cyclopium* Westling, *Eupencillium* spp., *Aspergillus* sp., *A. flavus* Link., *A. fumigatus* Fres., *A. niger* VanTieghan and an unidentified bacterium were found antagonistic to *S. rolfsii* Sacc. in dual culture, maximum inhibition of mycelial growth of *S. rolfsii* was obtained with Th-2 isolate of *T. harzianum* (73.4%) and least with unidentified bacterium (2.06%).

Mukerjee *et al*. (1995) reported that *Gliocladium virens* and *T. harzianum* were equally effective in parasitizing the hyphae of *S. rolfsii*. However, *G. virens* readily parasitized the sclerotia of the *S. rolfsii*.

Mannona *et al*. (1997) reported that, a new tetracyclic diterpene having a molecular formula of $C_20H_28O_2$ and a molecular mass of 300 a.m.u was isolated from the culture filterate of strain of *T. viride*. The pure compound showed antifungal activity against *S. rolfsii*.

Among the four antagonists *Aspergillus niger*, native isolate of *T. viride* exotic isolate of *T. viride* and *T. harzianum* tested, native isolate of *T. viride* was found to be superior in suppression of *S. rolfsii* isolated from infected bell pepper plants under *in vitro* conditions followed by exotic isolate of *T. viride* and *T. harzianum* (Anitha chowdhary, 1997).

Rajendra *et al.* (1998) reported that the forty fluorescent pseudomonad strains isolated from rhizoplanes of various plants grown in Vertisols. Based on their ability to form the zone of inhibition *in vitro*, all the strains inhibited the growth of *S. rolfsii* to varying levels ranging from 1 mm zone of inhibition to as high as 47 mm indicating antibiotic production from them. The strain FPD-10 isolated from roots of silver oak seedling induced the highest inhibition of 47 mm followed by the groundnut strain FPD-15 which showed 43 mm zone of inhibition.

Thirubhuvanamala *et al*. (1999) screened nine antagonists were screened for their antagonistic effect against tomato stem rot pathogen (*S. rolfsii* Sacc.). All the nine antagonists tested inhibited mycelial growth of the pathogen by more than 50 per cent. Maximum inhibition of 85.8 per cent and 84.7 per cent were recorded by bacterial antagonists *B. subtilis* and *P. fluorescens* followed by fungal antagonists *T. harzianum* and *T. viride*.

Sharma *et al*. (1999) reported that the *Trichoderma harzianum* and *Absidia cylindrospora* were most effective in inhibiting mycelial growth of *Sclerotinia sclerotiorum* (Lib) de Bary causing chickpea stem rot in dual cultures. *T. harzianum* caused maximum inhibition (75%) of mycelial growth followed by *A. cylindrospora* and *T. viride*, while *Gliocladium virens* caused least pathogen inhibition.

Anitha Mazinder Buragohain *et al*. (2000) reported that the antagonistic activity of *Trichoderma* spp. was demonstrated on suppression of *S. rolfsii* in *in vitro* tests. The inhibitory zone developed by *T. harzianum, T. viride, T. koningii* were 7.6 mm, 5.5 mm and 4.3 mm respectively *in vitro*.

Biswas *et al*. (2000) reported the efficacy of 11 isolates of *Trichoderma harzianum* and reported that the three isolates, viz., T8, T10 and T2 were effective against groundnut isolate of *Sclerotium rolfsii* (*Corticium rolfsii*), and they overgrew the pathogen up to 92, 85 and 79 per cent respectively, *in vitro*.

Girija and Umamaheswaran (2003) reported the effect of the biogas against basal rot pathogen of balsam (*S. rolfsii*) *in vitro* and showed that *Trichoderma virens* gave maximum inhibition (65.8%) followed by 45.8% inhibition by B1 isolate of *Bacillus* sp.

In vitro efficacy of antagonistic mycoflora and bacteria against *S. rolfsii* was evaluated by using dual culture technique. *Trichoderma* isolate-1 (T1) and *Pseudomonas* sp. (B1) were found to be potential native antagonists that inhibited growth and sclerotial population of *S. rolfsii* to a maximum of 69.76%, 90.86% and 43.10%, 71.00% respectively (Arunasri *et al*., 2003).

In vitro efficacy of antagonistic mycoflora against *S. rolfsii* was evaluated dual culture technique by Rajani (2004) and reported that *Trichoderma* isolate-2 (TG2) was found to be potential native antagonistic fungus that inhibited mycelial growth and sclerotial population of *S. rolfsii* to a maximum extent of 67.83 and 92.60% respectively .

The worldwide interest in Pseudomonads group as biocontrol agents was sparkled by studies initiated at the University of California, Berkley during the 1970s (Weller, 1988).

Ganeshan and Gnanmanickam (1987) reported that, native strains of *Pseudomonas fluorescens* restricted mycelial growth of *S. rolfsii* on agar plates. Sclerotia showed 10-20 per cent germination loss after immersion in a bacterial cell suspension for one hour and 50-60 per cent after one week.

Elangovan and Gnanaman (1992) reported the *in vitro* antibiosis of rhizosphere isolates of *Pseudomonas fluorescens* against *Sclerotium oryzae*. Of the 85 strains screened, nineteen were more effective than others and caused inhibition zones that ranged from 6.0 to 30.0 mm in diameter.

Laha *et al*. (1992) reported that in *in vitro* plot assays, 44 per cent of isolates strongly restricted the growth of *Rhizoctonia solani*. F-13 showed maximum growth suppression (85%).

Dickman and Mitra (1992) and Dickman and Chet (1998) have identified some Pseudomonads which were capable of degrading the toxin oxalic acid, produced by *S. rolfsii.T. viride, T. harzianum* tested were effective in inhibiting the oxalic acid production except yeast. *P. fluorescens* had minimum production of oxalic acid followed by *T. viride and B. subtilis*.

Laha *et al*. (1996) reported that sixteen out of forty eight fluorescent pseudomonads isolates from cotton rhizosphere were found to be antagonistic to *S. rolfsii*. The level of pathogen suppression was substantially reduced when the medium was supplemented with ferric chloride. The sclerotial viability was reduced when immersed in bacterial suspension or their cell-free culture filterates. The

fluorescent Pseudomonads (FP) isolates were found to be cyanogenic and their volatile metabolites substantially suppressed the pathogen growth. In greenhouse experiments, the isolate FP-47 was most effective in reducing the disease.

Laha *et al*. (1996) investigated the *in vitro* inhibitory effect of fluorescent Pseudomonads on the growth of *Sclerotium rolfsii* in presence / absence of ferric iron. Thirty three per cent of FP isolates inhibited the growth of *S. rolfsii* in dual culture on PAF medium. The inhibition zone ranged from 3 mm (FP-23) to 14 mm (FP-30). The isolates like FP-25, FP-28, FP-43, FP-47, etc., showed consistently good antagonistic effect. The antagonistic effect and fluorescent pigment production was, however, drastically reduced in ferric chloride amended PAF medium indicating the production of some antifungal compounds by FP's only under iron stress condition.

Harinarayana (1999) reported that the growth of *S. rolfsii* of bell pepper was inhibited to an extent of 53.7 per cent by *Pseudomonas fluorescens.*

Fourteen isolates of *Trichoderma* and *Gliocladium* species were tested *in vitro* against *Sclerotium rolfsii*, the causal organism of foot rot/collar rot of sunflower. Two isolates of *T. viride*, four isolates of *T. harzianum*, one each of *T. hamatum, T. koningii, T. polysporum, G. virens, G. deliquecens* and *G. roseum* inhibited mycelial growth of the pathogen significantly. Among *Trichoderma* species, *T. harzianum* isolates PDBC TH2 gave 61.4% inhibition of mycelial growth followed by PDBCTH8 (55.2%) and PDBCTH7 (54.9%). Among *Gliocladium* isolates, *G. virens* gave maximum inhibition (39.9%) of mycelial growth. Suppression of sclerotial production by the antagonists ranged from 31.8 to 97.8%. Complete inhibition of sclerotial germination was obtained with the culture filterates

of *T. harzianum* PDBCTH2, 7 and 8. *T. pseudokoningii* and *G. deliquescens*, the three *T. harzianum* isolates and the *T. viride* isolate (PDBCTV4) were superior under greenhouse conditions (65.4%), PDBCTH2 (61.6%) and were superior to the fungicide, captan. *G. deliquescens* gave maximum (55.7%) disease control among *Gliocladium* spp. (Prasad *et al*., 2000).

Effect of *Trichoderma* spp. viz., *T. harzianum*, *T. viride* and *T. koningii* were tested *in vitro* using dual culture technique to assess the antagonistic potential of the three *Trichoderma* spp. and poisoned food technique was used to study the efficacy of two chemicals viz., thiram 75 WP and Dithane M-45 75 WP @ 0.1% of its commercial product against the *S. rolfsii*. Out of three *Trichoderma* spp. *T. harzianum* was more inhibitory to *S. rolfsii* which showed 61.5% inhibition in mycelial growth of the pathogen. This was followed by *T. viride* and *T. koningii* respectively causing 59.1% and 57.2% growth inhibition. Sclerotial production was reduced significantly ranged between 84.1% and 94.2%. *T. harzianum* inhibited more than 90% sclerotial production followed by *T. viride* 86.8% and *T. koningii* 84.1%. Dithane M-45 inhibiting mycelial growth (76.5%) and sclerotial production (98.6%) of *S. rolfsii* compared with thiram where mycelial growth and sclerotial production were 70.3% and 96.5% respectively (Pranab Datta and Das, 2002).

Tripathi and Johri (2002) reported that the antagonistic potential of fluorescent pseudomonads (FLP) recovered from rhizoplane (Pen-4) and rhizosphere of pea (PRS-1) were studied for *in vitro* inhibition of *Colletotrichum dematium*, *Rhizoctonia solani* and *Sclerotium rolfsii*. Pen-4 and PRS-1 showed strong antagonism against C. dematium and R. solani by 59 and 69% respectively in iron-rich medium but were infective in absence of Fe^{3+}.

Durai (2004) reported that the three bacterial isolates of *P. fluorescens* inhibited mycelial growth of the pathogen *S. rolfsii* to a maximum extent of 71.76 per cent in dual culture technique.

2.6 *IN VIVO* EFFICACY OF BIOCONTROL AGENTS AGAINST *S. ROLFSII*

Labakhua and Donadze (1975) reported that, southern root rot of wheat is widespread in Western Georgia. In laboratory, field and pot trials *Trichoderma lignorum* (*T. viride*) inhibited the development of *S. rolfsii*. The enrichment of tomato rhizosphere with *T. viride* is recommended as a promising control measure.

Lozano and Pineda Lopez (1977) reported the good control of the *S. rolfsii* infection in tomato when tomato seedlings were inoculated with *Penicillium* sp. under glasshouse conditions. They also reported that the two isolates of *Pencillium* sp. inhibited the production and germination of sclerotia of *S. rolfsii*.

Agarwal *et al*. (1977) reported that, *Trichoderma harzianum* and *Bacillus subtilis* could check the mortality of lentil caused by *Sclerotium rolfsii* in pot culture experiments. Both the cultures were more effective when applied to seed rather than to the soil.

In glasshosue tests, Mathur and Sarbhoy (1978) obtained good control of sclerotial root rot sugarbeet caused by *S. rolfsii* by the application of *T. harzianum* and *T. viride* (20 and 13.3 per cent respectively).

Under greenhouse conditions, incorporated wheat bran inoculum of *T. harzianum* in pathogen infested soil significantly reduced bean (*Phaseolus vulgaris*) diseases caused by *S. rolfsii, R. solani* or both, but its biocontrol capacity

was inversely correlated with temperature. The wheat bran inoculum of *T. harzianum* increased growth of bean plants in a noninfested soil and it controlled *S. rolfsii* more effectively than a conidial suspension of the same antagonist. An uninoculated wheat bran preparation increased disease incidence. In naturally infested soil *T. harzianum* inoculum significantly decreased diseases caused by *S. rolfsii* (or) *R. solani* in field experiments with beans, cotton (or) tomatoes, and significantly increased the yield of beans (Elad *et al*., 1980).

Tokeshi *et al*. (1980) reported that, on inoculating cuttings in the glasshouse with isolates T1, T4 and T5 of *Trichoderma* spp. and T2 of *T. lignorum* and then with *S. rolfsii* the number of healthy plants increases by 20.9 to 50 per cent. In the field the number of healthy plants rose by 20 per cent when T4 precolonized the substrate inoculated with *S. rolfsii*.

Inwang and Chamswarng (1986) evaluated the efficacy of microorganisms isolated from the cultivated soils against *S. rolfsii* causing stem rot of tomato under glasshouse conditions. The incorporation of mixed sorghum seed inoculum preparation of either *T. harzianum* (or) *T. viride* with similar preparation of *S. rolfsii* at the ratio of 3:2 prior inoculation significantly reduced tomato stem rot by 99.4 and 98.8 per cent, respectively.

Muthamilan and Jeyarajan (1997) observed that seed pelleting with *Trichoderma harzianum* and *Trichoderma viride* against root rot groundnut caused by *S. rolfsii* was found to be effective in controlling the disease. They also reported that, seed treatment with the above bio-agents increased the seed germination upto 90-95 per cent when compared to 55 per cent.

Latunde (1993) tested two simple formulations of an antagonistic strain of *T. koningii* against southern blight disease caused by *S. rolfsii* in seedling potted outdoor and field grown tomatoes (cultivars life No.1 and Ibadan local). Corn cob germling inoculum and mycelium powder of *T. koningii* significantly controlled symptoms of damping-off, blight and wilting in both tomato cultivars. The populations of the antagonist increased from an initial 1×10^4 to about 1×10^6 cfu g^{-1} soil in the protected plants. Moreover, sclerotial counts decreased significantly in these soils and those sclerotia found had been parasitised by *T. koningii*. *Trichoderma* protected plants were more vigorous than those in the other treatment categories.

Marmara and Paningbatan (1993) reported that seed coating with conidial suspension of *T. viride* protected mungbean against *S. rolfsii* infection, in the pot experiments. Simultaneous application of *T. viride* with *S. rolfsii* and application of 5 days after *S. rolfsii* inoculation gave a relative protection of 66.00 and 67.81 per cent respectively. *T. viride* treatments also enhanced the growth of mungbean seedling in terms of mean height increments (45-68%). *T. viride* did not affect the germination of coated seeds. In field conditions, seed coating with *T. viride* conidial suspension of 10^9 ml^{-1} protected mungbean from infection by *S. rolfsii* by 37.69 per cent.

Amar Singh and Dhanbir Singh (1994) reported that complete inhibition of sclerotial germination of *S. rolfsii* in *T. harzianum*, *T. viride* and *Gliocladium* spp. treated sclerotia after 30 days of incubation in soil wheat bran substrate. Seed treatment with bioagents recorded improved growth and higher population of *T. viride* indicating its high rhizosphere competence.

Seed tretment with 10^9 conidia ml^{-1} conidial suspension of *Trichoderma* spp. decreased the stem rot disease of sweet pepper caused by *S. rolfsii* by 8.78 per cent. Seedling dip of the same suspension also protected sweet pepper treatments from infection by *S. rolfsii* both under greenhouse and natural conditions by 76.5 and 73.04 per cent, respectively (Paningbaton, 1994).

Jeyarajan and Ramakrishnan (1995) developed a talc based formulation of *T. viride* for dry seed treatment of oilseeds and pulses by using fermenter grown bio-mass in molasses yeast medium which supported maximum growth of *T. harzianum* and *T. viride*. Mixing of wheat bran culture of *T. harzianum*, *T. viride* and *Gliocladium* spp. @ 10 kg^{-1} of soil reduced the seedling mortality due to collar rot disease caused by *S. rolfsii*. These bio-agents reduced the disease to 12.71, 14.72 and 17.98 per cent, respectively as compared to 86 per cent in check under glasshouse conditions.

Under glass conditions, complete control of the disease was observed when *T. viride* (native) inoculated on the same day as *S. rolfsii* and / or three days prior to inoculation with *S. rolfsii*. However, inoculations with *T. viride* three days after inoculation with *S. rolfsii* were ineffective in reducing the sclerotial wilt disease in bell pepper (Anitha Chowdhary, 1997).

Sharma *et al*. (1999) conducted pot culture experiments under glasshouse conditions. Coating of seeds with different biocontrol agents like *Trichoderma harzianum* and *Absidia cylindrospora* reduced the *Sclerotinia sclerotiorum* causing chickpea stem rot. Minimum incidence (4.52) of the disease was recorded in treatment whereas seeds were coated with *T. harzianum* as compared to control (43.44%).

Ganeshan and Gnanmanickam (1987) reported that in greenhouse tests, 99 per cent of groundnut plants were protected from *Sclerotium rolfsii* infection when inoculated with *P. fluorescens* (10^8 cfu ml^{-1}). Non-incubated *S. rolfsii* infected plants wilted (or) died in 10 days and fresh weight of tops were significantly lower than those of plants inoculated with the bacteria and infected with *S. rolfsii*.

Elangovan and Gnanamanickam (1992) reported that by the introduction of *Pseudomonas fluorescens* on rhizosphere of rice can effectively control stem rot of rice caused by *Sclerotium oryzae*.

Gamliel and Katan (1993) reported that compared to non-solarised soil, incidence of disease caused by *Fusarium oxysporum* f.sp. *vasinfectum* in cotton and *S. rolfsii* in bean was significantly reduced in solarised soil by the introduction of fluorescent pseudomonads like *P. fluorescens, P. putida* and *P. alcaligenes*.

Ray and Mukerjee (1997) screened 68 isolates of microorganisms against certain soil borne fungal pathogens of which 11 were found to be inhibitory. Among them *Bacillus* strain S_{12} and S_{17} showed high antagonistic properties followed by S_{11} and S_{16} strains against *S. rolfsii*.

Vidyasekharan *et al.* (1997) reported that two day-old bacterial suspensions of *Pf*1 and *Pf*2 used as seed treatment, effectively controlled pigeonpea wilt incidence compared to the untreated control. But 10-day old suspensions were ineffective in controlling the disease. All freshly prepared carrier based formulations were effective in controlling the disease. The talc formulations were effective in controlling the disease even after 180 days of storage.

Thribhuvanamala *et al*. (1999) reported that effect of biocontrol agents against *S. rolfsii* by soil application under pot culture condition. Among the antagonists *T. harzianum* was highly effective against the stem rot pathogen *S. rolfsii* thereby recording least stem rot incidence of 20.0 per cent at 60 DAS. The next best effective treatment were *T. viride* and *P. fluorescens* which recorded 26.7 per cent and 26.7 per cent incidence respectively.

Rangeswaran and Prasad (2000) reported *in vitro* testing of the three hundred rhizosphere bacteria for antagonism against *Sclerotium rolfsii*, the causal organism of root/collar rot in sunflower. In pot culture experiments, eleven antagonists were tested for suppression of *S. rolfsii* rot of sunflower in greenhouse as seed and soil treatment. Number of disease free plants (63%) was highest on *P. fluorescens* (PDBC AB2) and *P. puitida* (PDBC AB19) seed treatment which was almost the same as that of fungicide (67%) treated pots.

Kalappanavar and Patil (2000) reported that four antagonists viz., *Trichoderma harzianum* Rifai, *T. viride* Pers ex. Fr., *Bacillus subtilis* Corh. and *Pseudomonas fluorescens* (Triv) Migula were used as seed treatment. The per cent survival of seedlings of *T. harzianum* 4 g kg^{-1} of seeds (95.30%) and another *Trichoderma harzianum* 6 g kg^{-1} of seeds (91.80%) and *B. subtilis* on par and were very effective in reducing the incidence of the disease *P. fluorescens* was the least effective bioagent served.

Vanitha and Suresh (2002) reported on effect of biocontrol agents and amendments (non chemicals) on the management of collar rot of brinjal. Lesser disease incidence of collar rot was recorded (9.44%) in *T. viride* seed treatment + soil application of adathoda leaf powder and FYM treated plots. The fungicide

(carbendazim) seed treatment alone given recorded 10.83% of disease incidence in this experiment which used were effectively control the disease incidence compared to control, the disease incidence of 39.30 per cent, with regard to yield the highest of 12000 kg P lot^{-1} was registered in both *T. viride* (ST) + Adathoda leaf powdered application. FYM (SA) treated plots as well as the fungicide carbendazim treated plots.

2.7 SENSITIVITY OF BIOCONTROL AGENTS AGAINST AGROCHEMICALS

2.7.1 Sensitivity of biocontrol agents with fungicides

Mukhopadyay *et al*. (1986) tested the effect of metalaxyl on radial growth of *T. harzianum* at 0.1, 1, 10 and 100 ppm concentrations and reported that there was no effect of metalaxyl on the growth and sporulation of *T. harzianum* upto 100 ppm concentration.

Sawant and Mukhopadyay (1990) observed that the radial growth of *T. harzianum* was not inhibited by metalaxyl at concentration of 50 ppm while 19 and 30 per cent inhibition was observed at 500 and 1000 ppm, respectively.

Sharma and Mishra (1995) studied the effect of four fungicides on the growth and spore germination of *T. harzianum* under *in vitro* conditions. Fungicides metalaxyl, chlorothalonil and captafol showed little inhibition while thiram was highly inhibitory even at lower concentrations.

Singh *et al*. (1995) screened isolates of *Trichoderma* sp. against fungicides like captafol, mancozeb and thiram. The growth of the isolates was not inhibited at 500 ppm concentration with captafol and mancozeb but thiram at 200 ppm concentration completely inhibited the growth.

The sensitivity of eight species of *Trichoderma* and a single species of *Gliocladium* to potassium phosphonate (antifungal compound) revealed no significant effect even at concentrations as high as 1200 ppm, while in *T. aureoviride* and in *T. pseudokoningii* increased sporulation was noticed with potassium phosphonate compared with control (Rajan and Sharma, 1996).

Karpagavalli (1997) reported the effect of different fungicides (viz., carbendazim, thiram, copper oxychloride) on the growth of *T. harzianum* and *T. viride* at 500, 1250 and 2500 ppm concentrations *in vitro*. All the fungicides inhibited the growth of antagonistic fungi at all concentrations in liquid medium. When compared to control they recorded 430.00 mg and 410.00 mg dry weight for *T. harzianum* and *T. viride* respectively. Among the fungicides tried, COC recorded the lowest inhibition followed by thiram in *T. harzianum*. In case of *T. viride* the mycelial dry weight in 500 and 1250 ppm concentrations of COC was on par with the control. Inhibition was maximum in carbendazim at 2500 ppm concentration. The mycelial dry weight decreased with increased concentration of fungicides.

Results revealed that *T. viride* did not show sensitivity with the lower doses of Vitavax, Rovilan, Indofil M-45, Thiram, Captafol and Ridomil. Bayleton and bavistin were inhibitory to *T. viride*, therefore, these two fungicides cannot be used in integrated management strategies (Abha Agarwal and Tripathi, 1999).

Gupta *et al*. (1999) reported that the biocontrol agent *Trichoderma pseudokoningii*, chemical fungicide (Dithane M-45 as mancozeb) and phytohormones (Indole-3-acetic acid, IAA and 1-Naphthalene acetic acid, NAA) were evaluated individually and in combination for their effects on disease control and plant development. In plates, *T. pseudokoningii* was compatible with Dithane M-45 at 0.1% and IAA and NAA at 20 ppm concentrations.

The compatibility of certain biocontrol agents *T. harzianum, Verticillium chlamedosporium* and *T. pseudokoningii* with pesticides and fertilizers was investigated. Compatibility with Dithane M-45, carbofuran and sebufos, with urea, superphopaphate, muriate of potash and NPK 15:15:15 and with neem seed cake (*Azadirachta indica*) was determined by exposing the biocontrol agents to medium treated with 100, 500, 1000 and 2000 ppm. Carbofuran, sebufos, neem seed cake and the chemical fertilizers were compatible with all the biocontrol agents at all the concentrations tested. Dithane M-45 was compatible with all the biocontrol agents at low concentrations (Sharma *et al*., 1999).

Six fungicides (iprodione, mancozeb, metalaxyl + thiram, thiram, tolclofos-methyl, zineb), four insecticides (pirimofos methyl, cypermethrin, dimethoate, malathion) and one herbicide (chlorprophan + centrimide) were incorporated into agar at a range of concentrations up to twice the recommended dosage and the effects on radial growth and spore germination on *Coniothyrium minitans* was determined. Only the fungicides had any significant effect on *C. minitans. C. minitans* was highly sensitive to iprodione EC50 7-125 g a.i. ml^{-1}), moderately sensitive to thiram EC50 52-1065 g a.i. ml^{-1}) but less sensitive to the other tested pesticides (Whipps *et al*., 2001).

Budge and Whipps (2001) evaluated six fungicides, four insecticides and one herbicide for their effects on *Coniothyrium minitans* mycelial growth and spore germination *in vitro* agar plate tests. Only the fungicides had a significant effect with all three strains of *C. minitans* tested, being highly sensitive to iprodione (50% effective concentration EC50 7 to 18 (5 g a. i. ml^{-1}) moderately sensitive to thiram (EC50 52 to 1065 g a.i. ml^{-1}), but less sensitive to the remaining fungicides EC50 over 2005 g a.i. ml^{-1}).

Ramarethinam *et al*. (2001) reported that the mancozeb (75% WP) and copper oxychloride (88% w/w) at the concentrations of 100 ppm and 500 ppm did not inhibit the growth of *T. viride* to any statistically significant level; however, at a concentration of 1000 ppm, copper oxychloride completely inhibited the growth of *T. viride*. Fungicides like carbendazim (50% WP), hexaconazole (5% EC), propiconazole (25% WP) and a weedicide metalachlor (50% EC) completely inhibited the growth of *T. viride* even at 100 ppm concentration in *in vitro*.

Sharma *et al*. (2001) tested the sensitivity of *T. harzianum* against eight fungicides. Among them two are systemic and six are non-systemic. Among systemic fungicides metalaxyl was seven times higher than carbendazim as 2578 μg ml^{-1} of concentration of metalaxyl and 354 μg ml^{-1} of carbendazim inhibited 90% (ED90) growth of the fungus in *in vitro* metalaxyl (0.1%) and carbendazim (0.0065%) seemed to have a safe tolerance limit (ED50) for the bio-agent. Among six non-systemic fungicides captafol and chlorothalonil even at 2317 μg ml^{-1} and 2037 μg ml^{-1} were tolerable (ED90) by the fungus. The concentrations i.e., 169, 375 and 625 μg ml^{-1} of captan, captafol and chlorothalonil seemed to be a safe tolerance limit for the biocontrol agent. Mancozeb and copper oxychloride inhibited maximum growth (ED90) at 285 and 805 μg ml^{-1} but ED50 value of these were 231 μg ml^{-1} and 356 μg ml^{-1} only. However, thiram inhibited the growth to the maximum (ED90) at 145 μg ml^{-1} concentration only and 25 μg ml^{-1} seemed to be safe tolerance limit.

Malathi *et al*. (2002) evaluated the effect of carbendazim and thiophanate-methyl on the growth of *Pseudomonas fluorescens* (ARR 1G, ARR2, ARR10, CHAO, EP1, FP7, KKM2, Pf1, VPT2, VP4 and VPY10) isolates *in vitro*

and reported that carbendazim and thiophanate methyl at 100 ppm enhanced the growth of *P. fluorescens* isolates. The antagonistic bacteria multiplied even when the fungicide rate was increased to 500 ppm.

Trichoderma harzianum and *T. viride* antagonistic to *Pythium aphanidermatum* produced cellulolytic enzymes (C1 and Cx) on fungicide amended medium. Three fungicides i.e., bavistin, thiram and fytolan at 500, 1250 and 2500 μg ml^{-1} influenced the damping off incidence and enzyme production differently. As the concentration of fungicides increased there was decrease in the enzyme production. Different treatments influenced the production of cellulolytic enzymes which decreased with the increase in concentration of the fungicides. Enzyme C1 production was maximum in fytolan at concentration 500 ppm 16.50 μg ml^{-1}, followed by thiram (9.35 μg ml^{-1}) and bavistin (6.90 μg ml^{-1}) at 500 ppm in *T. harzianum* respectively (Karpagavalli and Ramabhadran, 2001).

Deepak Kumar and Dubey (2001) studied the compatibility between different biocontrol isolates and commonly used fungicides Benlate (benomyl), bavistin (carbendazim), Topsin-M (thiophanate methyl), thiram (tetramethyl thiuram disulphide), vitavax (carboxin), captaf (captan) at various concentrations and reported that Benomyl, carbendazim and thiophanate methyl inhibited cent per cent mycelial growth of *T. harzianum* at 0.025 and 0.05 concentrations *in vivo*. Next effective fungicide was carboxin (48.0 and 52.0 per cent inhibition at 0.025 and 0.05 concentrations) followed by captan and thiram. Thiram, carboxin and captan were effective against the pathogen but they were less effective against *T. harzianum*.

Anitha *et al*. (2001) screened carboxin and metalaxyl against fungal and bacterial antagonists in the laboratory and found that carboxin and metalaxyl did

not inhibit the growth of *T. viride*, while little inhibition of *G. virens* was noticed at 0.1 per cent concentration of carboxin.

Five different pesticides viz., MEMC, carbendazim, phorate, carbofuran and metribuzin were evaluated against *Trichoderma harzianum, T. viride* and *Chaetomium globosum* by poisoned-food technique *in vitro*. It was observed that both the fungicide (MEMC and carbendazim) and one insecticide (phorate) have been found to inhibit the mycelial growth of all the three tested bio-inoculants strongly up to 5 days of incubation. Carbofuran showed slight inhibitory effect on *T. harzianum* (37.82%), *T. viride* (5.20%) and *C. globosum* (1.22%). Hence it proved safer insecticide than phorate. Herbicide metribuzin found to inhibit more mycelial growth of *T. harzianum* (87.32%) and *T. viride* (61.85%) and total inhibition of *C. globosum* (Bhat and Sabalpara, 2001).

Sitansu *et al*. (2001) studied single (or) combination doses of iprodione (Rovral 50) and carbendazim (Bavistin 50% WP) both at 0.5, 1.0, 2.0 (or) 4.0 ppm and their compatibility with *Trichoderma harzianum* and *Gliocladium virens* which were tested for their bio-efficacy against rice sheath blight caused by *Rhizoctonia solani*.

Mc Lean *et al*. (2001) reported that the *Trichoderma harzianum* C52 is an effective biocontrol agent of the onion white rot pathogen *Sclerotium cepivorum*. Results indicated that *T. harzianum* was least sensitive to procymidone and captan and most sensitive to mancozeb, tebuconazole and thiram.

Batista *et al*. (2002) reported *in vitro* fungitoxicity of antagonists. The fungicides and rates used were; benomyl (0.5 g a.i.), methyl thiophanate (thiophanate-methyl) (1.4 g a.i.), the biocontrol agents *T. viride* (TR2), *T. harzianum*

(T25); *T. koningii* (T15), *T. polysporum* (Sn11) and combinations of antagonists. All fungicides tested interfered with mycelial growth of *Trichoderma* spp.

Desai *et al*. (2002) tested the efficacy of six commonly used fungicides, 12% carbendazim+63% mancozeb (campanion 75%), carbendazim (Bavistin 50 WP), carboxin (Vitavax 75 WP), 8% metalaxyl + 64% mancozeb (Matco 8-64 72 WP), mancozeb (indofil M-45 75 WP), mancozeb + thiophanate methyl and tricyclazole (Beam 75 WP). The per cent inhibition of hyphae and sporulation of *T. harzianum* in different test chemicals at 500 ppm ranged from 2.8 to 100 and 42.30 to 100% respectively. Similarly, the inhibition ranged at 1000 ppm was 4.49 to100 and 4.17 to 100% respectively. The stimulatory effect of MATCO on hyphal growth (2.80) and sporulation (42.30) at 500 ppm was recorded. Mancozeb at 500 ppm recorded a lower inhibition of hyphae (5.70%) and sporulation (11.02%).

Umamaheswari *et al*. (2002) tested the tolerance of eight *Trichoderma* isolates to six fungicides and reported that out of 8 isolates, isolate CIAH-225 and CIAH-240 could tolerate upto 500 ppm of copper oxychloride. Isolate CIAH-285, CIAH-151 and CIAH-149 were absolutely resistant at 250 ppm of this fungicide. In presence of mancozeb, isolate CIAH-175 showed better colonization with intensive synthesis of secondary metabolites even at 1000 ppm. This isolate was also resistant to metalaxyl + mancozeb (500 ppm). Isolate CIAH-186 showed excellent growth and conidiogenesis at 1000 ppm of wettable sulphur. This isolate was highly sensitive to thiophanate methyl. The sporulation of isolate CIAH-175 has been changed to yellow instead of green under the influence of metalaxyl + mancozeb and mancozeb.

Srinivasulu *et al*. (2002) reported *in vitro* efficacy of biological control agents (*T. viride*, *T. harzianum* and *T. hamatum*) against fungicides, 2% zinc sulfate, 1% Bordeaux mixture, 0.1% copper oxychloride, 0.1% bitertanol, 0.1% tridemorphs in controlling *Ganoderma lucidum* and *G. applanatum* and both causing basal stem rot in coconuts. All chemicals except zinc sulfate inhibited the growth of all *Trichoderma* spp.

Laboratory, pot and field experiments were conducted to evaluate the biological control of *Trichoderma harzianum*, *Gliocladium virens* and *Pseudomonas fluorescens* against *Fusarium oxysporum* f.sp. *lentis* infecting lentils and their compatibility with fungicides. Seed treatment with carbendazim + thiram and *Gliocladium virens* + *P. fluorescens* + carboxin were effective in the field in controlling 48.8 and 44.2% lentil wilt (De *et al*., 2003).

Narayana Bhat and Srivastava (2003) reported that mancozeb (indofil M-45) was fungistatic against *T. viride* at 500 ppm, whereas copper oxychloride (Blitox 50% WP) inhibited the growth of *Trichoderma* spp. at 1000 ppm and hexaconazole (contaf 5% E) is highly inhibitory to *Trichoderma* spp. even from 250 ppm concentration.

Girija and Umamaheswaran (2003) reported the compatibility of *T. virens* with carbendazim *in vitro* at three concentrations (100, 500 and 1000 ppm) concentrations and observed that the antagonist *T. virens* was compatible with carbendazim at 100 ppm concentration.

Haritha *et al*. (2003) studied that *in vitro* compatibility of fungicides with *Trichoderma* sp. reported that metalaxyl has inhibited the radial growth by 18.52 per cent over control even at 1000 ppm. Whereas, mancozeb and copper

oxychloride inhibited the radial growth of *Trichoderma* sp. by 76.66 and 44.44% at 1000 ppm and complete inhibition of growth at 100 ppm concentration of hexaconazole.

Arunasri (2003) reported that the *in vitro* compatibility of four fungicides tested on *Trichoderma* isolate-1 (T1) and *Pseudomonas* sp. (B1) at five concentrations viz., 50, 100, 250, 500 and 1000 ppm using poisoned food technique and inhibition zone technique. Thiram was found to be best compatible fungicide with both *Trichoderma* isolate-1 (T1) and *Pseudomonas* sp. (B1) as it inhibited growth to minimum extent of 31.39% of T1 and 2.22% of B1.

Desai *et al*. (2004) evaluated the thirteen agrochemicals involving six weedicides, five fungicides and two insecticides at 500, 1000 and 2000 ppm concentrations to assess their effect on native *Trichoderma harzianum* a biocontrol agent. All the tested agrochemicals were highly inhibitory to *T. harzianum*. Cent per cent inhibition of hypha was recorded in alachlor, carbendazim, Bavistin chlorpyriphos, glyphosate and thiram. Significantly lowest inhibition was recorded in acephate (8.45) followed by atrazine (27.50captan (32.45) and metalaxyl MZ (33.13) which differed significantly.

Durai (2004) evaluated two systemic and non-ystemic fungicides for their compatibility with *P .fluorescens*. Of the fungicides tested, thiram at 1000 ppm shown the highest inhibition (4.7%). Mancozeb was found tobe compatible with *P. fluorescens* (B1) even at 50 ppm concentration as the growth inhibition was nil, the inhibition was only 0.7 per cent even at 1000 ppm concentration.

2.7.2 Sensitivity of biocontrol agents against insecticides

Martinez Toledo *et al*. (1992) investigated the effects of two selected organophosphorus insecticides methyl pyrimfos and chlorpyrifos on soil microflora in an agricultural loam soil. The insecticides had concentrations of 10 to 300 $\mu g\ g^{-1}$. The presence of methyl pyrimfos at concentrations of 100 to 300 $\mu g\ g^{-1}$ or chlorpyriphos at concentrations from 10 to 300 $\mu g\ g^{-1}$ significantly decreased aerobic dinitrogen fixing bacteria and dinitrogen fixation. Nitrifying bacteria decreased at concentrations of 200 to 300 $\mu g\ g^{-1}$ of methyl pyrimfos. The presence of 10 to 300 $\mu g\ g^{-1}$ of chlorpyrifos decreased the total number of bacteria. However, fungal populations and denitrifying bacteria were not affected as a consequence of the addition of the organophosphorus insecticides to the agricultural soil, showing that these microorganisms can tolerate high amounts of these insecticides.

Jayaraj and Ramabhadran (1996) studied the effect of three commonly used soil insecticides viz., BHC, phorate and carbofuran meant for the control of soil borne pests for their *in vitro* influence on the growth, sporulation and cellulase production by *Trichoderma harzianum*, the insecticides were tested at 5, 10, 50, 100 and 500 concentrations. The biomass yield decreased with increase of concentration of chemicals. The minimum biomass production was noticed in phorate (75 mg) followed by BHC (90 mg) and carbofuran (100 mg) at 500 ppm. However, in the linear growth assay feeble growth (19 mm) was seen at 500 ppm in the case of BHC, whereas growth was almost nil in phorate and carbofuran at 500 ppm. The sporulation of *T. harzianum* was strikingly affected due to incorporation of insecticides. Sporulation was seen even upto 50 ppm concentration of all the chemicals. The production of cellulase was drastically affected by insecticides, the effect was up to 50 seen in the case of carbofuran followed by phorate and BHC.

Kumar (1998) reported significant reduction of radial growth and sporulation of *T. viride* when tested at 7000 ppm of imidacloprid.

Five different pesticides viz., phorate, carbofuran were evaluated against *Trichoderma harzianum, T. viride* and *Chaetomium globosum* by poisoned food technique *in vitro*. Carbofuran showed slight inhibitory effect on *T. harzianum* (37.82%), *T. viride* (5.20%) and *C. globosum* (1.22%) (Bhat *et al*., 2001).

Prasanna *et al*. (2002) studied the compatibility of thiomethoxam 70 WS on the growth and sporulation of *Trichoderma harzianum* and found that there was no inhibition of mycelial growth of *T. harzianum* in all concentrations tested except at 1.25 per cent. The spore count was 1 x 10^4 spores/ml at seven days after inoculation of *Trichoderma*.

Desai *et al*. (2002) reported the effects of acephate and chlorpyriphos on the growth and sporulation of native isolate of *T. viride*. Chlorpyriphos recorded cent per cent inhibition of both hypha and sporulation. Acephate recorded 10.26% and 17.72% inhibition of hypha and sporulation, respectively. Inhibition increased significantly with increase in concentration.

Tiwari *et al*. (2004) studied the non-target effect of 35 insecticides in the form of dust, granules, soluble powder, EC, SL, SC on the mycelial growth of *T. harzianum* at 500, 1000, 1500 and 2000 ppm concentrations. Among dust, granule and soluble form of insecticides, endosulfan (D), fenvalerate (D), carbaryl + lindane (G), cartap hydrochloride (SP) significantly inhibited the mycelial growth of *T. harzianum* of all concentrations. Whereas, chlorpyriphos (D),methyl parathion (D) and acephate (SP) are not inhibitory to *T. harzianum* and at par with control. Among EC formulations insecticides at all concentrations inhibited the mycelial

growth of the antagonist except dimethoate, ethyl demeton, malathion and indoxacarb.

2.7.3 Sensitivity of biocontrol agents against fertilizers

Jayaraj and Ramabhadran (1998) tested the seven nitrogenous salts, ammonium nitrate, calcium nitrate, sodium nitrate, potassium nitrate, ammonium sulphate, ammonium chloride and urea *in vitro* for their effect on growth, sporulation, production of cellulase and antifungal substances (AFS) by *Trichoderma harzianum*. It was reported that N sources at 0.2% level (w/v), ammonium nitrate recorded the maximum mycelial dry weight (500 mg), followed by sodium nitrate (450 mg) and ammonium sulphate (425 mg). Urea and calcium nitrate recorded the least growth, but maximum sporulation occurred in ammonium sulphate.

Desai and Srikant Kulkarni (2002) investigated that the urea, as a nitrogen source, was found to be lethal to native isolates of biocontrol agents *Trichoderma viride* and *T. harzianum*. Extent of inhibition over control of mycelium and sporulation of *T. viride* and *T. harzianum* ranged from 4.30 to 100; 9.68 to 100; and 4.52 to 100; 9.76 to 100 per cent, respectively. Cent per cent inhibition of growth and sporulation of all the two test fungi was recorded at 1000 ppm concentration. Regrowth study indicated fungistatic nature of urea.

2.7.4 Sensitivity of biocontrol agents with herbicides

T. harzianum was able to grow in the presence of the herbicide, diallate (Domsch *et al*., 1980), Sharma andMishra (1995) observed better tolerance of a strain of *T. harzianum* to 2,4-D as compared to fluchloralin and pendimethalin. The tolerance of *Trichoderma* to certain herbicides might be attributed to gradual

utilization of herbicides as a source of C or N by the organism. This has been observed in a strain of *Trichoderma viride* which grown on simazine and atrazine a sole C or N source (Domsch *et al*., 1980). Presence of proper enzyme system to disintegrate the toxic residue to basic non-toxic moieties.

Jayaraj and Radhakrishnan (2000) reported that the five herbicides, namely, alachlor, butachlor, 2,4-D, oxyfluorfen and pendimethalin were tested at 1, 5, 10 and 20 ppm concentrations for their *in vitro* influence on the growth, sporulation and cellulase production by *Trichoderma harzianum*. Among herbicides, alachlor was found to be relatively less toxic at lower concentrations. However, all the herbicides significantly reduced the sporulating and cellulase producing ability of the organism, especially at higher concentrations.

Jayaraj and Radhakrishnan (2000b) reported the effect of herbicides on survival of *T. harzianum* when applied to soil at 0, 1 and 3 ppm concentration. Pendimethalin application caused maximum reduction in growth and survival of *T. harzianum* when compared to alachlor.

Bhat *et al*. (2001) tested the effect of metribuzin against *Trichoderma harzianum, T. viride* and *Chaetomium globosum* by poisoned food technique. Herbicide metribuzin found to inhibit more mycelial growth of *T. harzianum* (87.32%) and *T. viride* (61.85%) and total inhibition of *C. globosum*.

Jaworska *et al*. (2002) reported that the effect of herbicides Afalon 45% SC (linuron), Pyramin Turbo 52% SC (chloridazon) and Stomp 33% EC (pendimethalin) on the growth and biological activity of *T. harzianum* and *T. viride*. Herein, pendimethalin strongly inhibited growth rate of tested fungi and *T. viride* was more sensitive to herbicides than *T. harzianum*.

2.8 EFFICACY OF AGROCHEMICALS AGAINST *PYTHIUM APHANIDERMATUM*

2.8.1 Fungicides

Gattani and Kaul (1951) reported that a combination of soil treatment with formaldehyde and seed treatment with ten per cent copper sulphate solution for one hour reduced the tomato damping-off incidence by 63 per cent.

In a study conducted for the control of damping-off chillies with seed dressing fungicides, Flit 406 (0.2%) gave best control while phygon (0.3%) and pura seed (0.2%) were found superior in controlling the disease (Dharam Vir and Grewal, 1961).

Govindappa and Grewal (1965) conducted experiments with fourteen seed dressing fungicides to reduce the incidence of pre-emergence damping-off in tomato. It was observed that the incidence could be reduced to 1.4, 7.1 and 7.9 per cent with Arasan (0.3%), Agrosan GN (0.3%) and Flit 406 (0.2%) respectively compared to 57.1 per cent in control.

Sahni *et al*. (1967) tested the relative efficacy of new proprietary fungicides against damping-off of chillies incited by *Pythium debaryanum*. Soil treatment with 0.2, 0.02 (solution) and 0.2 per cent suspension of Captan, Rhizoctol and Fytolon in water reduced post-emergence damping-off to an extent of 2.1, 4.6 and 9.8 per cent respectively as against 32.8 per cent in untreated control.

Elarosi *et al*. (1969) reported that seed dressing with 0.5 per cent Fernasan followed by 0.5 per cent captan 75 were the best in controlling damping-off in tomato. In further studies carried out, Michael *et al*. (1969) proved that seed

dressing with 0.5 per cent captan 75 and a soil drench with cuprosan (or) captan 50 at the rate of 0.3 g/ft^2 gave best results in controlling the disease.

Sonoda (1972) observed that tomato transplant damping-off was controlled by dipping the roots and stems of the transplants into a high concentration of Dfn. 4F (difoltan, 4 Flow) (0.5 lb a.i gal^{-1}) and a combination product of zinc and maneb before planting. Further, Sonoda (1976) reported that the seedling diseases incited by *Pythium myriotylum* and *P. aphanidermatum* could be controlled by incorporating fungicides into a planting mix. Truban (ETMT) at the rate of 4.9 g ha^{-1} for a 1200 hill ha^{-1} ground tomato crop gave excellent control.

Grover and Dutt (1972) reported that post-emergence damping off in tomato could be significantly reduced when untreated seeds were sown in fungus infested soil, drenched with 0.2 per cent of copper oxychloride, carboxin, oxycarboxin, Dithane M-45, Brassicol, Captan or Agrosan-GN.

Tripathi and Grover (1977) observed that concentrations of 0.3 per cent dichlozoline, S-7258 and captan were most effective in checking post-emergence damping-off tomato caused by *Pythium butleri* while captafol was best at 0.25 per cent and RH 893 at 75 μg ml^{-1} concentrations.

Nagarajan and Reddy (1980) indicated that the promising fungicide for the control of both damping-off and leaf blight of tobacco was metalaxyl (Ridomil 25 WP) @ 0.1, 0.2 and 0.3 per cent concentrations. Next best were Bordeaux mixture (0.4%), difolatan (0.2%) and fytolan (0.2%).

Sadhu and Gill (1982) tested the efficacy of captan, thiram, brassicol and bavistin in controlling damping-off of cauliflower both individually and in

combinations and noticed highest per cent germination and lowest seedling mortality with thiram seed treatment at 0.3 per cent.

Ohep *et al*. (1984) reported that incorporation of Etridiazole (Ethazol plus thiophanate methyl, 0.75g), fenaminosulf (0.5 g) and ethazol (0.5 g) in direct seeded tomatoes effectively controlled damping off caused by *Pythium aphanidermatum* whereas benomyl, chloroneb and captan were found ineffective in controlling the fungus.

In the *in vitro* studies, Jain *et al*. (1984) found that Ridomil (metalaxyl) completely inhibited the growth of *Pythium aphanidermatum* at 100 ppm.

Reddy and Nagarajan (1985) reported that three sprays of metalaxyl at 0.05 per cent, 0.1 per cent and 0.2 per cent concentration was the most effective in giving very high percentage control of the disease. Seed treatment with apron 35 SD or soil treatment with metalaxyl (ridomil 5 g) each followed by 2 sprays of metalaxyl (Ridomil 25 WP) @ 0.1 per cent also afforded good protection of the seedlings against the damping-off disease of tobacco.

The pre and post-emergence damping-off in cucumber could be effectively controlled through seed dressing with protective fungicides like captan at the rate of 5 g kg^{-1} seed and soil drenching with a combination of metalaxyl + zineb at 10 to 20 days after sowing (Deshpande and Bochow, 1986).

According to Patel *et al*. (1987) soil drench with metalaxyl (1.0 kg ha^{-1}) was as effective as Bordeaux mixture (6:3:100) @ in controlling *Pythium aphanidermatum* the causal agent of damping-off disease in tobacco nursery.

In combination, Patel *et al*. (1988) reported the efficacy of metalaxyl + ziram, when applied as soil drench at the rate of 5.6 lit ha^{-1} in controlling tobacco damping-off (C.0 *Pythium aphanidermatum*) when Ridomil (Metalaxyl), Vitavax (carboxin), Thiram and Homai (thiophanate methyl + thiram) were used as seed treatments and soil drenches.

In continuation, Patel *et al*. (1988) reported the efficacy of metalaxyl (700 g ha^{-1}) + ziram (1:6) when applied as soil drench at the rate of 5.6 l ha^{-1} in controlling tobacco damping-off as effectively as Bordeaux mixture (0.6%) besides improving the number of transplantable tobacco seedlings.

The effectiveness of metalaxyl in selectively inhibiting tomato damping-off agent *Pythium aphanidermatum* when metalaxyl (Ridomil), vitavax (carboxin), thiram and homai (thiophanate methyl + thiram) were used as seed treatments and soil drenches was proved by Taha *et al*. (1988).

Further studies carried out by Dharam Vir *et al*. (1989) proved that individual applications of 2-methoxy ethyl mercuric chloride (Emisan) at the rate of 1 g kg^{-1} seed or in combination with copper oxychloride (Blitox-50) at the rate of 1 + 1 g kg^{-1} seed were found to be best when Difolatan, Emisan, Blitox-50, topsin-m and their combinations were tested as seed treatments for the control of damping-off of tomatoes and chilli caused by *Pythium aphanidermatum, Rhizoctonia bataticola* and *Fusarium* sp.

Kassim *et al*. (1989) studied the effect of different concentrations of sodium chloride against damping-off agents of tomato (*Rhizoctonia solani, Fusarium solani* and *Pythium aphanidermatum*) and concluded that all salt levels showed increased infection of tomatoes in field soil.

Schulties (1989) reported that Nu-Flew AD, a combination of metalaxyl and chloroneb when used as seed treatment effectively controlled *Pythium ultimum* and *Rhizoctonia solani* respectively in cotton.

The efficacy of propamocarb-HCl in controlling *Pythium ultimum* in tomato and pepper besides improving plant growth and yield was reported by Wilde *et al*. (1989).

Chahal *et al.* (1990) determined the action of fosetyl-Al against *Pythium aphanidermatum* the causal agent of tomato damping-off and concluded that the fungicide has a very weak direct action but acts through the host by stimulating it's defense mechanism.

Wolf *et al*. (1990) developed a new screening and evaluating method for fungicides against *Pythium* sp. by treating their concentrations in an ascending series on an extra thick filter paper drenched with *Pythium* spore suspension and proved the efficacy of fosetyl-Al with low *in vitro* antifungal activity and high plant protective activity.

Shenoi and Abdul Wajid (1992) suggested two alternative schedules of metalaxyl (Ridomil MZ 72 WP) for overall management of three diseases viz., damping-off, blight and black shank in tobacco nurseries, i.e., first, by pre-sowing drench of fungicide to the soil @ 0.1 per cent concentration followed by foliar spray @ 0.2 per cent concentration at 30- DAS and second by only foliar sprays commencing early at 20 DAS, to be followed at 35 DAS and at 50 DAS if required @ 0.2 per cent concentration.

For the management of root knot nematodes and damping-off disease in tomato nursery, Gunasekharan *et al*. (1994) suggested that copper oxychloride 0.3

per cent drench and in combination with insecticides like carbofuran or fenamiphos or phorate at the rate of 1 kg a.i. ha^{-1} was effective against *Pythium* spp. and *Meloidogyne incognita* in tomato cultivar PKM1.

Chemical control of *Pythium aphanidermatum* (Edson.) Fitz – *Meloidogyne incognita* (Chitwood, 1949) disease complex in chilli (*Capsicum annum* L.) and brinjal (*Solanum melongena* L.) was evaluated in field. Seed treatment with Diafuran 3 G + Ridomil MZ-72 reduced pre-emergence damping-off 16.51 per cent, post-emergence damping-off 17.47 per cent significantly (Karthikeyan *et al*., 2000).

Twelve fungicides were screened against *Pythium aphanidermatum* pathogen causing seedling mortality of okra, in the laboratory. In case of *Pythium aphanidermatum*, the ED50 values of metalaxyl (10.48 μg ml^{-1}), captaf (17.78 μg ml^{-1}), carboxin and iprodione (25.12 μg ml^{-1}) were also on lower side, thus found to be effective. However, carbendazim, thiophanate methyl and ziram were not found very effective as they recorded high ED50 values of more than 149 μg ml^{-1} (Anitha *et al*., 2001).

Haritha (2003) screened five fungicides tested mancozeb, copper oxychloride, metalaxyl, chlorothalonil and hexaconazole using poisoned food technique against *P. aphanidermatum* and reported that Metalaxyl shown more per cent inhibition over control from 50 ppm onwards, whereas mancozeb and hexaconazole at 500 and 1000 ppm concentrations and COC complete inhibition from 250 ppm concentrations.

Insecticides

No information is available on *in vitro* and *in vivo* efficacy of insecticides against *Pythium* spp.

Fertilizers

No information is available on *in vitro* and *in vivo* efficacy of fertilizers against *Pythium* spp.

Herbicides

Wilfest and Weltzein (1980) reported a strong fungitoxic effect of chloridazon (Pyramin), diallate (Avadex), metaitron (Goltix) and phermidephan (Benetal) against *Pythium debaryanum* at the recommended concentration at 1/10 and 1/1000 dilutions.

2.9 EFFECT OF AGROCHEMICALS AGAINST *M. PHASEOLINA*

2.9.1 Fungicides

The growth of *M. phaseolina* incitant of charcoal rot of soybean was significantly less than control on PDA containing 5, 10 and 50 ppm of systemic fungicides BD18654 and thiophanate methyl (Kirckpatrick and Sinclair, 1973).

Shukla and Singh (1973) evaluated different fungicides to check root rot of sesame caused by *M. phaseolina*. Captan treated seeds showed less mortality of plants and gave the highest yields, followed by Dithane C90, Agrosan GN and thiram. Disease incidence was high in PCNB treated plot.

Ilyas *et al*. (1975) reported that mycelium of *M. phaseolina* the causal agent of charcoal rot of soybean was most sensitive to and equally inhibited by three benzimidazole fungicides viz., benomyl, thiabendazole and thiophanate-methyl,

intermediately sensitive to PCNB, carboxin and thiram and least sensitive to triforine, captan and ETMT under *in vitro* conditions.

Tripathi *et al*. (1977) screened systemic and non-systemic fungicides against *R. bataticola* in field. Among these, carbendazim, captan, captafol, quintozene and Agrosan GN, captafol gave maximum control of disease followed by thiram and captan. However, yield was maximum in quintozene and carbendazim treated plots.

Gupta and Bharadwaj (1980) used poisoned food technique to observe the inhibitory effect of various fungicides on radial growth of *R. bataticola*. Linear growth of fungus was minimum with benomyl and Dithane M-45 at 100 ppm concentration.

Chattopadhyay *et al*. (1981) studied seed mycoflora of six varieties of jute and found highest infestation of *M. pahseolina*, the incitant of seedling blight and stem rot in the variety JRC-321. Highest control was obtained when seeds were treated with 2.8 g carbendazim, 5.0 g dichloran + captan mixture per kg of seed.

Five formulations of four benzimidazole derived fungicides viz., carbendazim, benomyl, thiophanate methyl were compared for their toxicity towards two pathogenic isolates of *R. solani* and *R. bataticola* causing root rot of cowpea and sesamum, respectively, benomyl and carbendazim are inhibitory both the fungi (Taneja and Grover, 1982).

Anahosur *et al*. (1983) evaluated brassicol against *M. phaseolina* causing charcoal rot of sorghum under laboratory conditions and found that complete inhibition was not obtained even at 5000 ppm. However, it was toxic to some extent at 500 to 5000 ppm on PDA.

Chauhan (1986) compared efficacy of different fungicides for the control of seedling diseases of cotton due to *Rhizoctonia* sp. Maximum seed germination was observed in seeds treated with carbendazim followed by quintozene, seeds treated with fungicides gave better yield of seed cotton than control.

Benlate, Bavistin and Topsin M-70 gave 100 per cent growth inhibition of *M. phaseolina* at 250 and 500 ppm (Jadeja and Patel, 1988). Complete growth inhibition of *M. phaseolina* was obtained with benomyl while copper oxychloride gave minimum growth inhibition (Patel and Patel, 1990).

Patel and Patel (1990) tested different fungicides *in vitro* against *M. phaseolina* of sesamum among which benomyl, thiram and carbendazim were found at par and were significantly superior to the rest of the fungicides. Complete growth inhibition was obtained with benomyl at 0.05% concentration.

Peshney *et al.* (1992) studied the effect of fungicides viz., thiram, captan, PCNB, mancozeb, iprodione, carboxin, carbendazim, thiabendazole and tridemorph on the growth of *R. bataticola* causing charcoal rot of sorghum. The fungus was found to be highly sensitive to carbendazim and thiabendazole even at 0.006% concentration.

Singh and Kaiser (1995) evaluated some systemic and non-systemic fungicides *in vitro* against the charcoal rot pathogen of maize. Complete inhibition of growth of the pathogen was observed at a very low concentration of 30 ppm with carbendazim followed by mopsin (40 ppm), agrizin (100 ppm), rhizolex (120 ppm), derosal (200 ppm), foltaf (500 ppm), captaf (600 ppm) and thiram (1000 ppm).

Pushpavathi *et al*. (1998) reported that the efficacy of the non-systemic and systemic fungicides. For non-fungicides tested, 100% inhibition was observed at 500 ppm in copper oxychloride and at 1000 ppm in cheshnut compound whereas mancozeb failed to give 100% inhibition even at 1500 ppm. Among systemic fungicides tested 100% inhibition was observed at 50 ppm in hexaconazole, at 100 ppm in propiconzole and 500 ppm in carbendazim. The overall per cent reduction in colony diameter of the fungus was maximum in hexaconazole (93.10) followed by propiconazole (90.00).

Complete inhibition of *Rhizoctonia solani* was observed with Rhizolex at a concentration of 1 ppm and thiophanate methyl at a concentration of 20 ppm (Sharma and Rai, 1999).

The effect of six fungicides on the growth of *M. phaseolina* causing root rot disease in greengram was studied *in vitro*. Carbendazim (0.1%) completely inhibited the mycelial growth of the pathogen. The fungicides copper oxychloride (0.25%), thiram (0.1%), thiophanate methyl (0.1%), captan (0.1%) and methoxy ethyl mercuric chloride (0.05%) also suppressed the pathogen by 95.89, 91.11, 89.67, 78.56 and 77.44 per cent respectively (Ebenezar and Wesely, 2000).

Sharma and Tripathi (2001) reported that the efficacy of opus [cis-1-3-(2-chlorophenyl) 2-(4-fluorophenyl) oxiranyl) methyl]-1 H-1,2,4 – triazole] (0.1%), carbendazim (0.2%), propiconzole (0.1%), hexaconazole (0.1%), propineb (0.25%), mancozeb + thiophanate methyl (0.25%) against *M. phaseolina*. Seed treatment and two foliar sprays of propiconazole at 15 day interval resulted in the highest reduction in disease severity (30-32%) grain yield (950 – 1012 kg ha^{-1}) and 1000 grain weight (35 g).

Seed plus soil application of thiophanate methyl resulted in less disease incidence (12.2%) as compared to soil treatment (16.5%) or seed treatment (26.2%) alone in management of the sunflower wilt disease caused by *M. phaseolina* in pot culture (Padmalatha, 2002).

Anitha *et al*. (2001) screened against *Rhizoctonia solani* pathogen causing seedling mortality of okra in the laboratory. Of these, Carbendazim and captaf were highly effective against *R. solani* as their ED50 values were in a lower range of 31.62 to 39.81 μg ml^{-1}. On the other hand, mancozeb, ziram and copper oxychloride were least effective as their ED50 values were more than 100 μg ml^{-1}.

Desai and Srikant Kulkarni (2002) reported that the urea, as nitrogen source, was found to be lethal to test pathogen *Macrophomina phaseolina*. Extent of inhibition over control of mycelium and sporulation of *M. phaseolina* ranged from 4.24 to 100 and 12.00 to 100 per cent, respectively. Cent per cent inhibition of growth and sporulation of test fungi was recorded at 1000 ppm concentration.

The results from *in vitro* studies of Padmalatha (2002) on evaluation of four fungicides viz., thiophanate methyl, propiconazole, mancozeb and captafol at 75, 100, 250 and 500 ppm concentrations revealed that thiophanate methyl was found to be superior in suppressing the growth of *M. phaseolina* at all the concentrations trial followed by propiconazole .

Chattopadyay and Kalpana Sastry (2002) reported that carbendazim could cause 100% inhibition of mycelial growth of *M. phaseolina* evenat 25 ppm concentration in *in vitro* tests in plates.

Soil treatment with mixture of Demosan (6 kg ha^{-1}) + Brassicol (6 kg ha^{-1}) proved most effective against charcoal rot of cotton caused by *Rhizoctonia*

bataticola and soil application of the chemicals proved better as compared to seed treatment (Sharma and Sharma, 1976). Fungicides Topsin-M, Benlate, Brassicol, Demosan and Difolatan were the most promising fungicides for the control of root and stem rot of *Brassica juncea* caused by *Macrophomina phaseolina* (Rai and Srivastava, 1977).

Seed treatments with benlate at the rate of 0.3 per cent by weight was found most effective against seed borne infection of *Macrophomina phaseolina* in sunflower compared to hot water treatment at 52°C and 55°C for 10 min (Raut and Bhombe, 1983). In cowpea seed treatment with thiophanate methyl each at 0.1 per cent gave good disease control even at higher inoculum levels of *Rhizoctonia bataticola* (Gangopadyay and Grover, 1984).

In cotton seedling infection was minimum in benomyl, thiram and PCNB treated soils and maximum in vitavax treated soils. The soil was drenched with the fungicides at the rate of 100 μg g^{-1} soil. The soil was drenched with the fungicides at the rate of 100 μg g^{-1} soil (Dwivedi and Chaube, 1985). In sorghum population of *M. phaseolina* was reduced in soils treated with carbendazim (0.15%), mancozeb (0.2%) and PCB (0.2%) (Dwivedi and Dubey, 1987).

The mycelial growth of *R.* solani was inhibited by Bavistin (carbendazim 50% WP), Benlate (benomyl 50% WP) and Moncern (penoguran) at 10 ppm. In infested sand. the population density of the pathogen was decreased by treatment with Basamid (dazomit) and calcium cyanamide at concentration > 74 mg kg^{-1} and > 370 mg kg^{-1} respectively (Wu *et al*., 1990).

Gupta (1995) evaluated twenty fungicides including two seed treatments, six sprays and twelve combinations against stem blight of cowpea

caused by *M. phaseolina*. Seed treatment with carbendazim + thiram followed by one spray of mancozeb was found economical and superior in controlling the disease.

Seed treatment with bavistin (2 g kg^{-1} of seed) significantly reduced the severity of web blight of French bean caused by *Rhizoctonia solani* and soil drenching with bavistin also provided excellent control of the disease (Abraham Mathew and Gupta, 1996).

Mishra (1997) conducted a field trial using Topsin-M, kavach, bavistin and Dithane M-45 as seed dresser for control of stem and root rot of jute. The test revealed that seed treatment with Topsin-M @ 2 g kg^{-1} of seed significantly controlled by *M. phaseolina* over control.

Rajpurohit (1997) evaluated eight fungicides against stem and root rot of sesame caused by *M. phaseolina*. Seed treatment with carbendazim, carboxin, captan and thiram were found effective in reducing the disease.

Thiophanate methyl in combination with dichloromethane as solvent was found to be efficient than dry seed treatment with thiophanate methyl alone in controlling the charcoal rot disease which may be due to more infusion of fungicide into the seed followed by higher inoculation (Srinivasa Prasad, 1999).

2.9.2 Insecticides

No information available against *M.phaseolina* under *in vitro* and *in vivo*.

2.9.3 Fertilizers

Chattoopadhyay and Bineeta Sen (1996) reported that *Aspergillus niger* isolate A27 and *Trichoderma viride* isolate T4 were antagonistic to *Fusarium*

oxysporum causing wilt in muskmelon (*Cucumis melo*). Soil application of potash [KCl (SO)] caused maximum disease reduction (PDR) while seed treatment (s) with *A. niger* [A27 (S)] caused maximum reduction of pathogen population in rhizosphere soil. The biocontrol agents A27-1 and T4-1 (both bavistin tolerant strains) and carbendazim (bavistin) 0.1% were used as seed treatments for integration with KCl (30) 186.7 kg KCl ha^{-1} and soil amendment with sawdust (w/w) 7%. Both in pot and field experiments, T4-1 (S) + Bavistin + KCl (SO) was the most effective in reducing muskmelon wilt, where the PDR was 74.14.

Desai and Srikant Kulkarni (2002) evaluated the effect of urea on the growth and sporulation of *Macrophomina phaseolina* (Tassi) Goid and native isolate of *Trichoderma viride* and *T. harzianum*. Mycelial and sclerotial inhibition of *M. phaseolina* ranged from 4.24 to 100 and 12.00 to 100 per cent. Cent per cent inhibition of growth and sporulation of all the three test fungi was recorded at 1000 ppm concentration.

2.9.4 Herbicides

Anahosur *et al*. (1984) reported that the Ametoyne was the best herbicide which inhibited the growth compared to remaining four herbicides: the inhibition was maximum (60.15%) at 200 ppm and minimum (25.80%) at 250 ppm. Terbutryne, Prometryne, 2,4-D and Atrazine were completely ineffective in inhibiting the growth.

Vyas *et al*. (1986) studied efficacy of ten herbicides *in vitro* against *M. phaseolina* and reported the reduction of mycelial growth of the pathogen at 50, 100 and 500 mg/ml concentration of the herbicides. Field application of the herbicides, pre and post emergence and also reduced disease severity.

Jadeja (2003) screened nine weedicides against damping-off, leaf blight, stem canker, collar rot and fruit rot pathogens in brinjal. All the weedicides were screened at 250 ppm, 500 ppm and 1000 ppm concentrations. The weedicides viz., oxadiazon (Ronstar 25% EC), oxyfluorfen (Goal 23.6% EC), alachlor (Lasso 50% EC), fluazifop-p butyl (Fusilade 12.5% EC), butachlor (Narmadachlor 50% EC), fluchloralin (Basalin 45% EC), glyphosate (Glycel 41% SL), pendimethalin (Stomp 30% EC), paraquat (Gramaxone 24% SL). Maximum mean radial growth inhibition of 92.22 per cent was observed in oxadiazon. It was followed by oxyfloourfen and alachlor with 88.52 and 82.59 per cent mean inhibition, respectively.

2.10 EFFICACY OF AGRO CHEMICALS AGAINST *S. ROLFSII*

2.10.1 Fungicides

Subramanian (1964) screened certain fungicides *in vitro* for their efficacy against groundnut isolate of *S. rolfsii* by employing poisoned food and soil vial technique. Fungicides such as ceresan wet (100 and 1000 ppm) cheshnut compound (100 and 1000 ppm), and PCNB (100 and 1000 ppm) were found to be fungitoxic when tested by poisoned food technique. The study in soil vials revealed that ceresan in 100 and 1000 ppm concentration has good fungicidal effect.

Agnihotri *et al*. (1975) in *in vitro* tests showed that Demosan, Vitavax and PCNB (quintozene) in lower concentrations were more effective in restricting growth of *S. rolfsii*, which causes root rot of sugarbeet, than captan, thiram (or) benlate. Sclerotia were more resistant to fungicides than the mycelium. In soil vitavax produced a fungicidal effect while quintozene was fungistatic, the

latter, when applied (20 kg ha^{-1}) in the field before appearance of the disease, gave effective control.

Sharma *et al*. (1976) reported that sodium amactine completely inhibited the growth of *S. rolfsii* in culture at 10 ppm, mebenil and vitavax at 20 ppm. These chemicals were also effective in protecting maize seed against seed and soil borne inoculum of *S. rolfsii*.

Srikanth Kulkarni *et al*. (1986) tested 19 fungicides against *S. rolfsii in vitro*. Among these fungicides, vitavax (carboxin) performed best and completely inhibited growth of the pathogen at 50 ppm followed by Bayleton and Benodonil.

Singh and Dwivedi (1987) reported that streptopencillin, mycostatin and griseofulvin inhibited radial growth, sclerotial viability and dry weight of *S. rolfsii*. Salicylic acid, picric acid and 2,4-dinitrophenol reduced radial growth by upto 90 per cent. Mycelial dry weight and viability of sclerotia were significantly reduced with most of the phenolic compounds tested.

Singh and Dwivedi (1988) reported that, among 27 pesticides (14 fungicides, 7 herbicides and 6 isnecticides) tested against *S. rolfsii in vitro* the most promising results were obtained with Agrosan GN (phenyl mercury acetate + ethyl mercury chloride), MEMC (2-methoxy ethyl mercury chloride), Brassicol (quintozene), chloroneb, nitrogen, atrazine, BHC, lindane and nuvacron (monocrotophos). None of the compounds was fungicidal to the sclerotia of the pathogen.

Sahid *et al*. (1990) conducted *in vitro* tests with ten fungicides and reported that captan and ridomil were the most effective in inhibiting mycelial growth and sclerotial production of *S. rolfsii* which causes collar rot of lentil.

Kamnna *et al*. (1992) conducted i*n vitro* tests with certain fungicides and reported that tradimefon (Bayleton 25 WP) and chlorothalonil (Kavach 75 WP) were the most effective, followed by captafol (Foltaf 80 WP) in inhibiting the mycelial growth of *S. rolfsii* (Soft rot of coffee). Carbendazim and Bordeaux mixture were the least effective fungicides.

Narain and Kar (1990) reported that thiram (0.3%) and bavistin (0.15%) completely checked the mycelial growth of *S. rolfsii* in poisoned food technique studies.

Tiwari (1995) tested three systemic fungicides against *S. rolfsii* by *in vitro* method and reported that Contaf (hexaconazole) was found highly effective in reducing the infestation on sorghum grains and sclerotial germination. Effectiveness of contaf was followed by Bavistin and Topsin M.

Anitha Chowdary (1997) reported that in *in vitro* studies, complete inhibition of the growth bell pepper isolate of *S. rolfsii* was observed with 50, 100 and 250 ppm concentrations of Contaf (hexaconazole), 100 and 250 ppm concentrations of Bayleton (tridimefon) and 250 ppm concentration of Tilt (propiconazole) indicating that the Contaf gave good performance even at comparatively low concentration (50 ppm) followed by Bayleton (100 ppm).

Girija Ganeshan (1997) screened eleven fungicides *in vitro* against *S. rolfsii*, the causal agent of basal rot of cluster bean. Of these, Brassicol (0.2%), Dithane M-45 (0.1%), Foltaf (0.2%) and Thirate (0.2%) were effective in completely inhibiting the fungal growth.

Das and Panda (1997) evaluated *in vitro* efficacy of six fungicides viz., propiconazole, epoxiconazole, copper oxychloride, tridemorph, mancozeb and

carbendazim, against tuberose isolate of *S. rolfsii* and reported complete inhibition of mycelial growth with propiconazole at 110 μg ml^{-1}.

Johnson and Subramanyam (2000) studied *in vitro* efficacy of hexaconazole, penconazole, propiconazole, tricyclazole, mancozeb, carbendazim, chlorothalonil and copper oxychloride against groundnut isolate of *S. rolfsii* and observed complete inhibition of radial growth of the pathogen with hexaconazole and penconazole.

Mukherjee and Tripathi (2001) evaluated carbendazim, epoxiconazole, propiconazole, propineb, cyproconazole, hexaconazole, carboxin and mancozeb + thiophanate methyl, fungicides *in vitro* against *S. rolfsii*. And reported that propiconazole was found effective even at 50 μg ml^{-1}.

Rajev Pant and Mukhopadhyay (2001) reported that thiram at 75 μg a.i. ml^{-1} inhibited 78 per cent growth soybean of *S. rolfsii* .

Patibanda *et al*. (2002) reported that thiram had inhibited 27.77 and 66.66 per cent growth of *S. rolfsii* of groundnut at 50 and 100 μg ml^{-1} concentrations, respectively in *in vitro* studies.

Pranab Dutta and Das (2002) studied *in vitro* efficacy of thiram and mancozeb at 0.1 per cent concentration against tomato isolate of *S. rolfsii* and reported that thiram had inhibited 70.3 per cent of mycelial growth and 96.5 per cent of sclerotial production of *S. rolfsii*.

Narayana Bhat and Srivastava (2003) evaluated *in vitro* efficacy of captan thiophanate methyl and propiconazole at 25, 500 and 1000 ppm concentrations against *S. rolfsii* and found that propiconazole was effective even at 250 ppm concentration against *S. rolfsii*.

Thakur *et al*. (2002) evaluated the effect of six fungicides viz., bavistin, thiram, benomyl, captan, prochloraz and mancozeb on growth of *S. rolfsii*. Among the fungicides, bavistin, followed by benomyl and captan were significantly superior to rest of the fungicides by reducing growth of *S. rolfsii* to 1.09 from 8.60 in control when the concentration of fungicide was increased for 0.1 per cent to 0.3 per cent a gradual decrease was seen in the growth of *S. rolfsii*.

Bhoraniya *et al.* (2002) reported the inhibition of sclerotial germination of *S.rolfsii* by different pesticides viz., metalachlor, fluchloraline, alachlor, pendimethalin, 2,4-D sodium salt, mancozeb, captan, copper oxychloride, tridemorph, and carboxin, through soil plate technique. The effectiveness of carboxin (98.99%), followed by tridemorph (97.89%) and fluchloralin (94.02%) however, they were statistically at par (P=0.05), metalachlor, was also found effective in inhibiting the sclerotial germination (62.78%).

In vitro efficacy of four fungicides viz., Captan (Captaf 50 WP), propiconazole (Tilt 25 EC), thiophanate-methyl (Roko 70 WP) and thiram (Tagthiram 75 SD) was evaluated against *S. rolfsii* using poisoned food technique at five concentrations viz., 50, 100, 250, 500 and 1000 ppm. Propiconazole was found to be effective as it completely inhibited both mycelial growth and sclerotial population in crossandra (Arunasri, 2003).

In vivo

Many chemicals have been evaluated under field conditions by different methods like seed treatment, soil drenching, soil fumigation etc., for the control of diseases caused by *S. rolfsii* in different crops.

Many tests in the past indicated that *S. rolfsii* can be controlled by soil fumigation. Soil fumigation tests with chloropicrin (Davey and Leach, 1941; Godfrey and Young, 1943; McClellan *et al*., 1947; Abeygunawardena and Wood, 1957), methyl bromide (Godfrey and Young, 1943) and formaldehyde (Davey and Leach, 1941) have been recommended as control measures for *S. rolfsii*. A soil fumigant chlorobromopropene, has reduced losses from *S. rolfsii* in tomatoes (Abeygunawardena and Wood, 1957).

Soil drenching with ceresan wet (0.1%) proved to be most effective against wilt of chilli (Ramakrishnan and Damodaran, 1955) and sclerotial root rot of groundnut (Subramanian, 1964) caused by *S. rolfsii*.

Kandaswamy and Sundaram (1956) reported that drenching the soil with leytosol 0.5 per cent was the most efficient method of checking the wilt of chilli, caused by *S. rolfsii* and this was followed by ceresan wet (0.1%), Bordeaux mixture (0.1%) and cheshnut compound (10.02 in 2 gallons of water).

Soil application of PCNB (quintozene) has been found to be useful on a number of crops for the control of *S. rolfsii* (Ayecock, 1966; Thompson, 1978; Csinos, 1984; Hegan *et al*., 1986 and 1988; Jackson and Domicone, 1991).

Mukhopadhyay and Thakur (1971) evaluated two systemic fungicides in the glasshouse and field conditions for the control of sugarbeet root rot caused by *S. rolfsii*. Greenhosue studies using soil treated with carboxin and chloroneb at five concentrations (100, 300, 600, 900 and 1200 ppm) showed systemic protection of seedlings against infection by *S. rolfsii* for 20 days. Protection tended to increase with increase in fungicide concentration. Field studies demonstrated that soil drenching with carboxin and chloroneb at 2 and 15 kg / 300 litres, respectively, reduced the disease and increased the yield.

Khare *et al*. (1974) reported that Captan, Thiram, and Rhizoctol were better than other fungicides tested *in vivo* in reducing pre- and post-mergence mortality of lentil due to *S. rolfsii*.

Anilkumar *et al*. (1979) reported that Sicarol (phyracarbolid), Vitavax (carboxin) and Brestan (fentin acetate), when mixed dry with the soil were highly effective in killing buried sclerotia. As a soil drench Brestan was the most effective and persisted layer in the soil than any other fungicide.

Kulkarni (1980) reported that, in field trials *S. rolfsii* was controlled effectively by seed treatment with Panoram, Brassicol (quintozene), Panoctive-35 (quazatine) Vitavax (carboxin) and Plantavax (oxycarboxin), Bayleton (triadimefon), Bavistin (carbendazim), RH-124 and Calixin (tridemorph) were less effective. Seed treatment with 0.2 per cent of these chemicals protects wheat seedlings upto 35 days even in heavily infested soil.

Siddaramaiah and desai (1980) tested nine fungicides against *S. rolfsii* on flax by soil drenching and seed dressing. Maximum protection was obtained with soil drenches of Panoctine (quazatine), Captan and Brassicol (quintozene), while seedling stand and vigour was good with panoctine and Brassicol, Thiram, Brassicol and Panoctine gave good control by either method.

Soil drenching with Brassicol (0.3%), Vitavax (0.2%) and Rovral (0.4%) were found to be effective in checking pre- and post-emergence mortality of groundnut caused by *S. rolfsii* (Dhamnikar and Peshney, 1982).

Patil and Rane (1982) reported that soil drenching with Vitavax (0.2%), Brassicol (0.5%), and ceresan wet (0.2%) were effective in reducing the incidence of wilt on groundnut caused by *S. rolfsii* by 84, 80 and 76 per cent, respectively.

Punja *et al*. (1982) reported that, eruptive and hyphal germination of dried sclerotia *in vitro* were totally inhibited by Carboxin, Cycloheximide, Oxycarboxin and CGA 64251 (etaconazole) at 100 and 200 μg a.i. ml^{-1}. Other chemicals reduced germination and some had no effect. DCNA (dicloran) + Cycloheximide, Captan, Carboxin, PCNB (quintozene) + fertilizer, ammonium carbonate and ammonium sulphate controlled the fungus under natural conditions when applied at 14-day intervals over 3-5 months. Fungicides and N compounds such as ammonium carbonate may control the disease when used separately (or) combined.

Sivaprakasam and Kandaswamy (1983) screened two fungicides under *in vivo* conditions and reported that the drenching of soil around the plants with Vitavax 50 ppm and 20 ppm and Plantavax 50 ppm were effective in the control of collar rot of sweet potato, the mean per cent mortality being 25, 50 and 33.3, respectively.

Of eight fungicides viz., Baycor, Bayleton, Brestan, Captan, Indofil M-45, Sicarol, Thiram and Vitavax tested for their efficacy against *S. rolfsii* precolonized on straw pieces at four concentrations (10, 25, 50 and 100 ppm), Bayleton, Sicarol, and Vitavax were highly effective in killing the fungus in the precolonized tissue both as dry soil mix and soil drench at all the concentrations (Anilkumar and Panduranga Gowda, 1984).

Palakshappa *et al*. (1986) reported that soil drenching with Vitavax, Baytan, Agallol, Panolil and Brassicol were effective in controlling the foot rot of betelvine caused by *S. rolfsii*.

Palvi and Raut (1987) evaluated, six fungicides *in vitro* and reported that, Vitavax (carboxin), Hexathio (thiram), Hexocap (captan) and Emisan-6 gave effective control of *S. rolfsii* in pot experiments when used as seed dressings.

Brown *et al*. (1988) reported that stem rot disease of groundnut caused by *S. rolfsii* was controlled by the application of Propiconazole (Tilt) and Hexaconazole (contaf).

Several soil fumigants, such as Methyl bromide and Chloropicrin have been reported to be effective against stem rot of groundnut caused by *S. rolfsii* (Chang *et al*., 1989).

Sahid *et al*. (1990) tested ten fungicides *in vivo* and reported that Captan and Metalaxyl (Ridomil) were the most effective in inhibiting mycelial growth and sclerotial production of *S. rolfsii*. Germination of sclerotia was checked most effectively by Benlate (benomyl) and metalaxyl. Metalaxyl and benomyl at 500 ppm applied as seed treatment and soil drench respectively, gave 100% control of collar rot on lentil seedlings.

Sharma *et al*. (1990) obtained good control of root rot disease of sugarbeet by soil drenching with Brassicol (0.5%) and Demosan (0.1%) at the rate of 4 litres per plot (4 x 2.5 m) when the crop was 100 days old and also proved most effective in increasing the yield.

Several recently introduced triazole fungicides offer a greater level of control of stem rot of groundnut caused by *S. rolfsii* (Brennemann *et al*., 1991), if the triazole fungicides efficacy of diniconazole (spotters) and tebuconazole (folicur) has been confirmed in various field trials (Csinos*et al*., 1987; Csinos, 1989; Rudalph *et al*., 1989; Summer and Littrel, 1989; Hagan *et al*., 1991; Summer, 1991).

Application of cyproconazole (SAN 619) and tebuconazole (folicur) were found to reduce the disease and increased the yield (Culbreath *et al*., 1992). Propiconazole (Tilt) and hexaconazole (contaf) have also been reported to reduce the stem rot disease of groundnut (Brown *et al*., 1988).

Kadir and Daradjat (1991) tested the efficacy of five fungicides against sclerotial wilt of wheat caused by *S. rolfsii* under field conditions in dry season. Of these fungicides, propiconazole was found to be highly efficient in reducing the disease to an extent of 90.6 to 100 per cent.

Adiver and Anahosur (1995) obtained effective control of stem rot of groundnut caused by *S. rolfsii* with tebuconazole and cycproconazole to an extent of 64.1 and 47.7 per cent, respectively. However, propiconazole showed lesser degree of inhibition (25.8%).

Madhumeeta *et al*. (1995) reported that, tests with 7 fungicides, Folicur (tebuconazole) was most effective in preventing germination of soaked sclerotia of *S. rolfsii*. None of the sclerotia germinated following immersion in 0.01 per cent tebuconazole for 2 hours. In pot tests, inoculated plants wilted within 7 days but 100 per cent survival was obtained when plants were drenched with 0.01% tebuconazole after inoculation.

Tiwari (1995) tested three systemic fungicides (Contaf, Bavistin and Topsin-M) against *S. rolfsii* which causes root rot in gram and sunflower. They reported that all the three fungicides significantly reduced the disease. However, Contaf was most effective. In Contaf treated plots the seedling mortality was 14.1 per cent, compared with 44.97 per cent Bavistin, 49.12 per cent Topsin-M and 52.05 per cent in check. Number of sclerotia were 8-18 times less in contaf treated plots.

Anitha Chowdary (1997) reported that, soil drenching with hexaconazole (0.1%) was found highly significant in controlling the sclerotial wilt disease in bell pepper caused by *S. rolfsii* followed by cheshunt compound and Triadimefon (0.1%) under glasshouse conditions. The per cent mortality of plants significantly increased upto 7 days in pots treated with bayleton and cheshunt compound, but no increase was observed after 7 days whereas, no mortality was observed in pots treated with hexaconazole.

Virupaksha Prabhu *et al*. (2003) screened both systemic and non-systemic fungicides were screened against collar rot of cotton caused by *S. rolfsii* under laboratory conditions. The test fungicides were incorporated on active ingredient in potato dextrose agar medium so as to get 0.025, 0.05, 0.1 per cent and 0.1, 0.2, 0.3 per cent concentrations for systemic and non systemic fungicides. Hexaconazole (98.0%), propiconazole (86.0%, 96%) and tridemorph (86.0%) were found to be highly effective at all concentrations tested. Among non-systemic fungicides, captan inhibited 72.0 per cent mycelial growth of *S. rolfsii*. Thiram was reported to be effective against *S. rolfsii*.

2.10.2 insecticides

Mukhopadyay and Thakur (1977) evaluated the effectiveness of nine soil insecticides for the control of root rot caused by *S. rolfsii* in sugarbeet under laboratory, glasshouse and field conditions in India. A mixture of carbaryl and gamma-BHC and phorate, gamma-BHC and quinalphos alone all at 50 and 100 ppm were more effective than the other treatments in inhibiting the fungal growth and reducing sclerotial formation on potato dextrose agar medium at 28°C. Aldicarb, phorate, quinalphos and carbofuran all at 1 mg toxicant kg^{-1} soil protected seedlings

for 45 days in artificially inoculated pot soils in the glasshouse. Carbofuran at 2 kg toxicant ha^{-1} was the most effective in reducing the root rot incidence (1.83%) in an artificially inoculated field and increasing the crop yield, followed by quinalphos, phorate and aldicarb.

Backman and Hammond (1981) reported that, in field tests chlorpyriphos at insecticidal rates also reduced *S. rolfsii* stem rot in groundnut as effectively as registered fungicides. Laboratory tests indicated a synergism between the active and the inert ingredients of the emulsifiable concentrate formulation (Lorban 4 EC) in suppression of the fungus.

Hagan *et al*. (1986) reported the suppression of southern stem rot of groundnut caused by *Sclerotium rolfsii* by chlorpyriphos 15 G (2.24 kg a.i. ha^{-1}), PCNB (quintozene) 10 G (11.2 kg) and quintogene 10 G. Chlorpyriphos 15 G (11.23 + 2.24 kg a.i. ha^{-1}) on nine groundnut farms over 3 years. All the 3 treatments reduced loci counts in all years. Quintozene + chlorpyriphos generally gave the best stem rot suppression and yield response, but there was little difference in disease loci counts between chlorpyriphos and quintozene. Quintozene significantly increased yield compared with the control in 2 years, chlorpyriphos in only one year.

Hagan *et al*. (1989) reported that the insecticide chlorpyriphos suppressed southern stem rot caused by *S. rolfsii* on groundnut as effectively as the fungicide terrachlor (quintozene). The combination of quintozene + chlorpyriphos reduced stem rot damage, increased yield and was more effective than either the insecticide or fungicide alone.

Kucharek and Edmondson (1991) carried tests in commercial fields in Florida, USA between 1982 and 1989, to determine the effect of the

chlorpyriphos applied once in a granular form between 42 and 49 days after planting) on the occurrence of *S. rolfsii*, on groundnut cultivar Florunner. Chlorpyriphos reduced stem rot by an average of 17 per cent and yields increased in 6 of 7 tests by 320 kg ha^{-1} on an average. Infection foci were reduced by 27 and 51 per cent in tests in 1988 and 1989 respectively. Disease was also reduced within the foci. Chlorpyriphos at 500 ppm suppressed growth of two isolates of *S. rolfsii in vitro* by 63 and 43 per cent.

Chapin and Thomas (1993) showed that, in the standard fungicide programme, treatment with chlorpyriphos (Lorsban 15G) reduced incidence of southern stem rot of groundnut caused by *S. rolfsii* and injury caused by pod-boring lepidoptera, while increasing yield.

2.10.3 Fertilizers

Henis and Chet (1967) demonstrated loss of germinability in sclerotia of *S. rolfsii* at pH values of 9.8 (or) higher, either with or without ammonia. They also reported that 300 ppm of ammonia in distilled water completely inhibited the germination of sclerotia of *S. rolfsii* and pH values at 10.4 is also showed inhibiting effect even in the absence of ammonia.

In 1968, Henis and Chet reported that calcium ammonium nitrate had no effect on the survival of sclerotia of *S. rolfsii* 30 days after incubation. Urea at either level partially but significantly reduced the sclerotial population. Application of urea seems to have either increased the antibiotic producing organisms associated with sclerotia.

Ibrahim *et al.* (1977) in a trial with six pea cultivars showed that, Dilana proved most resistant to *Fusarium solani* and *Dechales Fruhe* Herleria to

Rhizoctonia solani and *S. rolfsii*. Applying the equivalent of 100 kg feddan^{-1} of NH_4NO_3 + 200 kg superphosphate + 100 kg K_2SO_4 in pot experiments increased plant survival and in field experiments increased survival and yield of *Pisum sativum*.

Jenkins and Averre (1986) reported that, the southern blight disease in vegetables caused by *S. rolfsii* is lower when ammonium fertilizers in the form of urea, ammonium nitrate and ammonium bicarbonate were applied, provided increased nitrogen levels are not detrimental to crop growth or yield. Ammonia released by ammonium fertilizers may directly inhibit sclerotial germination and retard mycelial growth of *S. rolfsii*.

Prasad *et al*. (1986) reported that some chemical fertilizers like ammonium sulphate, sodium nitrate were effective agaisnt mycelial growth of *S. rolfsii* when compared with control. Similarly, in other *in vitro* studies they reported that urea completely suppressed the formation of sclerotia.

Punja *et al*. (1986) reported that, three applications to deep ploughed plots of calcium ammonium nitrate or urea at 112 kg Ca (or) N ha^{-1} respectively, ammonium bicarbonate at 84 kg N ha^{-1} or PCNB (quintozene at 56 kg ha^{-1} reduced the percentage of dead plants at the end of the growing season to less than 5 per cent; on untreated plots, disease incidence was 16.8 per cent. Finally, they concluded that combining deep ploughing and applications of calcium fertilizer and ammonium bicarbonate provides effective and economical control of *S. rolfsii* on processed carrots.

There was significant reduction of germination and viability of sclerotia of *S. rolfsii* in natural sandy loam soil amended with nitrogenous

compounds (urea, ammonium sulphate, ammonium nitrate, ammonium chloride, sodium nitrate and potassium nitrate), only the nitrates were effective in sterilized soils (Fang and Liu, 1988).

Brenneman *et al*. (1990) evaluated ammonium bicarbonate against southernstem rot of *Sclerotinia (Corticium) rolfsii* and sclerotinia blights. Minor of groundnut in Georgia and Virginia respectively. *In vitro* studies indicated that the material provided little inhibition of mycelial growth of *S. minor* and *S rolfsii.* However, ammonium bicarbonate did effectively inhibit the formation of Sclerotia of *C. rolfsii in vitro.*

2.10.4 Herbicides

Grinstein *et al*. (1979) reported control of *S. rolfsii* in groundnut by means of herbicide, dinitroamine and biocontrol agent *T. harzianum*. Although dinitramine had no fungicidal effect on the pathogen, it increased the disease resistance of groundnut and tomato. In a field experiment on groundnut in soil naturally infested with *S. rolfsii*, dinitramine was more effective (60% disease reduction) than *T. harzianum*.

Wilfest and Weltzien (1980) reported the direct effects of herbicides used in sugarbeet production on 12 parasitic fungi. Chloridazon (Pyramin), di-allate (Avadex), metamitron (Goltix) and phenmedipham (Benetal) showed a strong fungitoxic effect at the recommended concentration and at 1/10 and 1/100 dilutions against test organisms such as *S. rolfsii*, *Phoma betae*, *Trichoderma hamatum* and *Pythium debaryanum*.

Vyas *et al*. (1986) showed that, ten herbicides incorporated into PDA at 50, 100 and 500 fg ml^{-1} reduced mycelial growth of *S. rolfsii, M. phaseolina* and

Fusarium oxysporum isolated from the soybean cv. JS-72-44. Sclerotial formation of *S. rolfsii* was also reduced. Field application of herbicides reduced severity of disease caused by these organisms. Pre-emergence herbicides were superior in increasing germination and reducing seedling mortality.

Tripathi *et al*. (1988) reported that during 1981-84, peas in soil infested by *Rhizoctonia bataticola, Aphanomyces euteiches* and *Sclerotium rolfsii* were treated with five herbicides (fluchloralin, nitrofen, methabenzthiasuron, 2,4-D and M-3174) in Jabalpur, India. The herbicides increased seedling emergence and reduced seedling instability.

Lal and Nagarajan (1988) evaluated the herbicides like Alachlor, basalin and Trifluralin against *S. rolfsii* causing collar rot disease of tobacco at 125, 250, 500, 1000 and 2000 ppm concentrations. The per cent growth inhibition 67.3 – 88.14 up to 500 ppm concentration. While cent per cent inhibition was at higher concentrations (100 and 200 ppm).

2.11 SYNERGISTIC/ANTAGONISTIC EFFECT OF BIOCONTROL AGENTS AND AGRO CHEMICALS ON TEST PATHOGENS *IN VITRO*

Alagarsamy and Sivaprakasam (1988) reported that the *in vitro* effect of antagonists in combination with carbendazim against *M. phaseolina* in cowpea. *T. viride* reduced the growth of *M. phaseolina* in the petriplates on the 3rd and 6th days inoculation and recorded 36.9 and 76.5% reduction over control. The benefit of antagonists in the suppression of disease symptoms has been widely reported (Baker and Cook, 1974; Papavizas and Lumsden, 1980). Bhaskaram and Seetharaman (1986) reported that seed treatment with *T. harzianum* effectively

inhibited the growth of *M. phaseolina* in petriplates besides enhancing the germination rate in pots from 40 to 72 per cent. Ramadoss and Sivaprakasam (1986) reported effective control of *M. phaseolina* infection in cowpea with carbendazim. The effect of integration of *Trichoderma* with chemicals was also reported by severalworkers (Ohr *et al*., 1973; Papavizas *et al*., 1982; Papavizas and Lewis, 1983). The control of *Armillaria mellea* (Vohl ex. Fr.) Kummer with a combination of methylbromide and *Trichdoerma* was found to be a classical example of integrated pest management involving the use of a pesticide with a biocontrol agent (Papavizas *et al*., 1982).

Goudar and Srikant Kulkarni (1999) evaluated the inhibition of *Fusarium udum* by antagonists in combination with chemicals viz., carbendazim and captan on PDA plates. The treatment combination of carbendazim (@ 0.05%) + *T.viride* (4 g/kg of seeds) inhibited 63% over other treatments.

Prasanna *et al*. (2002) investigated the effect of thiomethoxam 70 WS and *T. harzianum* on *Rhizoctonia solani in vitro* conditions. Seeds treated with thiamethoxam at 2.85, 4.28 and 10 g/kg seed in combination with *T. harzianum* at 4 g/kg inhibited 37.30, 35.95 and 32.40 per cent respectively.

2.12 COMBINED EFFECT OF BIO CONTROL AGENTS AND AGRO CHEMICALS ON TEST PATHOGENS *IN VIVO*

2.12.1 *Pythium aphanidermatum*

Soil fungicides may be used in combination with antagonists introduced into soil.

The positive effect of integrated control of *Pythium* was observed by integrated use of fungicide and biocontrol agent. Application of *T. harzianum*

preparation combined with the fungicide Prothiocarb to a rooting mixture infested with *Pythium aphanidermatum* resulted in a synergistic effect, reducing disease incidence in gypsophila cuttings better than either treatment alone (Sivan *et al*., 1984). These results were similar to those obtained with cucumber grown in *Pythium* infested soil. Integration of Dexon with the seed coating of *T. harzianum* reduced the percentage of diseased plants from 53 to 89, results superior to those of each treatment (Elad *et al*., 1983).

In an attempt to control *Pythium* damping-off in sugarbeet, Sawant and Mukhopadhyay (1990) reported that integration of the fungicide metalaxyl with *Trichoderma harzianum* had an effect in controlling the disease over their individual applications.

The antagonistic effect of *Gliocladium virens* on *Pythium aphanidermatum*, the incitant of tomato damping-off and the additive effect derived when the antagonist was applied in combination with seed dressing fungicides like Apron, captaf and thiram over their individual applications in controlling the disease was reported by De and Mukhopadhyay (1994).

A combination of *T. harzianum* and PCNB at 1-2 mg per g gave better control than either component alone against damping-off of bean, tomato and egg plant seedlings caused by *Rhizoctonia solani* (Hadar *et al*., 1979) and of stem rot of carnation in the glass house (Elad *et al*., 1981).

Sawant Indu and Mukhopadyay (1990) investigated that the metalaxyl insensitive *Trichoderma harzianum* isolate (IMI No.238493) was found antagonistic to *Pythium aphanidermatum*. In field, soil application of 17.5 g m^{-1} ridge of *T. harzianum* inoculum or seed treatment with 0.1 per cent metalaxyl

provided 100 per cent disease control. Lower concentrations of both *T. harzianum* and metalaxyl were less effective individually but when used in combination, they had an additive effect providing 84-100 per cent disease control.

Hegde and Anahosur (1998) reported that the application of neem cake + *T. harzianum* + Ridomil-MZ + garlic mustard seed extract + mulching of the wet soil with transparent polythene sheet in hot summer was the best treatment and resulted in maximum survival of betel vines 88.89 per cent compared to 11.11 per cent in control. The soil temperature increased from 24.5^{o}C to 29.6^{o}C. The population of *Phytophthora capsici* was reduced to 25.76 per cent from 89.76 per cent in control. Also there was considerable increase of colonies per gram of soil of *T. harzianum* (155.55 x 10^3) other fungi (47.33 x 10^3) bacteria (85.0 x 10^4) and actinomycetes (35.00 x 10^3) which have suppressed *P. capsici* with their antagonistic effect.

Jayaraj and Ramabhadran (1998) reported that potassium was incorporated to soil and inoculated with *T. harzianum* propagules individually as well as in combination along with the damping-off fungus *P. aphanidermatum*. The results demonstrated the enhanced survival and population of level of *T. harzianum* in potassium applied soil when compared to control. Whereas, the population of the pathogen (*Pythium aphanidermatum*) was reduced to the minimum due to potassium application.

Goudar *et al*. (1999) reported that compatibility of antagonists *T. viride* and *T. harzianum* @ 4 g kg^{-1} seeds with fungicides (carbendaim @ 0.05% and captan @ 0.02% as seed treatments for the control of fusarium wilt in pigeonpea caused by *F. udum* in glass house tests. Seeds treated with carbendazim and

carbendazim + *T. viride* showed 90% germination in comparison with 76% for the control. Treatment with carbendazim + *T. viride* also exhibited the lowest wilt incidence (16.0%) followed by carbendazim + *T. harzianum* (20.0%).

T. harzianum and *T. viride* antagonistic to *Pythium aphanidermatum* produced cellulolytic enzymes (C1 and Cx) in fungicide amended medium and showed profound influence on the damping-off incidence, shoot and root length and dry matter production of tomato seedlings. Three fungicides carbendazim, thiram and copper oxychloride at 500, 1250 and 2500, 5 g ml^{-1} influenced the damping-off incidence and enzyme production differently (Karpagavalli and Ramabadran, 2001).

Kaushik *et al*. (2002) reported that the soil solarization with 25 μm transparent polythene sheets during May-July resulted in significant reduction in soil population of the damping-off fungi viz., *Fusarium oxysporum* f.sp. *dalbergiae*, *F. solani*, *Pythium aphanidermatum*, *Rhizoctonia solani* and *R. bataticola* compared to non-solarised soil. Solarization coupled with biocontrol agents – *T. viride*, *T. harzianum*, *T. longibrachiatum* and *P. fluorescens* and sub-lethal doses of captan and carbendazim exhibited significantly higher seed germination and seedling survival of *A. nilotica, Albizia lebbeck, Azadirachta indica* and *Dalbergia sisso*.

Anitha and Tripathi (2000) reported sreenhouse studies and field experiments were conducted on integrated disease management of seedling diseases of okra caused by *Rhizoctonia solani* and *Pythium aphanidermatum* (Edson) Fitzp. By using a combination of varietal resistance, chemical and biological means of control. Seed tratment with carbendazim followed by soil application of *Trichoderma viride* Pers was proved effective as disease incidences recorded were 5 and 18.33 per cent Varsha Upahar and Pusa Sawani varieties, as compared to 45 and 62 per cent incidences observed in control respectively.

Deepa and Chaube (2002) reported that soil solarization reduced damping-off of cauliflower by over 40.1 per cent. Integration with chemicals and bio-agent as seed treatment with apron, *T. harzianum* and *P. fluorescens* was distinctly superior.

Lakra (2003) reported that pre-emergence damping-off of potato was 35.9, 27.1 and 4.8 per cent when seeds were treated with *B. subtilis, T viride* and captan @ 4 g kg^{-1}, respectively, as against more than 40 per cent in control. Incidence of post-emergence damping-off was minimum (5.5%) when seed and soil were treated with captan (4 g kg^{-1} seed and 5 g/m^2 respectively) followed by seed + soil treatment with *T. viride* @ 4 g kg^{-1} seed and 5 g/m^2 (13.5%) and seed and soil treatment with *B. subtilis* @ 4 g kg^{-1} seed and 5 g/m^2 (22.2%). The post-emergence damping-off in control was 42.6 per cent.

Rama Bhadra Raju and Raoof (2003) indicated that the improved strain of *T. viride* (B-16) tolerant to carbendazim, developed at DOR, Hyderabad was evaluated for the management of *Fusarium oxysporum* f.sp. *ricini*, causing castor wilt. The effectiveness of B-16 increased with the quantity used as seed treatment. B-16 seed treatment at 5, 7.5 and 10 g kg^{-1} resulted in 18.7, 23.4 and 30.4 per cent reduction in wilt, respectively over control. Seed dressing with carbendazim (0.2%) and B-16 (10 g kg^{-1}) combined soil application of B-16 @ 190 kg ha^{-1} (2.5 kg of formulation in 190 kg of farmyard manure) resulted in effective wilt control, where the proliferation of *T. viride* was maximum (18 x 103 cfu g^{-1}) and significant increase in yield (293.8%) over control was recorded. The build up of *T. viride* population was least in carbendazim treatment (3.8 x 10^3 cfu g^{-1}).

2.12.2 *M. phaseolina*

Mahadevamurthy *et al*. (1990) reported that the effect of fertilizer amendment of soil and antagonist treatment on sclerotial germination of *R. solani*, four replicates of 100 sclerotia each were used. The fertilizers like urea, superphosphate, muriate of potash, diammonium phosphate, DAP and NPK (40:25:10) were selected. One kilogram unsterilised soil was amended with 0.2 g of each fertilizer separately. Ten sclerotia coated with *A. niger*, *F.heterosporum*, *T. harzianum* and *T. viride* separately at the rate of 1.35×10^7, 9.30×10^6, 1.2×10^7 and 9.74×10^6 spores / sclerotium were kept in fertilizer amended soil between nylon nets. All the pots were watered daily and sclerotial germination was recorded after 30 days. Except for urea (6.50%) all other fertilizers viz., superphosphate (3.50%), muriate of potash (4.50%), diammonium phophate (4.50%) and NPK (30%) significantly reduced the sclerotial germination when compared to that of control (20.50%).

Venkateswar Rao (1998) reported that an integration of soil solarization (six weeks), *T. viride* (native) and mancozeb (0.3%) effectively (82.2%) controlled the stem and root rot of sesame caused by *Macorphomina phaseolina* under field conditions.

Mathivanan *et al*. (1997) observed better control of damping-off and root rot of cotton with carbendazim followed by soil application reduced plant mortality up to 72 per cent.

Kumar (1998) reported that the imidacloprid and *Trichoderma* combination was effective against *M. phaseolina* (Tassi), a root rot causing pathogen in cotton.

Rajeswari *et al*. (1999) reported that bio-efficacy of carbendazim tolerant isolate of *T. harzianum* and exotic isolates of *T. viride* and *T. virens* were evaluated against dry root rot pathogen at mungbean incited by *M. phaseolina* under glass house conditions. Integration of *T. harzianum* as soil application (5 g kg^{-1}) + seed treatment (108 c ml^{-1}) with sublethal doses of carbendazim (0.02%) significantly reduced dry root rot incidence (95.3%) over soil treatment (91.5%) and seed treatment alone (86.5%).

Datta *et al*. (2000) reported that the combination of four different carriers along with *Trichoderma harzianum* as seed treatment was tested in pot condition against *Rhizoctonia solani* causing soybean stem rot. Conidial suspension (1 x 108 conidia per ml) of the antagonist was used for seed treatment. Seed germination (%) and yield (g/plant) was found higher in all treatments irrespective of carrier and antagonist used. However seed germination and yield was found to be on par. The highest germination (85.33%) and yield (11.28 g/plant) and lowest disease index (1.5) were obtained when seeds were treated with *T. harzianum* + methyl cellulose. Seed treatment with sub-lethal doses of thiram (0.05 and 0.01%) and *T. harzianum* showed lower disease index, higher germination and yield than the lethal dose (0.3%) alone.

Dubey (2000) reported that the seeds treated with *G. virens* in integration with thiram gave maximum germination (93.0%), minimum disease incidence (8.6%) and intensity (9.9%) with highest yield (2020 kg ha^{-1}) followed by *G. virens* treated groundnut seeds against *Rhizoctonia solani*.

Jayasree *et al*. (2000) investigated that the *Pseudomonas fluorescens* strain *P.f1* effectively inhibited the mycelial growth of *Macrophomina phaseolina*,

the pathogen causing dry root rot in blackgram and sesame. Among various methods of *Pf.1* application, seed treatment + soil application recorded maximum yield in blackgram (1238 kg ha^{-1}) and sesame (1200 kg ha^{-1}) followed by seed treatment + soil drenching of carbendazim, which recorded grain yield to the extent of 1205 kg ha^{-1} for blackgram and 820 kg ha^{-1} for sesame. Control plots recorded the lowest yield of 458 kg ha^{-1} (blackgram) and 190 kg ha^{-1} (sesame).

Prasanthi *et al.* (2000) evaluated certain fungal and bacterial biocontrol agents as seed and soil application against safflower root rot caused by *R. bataticola*. Both seed treatment and soil drenching with antagonists increased safflower seedling percentage survival, seed treatment being more effective than soil drenching with highest survival rate with *T. viride* (83.33%) and *Pseudomonas fluorescens* (86.66%).

Bunker and Mathur (2001) evaluated three biocontrol agents viz., *T. harzianum, T. aureoviride* and *T. viride* were evaluated individually and in combinations and in integration with Bavistin seed treatment in pathogen infested soil in pots for suppression of dry root rot pathogen *Rhizoctonia solani* in bell pepper (*Capsicum frutescens*) cv. California wonder. Mortality in these treatments was 9.1 and 12.9 per cent as compared to 20 and 13 per cent in their integration with bavistin seed treatment after 45 days; and 12.0 per cent as against 14.7 and 17.3 after 60 days of sowing. In treatments where *Trichoderma* spp. were applied on seeds, their cfu ranged from 0.52 – 0.69 x 10^5 g^{-1} soil, and where bavistin seed treatment, their cfu ranged from 0.77 – 0.81 x 10^5 g^{-1} soil. The highest inoculum density of *Trichoderma* spp. (1.21 x 10^5 g^{-1} soil) was in the seed plus soil treatment of *T. harzianum* + *T. aureoviride* followed by seed plus soil application of

T. harzianum + *T. viride* (0.99 x 10^5 g^{-1} soil) and soil application of *T. harzianum* + *T. viride* in integration with bavistin seed treatment 90.92 x 10^5 g^{-1} soil).

Latha and Narasimhan *et al*. (2001) worked on the management of the root rot complex of blackgram caused by the fungus *Macrophomina phaseolina* and the cyst nematode *Heterodera cajani*, with special reference to fungal and nematodes using antagonists, organic amendments and chemicals under glasshouse conditions. *Pseudomonas fluorescens* as seed treatment (ST) @ 10 g kg^{-1}, carbofuran as soil application (SA) @ 3.3 kg ha^{-1} + carbofuran as ST @ 2 g kg^{-1} and *T. viride* as ST @ 4 g kg^{-1} + *P. fluorescens* as ST @ 10 g kg^{-1} + *Pecilomyces lilacinus* @ ST 1 g mycelium kg^{-1} recorded the minimum root incidence.

Mukerjee *et al*. (2001) reported the effect of integration of agrochemicals and biocontrol agents in the management of wilt complex of Frenchbean (*Phaseolus vulgaris* L.) caused by *Sclerotim rolfsii, Rhizoctonia solani* and *Fusarium oxysporum* f.sp. *phaseoli* under field conditions. Among the different treatments bioagent *G. virens* (0.2%) exhibited 96.0% germination, which turn over 89.22% increase over check. Among various fungicides contaf (0.1%) resulted 92.00% germination. Integration of Contaf + *G. virens* (0.05% + 0.1%) exhibited 100% germination, whereas in case of antracol + *G. virens* (0.025% + 0.1%) and opus + *G. virens* (0.025 + 0.1%) germination percentage was slightly lower that is 98.14% and 90.73% respectively. In untreated (check) plots the germination percentage remained 75.92, there was no seedling mortality upto 40 DAS in case of contaf + *G. virens* (0.05% + 0.1%) treated plots. Antracol + *G. virens* (0.025% + 0.1%) resulted in 5.66% wilt, while opus + *G. virens* (0.025% + 0.1%) exhibited 5.08% seedling wilt.

Gaikwad *et al*. (2002) studied about management of charcoal rot of sorghum using three biocontrol agents viz., *T. viride, T. harzianum* and *P. fluorescens* and the fungicides thiram and carbendazim. They have found that seed treatment with biocontrol agents and fungicides were highly effective against *M. phaseolina*.

Nagaraju *et al*. (2002) evaluated the efficacy of two antagonists *T. viride* and *T. harzianum* in reducing *R. solani* of paddy under transplanted conditions. The biological control agents were applied as basal treatments (or) as root dip + a spray (R+S). A chemical control treatment consisting of seed treatment with carbendazim (2 g kg^{-1} seed) + one spray of hexaconazole (2 ml $litre^{-1}$) was also applied. Among the biocontrol agents R+S treatment with *P. fluorescens* was the most effective, reducing the disease incidence by upto 62.13% of that in untreated control followed by T+S treatment with *T. viride* (58.87%) and the R+S *P. fluorescens* treatment reduced in the highest grain yield of rice 5414 kg ha^{-1} over-aged both years, 47.68% above the yield in the untreated control.

Suriachandraselvan and Seetharaman (2002) conducted pot culture experiments to study the efficacy of *Trichoderma viride* in combination with fungicides against *Macrophomina phaseolina* infection in blackgram. Seeds treated with carbendazim (2 g/kg) + *T. viride* (4 g/kg) recorded the minimum disease incidence of 7.9 per cent and maximum germination of 97.7 per cent, root length 9.6 cm, shoot length 7.8 cm and seedling vigour 1678 as against 42.6 per cent and 77.7 per cent, 5.1 cm, 4.2 cm and 737 respectively in control.

Padmalatha (2002) reported that combined application of thiophanate methyl + *T. harzianum* + neem cake resulted in the minimum seedling mortality (7.5%) and less disease incidence (8.2%) caused by *M. phaseolina* in sunflower.

Prasanna *et al*. (2002) reported that the reduction in the radial growth of *Rhizoctonia solani* was 40.2 per cent in presence of *T. harzianum,* whereas no inhibition was observed in thiomethoxam at 10 g kg^{-1} seed *in vitro*. In combination with thiomethoxam at 2.85 g kg^{-1} seed + *Trichoderma,* 4.28 g kg^{-1} seed + *Trichoderma* and 10 g kg^{-1} seed + *Trichoderma,* the reduction in radial growth of *R. solani* was 37.3, 35.95 and 32.4 per cent, respectively.

Rahman *et al*. (2003) studied the effect of soil solarization, captan and biocontrol agents in management of damping-off disease in solanaceous vegetable nursery. They concluded that the occurrence of damping-off disease in nurseries can be effectively controlled by soil solarization of nursery beds during peak summer (or) seed treatment followed by soil application with *T. viride*.

Durai (2004) conducted pot culture experiments on integrated disease management for charcoal rot of sesamum under glasshouse conditions. Out of 15 treatment combinations maximum disease reduction was achieved by integrated use of seed treatment with mancozeb (100 ppm) + soil application of native *T.viride* (10 g/kg soil) and *Pseudomonas fluorescens* (20 ml/kg of soil) as this treatment recorded PDI only 10.67. This treatment not only reduced the disease incidence to a maximum extent, but also recorded maximum plant height (22.29 cm), shoot length (5.41 cm), and root length (4.27 cm), maximum dry weight of shoot (76.28 mg) and root (52.31 mg of sesame when compared to all other treatments.

2.12.3 *S. rolfsii*

Grimstein *et al*. (1979) reported effective control of southern blight of groundnut by combining bio-control agent *T. harzianum* and a herbicide dinitroamine.

Elad *et al*. (1980) reported that combination of solar heating and methyl bromide with *T. harzianum* improved their efficiency and also resulted in efficient control of *S. rolfsii*. They also reported that, combining heat treatment and *T. harzianum* both at sublethal doses under glasshouse conditions, resulted in 90-100 per cent control of *S. rolfsii* disease in beans.

A combination of iprodione and the iprodione tolerant isolate of *T. harzianum* gave control of white rot of onion in a field naturally infested with *Sclerotium cepivorum* than the iprodione alone at 3 kg a.i. ha^{-1} (Abd-El Moity *et al*., 1982).

Chet *et al*. (1982) reported that coating Tris bulbs with a preparation of *T. harzianum* was highly effective under greenhouse conditions in reducing the incidence of diseases caused by *Rhizoctonia solani* and *S. rolfsii*. In field experiments pertaining to bulb production, the incidence of *R. solani* in plants and bulbs was reduced (upto 93%) and the yield increased (35-41%) by applying *T. harzianum* either as a bulb coating or broadcast application (biological treatment), treating the soil with quintozene (chemical treatment) or solarizing the soil by mulching it with transparent polyethylene (physical treatment) prior to planting. Combined treatments (chemical / biological or physical / biological) were the most effective. Bulb coating or broadcast application in field plots increased *Trihoderma* population density in the soil by 4-27 times.

Csinos *et al*. (1983) reported that the combination of *T. harzianum* and PCNB at 11 kg ha^{-1} reduced the stem rot of pea caused by *S. rolfsii*.

Maiti and Sen (1985) reported that, a combination of calcium ammonium nitrate + antagonist, *T. harzianum* was more effective in reducing stem blight of groundnut caused by *S. rolfsii* than urea + antagonist although all treatments were significantly effective. They also reported that *Trichoderma* inoculum when added along with nitrogenous fertilizers, and a combination with calcium ammonium nitrate @ 20 kg N ha^{-1} significantly increased the population of *Trichoderma* in 30 days.

Enkins and Averre (1986) gave an integrated programme for the management of southern blight of vegetables caused by *S. rolfsii*. This programme includes avoidance of problem fields, use of crop rotation, practice of clean cultivation, application of fertilizers which contain both calcium and ammonia, control of weeds and finally apply post plant fungicide registered for controlling southern blight on the target host.

Punja *et al*. (1986) stated that combining deep ploughing and application of calcium fertilizers and ammonium bicarbonate provided effective and economical control of carrot rot caused by *S. rolfsii*.

Kuruvilla Jacob (1989) reported that, integration of carbendazim seed treatment and soil drench with *T. harzianum* was inferior than either of the methods used alone in reducing root rot of urd bean. He also suggested the use of fungicide tolerant strains of *Trichoderma* in integrated strategy.

Mahapatra and Dash (1990) reported that, the efficacy of treatments for the control of *S. rolfsii* infection of *Piper betle* was investigated. Soil drench

followed soil amendment with *Trichdoerma harzianum* at 100 g kg^{-1} soil and solarisation with white polythene mulch for 30 days.

In 1990, Wokocha reported the effect of simultaneous applications of *T. viride* with PCNB (quintozene), captan (or) Aldrex T (thiram + aldrin) on the basal stem rot (*S. rolfsii*) of tomato in artificially inoculated field plots in Samaru (Northern Ginea Savana zone) during 1978-80. The results showed that a combination of *T. viride* with PCNB and *T. viride* alone gave good disease control during both dry and wet seasons. PCNB alone was less effective, giving a disease severity index (DSI) of 15.6% whereas captan and Aldrex T were ineffective with DSI of 84.9% and 79.2% respectively, during wet season trials when disease incidence were generally high. Combined applications with *T. viride* significantly enhanced the effect of three fungicides in disease control, giving maximum control of the disease by recording DSI of 0.0% (*T. viride* + PCNB), 16.4% (*T. viride* + captan) and 19.0% (*T. viride* + Aldrex T). *T. viride* thus provided a synergistic effect which substantially increased the control capabilities of PCNB, captan and Aldrex T.

Onion and garlic crop rotation with groundnut, application of *T. harzianum* and carbendazim (0.2%) drenching effectively protected groundnut from damage by *S. rolfsii*. The stem rot and pod rot incidence was reduced by 46.16 and 27.60 per cent, respectively due to these management strategies. The treatments not only reduced the population of *S. rolfsii* in the soil but also increased that of antagonist, *T. harzianum* and increased the pod yield and kernel weight by 17.49 and 29.33 per cent, respectively (Asghagri and Mayee, 1991).

Ashgari *et al*. (1991) reported that onion and garlic crop rotation with groundnut crops, application of *T. harzianum* and soil drenching with 0.2% carbendazim reduced stem rot by 44-60% and pod rot by 27-60% on groundnut infected by *S. rolfsii*. Treatment increased pod yields by 17-47% and seed weight by 29-33%.

Olives and Mont (1993) tested the activity of captan, difolatan (captafol), PCNB (quintozene) and *T. viride* against *S. rolfsii in vitro* at 0.5 and 1 g a.i/300 ml of PDA medium and under greenhouse conditions in barley and bean seedlings. *T. viride* inhibited *S. rolfsii* growth *in vitro*. Of the fungicide only quintozene inhibited sclerotial formation for > 3 months. Under greenhouse conditions, *T. viride* and quintozene gave the best control of *S. rolfsii* in barley and beans.

Bicci *et al*. (1994) reported that, stem rot of groundnut caused by *S. rolfsii* was effectively controlled by fungicide application (PCNB – quitozene) combined with urea and calcium ammonium nitrate. They also reported that *T. harzianum* suppressed *S. rolfsii* upto 71.4% and in micro plots with buried sclerotia, 8 weeks of soil solarization killed 95.4% of the sclerotia.

Muthamilan and Jeyarajan (1996) reported that seed treatment with *T. harzianum* and *Rhizobium* added to soil on 6 days after sowing plus carbendazim (0.1%) soil drenching on 30 DAS was more efficient in reducing root rot of groundnut caused by *S. rolfsii* than other treatments tested under glasshouse conditions.

Yan-Sittuang (1996) reported that, the minimum inhibitory concentration of a mixture of 10 per cent Ridomil (metalaxyl) + 40 percent copper

dicarboxylic acid, bayleton (triadimefon) and carbandazol (carbendzim) for the *Trichoderma* spp. were 4 x 10^{-3}, 3 x 10^{-3} and 4 x 10^{-5} respectively. Triadimefon at 3 x 10^{-4} inhibited mycelial growth. Sclerotia production and germination of *S. rolfsii* from capsicum by 41.58, 3.60 and 3.58 per cent respectively. Population of *Trichoderma* in soil were increased by all 3 fungicides.

Anitha Chowdary (1997) reported that the combined soil application of *T. viride*, Cheshunt compound and neem cake completely controlled the disease of bell pepper caused by *S. rolfsii* whereas, in individual treatments with *T. viride*, cheshunt compound and neem cake the per cent mortality rates were 20.5, 22.86 and 47.08 respectively under glasshouse conditions.

Uma Singh and Thapliyal (1998) investigated that the seed and seedling rot caused by *S. rolfsii* reduced the soybean plant stand and number of normal seedlings, maximum reduction in pre-emergence rot was obtained with vitavax 200 + *T. harzianum* and vitavax 200 + *G. virens* followed by vitavax 200, thiram, thiram + *T. harzianum*, thiram + *G. virens*, thiram + bavistin, *T. harzianum* and *G. virens*. Vitavax 200+ *T. harzianum* (36.7) and (5.6) or vitavax 200 + *G.virens* (36.7) and (4.8) were most effective for pre- as well as post-emergence seedling rot.

Integration of Contaf + *Gliocladium virens* (0.025% + 0.1%) was the best combination to manage wilt complex of trench bean (*Phaseolus vulgaris*) caused by *Sclerotium rolfsii, Rhizoctonia solani* and *Fusarium oxysporum f.sp. phaseoli* under field conditions (Mukerjee *et al*., 2001).

Pathak *et al*. (2001) investigated that the inoculating mustard (Varuna) seeds with seed and stem rot fungi (*S. sclerotiorum*) drastically reduced the

per cent germination. Seeds dressed with antagonists fungus viz., *Trichoderma viride, T. harzianum* and *Glicladium virens* plus carbendazim 50 WP (or) mancozeb increased per cent germination, plant height, dry plant weight and test weight of seeds. However, the best height of plants was obtained when *G. virens* was used in combination with either carbendazim (82.12) or mancozeb (87.87 cm). Dry weight was maximum under combination of *G. virens* + mancozeb (2.897 g) followed by *T. harzianum* (2.258 g) and *G. virens* + carbendazim (2.225 g).

The effect of carbendazim and thiophanate methyl on the growth of *Pseudomonas fluorecens* (ARR1G, ARR2, ARR10, CHAO, FP1, FP7, KKM1, KM2, *Pf*1, VPT2, VPT4 and VPY10) isolates was evaluated under glasshouse conditions. The combined application of antagonist *P. fluorescens* + thiophanate methyl resulted in the highest plant survival rate (81.67%) (Malathi *et al*., 2002).

Patibanda *et al*. (2002) reported that the integration of antagonist (soil application) and fungicidal seed coating resulted in synergistic effect on disease reduction in safflower caused by *S. rolfsii* compared to their individual applications. Thiram alone at 0.1% seed treatment showed very poor control (34.00%) and same treatment in combination with *Trichoderma* soil application required higher dose (4 g/kg soil) for 100% control.

Tripathi and Johri (2002) investigated in vitro integrated use of fungicides and fluorescent pseudomonads recovered from rhizoplane (PEn-4) and rhizosphere of pea (PRS-1) and wheat (WRS-24) were enhanced the inhibitory potential against *Colletotrichum dematium*, *Rhizoctonia solani* and *Sclerotium rolfsii*. In association with vitavax, WRS-24 inhibited *C. dematium* by only 1%; this was in contrast to 39% inhibition by vitavax alone. However, average mycelial

extension of *R. solani* and *S. rolfsii* against PEn-4 and WRS-24 was 78, 84 and 21, 41 (mm) dia respectively against 23, 46 on bavistin containing medium.

Bhorania *et al*. (2003) reported that the efficacy of carbendazim (0.050%), thiophanate methyl (0.075%), COC (0.200%), carboxin (0.075%), mancozeb (0.225%), captan (0.225%), neem oilcake 66 g per plant, mustard oil cake 66 g per plant, castor oil cake 66 g per plant and *T. harzianum* (10^8 spores ml^{-1}) against stem rot caused by *S. rolfsii* in chilli cv. Reshampatta was evaluated in Gujarath at 45 days after sowing. *S. rolfsii* culture containing mycelia and Sclerotia was applied to each plant by band placement method. At one week after inoculation, *T. harzianum* suspension, oilseed cakes and fungicides were applied as soil drench around the inoculated plants. Thiophnate methyl resulted in the highest disease control percentage (84.56%), followed by carboxin (84.26%) and castor oil cake (78.57%). All the treatments significantly reduced plant mortality (22.17 – 44.88% vs 80.68%) in the control.

Among nine treatments imposed in pot culture experiment, treatment T7 seedling root dip in thiram @ 0.1% + seedling root dip in effective antagonists + soil application of effective antagonists (*Trichoderma* isolate-1 and *Pseudomonas* sp.) was found to be superior as it recorded least PDI of 6.66% and maximum plant height (16.17 cm), dry weight of shoot (113.67 mg) and root (53 mg) of crossandra compared to all other treatments (Arunasri, 2003).

Table 2: Details of agrochemicals employed in the investigation

S. No.	Trade name	Common name	Active ingredient	Chemical name	Source of supply
A.	**FUNGICIDES**				
1.	Blitox	Copper oxychloride	50% WP	Dicopper chloride trihydroxide	Rallies India Ltd. Agrochemicals Division, Regd. Office, Rallis House, 21, D Sukhadavala Marg, Mumbai
2.	Indofil M-45	Mancozeb	75% WP	Manganese ethylene bis-dithiocarbanate plus zinc	Indofil Chemicals Company – A Division of Modipon Ltd., Nirlon House, 3rd Floor, Dr A Beasant Road, Worli, P.O.Box 9112, Mumbai 400 025.
3.	Bavistin	Carbendazim	50% WP	Methyl benzimidazole – 2 yl carbamate	BASF India Ltd., P.O.Box No.19108, S K Ahire Marg, Mumbai – 400 025.
4.	Contaf	Hexaconazole	5% E	(RS)-2-2-4-dichlorophenyl-1-(IH-1,2,4-triazole-1-yl) hexane-2-ol	Rallis India Ltd. Agrochemicals Division, Regd. Office, 21 DS Sukhadavala Marg, Mumbai.
B.	**INSECTICIDES**				
5.	Dursban	Chlorpyriphos	20% EC	0,0-diethyl 0-3,5,6-trichloro-2-pyridyl phosphorothioate	EID Parry (India) Limited, Dame House, 234, NSC Road, Chennai – 600 001.
6.	Confidor	Imidacloprid	17.8% SL	1-(6-chloro-3-pyridyl methyl) N-nitroimidazolidin-2-yldeneamine	Bayer (India) Limited, Bayer House, Central Avenue, Hiranandani Gardens, Powai, Mumbai – 400 076.
7.	Marshal	Carbosulfan	50% EC	2,3-dihydro-2,2-dimethyl benzofuran-7-yl (dibutyl aminothio)= methyl carbamate	Rallis India Limited, 21, D S Marg, Mumbai – 400 001.

Table 2 contd…

S. No.	Trade name	Common name	Active ingredient	Chemical name	Source of supply
8.	Cruiser	Thiomethoxam	75 WS	S-2-ethylthio ethyl 0,0-dimethyl, phosphoro dithioate	Syngenta India Limited, Bldg No.12, Opp. Aarey Road, Gargaon (East), Mumbai – 400 063.
C.	**HERBICIDES**				
9.	Stomp	Pendimethalin	30% EC	N-(1-ethyl propyl)-2,6-dinitro-3,4-oxylidine.	BASF India Limited, Rhone Poulenc House, S K Ahire Marg, Worli, Mumbai – 400 025.
10.	Basalin	Fluchloralin	45% EC	N-propyl-N-(2' chloroethyl)-2,6-dinitro-n-trifluoromethyl aniline.	
D.	**INORGANIC FERTILIZERS**				
11.	Calcium ammonium nitrate	Calcium ammonium nitrate	25% N Ca – 8.1% Mg – 4.5%	Calcium ammonium nitrate	Gujarath Narmada Valley Fertilizers Company Limited, Gujarath.
12.	Diammonium phosphate (DAP)	Diammonium phosphate	46% P, 18% N	Diammonium phosphate P_2O_5 (41.6%)	Godavari Fertilizers and Chemicals Limited, Visakhapatnam.
13.	Single superphosphate	Single superphosphate	16% P Ca – 19.5% Mg – 0.3%	Single superphosphate	Bohra Industries Ltd., UMRA, Udaipur.
14.	Muriate of potash	Muriate of potash	51-60%	Potassium chloride	Liberty Phosphate Ltd., 14/75, Gidc, Nandesori, Vadodara.

CHAPTER III

MATERIALS AND METHODS

The present study was carried out in the Department of Plant Pathology of College of Agriculture, Acharya N.G. Ranga Agricultural University (ANGRAU), Rajendranagar, Hyderabad, Andhra Pradesh (A.P).

The general laboratory techniques followed for the present study were those described by Nene and Thapliyal (1993), Dhingra and Sinclair (1995) and Aneja (2001) for preparation of media, sterilization, isolation and maintenance of fungal and bacterial cultures with slight modifications wherever necessary.

3.1 GLASSWARE

The glassware used in the present study were petriplates (90 mm), conical flasks (250, 500, 1000 and 2000 ml), measuring cylinders (10, 50, 100, 500 and 1000 ml) and test tubes of Borosil make.

3.1.1 Cleaning of glassware

Glassware were first washed with a detergent, then placed in cleaning solution of the following composition.

Potassium dichromate	:	60 g
Concentrated sulphuric acid	:	60 ml
Distilled water	:	1000 ml

The glassware kept in the cleaning solution for 24 hours, later thoroughly washed with tap water and finally rinsed with distilled water and dried.

3.1.2 Sterilization of glassware

Glassware like petriplates, test tubes, pipettes etc., wrapped in butter paper and sterilized in hot air oven at 160°C for two hours.

3.2 STERILIZATION OF OTHER INSTRUMENTS

Inoculation needles, forceps, cork borers and blades were sterilized by passing through flame after dipping in alcohol.

3.3 MEDIA AND THEIR COMPOSITION

The following media were used in the present investigation.

(i) Potato Dextrose Agar (PDA)

Peeled and sliced potatoes	:	200 g
Dextrose	:	20 g
Agar	:	20 g

ii) *Trichoderma* selective medium (Elad and Chet, 1983)

$MgSO_4$	:	0.2 g
K_2HPO_4	:	0.9 g
KCl	:	0.15 g
NH_4NO_3	:	1.0 g
Glucose	:	3.0 g
Agar	:	15.0 g
Distilled water	:	1000 ml
*Rose Bengal	:	0.15 g
Chloremphenical	:	0.25 g
Metalaxyl	:	0.3 g

* Added just before plating.

(iii) Pseudomonas Agar (for fluorescens)

*Pseudomonas Agar	:	38 g
Glycerol	:	10 ml
Distilled water	:	1000 ml

(iv) King's B medium

Proteose peptone	:	20 g
K_2HPO_4	:	2.5 g
Glycerol	:	15 ml
$MgSO_4.7H_2O$	:	6 g
Agar	:	15 g
Distilled water	:	1000 ml

3.3.1 Preparation of media

(i) Potato Dextrose Agar (PDA)

PDA was used as the basal medium for culturing and multiplication of *Pythium aphanidermatum*, *Macrophomina phaseolina* and *Sclerotium rolfsii* for all the experiments unless otherwise mentioned.

PDA was prepared by boiling 200 g of peeled and sliced potato tubers in 500 ml of water for about 30 minutes. In another 500 ml water, 20 g agar was melted. Both of these were filtered through muslin cloth into a third container and dextrose was added to the filterate. The final volume of the medium was made upto one litre by adding water and the initial pH of the medium was adjusted to 6 by using 1N HCl and 1N NaOH before sterilization. The medium was sterilized in an autoclave at 15 kg / cm^2 (121.6^oC) for 20 minutes.

(ii) *Trichoderma* selective medium (TSM)

The medium was prepared by adding required quantities of the components in 1000 ml distilled water was sterilized in an autoclave at 15 kg / cm^2 (121.6^oC) for 20 minutes. This medium was used for isolation of *Trichoderma* spp. from commercial formulations.

(iii) Pseudomonas Agar (for fluorescens)

The medium was used to detect the fluorescens nature of the biocontrol agent *Pseudomonas fluorescens* and it's multiplication. It was prepared by taking 38 g of Pseudomonas agar and 10 ml of glycerol and dissolving them in 1000 ml of distilled water by boiling. The medium was sterilized in an autoclave at 15 kg / cm^2 (121.6^oC) for 20 minutes.

(iv) King's B medium

The medium was used in dual culture technique to study the antagonistic activity of bacterial biocontrol agents to the test pathogens. It was prepared by adding proteose peptone 20 g, 2.5 g, glycerol 15 ml and $MgSO_4.7H_2O$, 6 g in 500 ml distilled water. In other 500 ml distilled water, 15 g agar was melted. Both of these were mixed in a third container and the final volume of the medium was made upto one litre by adding distilled water. The medium was sterilized in an autoclave at 15 kg/cm^2 (121.6^oC) for 20 minutes.

3.4 SOURCE OF SEED

Seeds of the tomato cv. Pusa Ruby, brinjal cv. Shyamala and bhendi cv. Parbhani Kranthi used in experiments were obtained from the Vegetable Section, Agricultural Research Institute, ANGRAU, Rajendranagar, Hyderabad.

3.5 ISOLATION AND MAINTENANCE OF SOIL BORNE PATHOGENS

3.5.1 *Pythium aphanidermatum* (Edson) Fitz

Isolation of *P. aphanidermatum* was made by sowing mustard seeds (cv. Local) thickly in a pot and by maintaining high soil moisture till the damping-off of the seedlings was induced. The infected seedlings were used along with fungal growth for isolation of the pathogen.

The infected seedlings were thoroughly washed, basal portions were cut into small pieces of 1 to 2 cm long. The cut pieces were surface sterilized with 0.1 per cent mercuric chloride for half a minute, washed thrice with sterile distilled water to remove excess of mercuric chloride. Sterilised pieces were placed on plates containing PDA medium and were incubated at $28\pm2^{o}C$ for three days.

Fungal growth emerging from diseased host tissue was transferred directly to the PDA medium under aseptic conditions and incubated at $28\pm2^{o}C$. The culture was further purified by single hyphal tip method. Pure culture of *P. aphanidermatum* was maintained on PDA by periodic sub-culturing.

3.5.2 *Macrophomina phaseolina* (Tassi) Goid

The pathogen *M. phaseolina* was isolated from the roots of infected castor plants cv. Aruna showing typical charcoal rot symptoms by tissue segment method on potato dextrose agar (PDA) medium. Bits of 5-8 mm long were cut from root portions. The bits were surface sterilized with 0.1 per cent $HgCl_2$ for 30 seconds and washed thrice with sterile distilled water to remove excess of $HgCl_2$. These bits were then transferred to another petriplate containing sterile discs of blotting paper. The dried bits were subsequently transferred to the PDA containing

petriplates, incubated at 28±2°C for 3 days. The culture was further purified by hyphal tip method and maintained on PDA slants. Sub-culturing was done whenever required.

3.5.3 *Sclerotium rolfsii* Sacc.

Isolation of the pathogen, *S. rolfsii* was made from the diseased sunflower cv. Morden showing typical wilting symptoms. The infected roots of the diseased plants were washed under running tap water to remove adhering soil particles and other plant debris and were cut into small bits of 1 cm size. The bits were surface sterilized by immersing in 0.1 per cent $HgCl_2$ for 30 seconds and plated on PDA medium on petriplates after thorough washings in sterilized distilled water. The plates were incubated at 28±2°C temperature for 3 to 4 days. Fungal growth emerging from diseased root bits was transferred directly on to the PDA medium with the help of sterilized needle. The culture was further purified by hyphal tip method. Pure culture of the organism was maintained on PDA by periodical transfers.

3.6 IDENTIFICATION OF PATHOGENS

P.aphanidermatum was identified based on the description as given by Edson (Fitz) Patrick (1923), whereas, *M. phaseolina* and *S. rolfsii* were identified based on the descriptions as given by Barnett and Hunter (1972).

3.7 MICROSCOPIC EXAMINATION

Temporary aqueous mounts were prepared from the pure culture of the fungus and observed under the compound microscope. Photomicrographs of the pathogens were taken using stereo-binocular and compound microscope to describe them in detail.

3.8 PATHOGENICITY TESTS

3.8.1 *Pythium aphanidermatum*

Preparation of inoculum

The inoculum of *P. aphanidermatum* was prepared by using 300 g of autoclaved sorghum seeds in two per cent sucrose solution. The seeds were autoclaved successively for two days in 500 ml conical flasks at 15 kg/cm^2 (121.6^{o}C) for 20 minutes and were allowed to cool to room temperature before being inoculated with five mm discs of 3 to 4 days old culture of *P. aphanidermatum* grown on PDA. The flasks were incubated for seven days at 28$\pm$2°C in an incubator.

Inoculation

Pathogenicity test was conducted using susceptible tomato cultivar cv. Pusa Ruby. Nursery was raised in sterilized soil in plastic trays (45 x 30 x 10 cm). The inoculum of the pathogen grown on sorghum seeds was added to the soil @ 10 g/kg of soil and mixed thoroughly and moistened with water. The inoculated trays covered by polythene sheet were incubated for two days. On the third day, the seeds of tomato cv. Pusa Ruby sown at the rate of 100 seeds/tray. A check tray (control) was maintained without addition of inoculum to the soil. Observations on the seed germination and mortality of seedlings were recorded as soon as disease developed.

3.8.2 *Macrophomina phaseolina*

Pathogenicity tests were carried out using castor cv. Aruna. Inoculum multiplied on sorghum seeds (as mentioned in 3.8.1 of Materials and

Methods) was added to the top 6-7 cm layer of sterilizsed soil of pot at the rate of 10 g kg^{-1} soil mixed thoroughly and moistened with water. The pots were incubated for two days by covering with polythene sheets. On the 3rd day seeds were sown at the rate of 10 seeds per inoculated pot (9" dia) and control was maintained by treating the seeds with sterile distilled water. Periodical observations were made for symptom initiation and development. The reisolation from artificially infected plants was made and the culture thus obtained was compared with the original culture to confirm the identity of the pathogen.

3.8.3 *Sclerotium rolfsii*

Pathogenicity tests were carried out using susceptible sunflower cv. Morden. Plants were raised on sterilized soil in plastic trays (45 x 30 x 10 cm) and were inoculated by soil inoculation method.

Soil inoculation method

The inoculum of *S. rolfsii* was prepared by the method suggested by Avisohar Hershenzon and Shacked (1968). For this purpose 300 g of sorghum seeds were pre-soaked on two per cent sucrose solution and autoclaved successively for two days in 500 ml saline bottles at 15 kg/cm^2 for 20 minutes. The flasks were allowed to cool to room temperature before being inoculated with 5 mm discs of 3 to 4 days old culture of *S. rolfsii* grown on PDA. Seven discs per saline bottle (1000 ml) were added and the flasks were incubated for 7 days at $28\pm2^{o}C$ in an incubator.

Inoculum grown on sorghum seeds was added to the top 6-7 cm layer of sterilized soil in 9 inch dia earthen pots at the rate of 10 g/kg soil and mixed thoroughly and moistened with water. The pots were incubated for 2 days by covering with polythene sheets. On the fifth day, seeds of sunflower cv. Morden

were sown at the rate of five seeds/pot. A check pot (control) was maintained without addition of inoculum to the soil. Observations on per cent mortality of plants was recorded as soon as the disease developed.

3.9 ISOLATION AND MAINTENANCE OF NATIVE AND COMMERCIAL FORMULATIONS OF BIOCONTROL AGENTS

3.9.1 Native isolates of *Trichoderma* spp.

The native isolates of *T. viride* and *T. harzianum* were obtained from the Directorate of Oilseeds Research, Rajendranagar which were isolated from soil samples from rhizosphere of castor cv. Aruna. The pure cultures of *T. viride* and *T. harzianum* were maintained on PDA by periodic transfer, and designated as DOR 1 Tv (*T. viride*) and DOR 2 Th (*T. harzianum*). The exotic isolates of *T. viride* and *T.harzianum* were obtained from Nagarjuna Agricultural Research and Development Institute, Hyderabad, and the pure cultures of these were maintained on PDA by periodic transfer, and designated as NCC-58 Tv (*T.viride*), NCC-57 Th (*T.harzianum*) for further studies.

3.9.2 Commercial formulations of *Trichoderma* spp.

To isolate *Trichoderma* spp. from the commercial formulations, 4 g of the commercial formulation of each of the isolate was added to 100 ml sterile distilled water and 0.5 ml of the preparation was aseptically transferred into TSM containing plates. The inoculated plates were incubated at $28 \pm 2^{o}C$ for one week and the resultant *Trichoderma* colonies were isolated and reidentified. Cultures of *Trichoderma* spp. were maintained on PDA by periodic transfers for further studies.

3.9.3 Commercial formulations of *Pseudomonas fluorescens*

To isolate *P. fluorescens* from commercial formulations, 1 g of talc formulation of each of the isolate was added to 100 ml sterile distilled water and shaken thoroughly. 0.5 ml of the preparation was aseptically transferred into Pseudomonas agar medium containing plates. The inoculated plates were incubated at 28±2°C for four days and the resultant colonies were isolated and reidentified and used for further studies. The cultures of *P. fluorescens* isolates were maintained on Pseudomonas agar medium by periodic transfers for further studies.

The details of native and commercial biocontrol agents (BCA) used in the study, are given in Table 1.

Table 1: Details of native and commercial biocontrol agents used in the present study

Trade Name / Culture Number	Bioagent	Formu-lation	Manufacturing company / Source of supply
BCL Tv	*Trichoderma viride*	Talc	Biocontrol Laboratory, Department of Agriculture, Rajendranagar, Hyderabad.
DOR 1 Tv	*T. viride*	Culture	Directorate of Oilseeds Research, Rajendranagar, Hyderabad.
Sun Agro Derma Tv	*T. viride*	Talc	Sun Agro Industries, Porur, Chennai
NCC-58 Tv	*T. viride*	Culture	Nagarjuna Agriculture Research and Development Institute, Hyderabad.
Sun Agro Derma Th	*Trichoderma harzianum*	Talc	Sun Agro Industries, Porur, Chennai
DOR 2 Th	*T. harzianum*	Culture	Directorate of Oilseeds Research, Rajendranagar, Hyderabad.
NCC-57 Th	*T. harzianum*	Culture	Nagarjuna Agriculture Research and Development Institute, Hyderabad.
Vermigreen Th	*T. harzianum*	Talc	Vermigreen Biotech Centre, Hyderabad
Sun Agro Monus Pf	*Pseudomonas fluorescens*	Talc	Sun Agro Industries, Porur, Chennai
Vermigreen Pf	*P. fluorescens*	Talc	Vermigreen Biotech Centre, Hyderabad

3.10 MASS MULTIPLICATION OF BIOCONTROL AGENTS AND TEST PATHOGENS

The pathogens, *P. aphanidermatum, M. phaseolina* and *S. rolfsii* and different isolates of *Trichoderma* spp. multiplied *en masse* using sorghum grains in 1000 ml saline bottles (Plates 149, 150 and 151). Sorghum grains soaked overnight in two per cent sucrose solution and autoclaved and inoculated with three day old PDA grown fungal discs of five mm diameter in one litre saline bottles. The saline bottles inoculated with five discs (5 mm dia) each of either pathogen or biocontrol agent were incubated at 28±2°C. Fifteen day old culture of both the antagonists and pathogens were used for soil infestation.

3.11 *IN VITRO* EFFICACY OF COMMERCIAL FORMULATIONS OF BIOCONTROL AGENTS AGAINST SOIL-BORNE PLANT PATHOGENS

The antagonistic activity of both native and commercial biocontrol agents against the test pathogens was evaluated by dual culture technique (Nene and Thapliyal, 1993). In all four isolates, each of *T. viride*, *T. harzianum* and two isolates of *P. fluorescens* were used to test their antagonistic activity against the three test pathogens.

3.11.1 Fungal antagonists

Twenty ml of sterilized melted PDA medium was aseptically poured into 90 mm sterilized petriplates and allowed to solidify. Mycelial discs of (5 mm dia) the each of the antagonistic fungal and the test pathogens were cut with the sterilised cork borer from edge of the seven day old cultures and were placed on the solidified medium opposite to each other at equidistance, four replications were

maintained for each treatment. Suitable controls were maintained by placing only the pathogens, all the petriplates incubated at 28±2°C for seven days. The growth of the test pathogen and ability of the antagonist inhibit the pathogen was recorded by periodical observations. The per cent growth reduction was calculated by using formula given below.

$$R = \frac{CS - TS}{CS} \times 100$$

Where,

R = Per cent growth reduction of the pathogen
CS = Diameter of the pathogen colony in control.
TS = Diameter of the pathogen colony in treatment.

3.11.2 Bacterial antagonists

The bioassay was made as per the method suggested by Laha *et al*. (1996). Commercial isolates of *P. fluorescens* grown on Pseudomonas agar medium plates for two days at 28±2°C was used for the purpose. A loopful of bacterial growth was streaked at one end of the petriplates containing Kings B medium which have been pre-inoculated with mycelial discs of test pathogen at the other end of petriplate. The assay plates were incubated at 28±2°C for four days and observations were made on inhibition of mycelial growth of the test pathogens. For each test four replications and suitable controls were maintained. The per cent inhibition over control was calculated by adopting the following formula.

$$\text{Per cent inhibition of pathogen} = \frac{[\text{Growth of pathogen in control plate}] - [\text{Growth of pathogen in presence of bioagent}]}{\text{Growth of pathogen in control plate}} \times 100$$

3.12 SENSITIVITY OF COMMERCIAL BIOCONTROL AGENTS AGAINST DIFFERENT AGROCHEMICALS *IN VITRO*

Efficacy of four fungicides, three insecticides, four fertilizers and two herbicides (Table 2) was evaluated against the biocontrol agents.

3.12.1 Fungal antagonists

To test the sensitivity of fungal biocontrol agents against the fungicides (mancozeb, copper oxychloride, carbendazim and hexaconazole), insecticides (chlorpyriphos, imidacloprid and carbosulfan), fertilizers (calcium ammonium nitrate, diammonium phosphate, single super phosphate and muriate of potash) and herbicides (pendimethalin and fluchloralin) at 100, 500, 1000 and 2000 ppm concentrations, poisoned food technique in solid medium (PDA) was used.

For each treatment 60 ml PDA was taken in 100 ml conical flask and sterilized. To this medium specified quantity of the test chemical was added to get desired concentration at lukewarm temperature and mixed thoroughly by shaking the flasks. The poisoned medium was poured asceptically into sterilized petriplates and allowed to solidify. For each treatment four treatments were maintained. Mycelial discs (5 mm dia) of the test isolates of *Trichoderma* spp. culture (one week old) was cut from the periphery of the colony with sterile cork borer and transferred to the center of poisoned medium in each of the petriplate. Suitable controls were maintained by placing discs of isolates of *Trichoderma* spp. in petriplates containing untreated medium (i.e. without chemical). All the inoculated petriplates were incubated at $28 \pm 2^{o}C$ in a BOD. The colony diameter of the various isolates of *Trichoderma* spp. was measured in treatment plates when the colony growth in the control plate was full.

Per cent inhibition (I) of the growth of biocontrol agent over the control was calculated by using the following formula.

$$I = \frac{C - T}{C} \times 100$$

Where,

I = Per cent inhibition

C = Colony diameter of biocontrol agent in control.

T = Colony diameter of biocontrol agent in treatment.

3.12.2 Bacterial antagonists

By using inhibition zone technique (Nene and Thapliyal, 1993) sensitivity of the isolates of antagonistic bacteria with the agrochemicals was determined. Fifteen ml of King's B medium was poured in petriplates over which 5 ml of luke-warm King's B seeded with each bacterium was poured and rotated gently for uniform distribution. Four discs of sterilized Whatman No.1 filter paper of about 10 mm diameter dipped in agrochemical solution, air dried and placed over bacteria seeded King's B medium plates. Plates along with a control (discs dipped in sterile water) were incubated at $28 \pm 2^{o}C$ for seven days. The inhibition zone (mm) around the discs was measured and per cent inhibition of each antagonistic bacterium was calculated by using the following formula:

$$\text{Per cent inhibition of growth antagonistic bacterium} = \frac{\text{Growth in control (mm)} - \text{Growth in treatment (mm)}}{\text{Growth in control (mm)}} \times 100$$

3.13 EFFICACY OF AGROCHEMICALS AGAINST THE TEST PATHOGENS

Efficacy of the fungicides, insecticides, herbicides and fertilizers (Table 2) was evaluated against the test pathogens viz., *P. aphanidermatum*,

M. phaseolina and *S. rolfsii* by adopting poisoned food technique at 100, 500, 1000 and 2000 ppm concentrations. Four replications were maintained for each of the treatment along with suitable controls. For each treatment 60 ml of potato dextrose agar medium was taken in 100 ml conical flask and sterilized. To this medium specified quantity of the each of the chemical was added to get desired concentration at lukewarm temperature and mixed thoroughly by shaking the flask. The poisoned medium was equally distributed into four petriplates which were treated as replications and allowed to solidify. Five mm discs of each of the test pathogens (one week old) was cut from the periphery of the colony with sterile corkborer and transferred to the center of poisoned medium in each of the petriplate. Suitable controls were maintained by placing discs of the test pathogens in petriplates containing untreated medium. All the inoculated petriplates were incubated at $28\pm2^{o}C$. The colony diameter of the various test pathogens was measured in treatment plates when colony growth in control plate was full. Per cent inhibition (I) of the growth of the pathogen over the control was calculated by using the following formula.

$$\text{Per cent inhibition of pathogen} = \frac{\text{Diameter of the colony in control plate} - \text{Diameter of the colony in treated plate}}{\text{Diameter of the colony in control plate}} \times 100$$

3.14 SYNERGISTIC EFFECT OF BIOCONTROL AGENTS AND AGROCHEMICALS ON TEST PATHOGENS

3.14.1 Fungal Antagonists

To test the combined effect of the fungal biocontrol agents and the agrochemicals against the test pathogens, dual culture method was used in poisoned medium. For this, specified quantity of the each chemical was added to the sterilized

PDA medium at luke warm stage to get desired concentration of the chemical and each chemical was tested at 100, 500, 1000 and 2000 ppm concentrations. Four replications for each concentration of the chemical were maintained. Mycelial discs (5 mm in diameter) of the antagonist as well as the test pathogen were cut with the help of separate sterilized cork borers from the edge of three days old culture and then placed at opposite ends on the petriplate. The petriplates were incubated at $28 \pm 2^{o}C$ for five days. The medium inoculated with pathogen only served as control, the diameter of the mycelial growth was measured when control plates showed maximum growth. The growth of the test pathogen and the ability of the antagonist to inhibit the pathogen were recorded by periodical observations. The per cent growth reduction was calculated by using the formula as given below.

$$\text{Percent inhibition of pathogen} = \frac{CS - TS}{CS} \times 100$$

Where,

CS = Diameter of test pathogen colony in check

TS = Diameter of test pathogen colony in treatment.

3.14.2 Bacterial Antagonists

The synergistic combined effect of the isolates of *P. fluorescens* and the agrochemicals against three test pathogens tested on King's B medium on poisoned food technique. A loop of bacterial growth (two day old) was streaked at one end of the petriplates which have been pre-inoculated with mycelial discs of the test pathogens at another end of the petriplate. The assay plates were incubated at $28 \pm 2^{o}C$ for 4 days and observations were made on inhibition of mycelial growth of the pathogen. King's B medium plates inoculated with mycelial discs of seven day old cultures of respective pathogens served as control. For each test four

replications and a control were maintained. The percent inhibition over control was calculated by adopting the formula given in 3.11.2 of the materials and methods.

3.15 COMBINED EFFECT OF BIOCONTROL AGENTS AND AGROCHEMICALS ON TEST PATHOGENS UNDER GLASSHOUSE CONDITIONS

The combined effect of the potential antagonistic isolates and the agrochemicals were further tested for their potential ability in suppressing the colonization of the three test pathogens under glasshouse conditions. The trial was conducted pathogenwise with different combinations involving potential antagonistic isolates of *Trichoderma* spp. and effective chemicals and their concentrations under high soil inoculum pressure of the pathogens in pot culture. In all 13 combinations of treatments were tried in case of *P. aphanidermatum*, while 14 combinations of treatments each were tried in case of *S. rolfsii* and *M. phaseolina*. Earthen pots of 9 inch diameter and sterilized soil (formaldehyde sterilized) containing red and black soil and farmyard manure in the ratio of 1:1:1 were used for this study. In all three replications for each treatment were tried. The details of each treatment are as follows:

P. aphanidermatum

T_1 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with copper oxychloride (COC) @ 100 ppm

T_2 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with mancozeb @ 100 ppm

T_3 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with mancozeb @ 100 ppm

T_4 - Seed treatment with *T. harzianum* (Vermigreen Th) + Soil drenching with imidacloprid @ 100 ppm

T_5 - Seed treatment with *T. viride* (NCC-58 Tv) + Soil drenching with chlorpyriphos @ 100 ppm

T_6 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with carbosulfan @ 500 ppm

T_7 - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Soil drenching with calcium ammonium nitrate (CAN) @ 2000 ppm

T_8 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with diammonium phosphate (DAP) @ 2000 ppm

T_9 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with single superphosphate @ 500 ppm

T_{10} - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with muriate of potash (MOP) @ 2000 ppm

T_{11} - Seed treatment with *T. viride* (BCL Tv) + Pre-emergence soil drenching with pendimethalin @ 100 ppm

T_{12} - Seed treatment with (DOR 1 Tv) + Pre-plant soil drenching with fluchloralin @ 100 ppm

T_{13} - Pathogen check.

M. phaseolina

T_1 - Seed treatment with *T. harzianum* (Sun Agro Derma Th) + Soil drenching with copper oxychloride (COC) @ 100 ppm

T_2 - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Soil drenching with mancozeb @ 100 ppm

T_3 - Seed treatment with *T. viride* (NCC-58 Tv) + Soil drenching with imidacloprid @ 100 ppm

T_4 - Seed treatment with *T. harzianum* (Sun Agro Derma Th) + Soil drenching with imidacloprid @ 100 ppm

T_5 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with imidacloprid @ 100 ppm

T_6 - Seed treatment with *T. harzianum* (Vermigreen Th) + Soil drenching with chlorpyriphos @ 100 ppm

T_7 - Seed treatment with *T. harzianum* (Vermigreen Th) + Soil drenching with carbosulfan @ 100 ppm

T_8 - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with calcium ammonium nitrate (CAN) @ 500 ppm

T_9 - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with diammonium phosphate @ 2000 ppm

T_{10} - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with single superphosphate @ 2000 ppm

T_{11} - Seed treatment with *T. viride* (NCC-58 Tv) + Soil drenching with muriate of potash @ 2000 ppm

T_{12} - Seed treatment with *T. harzianum* (Sun Agro Derma Th) + Pre-emergence soil drenching with pendimethalin @ 100 ppm

T_{13} - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Pre-plant soil drenching with fluchloralin @ 100 ppm.

T_{14} - Pathogen check.

S. rolfsii

T_1 - Seed treatment with *T. harzianum* (NCC-57Th) + Soil drenching with copper oxychloride (COC) @ 100 ppm

T_2 - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with mancozeb @ 500 ppm

T_3 - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with imidacloprid @ 100 ppm

T_4 - Seed treatment with *T. viride* (NCC-58 Tv) + Soil drenching with chlorpyriphos @ 100 ppm

T_5 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with carbosulfan @ 2000 ppm

T_6 - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Soil drenching with calcium ammonium nitrate @ 2000 ppm

T_7 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with diammonium phosphate @ 2000 ppm

T_8 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with single superphosphate @ 2000 ppm

T_9 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with muriate of potash @ 500 ppm

T_{10} - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Soil drenching with muriate of potash @ 2000 ppm

T_{11} - Seed treatment with *T. viride* (NCC-58 Tv) + Pre-emergence soil drenching with pendimethalin @ 100 ppm

T_{12} - Seed treatment with *T. harzianum* (Vermigreen Th) + Pre-emergence soil drenching with pendimethalin @ 100 ppm

T_{13} - Seed treatment with *T. viride* (BCL Tv) + Pre-plant soil drenching with fluchloralin @ 100 ppm.

T_{14} - Pathogen check.

The inoculum of respective pathogens multiplied on sorghum grains was mixed at the rate of 10 g/kg of soil in upper 10 cm layer of autoclaved pot soil. Pots were sprinkled with water and incubated for two days after covering with polythene bags. On third day of inoculation the culture of bioagents grown on sorghum seeds were mixed at the rate of 10 g/kg of soil in the upper 10 cm layer of the same soil to which different pathogens were added. The potential isolates of *Trichoderma* spp. were multiplied on PDA medium in petriplates. The seven day old culture of each antagonistic isolate was used for seed treatment. Ten ml of sterile distilled water was added to each petriplate and the conidia gently freed from the culture surface by shaking and using sterile camel hair brush. Final concentration of spore suspension was adjusted to 10^8 spores/ml by adding sterile distilled water. The seeds of test cultivars pre-coated with carboxy methyl cellulase were dipped in this spore suspension for 15 minutes, air dried and sown in earthen pots pre-inoculated with test pathogens. On the same day seeds treated with different isolates of biocontrol agents were sown at the rate of 100 seeds/pot for tomato and brinjal cultivars, whereas 20 seeds/pot in case of *bhendi* cultivar, suitable controls were maintained with untreated seeds for each test cultivar. Per cent seed germination

was recorded on fifth day in all the treatments replication wise and pathogen wise. Seedling mortality was recorded at regular intervals up to 40 DAS in each treatment, pathogen wise and replication wise. To determine dry weight of seedlings, three seedlings were collected randomly from each treatment on 45 days after sowing. Seedlings from each treatment were wrapped separately in blotting papers and dried in hot air oven at 60^0C for 48 hours and dry weight was recorded. The effective agrochemicals at their respective concentrations were applied to the soil at the rate of 250 ml/pot after fifth day of inoculation with the respective pathogens. The pots were watered as and when required.

3.16 STATISTICAL ANALYSIS

The data obtained in different experiments was transformed using angular transformations wherever necessary (Panse and Sukhatme, 1978) and was statically analysed using CRD. The data pertaining to per cent seed germination, seedling mortality and seedling vigour were statistically analysed using RBD. Data on root and shoot length of seedlings were recorded on 35 DAS. Seedling vigour index was calculated following Abdul Baki and Anderson (1973) by multiplying germination percentage to the sum of root and shoot length.

Fluchloralin

In significant differences in radial growth of the pathogen *S. rolfsi* was found in fluchloralin amended medium with all the test isolates of *Trichoderma* spp. At lower concentrations (100 ppm) of fluchloralin, the growth test isolates of *Trichoderma* spp. was faster compared to the test pathogen. However, at higher concentrations (500, 1000 and 2000 ppm) the herbicide fluchloralin was inhibitory to the growth of the test pathogen as well as the test isolates of *Trichoderma* spp. The per cent growth inhibition of the test pathogen at higher concentrations of fluchloralin is due to the effect of the chemical rather than due to antagonistic fungal isolates (Table 71).

4.7.2 COMBINED EFFECT OF BACTERIAL BIOCONTROL AGENTS WITH VARIOUS AGROCHEMICALS AGAINST TEST PATHOGENS *IN VITRO*

4.7.2.1 Combined effect of bacterial biocontrol agents with various fungicides against test pathogens *in vitro*

Combined effect of the fungicides with the commercial isolates of *P. fluorescens* against the pathogens viz., *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* was studied at 100, 500, 1000 and 2000 ppm concentrations and the results are presented in Tables 72 to 74.

P. aphanidermatum

Significant differences in radial growth of the pathogen, *P. aphanidermatum* was observed with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermi Green Pf) tested in fungicides amended medium at different

concentrations (Table 72). However, there was no significant difference in the radial growth of pathogen between the bacterial biocontrol agents in combination with the fungicides. In COC amended medium the efficacy of the bacterial biocontrol agents increased with the increase in concentration. The per cent growth inhibition ranged between 6.9 and 17.64 in case of *P. fluorescens* (Sun Agro Monus Pf) and 6.39 and 16.17 in case of *P. fluorescens* (Vermigreen Pf). In mancozeb amended medium the per cent growth inhibition of *P. aphanidermatum* was between 16.47 and 17.35 with two bacterial isolates respectively at 100 ppm concentration. However, cent per cent inhibition of test pathogen was observed in mancozeb amended medium at 500, 1000 and 2000 ppm concentrations indicating the effect of fungicide only (Table 72). In carbendazim amended medium, no growth reduction of the pathogen was observed with two bacterial antagonists at 100 ppm concentration. While per cent inhibition of the growth of test pathogen was in between 15.29 and 29.70 in carbendazim amended medium with the two bacterial antagonists at 500, 1000 and 2000 ppm concentrations. In hexaconazole amended medium the growth of *P. aphanidermatum* was inhibited to an extent of 73.3 per cent by the two *P. fluorescens* isolates at 100 ppm concentration it was 81 per cent with the two bacterial isolates tested. Combined effect of the two bacterial antagonists with hexaconazole fungicide was observed at lower concentration. While, at higher concentration effect of the fungicide was clearly seen, as 95.29 to 97.64 per cent inhibition of the test pathogen was observed in hexaconazole amended medium at 1000 and 2000 ppm concentration (Plates 125 to 132).

M. phaseolina

Cent per cent inhibition of *M. phaseolina* was observed in mancozeb, carbendazim and hexaconazole amended medium at 100, 500, 1000 and 2000 ppm

concentrations indicating the effect of fungicide only (Table 73). While, no growth inhibition of the pathogen with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) was recorded in COC amended medium at 100, 500, 1000 and 2000 ppm concentrations and the pathogen overgrew the bacterial antagonistic isolates in these treatments (Plates 125 to 132).

S. rolfsii

Cent per cent inhibition of the test pathogen was observed in mancozeb and hexaconazole combination with the two commercial isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) at 100, 500, 1000 and 2000 ppm concentrations (Table 74). However, no growth inhibition of the pathogen was observed in COC and carbendazim amended medium with the two test isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) at 100, 500, 1000 and 2000 ppm concentrations and the pathogen overgrew the bacterial isolates at all concentrations (Plates 125 to 135).

4.7.2.2 Combined effect of bacterial biocontrol agents with various insecticides against test pathogens *in vitro*

Combined effect of the insecticides with the two commercial isolates of *P. fluorescens* against the pathogens viz., *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* was studied at 100, 500, 1000 and 2000 ppm concentrations and the results are presented in Tables 75 to 77.

P. aphanidermatum

Significant differences in radial growth of the pathogen *P. aphanidermatum* was observed with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) in insecticides amended medium at different

concentrations (Table 75). In insecticide amended media the efficacy of the bacterial biocontrol agents increased with increase in concentrations of the insecticide. Per cent growth inhibition of *P. aphanidermatum* ranged from 27.70 to57.66 and 27.04 to 35.44 in imidacloprid amended medium with Sun Agro Monus Pf and Vermigreen Pf isolates respectively. In chlorpyriphos amended medium the growth inhibition of the pathogen was from 49.29 to 62.49 and 47.64 to 62.65 per cent with Sun Agro Monus Pf and Vermigreen Pf isolates respectively. The growth of the pathogen was inhibited from 35.80 to 62.10 and 39.69 to 52.46 per cent with Sun Agro Monus pf and Vermigreen Pf isolates in carbosulfan amended medium respectively (Plates 133 to 138).

M. phaseolina

Significant difference in radial growth of the pathogen *M. phaseolina* was observed with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) tested in insecticide amended medium at different concentrations (Table 76). However, there was no significant difference in the radial growth of pathogen between the bacterial biocontrol agents in combination with the insecticides. In imidacloprid, chlorpyriphos and carbosulfan amended medium the efficacy of the bacterial biocontrol agents increased with increase in concentrations. The per cent growth inhibition ranged between 39.47 to 54.15 in case of both the isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf), 54.67 to 74.84 and 45.20 to 65.24 in imidacloprid, chlorpyriphos and carbosulfan amended medium respectively in case of both the isolates of *P. fluorescens* at 100, 500, 1000 and 2000 ppm (Table 76 and Plates 133 to 138).

S. rolfsii

Significant differences in radial growth of the pathogen *S. rolfsii* was observed with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) tested in insecticides amended medium at different concentrations (Table 77). However, there was no significant differences in the radial growth of the pathogen between the bacterial biocontrol agents in combination with the insecticides at 500, 1000 and 2000 ppm concentrations. In imidacloprid amended medium the efficacy of the bacterial biocontrol agents increased with increase in concentrations. The per cent growth inhibition ranged between 25.12 to 49.68 in case of Sun AgroMonus Pf and 21.89 to 50.36 in case of Vermigreen Pf (Table 77). Significant differences between the two commercial isolates of *P. fluorescens* in chlorpyriphos amended medium at 100, 500 and 1000 ppm concentrations. The per cent growth inhibition ranged between 48.54 to 61.79 in case of Sun Agro Monus Pf and 46.52 to 61.03 in case of Vermigreen Pf (Table 77). Whereas, there is no significant difference between two isolates of bacterial biocontrol isolates in carbosulfan amended medium at 100, 500 ppm concentrations. The per cent growth inhibition ranged between 34.34 to 58.47 in case of commercial isolate of Sun Agro Monus Pf and 34.75 to 59.10 in case of Vermigreen Pf (Table 77 and Plates 133 to 138).

4.7.2.3 Combined effect of bacterial biocontrol agents with various fertilizers against test pathogens *in vitro*

P. aphanidermatum

Significant differences in radial growth of the pathogen *P. aphanidermatum* was observed with the two isolates of *P. fluorescens* (Sun Agro

Monus Pf and Vermigreen Pf) tested in fertilizers amended medium at different concentrations (Table 78). However, there was no significant difference in the radial growth of the pathogen between the two bacterial biocontrol agents in combination with the fertilizers at 100, 500, 1000 and 2000 ppm concentrations. With increase in concentration of CAN and DAP there was corresponding increase in radial growth of the pathogen. While, in SSP and MOP amended medium, with increase in concentration of these fertilizers, there was corresponding decrease in the radial growth of the pathogen was observed (Table 78). In CAN and DAP amended medium, the rapid growth of *P. aphanidermatum* was less at 1000 and 2000 ppm concentration compared to lower concentrations (100 and 500 ppm) of the fertilizers (Plates 139 to 146).

M. phaseolina

Among the four fertilizers, significant differences in radial growth of the pathogen *M. phaseolina* was observed with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) tested at different concentrations (Table 79). However, there was no significant differences in the radial growth of pathogen between the two bacterial biocontrol agents in combination with the fertilizers. In CAN and DAP fertilizers amended medium the efficacy of the bacterial biocontrol agents increased with increase in concentrations. While, in SSP and MOP amended medium the efficacy of the bacterial biocontrol agents decreased with increase in concentrations. The per cent growth inhibition ranged between 24.68 to 55.89, 32.62 to 58.68, 4.24 to 3.71 and 3.45 to 2.87 in case of both the commercial isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) in CAN, DAP, SSP and MOP amended medium respectively (Table 79 and Plates 139 to 146).

S. rolfsii

Significant difference in the radial growth of the pathogen *S. rolfsii* was observed in combination of all the fertilizers and bacterial biocontrol agents tested (Table 80). However, there was significant difference in the radial growth of the pathogen between the bacterial biocontrol agents in combination with the fertilizers. In CAN, DAP, SSP and MOP amended medium the efficacy of the bacterial biocontrol agents increased with increase in concentrations. The per cent growth inhibition ranged between 7.96 to 13.15; 6.90 to 31.12; 6.14 to 30.48 and 7.18 to 48.12 in case of both the isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) in CAN, DAP, SSP and MOP amended medium respectively (Table 80 and Plates 139 to 146).

4.7.2.4 Combined effect of bacterial biocontrol agents with various herbicides against test pathogens *in vitro*

The combined effect of herbicides and bacterial biocontrol agents against test pathogens viz., *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* was studied at different concentrations and the results are presented in Tables 81 to 83.

P. aphanidermatum

Significant differences in radial growth of the pathogen *P. aphanidermatum* was observed with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) tested in herbicide amended medium at different concentrations (Table 81). However, there was no significant differences in the radial growth of the pathogen between the bacterial biocontrol agents at all concentrations. In pendimethalin and fluchloralin amended medium the efficacy of the bacterial biocontrol agents increased with increase in concentrations. The per

cent growth inhibition of the pathogen ranged between 59.45 to 76.03, 58.65 to 76.84 and 56.71 to 74.48 and 55.70 to 75.55 in case of both the commercial isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) in pendimethalin and fluchloralin amended medium at all the concentrations respectively (Table 81 and Plates 147 and 148).

M. phaseolina

Among two herbicides, the significant differences in radial growth of the pathogen *M. phaseolina* was observed with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) tested in herbicide amended medium at different concentrations (Table 82). However, there was significant difference in the radial growth of the pathogen at lower concentration (100 ppm) compared to higher concentrations (500,1000 and 2000 ppm). In pendimethalin and fluchloralin amended media the efficacy of the bacterial biocontrol agents increased with the increase in concentrations. The per cent growth inhibition of the pathogen ranged between 54.17 to 82.90 and 52.25 to 80.83 in case of the isolates of *P. fluorescens* at 100,500,1000 and 2000 ppm concentrations (Table 82 and Plates 147 and 148).

S. rolfsii

Significant differences in the radial growth of the pathogen *S. rolfsii* was observed with the two isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermigreen Pf) in herbicide amended medium at different concentrations. However, there was no significant difference in the radial growth of the pathogen between two bacterial isolates in combination with herbicides (pendimethalin and fluchloralin) at 100, 500 and 1000 ppm concentrations (Table 83). In herbicides amended medium the efficacy of the bacterial biocontrol agents increased with

increase in concentrations. While, the radial growth of the pathogen *S. rolfsii* decreased with increase in concentrations. The per cent growth inhibition ranged between 12.18 to 46.23 and 11.20 to 52.01 in case of both the isolates of *P. fluorescens* in pendimethalin and fluchloralin amended medium at 100,500,1000 and 2000 ppm concentrations (Table 83 and Plates 147 and 148).

4.8 COMBINED EFFECT OF BIOCONTROL AGENTS AND AGROCHEMICALS AGAINST TEST PATHOGENS UNDER GLASSHOUSE CONDITIONS

Combined effect of potential biocontrol agents and agrochemicals was studied for their ability in suppressing the colonization of the test pathogens viz., *P. aphanidermatum, M. phaseolina* and *S. rolfsii* under artificially inoculated conditions in glasshouse using tomato, brinjal and bhendi as test cultivars. The effect of different treatments on seed germination, seedling mortality and seedling parameters like root and shoot lengths dry weight and seedling vigour index was studied and the results are presented here under in pathogen wise and crop wise (Tables 84 to 92).

4.8.1 Effect of different treatments on *P. aphanidermatum* infection and on seedling parameters of tomato, brinjal and bhendi crops

Tomato

The germination of seeds of tomato cv. Pusa Ruby in all the treatments (46.24 to 89%) was significantly higher as compared to pathogen check (36%). Maximum seed germination (89%) was obtained in T1 (seed treatment with native isolate of *T. harzianum* (DOR-2 Th) and soil drenching with COC 100 ppm) treatment followed by T2 (seed treatment with *T. harzianum* (DOR 2 Th) and soil

drenching with mancozeb 100 ppm) treatment (86%). While T12 (seed treatment with *T. viride* (DOR 1 Tv) and pre-plant application of fluchloralin with 100 ppm) recorded the minimum seed germination of 46.24 per cent (Table 84).

All the treatments significantly reduced the seedling mortality (post-emergence) compared to the pathogen check. The per cent decrease in seedling mortality in various treatments ranged from 43.26 to 73.75. (Table 84).Maximum reduction in seedling mortality(73.75 %) was recorded in T_1 [a combination of seed treatment with *T. harzianum*(DOR-2 Th) and soil drenching with COC @ 100 ppm] followed by T_3 [seed treatment with *T. harzianum* (NCC-57 Th) and soil drenching with mancozeb @ 100 ppm] treatment which was on par with T_1 treatment. The treatments T_5, T_6, T_7,T_9, T_{10},T_{11} were on par with each other with regard to reducing seedling mortality due to *P. aphanidermatum* (Table 84 and Plates 152 ,155 and 158).

There was significant increase in root and shoot length in various treatment combinations compared to pathogen check. Maximum root length of 3.86 cm, and shoot length of 6.73 cm was recorded in T_1 [Seed treatment with native isolate of *T. harzianum* and soil drenching COC 100 ppm] treatment followed by T_2 [seed treatment with native isolate of *T. harzianum* (DOR-2 Th) and soil drenching with mancozeb 100 ppm]treatment. While T_{10} treatment [seed treatment of native isolate DOR 1 *T. viride* and pre-sowing application of MOP at 2000 ppm] recorded minimum root and shoot lengths of 3.2 and 5.93 cm respectively (Table 84).

All the treatment combinations promoted significantly greater seedling vigour index compared to pathogen check.. Seedling vigour index ranging from 572.08 to 931.83 was obtained with various treatments. Maximum vigour

index (931.83) was recorded in T_1 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with COC 100 ppm] treatment followed by T_2[seed treatment with *T. harzianum* (DOR 2 Th) and soil drenching with mancozeb 100 ppm] treatment recording seedling vigor index of 910.74. While, minimum vigour index of 572.08 was recorded in T_{10} [seed treatment with native *T. viride* (DOR 1 Tv) and pre-sowing application of fertilizer MOP @ 2000 ppm] treatment. The pathogen check recorded a seedling vigour index of 255.56 only (Table 84).

The dry weight of the tomato seedlings increased in all the treatments compared to control. Highest (42.78%) increase of dry weight of seedlings was recorded in T_1 (seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with COC 100 ppm], followed by T_4[seed treatment with commercial isolate of *T. harzianum* (Vermigreen Th) and soil drenching with imidacloprid 100 ppm] and T_5 [seed treatment with *T. viride* (NCC-58 Tv) and soil drenching with chlorpyriphos 100 ppm)] treatments which were at par with T_7 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with CAN 100 ppm], T_8 [Seed treatment with commercial isolate of *T. harzianum* and pre-sowing application of DAP 2000 ppm] and T_{11} [seed treatment with *T. viride* (BCL Tv) and pre-emergence application of 100 ppm] treatments (Table 84).

Brinjal

All the treatment combinations significantly increased the seed germination of brinjal cultivar Shyamala compared to the pathogen check (Table 85). Maximum (82.66 %) seed germination was obtained in T_1 [(seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with COC 100 ppm)]

treatment. While, least (44%) seed germination was recorded in T_{11} and T_{12} treatment which were at par statistically. Where as, T_2, T_4, T_5, T_6, T_7, T_8, T_9 and T_{10} treatments, the seed germination percentage varied between 56.33 and 67.00 per cent (Table 85).

All the treatment combinations significantly reduced the seedling mortality (post-emergence) as compared to the pathogen check. The reduction in seedling mortality in various treatments ranged from 22.66 to 78.05 per cent. Among all the treatments, T_1 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with COC 100 ppm] and T_3 [seed treatment with *T. harzianum* (NCC 57 Th) and soil drenching with mancozeb 100 ppm] treatments significantly differed with pathogen check and were at par with each other. The next best treatment was T_2 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with mancozeb 100 ppm] which recorded 70.92 per cent seedling mortality due to *P. aphanidermatum*. Treatments T_4, T_5, T_6, T_7, T_8, T_9, T_{10} and T_{11} were on par with each other in reducing seedling mortality (Table 85 and Plate 155).

The shoot and root lengths increased significantly over control. In T_1 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with COC 100 ppm] treatment root and shoot lengths were 1.8 and 2.9 cm respectively. While all other treatments were on par with each other in respect of shoot and root lengths (Table 85).

Seedling vigour index ranged between 216.87 to 388.50 in various treatments. Maximum vigour index (388.50) was recorded in T_1 [(seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with COC 100

ppm)] treatment followed by T_2 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with mancozeb 100 ppm] treatment recording vigour index of 283.2. Minimum vigour index of 216.87 was recorded in T_5 [seed treatment with commercial isolate of *T. viride* (NCC-58 Tv) and soil drenching with chlorpyriphos 100 ppm] treatment as against pathogen check which recorded a vigour index of 79.2 only. All the treatment combinations significantly recorded greater seedling vigour indices compared to pathogen check (Table 85).

The dry weight of seedlings was also increased significantly over control. Among all the treatments, maximum increase (78.15 %) was recorded T_1 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with copper oxychloride @100 ppm] treatment. The next best treatments were T_2 and T_3 where in 50.48 and 34.95 per cent increase in dry weight of seedlings was recorded. In T_3, T_8 and T_9 treatments the dry weight recorded were on par with each other (Table 85).

Bhendi

All treatment combination significantly increase seed germination compared to pathogen check. Cent per cent seed germination was recorded in T_1 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with COC 100 ppm] treatment significantly compared with pathogen inoculated check. The per cent seed germination ranged between 90.3 to 100. The seed germination of 90.3% was recorded in T_{11} and T_{12} treatments which were on par with each other. In all the treatments, the seed germination recorded was 98.3% and on par with each other (Table 86).

All the treatment combinations reduced the seedling mortality (post-emergence) compared to the pathogen check (Table 86). The per cent reduction in seedling mortality in various treatments ranged from 69.60 to 89.84. Highest per cent reduction in seedling mortality was recorded in T_1 [seed treatment with *T. harzianum* (DOR 2 Th) and soil drenching with COC 100 ppm] treatment. The next best treatment was T_2 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with mancozeb 100 ppm] which recorded 88.84 per cent reduction in seedling mortality due to *P. aphanidermatum*. In T_3, T_4, T_5 and T_6, T_7, T_8, T_9 treatments decreased per cent respectively seedling mortality was on par with each other (Table 86 and Plate 158).

The root and shoot lengths increased significantly over control. In treatment T_3, the shoot and root lengths were 10.03 cm and 3.80 cm compared to 6.70 cm and 2.67 cm in pathogen inoculated check. In all the treatments, the root and shoot length were on par with each other (Table 86).

Seedling vigour index ranging from 1236.57 to 1359.48 was obtained with various treatments. Maximum seedling vigour index (1359.48) was recorded in T_3 [seed treatment with commercial isolate of *T. harzianum* (NCC-57 Th) and soil drenching with mancozeb 100 ppm] treatment followed by T_2 treatment recording 1325.08. Whereas minimum seedling vigour index (1236.57) was recorded in T_{11} treatment as against 827.37 vigour index in pathogen check (Table 86).

Results Table 86 indicated that the dry weight of seedlings also increased significantly over control. In T_1 [seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching COC 100 ppm)] 32.80 per cent increase dry weight was recorded over control. Where as in T_2 and T_3 treatments

3.80 per cent dry weight and 26.38 per cent increase over control was recorded respectively. In T_4 and T_5, T_6, T_7, T_9 and T_{11}, T_{12} treatments the dry weight recorded were on par with each other.

4.8.2 Effect of different treatments on *M. phaseolina* infection and on seedling parameters of tomato, brinjal and bhendi crops

Tomato

The germination of seeds of tomato cv. Pusa Ruby in all the treatment combinations was significantly higher (62.33 to 87.00 %) as against 36.0 per cent pathogen check . Maximum seed germination (87.0 %) in T_1 [seed treatment with commercial isolate of *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC 100 ppm] treatment followed by T_2 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm], which were on par with each other. While in the T_{13} (seed treatment with *T. viride* (Sun Agro Derma Tv) and pre-plant application of fluchloralin 100 ppm] minimum seed germination of 62.33% was recorded. In all other treatments [T_4, T_5, T_7, T_8, T_9, T_{10}, T_{11} and T_{12}] per cent germination recorded was on par with each other (Table 87).

Table 87 indicates 44.93 per cent decrease in the seedling mortality was recorded in T_2 [(seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm] treatment followed by T_1 [seed treatment with commercial isolate of *T. harzianum* (Sun Agro Derma Th) and soil drenching with mancozeb 100 ppm] and T_3 [seed treatment with commercial isolate of *T. viride* (NCC-58 Tv) and soil drenching with imidacloprid 100 ppm

treatments] where 44.93 and 34.12 per cent decrease over control was recorded. (Table 87 and Plate 153).

Significant differences in root and shoot lengths were observed in various treatments compared to pathogen check. Maximum root length of 3.79 cm and shoot length of 6.92 cm recorded with T_2 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm] treatment. While in all other treatments the root and shoot lengths were on par with each other (Table 87).

Seedling vigour index ranging from 644.49 to 931.77 was obtained with various treatments. Maximum vigour index (931.77) was recorded in T_2 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm] treatment followed by T_1 [(seed treatment with native isolate *T. harzianum* (DOR 2 Th) and soil drenching with COC 100 ppm)] treatment recording vigour index of 885.54. Minimum vigour index of 644.49 was recorded in T_{13} treatment, which significantly differed with pathogen check (Table 87).

Significant increase in dry weight of seedlings was recorded 41.80 per cent over pathogen check. Maximum dry weight increased was recorded in T_5 [seed treatment with commercial isolate *T. harzianum* (NCC 57 Th) and soil drenching with imidacloprid 100 ppm] followed by T_3 and T_6 treatments with 40.83 and 37.89 per cent increase over control. Where as in T_4, T_8, T_9 and T_{10}, T_{11}, T_{13} treatments, the dry weights recorded were on par with each other (Table 87).

Brinjal

The germination of seeds of brinjal cv. Shyamala in all the treatments was significantly higher as compared to pathogen check. Maximum seed germination (81.66%) was recorded in T_2 (seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm) treatment followed by T_1 [(Seed treatment with commercial isolate *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC 100 ppm)] treatment (80.33%). While in T_{13} [(seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv)] and pre plant soil drenching with fluchloralin @ 100 ppm treatment the minimum seed germination of 41.41 per cent (Table 88).

All the treatments significantly reduced the seedling mortality (post emergence) as compared to the pathogen check. The per cent reduction in seedling mortality was ranged from 41.41 to 76.62 in various treatment combinations. Maximum decrease in seedling mortality (76.62 %) was recorded in T_1 [seed treatment with *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC @ 100 ppm] treatment and minimum (41.41 %) was recorded in T_{13} [seed treatment with *T.viride* (Sun Agro Derma Tv) and pre plant application of fluchloralin @ 100 ppm] treatment. All other treatments were statically on par with each other in respect of reduction in seedling mortality (Table 88 and Plate 156).

All the treatments recorded significantly higher root and shoot length compared to check and on par with each other. Maximum root length of 1.83 cm and shoot length of 3 cm was recorded with T_2 treatment followed by T_1 [(seed treatment with native isolate *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC 100 ppm] treatment (Table 88).

In brinjal seedling vigour index ranged from 258.45 to 394.41 was recorded in various treatment combination. Maximum vigour index of 394.41 was recorded in T2 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm] treatment followed by T_1 [seed treatment with commercial isolate of *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC 100 ppm]treatment recording. Minimum vigour index of 258.45 was recorded in T_{11} treatment, as against vigour index of 79.2 only in pathogen check (Table 88).

Significant differences in dry weight of brinjal seedlings increase (98.23 %) was observed in all treatment combinations various treatments of brinjal dry weight of seedlings. compared to pathogen check. Maximum dry weight of the seedlings was recorded in T_1 [(seed treatment with commercial isolate *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC 100 ppm)] treatment. Next best treatments were T_2 and T_3 which recorded 92.47 and 86.72 per cent increase in dry weight over control. In T_3, T_4, T_6 ,T_8, T_{10} and T_{12} treatments the dry weights recorded were on par with each other (Table 88).

Bhendi

All the treatment combinations differed significantly with pathogen check in effect of germeination was observed in T_2 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm] treatment, T_9 [seed treatment with native isolate of *T. viride* (DOR 1 Tv) and soil application of DAP 2000 ppm and T11[seed treatment with *T. viride* (NCC 58 Tv) and soil drenching with muriate of potash @ 2000 ppm] treatments which were

on par. Whereas 98.3 per cent germination of seeds was recorded in all other treatments which were on par with each other (Table 89)

All the treatment combinations significantly reduced the seedling mortality (post-emergence) as compared to the pathogen check. The per cent reduction in mortality ranged from 61.02 to 77.15 in various treatments. Maximum reduction in seedling mortality was observed in T2 [seed treatment with commercial isolate *T.viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm] treatment followed by T_1 [seed treatment with commercial isolate of *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC 100 ppm] and T_9 [seed treatment with native *T. viride* (DOR 1 Tv) and soil drenching with DAP @ 2000 ppm] treatments which recorded 79.49 per cent seedling mortality and on par with each other (Table 89 and Plate 159)

The shoot and root lengths in different treatments increased significantly compared to pathogen check. In T_2 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm] treatment the root length was 3.70 cm and shoot length was 9.76 cm, while all the treatments were on par with each other (Table 89).

In bhendi, seedling vigour index ranged from 1218.92 to 1346.0 in various treatments. Maximum seedling vigour index of 1346.00 was recorded in T2 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm] treatment followed by T3 (seed treatment with commercial isolate of *T. viride* (NCC-58 Tv) and soil drenching with imidacloprid @ 100 ppm] treatment (827.37). While, minimum seedling vigour index (1218.92) was recorded in T6 treatment (Table 89).

The dry weight of seedlings increased significantly over pathogen check. Maximum dry weight increase (38.76 %) was recorded in treatment T_2 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb 100 ppm] followed by T_1 [(seed treatment with commercial isolate of *T. harzianum (*Sun Agro Derma Th) and soil drenching with COC @ 100 ppm] treatment with 37.60 per cent increase over control. In T_4, T_5 and T_6 and T_9 treatments the dry weights recorded were on par with each other (Table 89).

4.8.3 Effect of different treatments on *S. rolfsii* infection and on seedling parameters of tomato, brinjal and bhendi crops

Tomato

The per cent (70.33 to 81.33) germination of seeds of tomato cv. Pusa Ruby in all the treatment combinations was significantly higher compared to the pathogen check (36%). Maximum seed germination was observed in T_6 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil application of CAN 2000 ppm], T8 [seed treatment with *T. harzianum* (DOR 2 Th) and soil application with 2000 ppm], and T9 [seed treatment with native isolate of *T. viride* (DOR 1 Tv) and soil drenching with mancozeb 100 ppm] treatments which recorded 81.3, 81.3 and 81.0 per cent germination respectively. While, all other treatments T_3, T_4, T_5, T_9, T_{10}, T_{11}, T_{12} and T_{13} were on par with each other in respect of germination of seeds (Table 90)

All the treatment combinations significantly reduced seedling mortality (post emergence) as compared to the pathogen check. The reduction in seedling mortality ranged from 28.81 to 77.16 per cent in various treatments.

Maximum reduction in seedling mortality was recorded in T_6 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with CAN 2000 ppm] treatment. The treatments T_4, T_5, T_7, T_{10}, T_{11} and T_{12} were on par with each other. While minimum reduction in seedling mortality (28.81%) was observed in T_{13} treatment (Table 90 and Plate 157)

The root and shoot lengths increased significantly over pathogen check. Maximum root length of 3.88 cm and shoot length of 6.60 cm was recorded in T_2 [seed treatment with isolate of *T. viride* (DOR 1 Tv) and soil drenching with mancozeb 500 ppm] treatment followed by T1 [seed treatment with commercial isolate of *T. harzianum* (NCC 57 Th) and soil drenching with COC 100 ppm] treatment which recorded root and shoot length of 3.8 and 5.0 cm respectively. Whereas, root and shoot lengths of .60 and 4.50 cm were recorded in pathogen check (Table 90).

Seedling vigour index ranging from 647.04 to 848.88 was obtained with various treatments. Maximum seedling vigour index (848.88) was recorded in T_2 (seed treatment with native isolate of *T. viride* [(DOR 1 Tv) and soil drenching with mancozeb @ 500 ppm)] treatment followed by T_6 [(seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil application of CAN 2000 ppm)] treatment recording 814.92. Minimum seedling vigour index 647.04 was recorded in T_7 treatment, as against a seedling vigour index of 255.6 was in pathogen check (Table 90)

Dry weight of the seedlings was increased significantly over pathogen check. In T_7 [seed treatment with commercial isolate of *T. harzianum* (NCC-57 Th) and soil application of DAP 2000 ppm] and T_{11} [seed treatment with

commercial isolate *T. viride* (NCC-58 Tv) and pre-emergence application of 100 ppm] treatment. The increase in dry weight was 41.32 and 38.63 per cent respectively. The next best treatments were T_1 (39.36), T_3 (34.71) were recorded regarding dry weight. (Table 90).

Brinjal

The germination percentage (69.33 to 87.66) of seeds of brinjal cv. Shyamala in all the treatments was significantly higher as compared to the pathogen check (33%). Maximum seed germination (87.66%) was observed in T_2 [(seed treatment with native isolate of *T. viride* (DOR 1 Tv) and soil drenching with mancozeb 500 ppm] treatment followed by T_1 [seed treatment with commercial isolate of *T. harzianum* (NCC-57 Th) and soil drenching with COC 100 ppm)] treatment. While minimum seed germination 69.33 was recorded in T_5 treatment (Table 91).

All the treatments significantly reduced seedling mortality (post-emergence) as compared to pathogen. The per cent reduction seedling mortality in various treatment combinations ranged from 42.57 to 80.18. Maximum reduction in seedling mortality (80.18 %) was recorded in T_2 [seed treatment with the native isolate of *T. viride* (DOR 1 Tv) and soil drenching with mancozeb at the rate of 500 ppm]. Minimum reduction in seedling mortality (42.57%) was recorded in T_{13}. All other treatments were statically on par with each other in reducing per cent seedling mortality (Table 91 and Plate 159).

The root and shoot lengths were increased significantly over pathogen check. Maximum root length of 1.84 cm and shoot length of 2.80 cm was recorded in T_2 [seed treatment with native isolate of *T. viride* (DOR 1 Tv) and soil

drenching with mancozeb 500 ppm] treatment, whereas, root length of 0.80 cm and shoot length of 1.60 cm recorded in pathogen check (Table 91).

Seedling vigour index ranging from 272.04 to 392.70 was obtained with various treatments. Maximum seedling vigour index (392.71) was recorded in T_2 [(seed treatment with native isolate of *T. viride* (DOR 1 Tv) and soil drenching with mancozeb 500 ppm)] treatment recording 392.71 seedling vigour index. Minimum seedling vigour index of 272.04 was recorded in T_7 treatment, whereas, it was 121.77 in pathogen check (Table 91)

In all treatment combinations dry weight of seedlings increased significantly over pathogen check. Maximum increase (88.93%) in dry weight was recorded in T_7 [seed treatment with native isolate of T. viride (DOR 1 Tv) and soil drenching with mancozeb @ 500 ppm] treatment. While minimum dry weight increase (47.78 %) was recorded in T_{11} [seed treatment with commercial isolate of *T. viride* (NCC 58 Tv) and pre emergence application of pendimethalin @ 100 ppm] the dry weight increase in T_2 and T_6 treatments was on par with each other (Table 91)

Bhendi

Significant differences in seed germinations were observed among the treatments. The germination percentage of various treatment combinations from 98.3 to 100%. Maximum seed germination (100%) was recorded in T_1 and T_2 treatments compared with pathogen check (88.3%) which were on par. In all other treatments the germination percentage recorded was 98.3 which were at par with each other (Table 92).

Significant seedling reduction in mortality of bhendi was recorded over pathogen check. Maximum reduction in seedling mortality (72.49%) was

recorded in T_1 [(seed treatment with commercial isolate of *T. harzianum* (NCC-57 Th) and soil drenching with COC 100 ppm] T_2 [seed treatment with native isolate of *T. viride* (DOR 1 Tv) and soil drenching with mancozeb 500 ppm] and T_6 [seed treatment with commercial isolate of *T. viride* (Sun Agro Derma Tv) and soil application of CAN 2000 ppm] treatments which were on par with each other. While, minimum seedling mortality (58.79%) recorded in T_{11} treatment (Table 92 and Plate 160).

Root and shoot lengths of bhendi differed significantly in various treatment combination s compared to pathogen check. Maximum root length of 3.62 cm and shoot length of 9.30 cm was recorded in T_8 [seed treatment with *T. harzianum* (DOR Th) soil application of SSP at 2000 ppm] treatment as against 2.67 and 6.70 cm of root and shoot lengths of bhendi seedlings compared to pathogen check, whereas 2.67 and 6.70 cm in pathogen check. While minimum root and shoot lengths of 3.59 and 8.03 cm in T_{10} treatment (Table 92)

Seedling vigour index of bhendi significantly increased over pathogen check and ranged from 1202.32 to 1270.83, as against 827.37 in pathogen check. Maximum seedling vigour index (1270.83) was recorded in T_2 treatment. While, minimum seedling vigour index 1202.32 was recorded in T_{13} treatment (Table 92).

The dry weight of seedlings increased significantly over pathogen check. Among various treatments T_2 [seed treatment with native isolate of *T. viride* (DOR 1 Tv) and soil drenching with mancozeb 500 ppm] treatment recorded , 38.99 % increase over control. While all other treatments T_3, T_4, T_{10}, T_{12} , T_5, T_7, and T_9 recorded similar increase in dry weight and a on par with each other (Table 92).

Table 3: *In vitro* effect of antagonistic fungi and bacteria against *P. aphanidermatum*

S. No.	Biocontrol isolates	Radial growth* (mm)	Per cent growth reduction over control
1.	*Trichoderma viride* (BCL Tv)	19.00 (25.83)	56.95
2.	*T.viride* (DOR 1 Tv)	21.15 (27.43)	54.28
3.	*T.viride* (Sun Agro Derma Tv)	16.50 (23.95)	60.08
4.	*T. viride* (NCC-58 Tv)	10.00 (18.42)	68.46
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	16.30 (23.43)	60.95
6.	*T. harzianum* (DOR 2 Th)	13.50 (21.54)	64.10
7.	*T. harzianum* NCC-57 Th	20.50 (26.91)	55.15
8.	*T. harzianum* (Vermi Green Th)	21.75 (27.78)	53.70
9.	*Pseudomonas fluorescens* (Sun Agro Monus Pf)	48.50 (44.14)	34.32
10.	*P. fluorescens* (Vermigreen Pf)	46.25 (42.85)	36.24

SEm± = 0.4711
CD (P=0.05) = 1.3558

* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 4: *In vitro* effect of antagonistic fungi and bacteria against *M. phaseolina*

S. No.	Antagonists of fungi	Radial growth* (mm)	Per cent growth reduction over control
1.	*Trichoderma viride* (BCL Tv)	7.50 (15.88)**	76.37
2.	*T. viride* (DOR 1 Tv)	9.75 (18.19)	72.93
3.	*T. viride* (Sun Agro Derma Tv)	10.00 (19.42)	72.59
4.	*T. viride* (NCC-58 Tv)	11.00 (19.36)	71.19
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	10.58 (18.97)	71.77
6.	*T. harzianum* (DOR 2 Th)	10.75 (19.13)	71.53
7.	*T. harzianum* NCC-57 Th	11.50 (19.81)	70.52
8.	*T. harzianum* (Vermi Green Th)	13.50 (21.55)	67.93
9.	*Pseudomonas fluorescens* (Sun Agro Monus Pf)	50.00 (45.00)	33.04
10.	*P. fluorescens* (Vermigreen Pf)	52.25 (46.29)	31.12

SEm± = 0.3608
CD (P=0.05) = 1.0384

* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 5: *In vitro* effect of antagonistic fungi and bacteria against *S. rolfsii*

S. No.	Antagonists of fungi	Radial growth* (mm)	Per cent growth reduction over control
1.	*T richoderma viride* (BCL Tv)	26.00 (30.65)**	54.39
2.	*T. viride* (Native Tv)	21.50 (27.62)	58.90
3.	*T. viride* (Sun Agro Derma Tv)	20.50 (26.91)	59.96
4.	*T. viride* (NCC-58 Tv)	21.00 (27.27)	59.42
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	26.25 (30.81)	54.15
6.	*T. harzianum* (DOR 2 Th)	20.75 (27.09)	59.69
7.	*T. harzianum* NCC-57 Th	20.25 (26.73)	60.22
8.	*T. harzianum* (Vermi Green Th)	57.00 (49.02)	27.06
9.	*Pseudomonas fluorescens* (Sun Agro Monus Pf)	49.50 (44.71)	33.47
10.	*P. fluorescens* (Vermigreen Pf)	45.50 (42.42)	36.88

SEm± = 2.8356
CD (P=0.05) = 8.1607

* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 6: Sensitivity of fungal antagonists against copper oxychloride at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	80.00 (63.44)**	5.60	78.00 (62.03)	7.70	75.00 (60.04)	10.66	74.00 (59.35)	11.69
2.	*T. viride* (DOR 1 Tv)	80.00 (63.44)	5.60	79.50 (63.08)	6.14	74.50 (59.67)	11.21	73.00 (58.69)	12.67
3.	*T. viride* (Sun Agro Derma Tv)	80.50 (63.81)	5.05	79.50 (63.09)	6.13	77.00 (61.36)	8.70	71.00 (57.42)	14.56
4.	*T. viride* (NCC-58 Tv)	82.00 (64.91)	3.42	80.50 (63.80)	5.07	77.00 (61.36)	8.70	77.00 (61.36)	8.70
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	82.00 (64.91)	3.42	74.00 (59.38)	11.65	73.50 (59.02)	12.18	63.75 (52.78)	21.47
6.	*T. harzianum* (DOR 2 Th)	81.75 (64.73)	3.68	62.50 (52.20)	22.33	39.25 (38.78)	42.30	30.75 (33.67)	49.90
7.	*T. harzianum* (NCC-57 Th)	81.75 (64.71)	3.71	74.50 (59.68)	11.20	57.00 (49.02)	27.06	36.50 (36.90)	45.09
8.	*T. harzianum* (Vermigreen Th)	81.50 (64.53)	3.98	73.50 (59.05)	12.14	69.00 (56.17)	16.42	57.75 (44.51)	49.09

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.93	0.65	1.86
CD (P=0.05)	1.82	1.28	3.64

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 7: Sensitivity of fungal antagonists against mancozeb at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	81.75 (64.71)**	3.71	72.00 (58.05)	13.62	60.50 (51.07)	24.01	30.50 (33.51)	50.14
2.	*T. viride* (DOR 1 Tv)	81.25 (64.35)	4.25	72.25 (58.21)	13.39	59.50 (50.48)	24.89	31.50 (34.13)	50.01
3.	*T. viride* (Sun Agro Derma Tv)	82.50 (65.28)	2.87	74.00 (59.35)	11.69	51.00 (45.57)	32.19	41.50 (40.10)	40.33
4.	*T. viride* (NCC-58 Tv)	82.00 (64.91)	3.42	72.50 (58.38)	13.13	61.00 (51.63)	23.18	40.00 (39.22)	41.44
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	84.50 (66.81)	0.59	76.00 (60.67)	9.73	61.75 (51.80)	22.92	40.25 (39.37)	41.42
6.	*T. harzianum* (DOR 2 Th)	82.50 (65.30)	2.84	71.25 (57.59)	14.31	62.25 (52.09)	22.49	39.75 (39.06)	41.88
7.	*T. harzianum* (NCC-57 Th)	83.50 (66.04)	1.74	75.75 (60.52)	9.95	62.75 (52.38)	22.06	39.75 (39.04)	41.91
8.	*T. harzianum* (Vermigreen Th)	83.00 (65.67)	2.29	76.75 (61.20)	8.94	43.00 (40.96)	39.05	27.50 (31.60)	52.98

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.49	0.35	0.99
CD (P=0.05)	0.97	0.69	1.95

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 8: Sensitivity of fungal antagonists against carbendazim at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
2.	*T. viride* (DOR 1 Tv)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
3.	*T. viride* (Sun Agro Derma Tv)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
4.	*T. viride* (NCC-58 Tv)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
6.	*T. harzianum* (DOR 2 Th)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
7.	*T. harzianum* (NCC-57 Th)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
8.	*T. harzianum* (Vermigreen Th)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.01	0.01	0.02
CD (P=0.05)	0.05	0.05	0.10

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 9: Sensitivity of fungal antagonists against hexaconazole at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	0.00 (0.00)**	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
2.	*T. viride* (DOR 1 Tv)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
3.	*T. viride* (Sun Agro Derma Tv)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
4.	*T. viride* (NCC-58 Tv)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
6.	*T. harzianum* (DOR 2 Th)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
7.	*T. harzianum* (NCC-57 Th)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
8.	*T. harzianum* (Vermigreen Th)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.01	0.01	0.02
CD (P=0.05)	0.05	0.05	0.10

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 10: Sensitivity of fungal antagonists against imidacloprid at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	85.00 (67.21)**	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
2.	*T. viride* (DOR 1 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
3.	*T. viride* (Sun Agro Derma Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	*T. viride* (NCC-58 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
6.	*T. harzianum* (DOR 2 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
7.	*T. harzianum* (NCC-57 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
8.	*T. harzianum* (Vermigreen Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.15	0.11	0.31
CD (P=0.05)	0.31	0.22	0.62

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 11: Sensitivity of fungal antagonists against chlorpyriphos at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	74.75 (59.83)**	10.98	66.50 (54.63)	18.71	54.25 (47.43)	29.43	42.00 (40.39)	39.90
2.	*T. viride* (DOR 1 Tv)	74.00 (59.34)	11.70	42.75 (40.82)	39.26	40.75 (39.66)	40.99	31.00 (33.82)	49.68
3.	*T. viride* (Sun Agro Derma Tv)	84.75 (67.01)	0.29	61.75 (51.80)	22.92	56.50 (48.73)	27.49	52.50 (41.57)	30.90
4.	*T. viride* (NCC-58 Tv)	83.25 (65.85)	2.02	51.50 (45.85)	31.78	81.75 (64.72)	43.70	80.25 (63.62)	55.34
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	83.00 (65.65)	2.32	54.00 (47.29)	29.63	48.50 (44.14)	34.32	29.50 (32.89)	51.06
6.	*T. harzianum* (DOR 2 Th)	85.00 (67.21)	0.00	53.00 (47.00)	30.06	83.00 (65.65)	32.32	23.50 (28.99)	56.86
7.	*T. harzianum* (NCC-57 Th)	81.75 (64.72)	3.70	44.00 (41.55)	38.17	59.50 (50.47)	24.90	48.50 (44.14)	34.32
8.	*T. harzianum* (Vermigreen Th)	60.75 (51.21)	23.80	50.75 (45.53)	32.40	56.50 (48.73)	27.49	63.00 (52.54)	21.82

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.28	0.20	0.57
CD (P=0.05)	0.56	0.39	1.13

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 12: Sensitivity of fungal antagonists against carbosulfan at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	59.75 (50.62)**	24.68	58.75 (50.04)	25.54	50.75 (45.43)	32.40	34.50 (35.96)	46.49
2.	*T. viride* (DOR 1 Tv)	51.00 (45.57)	32.19	48.50 (44.14)	34.32	44.75 (41.98)	37.53	33.25 (35.20)	47.62
3.	*T. viride* (Sun Agro Derma Tv)	62.50 (52.24)	22.27	53.75 (47.15)	29.84	41.50 (40.10)	40.33	23.75 (29.16)	56.61
4.	*T. viride* (NCC-58 Tv)	80.00 (63.43)	5.62	79.25 (62.90)	6.41	64.00 (53.13)	20.94	62.00 (51.94)	22.71
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	64.50 (53.43)	20.50	56.00 (48.44)	27.92	46.00 (42.70)	36.46	24.75 (29.83)	55.61
6.	*T. harzianum* (DOR 2 Th)	65.50 (54.03)	19.61	60.00 (50.77)	24.46	50.00 (45.00)	33.04	34.50 (35.96)	46.79
7.	*T. harzianum* (NCC-57 Th)	72.75 (58.54)	12.89	51.75 (46.00)	31.55	43.75 (41.40)	38.40	29.50 (32.89)	51.06
8.	*T. harzianum* (Vermigreen Th)	55.00 (47.86)	28.79	45.50 (42.41)	36.39	40.75 (39.66)	40.99	30.25 (33.35)	50.37

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.26	0.18	0.53
CD (P=0.05)	0.52	0.37	1.04

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 13: Sensitivity of fungal antagonists against calcium ammonium nitrate (CAN) at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	85.00 (67.21)**	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
2.	*T. viride* (DOR 1 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
3.	*T. viride* (Sun Agro Derma Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	*T. viride* (NCC-58 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
6.	*T. harzianum* (DOR 2 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
7.	*T. harzianum* (NCC-57 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
8.	*T. harzianum* (Vermigreen Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.15	0.11	0.31
CD (P=0.05)	0.31	0.22	0.62

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 14: Sensitivity of fungal antagonists against Diammonium Phosphate (DAP) at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	85.00 (67.21)**	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
2.	*T. viride* (DOR 1 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
3.	*T. viride* (Sun Agro Derma Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	*T. viride* (NCC-58 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
6.	*T. harzianum* (DOR 2 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
7.	*T. harzianum* (NCC-57 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
8.	*T. harzianum* (Vermigreen Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.15	0.10	0.30
CD (P=0.05)	0.30	0.21	0.60

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 15: Sensitivity of fungal antagonists against single super phosphate (SSP) at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	85.00 (67.21)**	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
2.	*T. viride* (DOR 1 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
3.	*T. viride* (Sun Agro Derma Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	*T. viride* (NCC-58 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
6.	*T. harzianum* (DOR 2 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
7.	*T. harzianum* (NCC-57 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
8.	*T. harzianum* (Vermigreen Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.13	0.09	0.27
CD (P=0.05)	0.26	0.18	0.53

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 16: Sensitivity of fungal antagonists against muriate of potash (MOP) at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	85.00 (67.21)**	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
2.	*T. viride* (DOR 1 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
3.	*T. viride* (Sun Agro Derma Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	*T. viride* (NCC-58 Tv)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
6.	*T. harzianum* (DOR 2 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
7.	*T. harzianum* (NCC-57 Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
8.	*T. harzianum* (Vermigreen Th)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.13	0.09	0.26
CD (P=0.05)	0.26	0.18	0.52

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 17: Sensitivity of fungal antagonists against pendimethalin at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	70.75 (57.26)**	14.80	54.00 (47.29)	29.63	44.00 (41.56)	38.16	4.00 (11.49)	82.90
2.	*T. viride* (DOR 1 Tv)	82.00 (64.89)	3.45	19.00 (25.83)	61.56	14.00 (21.96)	67.32	3.25 (10.36)	84.58
3.	*T. viride* (Sun Agro Derma Tv)	82.25 (65.08)	3.16	49.75 (44.85)	33.26	39.50 (38.93)	42.07	23.75 (29.16)	56.61
4.	*T. viride* (NCC-58 Tv)	85.00 (67.21)	0.00	54.00 (47.29)	29.63	54.50 (47.58)	42.68	14.25 (22.17)	67.03
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	79.50 (63.08)	6.14	14.25 (22.17)	67.01	9.00 (17.44)	74.05	4.00 (11.49)	82.90
6.	*T. harzianum* (DOR 2 Th)	80.50 (63.80)	5.04	38.00 (38.00)	43.46	7.50 (15.85)	76.41	5.00 (12.88)	80.83
7.	*T. harzianum* (NCC-57 Th)	85.00 (67.21)	0.00	85.50 (67.53)	3.98	49.50 (44.71)	33.47	4.00 (11.49)	82.90
8.	*T. harzianum* (Vermigreen Th)	85.00 (67.21)	0.00	71.50 (57.73)	14.10	64.75 (53.58)	20.27	22.25 (28.14)	58.13

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.73	0.52	1.47
CD (P=0.05)	1.44	1.02	2.89

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 18: Sensitivity of fungal antagonists against fluchloralin at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	53.00 (46.72)**	30.48	11.25 (19.57)	70.88	8.00 (16.41)	75.58	2.25 (8.59)	87.21
2.	*T. viride* (DOR 1 Tv)	56.25 (48.29)	27.70	6.00 (14.15)	78.94	3.75 (11.14)	83.42	2.50 (9.05)	86.53
3.	*T. viride* (Sun Agro Derma Tv)	57.25 (49.17)	26.84	21.00 (27.27)	59.42	20.75 (27.09)	59.69	7.00 (15.32)	77.20
4.	*T. viride* (NCC-58 Tv)	81.00 (64.17)	4.52	18.00 (25.10)	62.65	6.25 (14.46)	78.48	4.75 (12.54)	81.34
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	64.25 (53.28)	20.72	5.25 (13.23)	80.31	3.75 (11.14)	83.42	1.25 (6.33)	90.58
6.	*T. harzianum* (DOR 2 Th)	54.00 (47.29)	29.63	5.00 (12.89)	80.82	3.25 (10.36)	84.73	1.25 (6.33)	90.58
7.	*T. harzianum* (NCC-57 Th)	58.75 (50.04)	25.54	17.75 (24.91)	62.93	16.75 (24.15)	64.06	6.00 (4.15)	93.82
8.	*T. harzianum* (Vermigreen Th)	54.75 (47.72)	28.99	22.25 (28.14)	58.13	11.25 (19.57)	70.88	6.50 (14.76)	78.03

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.31	0.22	0.62
CD (P=0.05)	0.61	0.43	1.22

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 41: Combined effect of fungal biocontrol agents with copper oxychloride against *M. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	37.00 (37.46)**	44.26	44.25 (40.53)	39.69	53.00 (46.72)	30.48	63.25 (52.68)	21.61
2.	*T. viride* (DOR 1 Tv)	33.25 (35.21)	47.61	42.25 (40.54)	39.68	46.50 (42.99)	67.21	58.50 (49.82)	25.87
3.	*T. viride* (Sun Agro Derma Tv)	29.00 (32.57)	51.53	33.25 (35.20)	47.62	38.00 (38.05)	43.38	43.50 (41.26)	38.61
4.	*T. viride* (NCC-58 Tv)	30.50 (33.51)	50.14	38.25 (38.20)	43.16	57.50 (49.31)	26.63	58.75 (50.04)	25.54
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	24.00 (29.32)	56.37	32.50 (34.75)	48.29	44.00 (41.55)	38.17	58.75 (50.04)	25.54
6.	*T. harzianum* (DOR 2 Th)	24.50 (29.66)	55.86	40.25 (39.37)	40.85	59.50 (50.47)	24.90	61.50 (51.65)	23.15
7.	*T. harzianum* (NCC-57 Th)	35.75 (36.72)	45.36	40.75 (39.66)	40.99	47.00 (43.27)	35.61	62.75 (52.39)	22.05
8.	*T. harzianum* (Vermigreen Th)	40.50 (39.52)	41.19	53.50 (47.00)	20.39	58.00 (49.60)	26.20	59.50 (50.47)	24.90

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.2889	0.2043	0.5779
CD (P=0.05)	0.5663	0.4005	1.1327

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 42: Combined effect of fungal biocontrol agents with mancozeb against *M.. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	10.75 (19.12)**	71.55	8.00 (16.41)	75.58	5.00 (12.88)	80.83	1.75 (7.39)	89.00
2.	*T. viride* (DOR 1 Tv)	8.00 (16.41)	75.98	7.25 (15.59)	76.80	4.50 (12.29)	81.71	1.25 (6.33)	90.58
3.	*T. viride* (Sun Agro Derma Tv)	6.25 (14.42)	78.54	4.50 (12.22)	81.81	2.00 (7.99)	88.11	1.50 (6.79)	89.89
4.	*T. viride* (NCC-58 Tv)	6.50 (14.71)	78.11	5.75 (13.84)	79.40	2.25 (8.45)	87.42	1.25 (6.33)	90.58
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	10.25 (18.62)	72.29	6.75 (15.05)	77.63	4.50 (12.22)	81.81	1.75 (7.39)	89.00
6.	*T. harzianum* (DOR 2 Th)	8.75 (17.14)	74.49	6.75 (15.05)	77.63	4.50 (12.22)	81.81	1.25 (6.33)	90.58
7.	*T. harzianum* (NCC-57 Th)	7.75 (16.15)	75.97	5.50 (13.54)	79.85	4.25 (11.88)	82.32	1.50 (6.93)	89.68
8.	*T. harzianum* (Vermigreen Th)	12.75 (20.87)	68.94	14.25 (22.15)	67.04	8.75 (17.18)	74.43	4.00 (11.49)	82.90

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.4626	0.3271	0.9252
CD (P=0.05)	0.9067	0.6411	1.8134

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 48: Combined effect of fungal biocontrol agents with imidacloprid against *M. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	2.00 (7.99)**	88.11	1.50 (6.93)	89.68	20.50 (26.91)	59.96	17.50 (24.71)	63.23
2.	*T. viride* (DOR 1 Tv)	1.75 (7.53)	88.79	1.50 (6.93)	89.68	20.50 (26.91)	59.96	23.75 (29.16)	56.61
3.	*T. viride* (Sun Agro Derma Tv)	1.75 (7.53)	88.79	5.75 (13.52)	79.88	27.50 (31.62)	52.95	30.00 (33.20)	50.60
4.	*T. viride* (NCC-58 Tv)	1.00 (5.73)	91.47	1.50 (6.93)	89.68	3.50 (10.75)	84.00	16.00 (23.57)	64.93
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	1.00 (5.73)	91.47	1.75 (7.53)	88.79	16.25 (23.77)	64.63	19.25 (25.99)	61.33
6.	*T. harzianum* (DOR 2 Th)	1.50 (6.93)	89.68	1.25 (6.33)	90.58	20.00 (26.56)	60.48	22.50 (28.30)	57.89
7.	*T. harzianum* (NCC-57 Th)	1.00 (5.73)	91.47	5.75 (13.76)	79.52	12.25 (20.45)	69.57	8.00 (16.41)	75.58
8.	*T. harzianum* (Vermigreen Th)	1.00 (5.73)	91.47	4.25 (11.83)	82.39	39.75 (39.08)	41.85	42.50 (40.68)	39.47

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.44	0.31	0.89
CD (P=0.05)	0.87	0.62	1.75

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 49: Combined effect of fungal biocontrol agents with chlorpyriphos against *M. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	1.50 (6.93)**	89.68	5.75 (13.86)	79.37	15.50 (23.18)	65.63	23.50 (28.99)	56.86
2.	*T. viride* (DOR 1 Tv)	1.75 (7.53)	88.79	2.00 (8.13)	87.90	2.25 (8.59)	87.21	3.25 (10.29)	84.68
3.	*T. viride* (Sun Agro Derma Tv)	3.75 (11.14)	83.42	7.50 (15.88)	76.37	10.50 (18.88)	71.90	16.75 (24.15)	64.06
4.	*T. viride* (NCC-58 Tv)	4.00 (11.49)	82.90	7.00 (15.32)	77.20	15.25 (22.98)	65.80	10.00 (18.42)	72.59
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	2.00 (7.99)	88.11	5.50 (13.54)	79.85	11.75 (20.03)	70.19	12.25 (20.47)	69.54
6.	*T. harzianum* (DOR 2 Th)	2.00 (7.99)	88.11	7.25 (15.59)	76.80	16.75 (24.15)	64.06	18.50 (25.47)	62.10
7.	*T. harzianum* (NCC-57 Th)	3.25 (10.17)	84.86	5.50 (13.54)	79.85	16.00 (23.57)	64.93	18.50 (25.46)	62.11
8.	*T. harzianum* (Vermigreen Th)	0.75 (4.30)	93.60	8.00 (16.41)	75.58	23.00 (28.65)	57.37	24.50 (29.66)	55.86

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.3749	0.2499	0.7498
CD (P=0.05)	0.7348	0.4899	1.4696

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 50: Combined effect of fungal biocontrol agents with carbosulfan against *M. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	1.00 (5.73)**	91.47	3.75 (11.14)	83.42	1.00 (5.73)	91.47	2.75 (9.51)	85.85
2.	*T. viride* (DOR 1 Tv)	1.00 (5.73)	91.47	3.25 (10.36)	84.58	1.25 (6.33)	90.58	2.75 (9.44)	85.95
3.	*T. viride* (Sun Agro Derma Tv)	1.25 (6.33)	90.58	1.50 (6.93)	89.68	1.75 (7.53)	88.75	8.00 (16.41)	75.58
4.	*T. viride* (NCC-58 Tv)	1.00 (5.73)	91.47	4.25 (11.83)	82.39	2.75 (9.51)	85.85	6.25 (14.44)	78.51
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	1.00 (5.73)	91.47	4.00 (11.49)	82.90	2.25 (8.59)	87.21	1.75 (7.53)	88.79
6.	*T. harzianum* (DOR 2 Th)	1.00 (4.90)	91.47	4.25 (11.83)	82.39	2.75 (9.51)	85.85	2.25 (8.45)	87.42
7.	*T. harzianum* (NCC-57 Th)	1.00 (5.73)	91.47	2.00 (8.13)	87.90	3.00 (9.90)	85.27	2.75 (9.51)	85.85
8.	*T. harzianum* (Vermigreen Th)	0.75 (4.34)	93.54	1.50 (6.93)	89.68	2.75 (9.51)	85.85	2.50 (9.05)	86.53

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.45	0.31	0.90
CD (P=0.05)	0.88	0.62	1.77

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 58: Combined effect of fungal biocontrol agents with CAN against *M. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	10.25 (18.65)**	72.25	10.50 (18.90)	71.87	11.00 (19.36)	71.19	7.00 (15.32)	77.20
2.	*T. viride* (DOR 1 Tv)	6.00 (14.15)	78.94	5.00 (1.88)	80.83	11.00 (19.36)	71.19	8.50 (16.94)	74.79
3.	*T. viride* (Sun Agro Derma Tv)	9.75 (18.19)	72.93	8.50 (16.94)	74.79	8.50 (16.91)	74.84	9.00 (17.43)	74.06
4.	*T. viride* (NCC-58 Tv)	12.50 (20.70)	69.20	15.00 (22.78)	66.10	11.00 (19.36)	71.19	8.25 (16.68)	75.18
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	7.75 (16.15)	75.97	10.50 (18.90)	71.87	11.00 (19.36)	71.19	8.75 (17.20)	74.40
6.	*T. harzianum* (DOR 2 Th)	7.75 (16.15)	75.97	10.25 (18.66)	72.73	11.25 (19.59)	71.29	8.00 (16.42)	75.56
7.	*T. harzianum* (NCC-57 Th)	9.75 (18.19)	72.93	7.50 (15.85)	76.41	8.50 (16.94)	74.79	5.75 (13.86)	79.37
8.	*T. harzianum* (Vermigreen Th)	20.25 (26.74)	60.21	21.25 (27.44)	59.17	23.00 (28.65)	57.51	19.50 (26.20)	61.01

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.25	0.18	0.51
CD (P=0.05)	0.50	0.33	1.00

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 59: Combined effect of fungal biocontrol agents with DAP against *M. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	15.00 (22.78)**	66.10	11.00 (19.36)	71.19	11.00 (19.36)	71.19	10.50 (18.90)	71.87
2.	*T. viride* (DOR 1 Tv)	4.75 (12.57)	81.29	10.00 (18.42)	72.59	5.50 (13.54)	79.85	7.25 (15.59)	76.80
3.	*T. viride* (Sun Agro Derma Tv)	12.00 (20.24)	69.88	9.25 (17.68)	73.69	11.00 (19.36)	71.19	9.25 (17.68)	73.69
4.	*T. viride* (NCC-58 Tv)	12.25 (20.47)	69.54	10.00 (18.42)	72.59	10.50 (18.88)	71.90	8.25 (16.69)	75.16
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	15.00 (22.78)	66.10	10.75 (19.13)	71.53	11.50 (19.80)	70.54	8.50 (16.94)	74.79
6.	*T. harzianum* (DOR 2 Th)	14.75 (22.58)	66.40	9.75 (18.19)	72.93	11.25 (19.58)	71.16	8.25 (16.68)	75.18
7.	*T. harzianum* (NCC-57 Th)	7.75 (16.15)	75.97	5.50 (13.54)	79.85	7.50 (15.88)	76.37	9.50 (17.94)	73.30
8.	*T. harzianum* (Vermigreen Th)	16.50 (23.96)	64.35	16.0 (23.57)	64.93	15.50 (23.17)	65.52	13.00 (21.09)	68.62

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.29	0.20	0.58
CD (P=0.05)	0.57	0.40	1.15

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 60: Combined effect of fungal biocontrol agents with SSP against *M. Phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	11.75 (20.05)**	70.19	14.25 (22.17)	67.01	10.75 (19.13)	71.53	10.00 (18.42)	72.59
2.	*T. viride* (DOR 1 Tv)	10.75 (19.13)	71.53	7.25 (15.61)	76.74	6.75 (15.05)	77.60	5.75 (13.86)	79.37
3.	*T. viride* (Sun Agro Derma Tv)	14.00 (21.96)	67.32	14.00 (21.96)	67.32	12.50 (20.70)	69.20	12.25 (20.48)	69.52
4.	*T. viride* (NCC-58 Tv)	13.50 (21.55)	67.93	15.25 (22.97)	65.82	19.50 (26.19)	61.03	16.25 (23.76)	64.64
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	11.00 (19.36)	71.19	9.00 (17.44)	74.05	7.50 (15.88)	76.37	8.50 (16.91)	74.84
6.	*T. harzianum* (DOR 2 Th)	10.75 (19.13)	71.53	7.50 (15.82)	76.46	9.00 (17.44)	74.05	7.75 (16.15)	75.97
7.	*T. harzianum* (NCC-57 Th)	8.50 (16.94)	74.79	7.00 (15.32)	77.20	10.00 (10.42)	84.49	8.50 (16.94)	74.79
8.	*T. harzianum* (Vermigreen Th)	27.50 (31.62)	52.95	31.50 (34.13)	49.21	24.00 (29.33)	56.36	30.25 (33.26)	50.36

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.26	0.18	0.52
CD (P=0.05)	0.51	0.36	1.02

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 61: Combined effect of fungal biocontrol agents with MOP against *M. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	7.50 (15.85)**	76.41	9.00 (17.39)	74.12	5.00 (12.88)	81.72	3.50 (10.64)	84.16
2.	*T. viride* (DOR 1 Tv)	5.50 (13.49)	79.77	9.00 (17.39)	74.12	5.00 (12.88)	81.72	2.75 (9.51)	85.85
3.	*T. viride* (Sun Agro Derma Tv)	6.50 (14.71)	78.11	9.00 (17.39)	74.12	4.75 (12.57)	81.29	2.75 (9.51)	85.85
4.	*T. viride* (NCC-58 Tv)	7.00 (15.32)	77.20	8.50 (16.93)	74.81	4.25 (11.88)	82.32	2.50 (9.05)	86.53
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	17.50 (24.71)	63.23	19.50 (26.20)	61.01	16.50 (23.96)	64.35	13.50 (21.55)	67.93
6.	*T. harzianum* (DOR 2 Th)	18.25 (25.28)	62.38	33.25 (35.20)	47.62	33.00 (35.06)	47.83	21.25 (27.44)	59.17
7.	*T. harzianum* (NCC-57 Th)	23.00 (28.65)	57.37	31.50 (34.13)	49.21	20.00 (26.55)	60.49	24.75 (29.83)	55.61
8.	*T. harzianum* (Vermigreen Th)	23.50 (28.99)	56.86	34.25 (35.81)	46.71	23.75 (29.16)	56.61	28.50 (32.26)	52.00

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.39	0.27	0.78
CD (P=0.05)	0.76	0.54	1.53

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 68: Combined effect of fungal biocontrol agents with pendimethalin against *M. phaseolina* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	8.00 (16.41)**	75.58	12.50 (20.68)	69.23	23.50 (28.99)	56.86	7.25 (15.61)	76.77
2.	*T. viride* (DOR 1 Tv)	8.00 (16.41)	75.58	13.75 (21.76)	67.62	23.50 (28.99)	56.86	8.50 (16.91)	74.87
3.	*T. viride* (Sun Agro Derma Tv)	7.50 (15.82)	76.46	13.25 (21.33)	68.26	22.00 (27.96)	58.39	8.00 (16.38)	75.62
4.	*T. viride* (NCC-58 Tv)	8.00 (16.41)	75.58	15.00 (22.75)	66.15	22.25 (28.14)	58.13	9.00 (17.39)	74.12
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	3.25 (10.29)	84.68	13.25 (21.33)	68.26	23.50 (28.98)	56.88	8.00 (16.38)	75.62
6.	*T. harzianum* (DOR 2 Th)	7.75 (16.10)	76.04	12.50 (20.68)	69.23	24.75 (29.83)	55.61	6.50 (14.71)	78.11
7.	*T. harzianum* (NCC-57 Th)	9.00 (17.44)	74.05	14.50 (22.37)	66.71	22.25 (28.14)	67.21	5.75 (13.80)	79.46
8.	*T. harzianum* (Vermigreen Th)	8.00 (16.41)	75.58	15.50 (23.17)	76.93	23.50 (28.99)	56.88	7.50 (15.82)	76.46

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.39	0.27	0.79
CD (P=0.05)	0.77	0.54	1.55

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 39: Combined effect of fungal biocontrol agents with copper oxychloride against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	8.00 (16.41)**	72.79	12.25 (20.48)	66.05	17.25 (24.53)	59.34	23.25 (28.82)	52.22
2.	*T. viride* (DOR 1 Tv)	7.25 (15.61)	74.12	7.50 (15.82)	73.77	9.00 (17.44)	71.09	11.75 (20.04)	66.78
3.	*T. viride* (Sun Agro Derma Tv)	12.00 (20.26)	66.46	15.75 (23.38)	61.24	20.50 (26.73)	55.69	20.25 (26.93)	55.37
4.	*T. viride* (NCC-58 Tv)	8.25 (16.68)	72.35	12.50 (20.70)	65.68	24.00 (29.33)	51.38	27.75 (31.70)	47.45
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	9.75 (18.18)	69.86	13.50 (21.55)	64.27	20.75 (27.09)	55.09	26.25 (30.81)	48.93
6.	*T. harzianum* (DOR 2 Th)	6.50 (14.76)	75.53	7.50 (15.88)	73.67	8.00 (16.41)	72.79	11.35 (20.03)	66.79
7.	*T. harzianum* (NCC-57 Th)	7.75 (16.14)	73.24	17.50 (24.71)	59.04	26.50 (30.96)	48.68	32.50 (34.75)	42.40
8.	*T. harzianum* (Vermigreen Th)	14.50 (22.36)	62.93	21.00 (27.29)	54.76	31.00 (33.82)	43.94	37.75 (37.90)	37.17

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.3601	0.2546	0.7201
CD (P=0.05)	0.7057	0.4840	1.4114

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 40: Combined effect of fungal biocontrol agents with mancozeb against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	12.25 (20.48)**	66.05	8.25 (16.68)	72.35	2.25 (8.59)	85.76	0.75 (4.30)	92.87
2.	*T. viride* (DOR 1 Tv)	3.75 (11.14)	81.53	2.75 (9.51)	84.23	1.75 (7.53)	87.51	0.50 (2.86)	95.25
3.	*T. viride* (Sun Agro Derma Tv)	3.75 (11.14)	81.53	2.50 (9.05)	84.99	1.75 (7.53)	87.51	0.50 (2.86)	95.25
4.	*T. viride* (NCC-58 Tv)	4.00 (4.49)	80.95	3.00 (9.90)	83.59	1.75 (7.53)	87.51	0.50 (2.86)	95.25
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	13.50 (21.55)	64.27	8.50 (16.91)	71.97	3.00 (9.90)	83.59	0.75 (4.30)	92.87
6.	*T. harzianum* (DOR 2 Th)	1.50 (6.93)	88.51	1.75 (7.53)	87.51	2.25 (8.59)	85.76	0.00 (0.00)	100.00
7.	*T. harzianum* (NCC-57 Th)	1.50 (6.93)	88.51	2.25 (8.59)	87.56	2.50 (9.05)	84.94	0.25 (1.43)	97.62
8.	*T. harzianum* (Vermigreen Th)	35.50 (36.56)	39.39	21.75 (27.79)	63.88	3.00 (9.90)	83.59	0.25 (1.43)	97.62

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.6061	0.4285	1.2121
CD (P=0.05)	1.1879	0.8400	2.3757

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 45: Combined effect of fungal biocontrol agents with imidacloprid against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	4.00 (11.49)**	80.95	15.00 (22.76)	62.27	20.50 (26.91)	55.39	24.00 (29.33)	51.38
2.	*T. viride* (DOR 1 Tv)	19.25 (26.02)	56.87	24.75 (29.83)	50.55	21.50 (27.62)	54.21	34.50 (35.96)	40.39
3.	*T. viride* (Sun Agro Derma Tv)	16.00 (23.57)	60.93	19.25 (26.02)	56.02	17.50 (24.72)	59.02	20.50 (26.91)	55.39
4.	*T. viride* (NCC-58 Tv)	8.50 (16.91)	71.97	5.50 (13.49)	77.63	5.50 (13.49)	77.63	18.50 (25.46)	57.79
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	21.25 (27.44)	54.51	22.00 (27.96)	53.65	25.50 (30.24)	49.87	31.50 (34.13)	43.42
6.	*T. harzianum* (DOR 2 Th)	11.50 (19.80)	67.18	17.50 (24.71)	59.04	17.50 (24.71)		25.50 (30.32)	49.74
7.	*T. harzianum* (NCC-57 Th)	3.50 (10.64)	82.36	9.50 (17.92)	70.26	11.50 (19.80)	67.18	17.25 (24.53)	59.34
8.	*T. harzianum* (Vermigreen Th)	2.00 (7.99)	86.75	7.75 (16.41)	73.24	12.75 (20.91)	65.34	22.50 (28.30)	53.09

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.36	0.25	0.72
CD (P=0.05)	0.70	0.50	1.41

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 46: Combined effect of fungal biocontrol agents with chlorpyriphos against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	10.25 (18.66)**	69.07	11.00 (19.36)	67.90	13.25 (21.34)	64.62	12.00 (20.26)	66.41
2.	*T. viride* (DOR 1 Tv)	7.75 (16.15)	73.23	10.25 (18.66)	69.07	8.25 (16.67)	72.36	12.75 (20.91)	65.34
3.	*T. viride* (Sun Agro Derma Tv)	13.00 (21.12)	64.99	10.25 (18.66)	69.07	11.75 (20.03)	66.79	13.75 (21.76)	63.93
4.	*T. viride* (NCC-58 Tv)	6.50 (14.76)	75.53	9.25 (17.70)	70.66	9.50 (17.94)	70.26	18.75 (25.65)	57.48
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	13.50 (21.55)	64.27	11.50 (19.81)	67.16	5.75 (13.06)	78.35	6.25 (14.46)	76.03
6.	*T. harzianum* (DOR 2 Th)	7.25 (15.61)	74.12	5.50 (13.54)	77.55	9.25 (17.70)	70.66	8.75 (17.20)	71.49
7.	*T. harzianum* (NCC-57 Th)	10.50 (18.90)	68.67	13.25 (21.34)	64.62	8.50 (16.94)	71.92	20.75 (27.09)	55.09
8.	*T. harzianum* (Vermigreen Th)	6.50 (14.76)	75.73	15.00 (22.78)	62.24	7.75 (16.15)	73.23	10.50 (10.90)	81.93

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.2008	0.1339	0.4016
CD (P=0.05)	0.3936	0.2624	0.7871

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 47: Combined effect of fungal biocontrol agents with carbosulfan against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	11.00 (19.36)**	67.90	19.00 (25.83)	57.18	11.50 (19.80)	67.18	12.00 (20.26)	66.41
2.	*T. viride* (DOR 1 Tv)	16.00 (23.57)	60.93	14.00 (21.96)	63.60	14.50 (22.36)	62.93	19.00 (25.82)	57.17
3.	*T. viride* (Sun Agro Derma Tv)	18.50 (25.46)	57.79	18.50 (25.46)	57.79	20.50 (26.91)	55.39	14.56 (22.32)	62.93
4.	*T. viride* (NCC-58 Tv)	17.75 (24.91)	58.71	13.75 (21.73)	63.98	14.00 (21.96)	63.60	19.50 (26.19)	56.58
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	17.25 (24.53)	59.34	17.50 (24.71)	59.04	12.50 (20.70)	65.88	11.75 (20.03)	66.79
6.	*T. harzianum* (DOR 2 Th)	15.00 (22.78)	62.24	10.00 (18.42)	69.46	22.25 (20.13)	66.13	25.50 (30.32)	49.74
7.	*T. harzianum* (NCC-57 Th)	12.25 (20.47)	66.06	13.00 (21.12)	65.01	10.0 (18.42)	69.46	23.25 (28.82)	52.22
8.	*T. harzianum* (Vermigreen Th)	19.50 (26.19)	56.58	14.00 (21.96)	63.60	23.25 (28.82)	52.22	23.00 (28.65)	52.51

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.30	0.21	0.61
CD (P=0.05)	0.60	0.42	1.20

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 54: Combined effect of fungal biocontrol agents with CAN against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	15.50 (23.17)**	61.59	20.00 (26.56)	55.97	21.50 (27.62)	54.21	24.25 (29.49)	51.11
2.	*T. viride* (DOR 1 Tv)	17.00 (24.34)	59.65	19.25 (26.01)	56.88	20.00 (26.56)	55.97	20.75 (27.09)	55.09
3.	*T. viride* (Sun Agro Derma Tv)	13.00 (21.11)	65.00	15.75 (23.38)	61.24	10.50 (18.90)	68.67	8.25 (16.68)	72.35
4.	*T. viride* (NCC-58 Tv)	15.00 (22.78)	62.24	19.50 (26.19)	56.58	17.00 (24.34)	59.65	15.75 (23.38)	61.24
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	20.25 (26.73)	55.69	17.75 (24.91)	58.71	15.50 (23.18)	61.67	15.75 (23.37)	61.23
6.	*T. harzianum* (DOR 2 Th)	21.25 (27.44)	54.51	17.25 (24.53)	59.34	16.25 (23.76)	60.61	16.25 (23.77)	60.60
7.	*T. harzianum* (NCC-57 Th)	12.25 (20.48)	66.05	10.75 (19.13)	68.29	14.00 (21.96)	63.60	10.00 (18.42)	69.46
8.	*T. harzianum* (Vermigreen Th)	21.50 (27.61)	54.23	22.50 (28.30)	53.09	20.25 (26.73)	55.69	19.75 (26.38)	56.27

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.2383	0.1685	0.4766
CD (P=0.05)	0.4671	0.3303	0.9341

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 55: Combined effect of fungal biocontrol agents with DAP against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	38.25 (38.18)**	36.17	21.50 (27.61)	54.23	20.25 (26.73)	55.69	25.00 (29.98)	50.30
2.	*T. viride* (DOR 1 Tv)	26.75 (31.14)	48.38	10.50 (18.90)	68.67	19.50 (26.50)	56.07	17.00 (24.34)	59.65
3.	*T. viride* (Sun Agro Derma Tv)	22.25 (28.13)	53.37	19.50 (26.19)	56.58	18.50 (25.46)	58.13	17.50 (24.71)	59.04
4.	*T. viride* (NCC-58 Tv)	12.25 (20.47)	66.06	15.00 (22.78)	62.24	15.76 (23.38)	61.24	12.50 (20.68)	65.72
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	17.75 (24.91)	58.71	21.00 (27.62)	54.21	17.75 (24.91)	58.71	15.25 (22.97)	61.92
6.	*T. harzianum* (DOR 2 Th)	18.25 (25.28)	58.09	20.00 (26.55)	55.99	17.25 (24.53)	59.34	14.50 (22.37)	61.92
7.	*T. harzianum* (NCC-57 Th)	3.50 (10.75)	82.18	9.00 (17.44)	71.09	8.75 (17.81)	70.47	3.27 (10.29)	82.81
8.	*T. harzianum* (Vermigreen Th)	24.50 (29.66)	50.83	24.75 (29.83)	50.55	29.00 (32.58)	46.49	27.50 (31.62)	47.58

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.32	0.23	0.65
CD (P=0.05)	0.63	0.45	1.27

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 56: Combined effect of fungal biocontrol agents with SSP against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	22.00 (27.96)**	53.65	31.25 (33.98)	43.67	21.25 (27.44)	54.51	20.00 (26.56)	55.97
2.	*T. viride* (DOR 1 Tv)	16.25 (23.75)	60.63	20.25 (26.74)	55.67	24.50 (29.66)	50.83	20.00 (26.56)	55.97
3.	*T. viride* (Sun Agro Derma Tv)	15.50 (23.17)	61.59	23.75 (29.15)	51.68	26.50 (30.97)	48.66	17.00 (24.32)	59.68
4.	*T. viride* (NCC-58 Tv)	15.00 (22.78)	62.24	14.25 (22.16)	63.26	14.50 (22.36)	62.93	13.00 (21.12)	64.99
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	16.50 (23.95)	60.23	31.50 (34.13)	43.42	35.25 (36.41)	39.64	21.25 (27.44)	54.51
6.	*T. harzianum* (DOR 2 Th)	31.00 (33.83)	43.92	25.00 (29.99)	50.29	20.25 (26.74)	55.67	19.00 (25.82)	57.20
7.	*T. harzianum* (NCC-57 Th)	14.50 (22.36)	62.93	4.25 (11.83)	80.39	14.25 (22.17)	63.52	10.50 (18.88)	68.70
8.	*T. harzianum* (Vermigreen Th)	20.00 (26.56)	55.97	24.00 (29.33)	51.38	25.50 (30.32)	49.74	31.50 (34.13)	43.42

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.28	0.19	0.56
CD (P=0.05)	0.54	0.38	1.09

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 57: Combined effect of fungal biocontrol agents with MOP against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	6.75 (15.05)**	75.05	16.75 (24.15)	58.97	4.25 (11.88)	80.30	4.25 (11.88)	80.30
2.	*T. viride* (DOR 1 Tv)	7.00 (15.32)	74.60	11.50 (19.71)	67.32	2.50 (9.05)	84.99	0.50 (2.86)	95.25
3.	*T. viride* (Sun Agro Derma Tv)	11.50 (19.81)	67.16	6.50 (14.76)	75.53	2.50 (9.05)	84.99	0.75 (4.30)	92.87
4.	*T. viride* (NCC-58 Tv)	7.50 (15.88)	73.67	6.75 (15.05)	75.05	2.75 (9.51)	84.23	0.75 (4.30)	92.87
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	8.50 (16.91)	71.97	12.50 (20.70)	65.68	9.50 (17.92)	70.29	2.75 (9.51)	84.23
6.	*T. harzianum* (DOR 2 Th)	9.50 (17.92)	70.29	16.00 (23.57)	60.93	8.25 (16.65)	72.40	3.25 (10.29)	82.94
7.	*T. harzianum* (NCC-57 Th)	8.00 (16.38)	72.84	7.50 (15.88)	73.67	10.25 (10.65)	82.34	3.25 (10.29)	82.94
8.	*T. harzianum* (Vermigreen Th)	6.75 (15.03)	75.08	13.50 (21.54)	64.29	8.50 (16.91)	71.97	3.25 (10.29)	82.94

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.51	0.36	1.02
CD (P=0.05)	1.00	0.70	2.00

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 66: Combined effect of fungal biocontrol agents with pendimethalin against *P. aphanidermatum* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	1.25 (6.33)**	89.50	1.50 (6.93)	88.51	4.25 (11.83)	80.39	12.75 (20.91)	65.34
2.	*T. viride* (DOR 1 Tv)	9.50 (17.94)	70.26	7.00 (15.32)	74.60	13.75 (21.75)	63.94	9.25 (17.68)	70.69
3.	*T. viride* (Sun Agro Derma Tv)	12.00 (20.26)	66.41	10.00 (18.42)	69.46	11.00 (19.36)	67.90	5.00 (12.88)	78.65
4.	*T. viride* (NCC-58 Tv)	6.50 (14.71)	76.51	7.50 (15.82)	73.77	13.75 (21.75)	63.94	13.50 (21.54)	64.62
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	12.75 (20.91)	65.34	10.25 (18.65)	69.08	15.25 (22.97)	61.92	21.25 (27.43)	54.53
6.	*T. harzianum* (DOR 2 Th)	2.50 (8.84)	85.34	12.75 (20.91)	65.34	10.75 (19.13)	68.29	9.25 (17.68)	70.69
7.	*T. harzianum* (NCC-57 Th)	8.50 (16.91)	71.97	7.50 (15.85)	73.72	20.00 (26.56)	55.97	18.25 (25.28)	57.59
8.	*T. harzianum* (Vermigreen Th)	4.75 (12.54)	79.21	11.00 (19.36)	67.90	10.75 (19.12)	68.30	8.25 (16.68)	72.35

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.37	0.26	0.75
CD (P=0.05)	0.74	0.52	1.48

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 43: Combined effect of fungal biocontrol agents with copper oxychloride against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	30.50 (33.51)**	50.14	36.25 (37.01)	44.98	63.50 (52.83)	21.39	70.50 (57.10)	15.04
2.	*T. viride* (DOR 1 Tv)	24.50 (29.66)	55.86	28.00 (31.94)	52.47	34.50 (46.49)	46.49	52.50 (46.43)	30.91
3.	*T. viride* (Sun Agro Derma Tv)	23.50 (28.99)	56.88	25.00 (29.99)	53.37	34.00 (35.66)	46.94	47.00 (43.27)	35.61
4.	*T. viride* (NCC-58 Tv)	25.00 (29.99)	55.37	28.25 (38.10)	52.23	33.75 (35.51)	47.16	53.00 (46.72)	30.48
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	11.00 (19.36)	71.19	27.75 (31.78)	52.71	36.75 (37.71)	44.48	45.75 (42.56)	36.67
6.	*T. harzianum* (DOR 2 Th)	23.25 (28.82)	57.11	30.50 (33.51)	50.14	37.25 (37.61)	44.04	52.25 (46.29)	31.12
7.	*T. harzianum* (NCC-57 Th)	6.50 (14.71)	78.11	8.00 (16.41)	75.58	11.50 (19.74)	70.62	19.50 (26.19)	61.03
8.	*T. harzianum* (Vermigreen Th)	37.50 (37.75)	43.82	40.00 (39.23)	41.63	50.50 (42.28)	37.09	70.50 (57.10)	15.04

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.2989	0.2108	0.5962
CD (P=0.05)	0.5843	0.4131	1.1685

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 44: Combined effect of fungal biocontrol agents with mancozeb against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	7.00 (15.23)**	77.33	10.00 (18.42)	72.59	17.00 (24.34)	63.78	23.00 (28.65)	57.37
2.	*T. viride* (DOR 1 Tv)	2.75 (9.44)	85.95	2.00 (7.99)	88.11	7.75 (16.14)	75.98	0.75 (4.30)	93.60
3.	*T. viride* (Sun Agro Derma Tv)	20.00 (26.55)	60.49	14.00 (21.96)	67.32	9.25 (17.68)	73.69	7.50 (15.88)	76.37
4.	*T. viride* (NCC-58 Tv)	28.25 (32.10)	52.23	9.25 (17.65)	73.73	4.00 (11.49)	82.90	2.50 (8.84)	86.84
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	6.75 (15.00)	77.68	10.00 (18.40)	72.59	15.75 (23.37)	65.22	22.00 (27.96)	58.39
6.	*T. harzianum* (DOR 2 Th)	4.75 (12.57)	81.29	6.25 (14.44)	78.51	9.25 (17.68)	73.69	1.00 (4.90)	92.70
7.	*T. harzianum* (NCC-57 Th)	20.50 (26.91)	59.96	16.00 (23.57)	64.93	12.25 (20.43)	69.60	8.75 (17.18)	74.43
8.	*T. harzianum* (Vermigreen Th)	36.25 (37.01)	44.93	9.50 (17.72)	73.63	5.50 (13.54)	79.85	4.50 (12.29)	81.71

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.4829	0.3414	0.9657
CD (P=0.05)	0.9464	0.6692	1.8928

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 51: Combined effect of fungal biocontrol agents with imidadoprid against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	15.50 (23.18)**	65.51	3.75 (11.14)	83.42	29.00 (32.58)	51.52	29.50 (32.89)	51.06
2.	*T. viride* (DOR 1 Tv)	0.50 (2.86)	95.74	1.00 (5.73)	91.47	1.25 (6.33)	90.58	4.75 (12.57)	81.23
3.	*T. viride* (Sun Agro Derma Tv)	49.25 (44.57)	33.68	45.50 (42.41)	37.19	21.25 (27.44)	59.17	16.00 (23.57)	64.93
4.	*T. viride* (NCC-58 Tv)	3.50 (10.64)	84.16	14.00 (21.89)	67.43	22.25 (28.14)	58.13	23.75 (29.16)	56.61
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	4.50 (12.22)	81.81	7.25 (15.51)	76.80	20.50 (26.91)	59.96	21.25 (27.44)	59.17
6.	*T. harzianum* (DOR 2 Th)	0.75 (4.30)	93.60	7.75 (16.15)	75.97	23.75 (29.16)	56.61	20.75 (27.09)	59.69
7.	*T. harzianum* (NCC-57 Th)	4.00 (11.53)	82.84	10.75 (19.13)	71.53	7.75 (16.14)	75.98	19.00 (25.83)	61.58
8.	*T. harzianum* (Vermigreen Th)	4.75 (12.57)	81.29	22.00 (27.96)	58.53	43.00 (40.93)	39.10	48.50 (44.14)	34.32

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.40	0.28	0.89
CD (P=0.05)	0.80	0.56	1.60

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 52: Combined effect of fungal biocontrol agents with chlorpyriphos against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	1.00 (5.73)**	91.47	1.50 (6.93)	89.68	11.25 (19.59)	70.85	22.25 (28.14)	58.12
2.	*T. viride* (DOR 1 Tv)	0.50 (2.86)	95.74	2.00 (8.13)	87.90	10.00 (18.38)	72.65	25.75 (30.49)	54.63
3.	*T. viride* (Sun Agro Derma Tv)	0.75 (4.30)	93.60	2.75 (9.51)	85.85	5.25 (13.20)	80.36	20.75 (27.08)	59.70
4.	*T. viride* (NCC-58 Tv)	0.50 (2.86)	95.74	1.50 (6.93)	89.68	6.25 (14.37)	78.61	8.75 (17.20)	74.40
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	2.75 (9.51)	85.85	5.25 (13.20)	80.36	11.00 (19.36)	71.19	13.75 (21.76)	67.62
6.	*T. harzianum* (DOR 2 Th)	3.75 (11.14)	83.42	3.75 (11.14)	83.42	11.50 (19.81)	70.52	23.50 (28.99)	56.86
7.	*T. harzianum* (NCC-57 Th)	9.25 (17.68)	73.69	4.75 (12.54)	81.34	12.50 (20.68)	69.23	24.25 (29.49)	56.42
8.	*T. harzianum* (Vermigreen Th)	6.75 (15.05)	77.60	7.25 (15.61)	76.77	11.25 (19.59)	71.29	15.00 (22.78)	66.10

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.44	0.29	0.88
CD (P=0.05)	0.86	0.57	1.73

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 53: Combined effect of fungal biocontrol agents with carbosulfan against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	12.25 (20.48)**	69.52	8.75 (17.20)	74.40	12.75 (20.91)	68.88	10.50 (18.90)	71.87
2.	*T. viride* (DOR 1 Tv)	13.75 (21.76)	67.52	8.50 (16.94)	74.79	13.75 (21.67)	67.75	11.25 (19.59)	70.85
3.	*T. viride* (Sun Agro Derma Tv)	11.50 (19.81)	70.52	8.50 (16.94)	74.79	9.00 (17.45)	74.03	8.25 (16.68)	75.30
4.	*T. viride* (NCC-58 Tv)	10.00 (18.43)	72.57	11.75 (20.04)	70.18	9.50 (17.94)	73.03	7.50 (15.88)	76.33
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	15.75 (23.38)	65.21	7.75 (16.15)	75.97	6.50 (14.76)	78.03	5.00 (12.92)	80.77
6.	*T. harzianum* (DOR 2 Th)	9.25 (17.70)	73.76	13.50 (21.55)	67.93	11.75 (20.04)	70.18	9.00 (17.45)	74.03
7.	*T. harzianum* (NCC-57 Th)	19.50 (26.20)	61.01	18.75 (25.65)	61.83	10.25 (18.66)	72.33	12.75 (20.91)	68.38
8.	*T. harzianum* (Vermigreen Th)	16.00 (23.57)	64.93	14.50 (22.37)	66.71	13.25 (21.34)	68.24	13.00 (21.13)	68.56

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.16	0.11	0.32
CD (P=0.05)	0.31	0.22	0.63

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 62: Combined effect of fungal biocontrol agents with CAN against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	27.00 (31.30)**	53.42	20.50 (26.91)	59.96	16.50 (23.96)	64.35	11.00 (19.36)	71.19
2.	*T. viride* (DOR 1 Tv)	22.50 (28.30)	57.89	20.25 (26.74)	60.21	15.25 (22.97)	65.82	10.25 (18.65)	72.25
3.	*T. viride* (Sun Agro Derma Tv)	21.50 (27.61)	58.91	17.25 (24.53)	63.50	11.50 (19.80)	70.54	6.75 (15.03)	77.63
4.	*T. viride* (NCC-58 Tv)	21.00 (27.25)	59.45	16.00 (23.57)	64.93	14.50 (22.36)	66.73	12.25 (20.48)	69.54
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	20.00 (26.56)	60.48	17.00 (24.34)	63.78	14.00 (21.96)	67.32	9.25 (17.68)	73.69
6.	*T. harzianum* (DOR 2 Th)	9.00 (17.44)	60.48	16.75 (24.15)	64.06	13.00 (21.13)	68.56	10.00 (18.40)	72.62
7.	*T. harzianum* (NCC-57 Th)	77.00 (61.54)	74.05	7.00 (15.32)	77.20	9.25 (17.70)	73.66	8.25 (16.68)	75.18
8.	*T. harzianum* (Vermigreen Th)	85.00 (67.21)	8.73	36.50 (37.16)	44.71	23.75 (29.16)	56.61	19.50 (26.19)	61.07

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.28	0.20	0.56
CD (P=0.05)	0.55	0.39	1.11

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 63: Combined effect of fungal biocontrol agents with DAP against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	25.50 (30.32)**	54.88	20.00 (26.56)	60.48	20.75 (27.09)	59.69	20.50 (26.91)	59.96
2.	*T. viride* (DOR 1 Tv)	20.50 (26.91)	59.96	25.50 (30.32)	54.88	24.75 (29.85)	55.61	19.50 (26.20)	61.01
3.	*T. viride* (Sun Agro Derma Tv)	20.50 (26.91)	59.96	15.50 (26.20)	61.01	18.75 (25.65)	61.83	19.00 (25.84)	65.46
4.	*T. viride* (NCC-58 Tv)	13.25 (21.34)	68.24	20.00 (26.56)	60.48	18.50 (25.46)	62.11	21.50 (27.61)	58.91
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	25.00 (29.99)	55.37	27.00 (31.30)	53.42	26.25 (30.81)	54.15	21.00 (27.27)	59.42
6.	*T. harzianum* (DOR 2 Th)	27.80 (31.62)	52.95	24.75 (29.83)	55.61	23.50 (28.99)	56.86	23.25 (28.66)	57.11
7.	*T. harzianum* (NCC-57 Th)	20.00 (26.56)	60.48	19.00 (25.83)	65.46	18.50 (25.46)	62.11	17.00 (23.80)	63.78
8.	*T. harzianum* (Vermigreen Th)	78.75 (62.55)	6.93	77.25 (61.51)	8.48	64.50 (53.43)	20.50	28.25 (32.10)	52.23

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.20	0.14	0.40
CD (P=0.05)	0.39	0.28	0.79

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 64: Combined effect of fungal biocontrol agents with SSP against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	25.25 (30.14)**	55.15	25.00 (29.98)	55.39	25.25 (30.14)	55.15	20.29 (26.73)	60.22
2.	*T. viride* (DOR 1 Tv)	24.75 (29.83)	55.61	26.50 (30.98)	53.90	23.50 (28.99)	56.86	20.00 (26.56)	60.48
3.	*T. viride* (Sun Agro Derma Tv)	26.50 (30.97)	53.92	40.00 (39.21)	41.66	20.50 (26.91)	59.96	18.50 (25.46)	62.11
4.	*T. viride* (NCC-58 Tv)	27.00 (31.30)	53.42	31.00 (33.83)	49.66	32.75 (34.90)	48.07	37.42 (37.61)	44.04
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	20.25 (26.74)	60.21	21.25 (27.44)	59.17	17.51 (24.71)	62.33	14.00 (21.96)	67.32
6.	*T. harzianum* (DOR 2 Th)	23.00 (28.65)	57.37	23.50 (28.99)	56.86	16.50 (23.95)	64.36	13.75 (21.75)	67.63
7.	*T. harzianum* (NCC-57 Th)	22.00 (27.96)	58.39	18.50 (25.46)	62.11	15.50 (23.17)	65.52	15.00 (22.78)	66.10
8.	*T. harzianum* (Vermigreen Th)	80.00 (63.43)	5.62	83.00 (65.64)	2.33	56.25 (48.59)	27.70	51.25 (45.71)	31.98

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.32	0.22	0.64
CD (P=0.05)	0.63	0.14	1.26

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 65: Combined effect of fungal biocontrol agents with MOP against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	22.00 (27.96)**	58.39	24.00 (29.30)	56.40	23.25 (28.82)	57.11	33.25 (35.21)	47.61
2.	*T. viride* (DOR 1 Tv)	21.25 (27.44)	59.17	20.00 (26.56)	40.65	14.75 (22.58)	66.40	21.25 (27.44)	57.17
3.	*T. viride* (Sun Agro Derma Tv)	22.00 (27.96)	58.39	30.50 (33.51)	50.14	21.75 (27.79)	58.65	16.25 (23.77)	64.63
4.	*T. viride* (NCC-58 Tv)	17.50 (24.72)	63.21	16.50 (23.96)	64.53	16.00 (23.57)	64.93	29.50 (32.87)	51.09
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	22.00 (27.96)	58.39	22.50 (28.30)	57.89	23.25 (28.82)	57.11	32.50 (34.74)	48.31
6.	*T. harzianum* (DOR 2 Th)	19.50 (26.19)	61.03	14.75 (22.58)	66.40	19.50 (26.20)	61.01	18.50 (25.47)	62.10
7.	*T. harzianum* (NCC-57 Th)	23.50 (28.99)	56.86	21.25 (27.71)	58.68	20.25 (26.73)	60.22	21.25 (27.44)	59.17
8.	*T. harzianum* (Vermigreen Th)	69.50 (56.48)	15.96	51.25 (45.71)	31.98	61.50 (51.65)	28.15	50.00 (45.00)	33.04

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.29	0.20	0.58
CD (P=0.05)	0.57	0.40	1.14

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 70: Combined effect of fungal biocontrol agents with pendimethalin against *S. rolfsii* at different concentrations

S. No.	Fungal biocontrol isolates	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)	Radial growth* (mm)	Growth reduction over control (%)
1.	*Trichoderma viride* (BCL Tv)	10.25 (18.66)**	72.23	11.00 (19.36)	71.19	13.25 (21.34)	68.24	12.00 (20.26)	69.85
2.	*T. viride* (DOR 1 Tv)	7.95 (16.15)	75.97	10.25 (18.66)	72.23	8.25 (16.67)	75.19	12.75 (20.91)	68.88
3.	*T. viride* (Sun Agro Derma Tv)	13.00 (21.12)	68.57	10.25 (18.66)	72.23	11.75 (20.03)	70.19	13.75 (21.76)	67.62
4.	*T. viride* (NCC-58 Tv)	6.50 (14.76)	78.03	9.25 (17.70)	73.66	9.50 (17.94)	73.30	8.75 (25.64)	61.83
5.	*Trichoderma harzianum* (Sun Agro Derma Th)	13.50 (21.53)	67.96	11.50 (19.81)	70.52	5.75 (13.86)	79.37	6.25 (14.46)	78.48
6.	*T. harzianum* (DOR 2 Th)	7.25 (15.61)	76.77	5.50 (13.54)	79.85	9.25 (17.70)	73.66	8.75 (17.20)	74.70
7.	*T. harzianum* (NCC-57 Th)	10.50 (18.90)	71.87	13.25 (21.34)	68.24	8.50 (16.94)	74.79	20.75 (27.09)	59.69
8.	*T. harzianum* (Vermigreen Th)	6.50 (14.76)	78.03	15.00 (22.78)	66.10	7.75 (16.15)	75.97	10.50 (18.90)	71.87

	Biocontrol isolates (B)	Concentrations (C)	B x C
SEm±	0.21	0.15	0.42
CD (P=0.05)	0.41	0.29	0.83

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 27: Efficacy of various fungicides on the radial growth of *P. aphanidermatum*

S. No.	Name of the fungicide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Copper oxychloride (Blitox 50% WP)	10.66 (19.00)**	68.50	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
2.	Mancozeb (Dithane M-45 72% WP)	47.50 (43.56)	5.86	70.00 (56.79)	27.79	0.00 (0.00)	100.00	0.00 (0.00)	100.00
3.	Carbendazim (Bavistin 50% WP)	73.50 (59.02)	2.17	44.00 (41.54)	31.14	18.50 (25.44)	57.83	8.00 (16.41)	72.79
4.	Hexaconazole (Contaf 5% EC)	50.00 (45.00)	25.41	10.00 (18.43)	69.45	0.00 (0.00)	100.00	0.00 (0.00)	100.00

SEm± = 0.44
CD (P=0.05) = 1.26
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 28: Efficacy of various fungicides on the radial growth of *M. phaseolina*

S. No.	Name of the fungicide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Copper oxychloride (Blitox 50% WP)	85.00 (67.21)**	0.00	84.75 (67.02)	0.28	81.50 (64.53)	3.98	80.75 (63.98)	4.80
2.	Mancozeb (Dithane M-45 72% WP)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
3.	Carbendazim (Bavistin 50% WP)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
4.	Hexaconazole (Contaf 5% EC)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00

SEm± = 0.27
CD (P=0.05) = 0.57
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 29: Efficacy of various fungicides on the radial growth of *S. rolfsii*

S. No.	Name of the fungicide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Copper oxychloride (Blitox 50% WP)	85.00 (67.21)	0.00	84.50 (66.81)	0.59	82.50 (65.28)	2.87	79.25 (62.90)	6.41
2.	Mancozeb (Dithane M-45 72% WP)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
3.	Carbendazim (Bavistin 50% WP)	85.00 (67.22)	0.00	85.00 (67.22)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	Hexaconazole (Contaf 5% EC)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00

SEm± = 0.32
CD (P=0.05) = 0.65
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 30: Efficacy of various insecticides on the radial growth of *P. aphanidermatum*

S. No.	Name of the insecticide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Thiomethoxam (Cruiser 70% WS)	70.50 (51.10)**	5.35	64.0 (53.13)	11.93	63.00 (52.53)	12.92	62.25 (52.09)	13.65
2.	Chloropyriphos (Dursban 80% EC)	54.50 (47.58)	21.13	46.00 (42.70)	29.22	43.25 (41.12)	31.84	42.00 (40.39)	33.05
3.	Imidacloprid (Confidor 17.8% SL)	65.00 (53.72)	10.95	64.75 (53.58)	11.18	65.50 (54.03)	10.44	60.00 (50.76)	15.86
4.	Carbosulfan (Marshal 50% EC)	69.50 (56.49)	6.36	67.00 (54.94)	8.93	63.25 (52.68)	12.68	58.00 (49.60)	17.78

SEm± = 0.57
CD (P=0.05) = 1.15
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 31: Efficacy of various insecticides on the radial growth of *M. Phaseolina*

S. No.	Name of the insecticide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Thiomethoxam (Cruiser 70% WS)	70.00 (56.79)**	15.50	55.25 (48.01)	28.67	45.25 (42.27)	37.10	20.25 (26.73)	60.22
2.	Chloropyriphos (Dursban 80% EC)	83.00 (65.64)	2.33	75.00 (60.22)	10.23	70.50 (57.10)	15.04	50.50 (45.28)	32.32
3.	Imidadopride (Confidor 17.8% SL)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	Carbosulfan (Marshal 50% EC)	44.35 (41.98)	37.53	34.75 (36.11)	46.27	33.00 (36.06)	46.34	29.50 (32.89)	51.06

SEm± = 1.19
CD (P=0.05) = 2.40
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 32: Efficacy of various insecticides on the radial growth of *S. rolfsii*

S. No.	Name of the insecticide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Thiomethoxam (Cruiser 70% WS)	84.50 (66.81)**	0.59	84.25 (66.64)	1.48	83.50 (66.04)	1.74	74.50 (59.67)	11.2
2.	Chloropyriphos (Dursban 80% EC)	63.50 (52.83)	21.39	40.50 (39.52)	41.19	25.00 (29.99)	55.37	22.50 (20.30)	57.89
3.	Imidaclooprid (Confidor 17.8% SL)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	Carbosulfan (Marshal 50% EC)	83.50 (66.04)	1.74	82.50 (65.27)	2.88	80.50 (63.80)	5.07	74.27 (59.50)	11.47

SEm± = 0.53
CD (P=0.05) = 1.06
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 33: Efficacy of various fertilizers on the radial growth of *P. aphanidermatum*

S. No.	Name of the fertilizer	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Calcium ammonium nitrate	75.00 (60.33)**	0.00	75.00 (60.33)	0.00	75.00 (60.33)	0.00	75.00 (60.33)	0.00
2.	Diammonium phosphate	75.00 (60.33)	0.00	75.00 (60.33)	0.00	75.00 (60.33)	0.00	75.00 (60.33)	0.00
3.	Single super phosphate	75.00 (60.33)	0.00	75.00 (60.33)	0.00	75.00 (60.33)	0.00	75.00 (60.33)	0.00
4.	Muriate of potash	75.00 (60.33)	0.00	75.00 (60.33)	0.00	75.00 (60.33)	0.00	75.00 (60.33)	0.00

SEm± = 0.50
CD (P=0.05) = 1.00
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 34: Efficacy of various fertilizers on the radial growth of *M. phaseolina*

S. No.	Name of the fertilizer	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Calcium ammonium nitrate	85.00 (67.21)**	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
2.	Diammonium phosphate	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
3.	Single super phosphate	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	Muriate of potash	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00

SEm± = 0.34
CD (P=0.05) = 0.61
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 35: Efficacy of various fertilizers on the radial growth of *S. rolfsii*

S. No.	Name of the fertilizer	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Calcium ammonium nitrate	84.50 (66.81)**	0.59	81.25 (64.34)	4.27	73.00 (58.71)	12.64	62.25 (52.09)	22.49
2.	Diammonium phosphate	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
3.	Single super phosphate	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
4.	Muriate of potash	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00

SEm± = 0.33
CD (P=0.05) = 0.53
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 36: Efficacy of various herbicides on the radial growth of *P. aphanidermatum*

S. No.	Name of the herbicide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Pendimethalin	63.50 (52.83)**	12.43	49.50 (44.71)	25.89	47.00 (43.29)	28.24	41.50 (40.10)	33.53
2.	Fluchloralin	9.00 (17.44)	71.09	8.25 (16.68)	72.35	7.25 (15.59)	74.15	7.00 (15.32)	74.60

SEm± = 0.53
CD (P=0.05) = 1.10
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 37: Efficacy of various herbicides on the radial growth of *M. phaseolina*

S. No.	Name of the herbicide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Pendimethalin	84.25 (66.62)**	0.87	82.50 (65.28)	2.87	79.25 (62.90)	6.41	55.25 (48.01)	28.56
2.	Fluchloralin	46.75 (43.13)	35.82	6.00 (14.15)	78.94	4.50 (12.22)	81.81	3.50 (10.25)	84.00

SEm± = 0.571
CD (P=0.05) = 1.18

* Mean of four replications

** Figures in parentheses are angular transformed values.

Table 38: Efficacy of various herbicides on the radial growth of *S. rolfsii*

S. No.	Name of the herbicide	Concentrations (ppm)							
		100		500		1000		2000	
		Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control	Radial growth* (mm)	% growth inhibition over control
1.	Pendimethalin	64.75 (53.58)**	20.27	32.00 (34.44)	48.75	30.00 (33.20)	30.60	0.75 (4.30)	93.60
2.	Fluchloralin	0.00 (0.00)	100	0.00 (0.00)	100	0.00 (0.00)	100	0.00 (0.00)	100

SEm± = 0.76
CD (P=0.05) = 1.59
* Mean of four replications
** Figures in parentheses are angular transformed values.

Table 19: *In vitro* compatibility of commercial isolate of *Pseudomomonas flourescens* (Vg Pf) with fungicides

S. No.	Name of the fungicides	* % inhibition of growth of *P. flourescens* Concentrations (ppm)			
		100	500	1000	2000
1.	Copper oxychloride	0.00 (0.00)**	2.23 (8.53)	4.46 (12.11)	7.88 (16.22)
2.	Mancozeb	0.00 (0.00)	2.78 (9.46)	3.91 (11.39)	7.30 (15.68)
3.	Carbendazim	0.00 (0.00)	3.33 (10.47)	5.04 (12.93)	8.43 (16.85)
4.	Hexaconazole	0.00 (0.00)	2.23 (8.53)	5.04 (12.93)	7.88 (16.22)

	Bacterial isolates (B)	Concentrations (C)	B x C
SEm±	0.1167	0.1167	0.2334
CD (P=0.05)	0.2367	0.2367	0.4735

* Mean of three replications; ** Figures in parentheses are angular transformed values.

Table 20: *In vitro* compatibility of commercial isolate of *Pseudomomonas flourescens* (SA Pf) with fungicides

S. No.	Name of the fungicides	* % Inhibition of growth of *P. flourescens* Concentrations (ppm)			
		100	500	1000	2000
1.	Copper oxychloride	0.00 (0.00)**	2.23 (8.53)	4.46 (12.11)	8.43 (16.85)
2.	Mancozeb	0.00 (0.00)	1.68 (7.27)	3.91 (11.39)	7.30 (15.68)
3.	Carbendazim	0.00 (0.00)	2.23 (8.53)	4.46 (12.11)	8.46 (16.85)
4.	Hexaconazole	0.00 (0.00)	2.23 (8.53)	5.04 (1.93)	8.46 (16.85)

	Bacterial isolates (B)	Concentrations (C)	B x C
SEm±	0.1814	0.1814	0.3627
CD (P=0.05)	0.3680	0.3680	0.2360

* Mean of three replications; ** Figures in parentheses are angular transformed values.

Table 22: *In vitro* compatibility of commercial isolate of *Pseudomomonas flourescens* (Vg Pf) with insecticides

S. No.	Name of the insecticides	* % Inhibition of growth of *P. flourescens* Concentrations (ppm)			
		100	500	1000	2000
1.	Imidacloprid	0.00	0.00	1.68	4.46
		(0.00)**	(0.00)	(7.27)	(12.11)
2.	Chlorpyriphos	0.00	1.13	1.68	4.46
		(0.00)	(6.03)	(7.27)	(12.11)
3.	Carbosulfan	0.00	0.00	0.55	1.68
		(0.00)	(0.00)	(4.05)	(7.27)

	Bacterial isolates (B)	Concentrations (C)	B x C
SEm±	0.1252	0.1446	0.2504
CD (P=0.05)	0.2574	0.2948	0.5148

* Mean of three replications; ** Figures in parentheses are angular transformed values.

Table 21: *In vitro* compatibility of commercial isolate of *Pseudomomonas flourescens* (SA Pf) with insecticides

S. No.	Name of the insecticides	* % Inhibition of growth of *P. flourescens* Concentrations (ppm)			
		100	500	1000	2000
1.	Imidacloprid	0.00	0.00	0.55	1.13
		(0.00)**	(0.00)	(4.05)	(6.03)
2.	Chlorpyriphos	0.00	0.00	2.28	2.23
		(0.00)	(0.00)	(10.30)	(8.53)
3.	Carbosulfan	0.00	0.00	0.00	1.68
		(0.00)	(0.00)	(0.00)	(7.27)

	Bacterial isolates (B)	Concentrations (C)	B x C
SEm±	0.1251	0.1445	0.2502
CD (P=0.05)	0.2572	0.2970	0.5144

* Mean of three replications; ** Figures in parentheses are angular transformed values.

Table 24: *In vitro* compatibility of commercial isolate of *Pseudomomonas flourescens* (Vg Pf) with fertilizers

S. No.	Name of the fertilizer	* % Inhibition of growth of *P. flourescens* Concentrations (ppm)			
		100	500	1000	2000
1.	Calcium ammonium nitrate	0.00 (0.00)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2.	Diammonium phosphate	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
3.	Single super phosphate	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
4.	Muriate of potash	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

	Bacterial isolates (B)	Concentrations (C)	B x C
SEm±	0.0107	0.0107	0.0214
CD (P=0.05)	0.0217	0.0217	0.0435

* Mean of three replications; ** Figures in parentheses are angular transformed values.

Table 23: *In vitro* compatibility of commercial isolate of *Pseudomomonas flourescens* (SA Pf) with fertilizers

S. No.	Name of the fertilizer	*% Inhibition of growth of *P. flourescens* Concentrations (ppm)			
		100	500	1000	2000
1.	Calcium ammonium nitrate	0.00 (0.00)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2.	Diammonium phosphate	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
3.	Single super phosphate	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
4.	Muriate of potash	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

	Bacterial isolates (B)	Concentrations (C)	B x C
SEm±	0.0107	0.0107	0.0214
CD (P=0.05)	0.0217	0.0217	0.0435

* Mean of three replications; ** Figures in parentheses are angular transformed values.

Table 26: *In vitro* compatibility of commercial isolate of *Pseudomomonas flourescens* (Vg Pf) with herbicides

S. No.	Name of the herbicide	* % Inhibition of growth of *P. flourescens* Concentrations (ppm)			
		100	500	1000	2000
1.	Pendimethalin (Stomp 35% EC)	0.00 (0.00)**	1.68 (7.27)	6.72 (15.00)	14.91 (22.91)
2.	Fluchloralin (Basalin 48% EC)	0.05 (2.05)	1.68 (7.27)	8.46 (16.85)	19.13 (25.91)

	Bacterial isolates (B)	Concentrations (C)	B x C
SEm±	0.2233	0.3157	0.4465
CD (P=0.05)	0.4690	0.6633	0.9381

* Mean of three replications; ** Figures in parentheses are angular transformed values.

Table 25: *In vitro* compatibility of commercial isolate of *Pseudomomonas flourescens* (SA Pf) with herbicides

S. No.	Name of the herbicide	* % Inhibition of growth of *P. flourescens* Concentrations (ppm)			
		100	500	1000	2000
1.	Pendimethalin (Stomp 35% EC)	0.00 (0.00)**	2.23 (8.53)	8.43 (16.85)	19.13 (25.91)
2.	Fluchloralin (Basalin 48% EC)	0.00 (0.00)	2.23 (8.53)	17.92 (5.03)	21.00 (27.27)

	Bacterial isolates (B)	Concentrations (C)	B x C
SEm±	0.1786	0.2526	0.3572
CD (P=0.05)	0.3753	0.5307	0.2505

* Mean of three replications; ** Figures in parentheses are angular transformed values.

Table 72: Combined effect of bacterial biocontrol agents with fungicides on radial growth of *P. aphanidermatum*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Copper Oxy Chloride				
Pseudomonas fluorescens (Sun Agro Monus Pf)	78.75 (62.51)**	6.90	73.50 (59.05)	12.14	73.25 (58.82)	13.82	70.00 (56.79)	17.64
Pseudomonas fluorescens (Vermigreen Pf)	77.25 (62.91)	6.39	74.25 (59.55)	11.39	72.00 (58.05)	15.29	71.25 (57.54)	16.17
				Mancozeb				
Pseudomonas fluorescens (Sun Agro Monus Pf)	71.00 (57.42)	16.47	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
Pseudomonas fluorescens (Vermigreen Pf)	70.25 (56.91)	17.35	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
				Carbendazim				
Pseudomonas fluorescens (Sun Agro Monus Pf)	85.00 (67.25)	0.00	72.00 (58.05)	15.29	65.45 (53.97)	23.23	60.00 (50.77)	29.41
Pseudomonas fluorescens (Vermigreen Pf)	85.00 (67.21)	0.00	71.00 (57.42)	16.47	63.25 (52.65)	25.58	59.75 (50.59)	29.70
				Hexaconazole				
Pseudomonas fluorescens (Sun Agro Monus Pf)	9.50 (17.92)	73.33	5.00 (12.88)	80.83	4.25 (11.83)	95.29	3.00 (9.97)	96.47
Pseudomonas fluorescens (Vermigreen Pf)	9.50 (17.92)	73.33	4.75 (12.54)	81.34	4.00 (11.54)	95.29	2.00 (8.13)	97.64
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm+	0.4218		0.1984		1.1028		
	CD(P=0.05)	1.1812		0.4561		2.2548		

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 75: Combined effect of bacterial agents with insecticides on radial growth of *P. aphanidermatum*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Imidacloprid				
Pseudomonas fluorescens (Sun Agro Monus Pf)	56.25 (4859)**	27.70	48.25 (43.99)	34.34	35.25 (36.29)	46.00	22.75 (28.45)	57.66
Pseudomonas fluorescens (Vermigreen Pf)	57.00 (49.03)	27.04	51.75 (46.00)	31.55	48.00 (43.85)	34.75	47.25 943.39)	35.44
				Chlorpyriphos				
Pseudomonas fluorescens (Sun Agro Monus Pf)	31.50 (34.12)	49.23	25.60 (30.96)	53.95	26.50 (30.98)	53.90	19.50 (25.21)	62.49
Pseudomonas fluorescens (Vermigreen Pf)	33.25 (35.19)	47.64	25.75 (30.44)	54.70	23.50 (29.00)	56.85	18.00 (25.10)	62.65
				Carbosulfan				
Pseudomonas fluorescens (Sun Agro Monus Pf)	39.75 (39.08)	41.85	27.25 (31.41)	35.80	22.50 (28.32)	57.86	18.50 (25.47)	62.10
Pseudomonas fluorescens (Vermigreen Pf)	42.25 (40.53)	39.69	34.00 (35.65)	46.95	31.00 (33.85)	49.63	28.00 (31.95)	52.46
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.4821		0.1624		1.1742		
	CD(P=0.05)	1.1324		0.5162		2.4131		

* Mean of four replications

** Figures in parentheses are angular transformed values.

Table 78: Combined effect of bacterial agents with fertilizers on radial growth of *P. aphanidermatum*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Calcium Ammonium Nitrate				
Pseudomonas fluorescens (Sun Agro Mons Pf)	79.00 (62.72)**	6.68	77.95 (59.25)	11.84	80.25 (63.58)	5.58	81.25 (64.30)	4.41
Pseudomonas fluorescens (Vermigreen Pf)	79.25 (62.91)	6.39	80.00 (63.47)	5.56	81.25 (64.30)	4.41	80.50 (63.79)	4.29
				Diammonium phosphate				
Pseudomonas fluorescens (Sun Agro Monus Pf)	80.25 (63.62)	5.34	80.25 (63.62)	5.00	81.50 (64.53)	5.29	82.00 (64.90)	3.52
Pseudomonas fluorescens (Vermigreen Pf)	80.50 (63.81)	5.05	81.00 (64.16)	4.53	82.00 (64.90)	3.52	82.00 (64.90)	3.52
				Single Super Phosphate				
Pseudomonas fluorescens (Sun Agro Monus Pf)	76.75 (61.19)	8.95	76.25 (60.85)	9.46	75.00 (60.00)	11.76	72.00 (58.05)	15.29
Pseudomonas fluorescens (Vermigreen Pf)	76.00 (60.67)	9.73	77.75 (61.86)	7.96	74.00 (59.34)	12.94	71.25 (57.54)	16.17
				Muriate of potash				
Pseudomonas fluorescens (Sun Agro Monus Pf)	77.75 (61.86)	7.93	76.75 (61.19)	8.95	75.00 (60.00)	11.76	71.00 (57.42)	16.47
Pseudomonas fluorescens (Vermigreen Pf)	77.50 (61.69)	8.21	76.75 (61.19)	8.95	74.00 (59.34)	12.94	71.00 (57.42)	16.47
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.7342		0.4137		1.1439		
	CD(P=0.05)	1.1978		0.4929		2.9128		

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 73: Combined effect of bacterial biocontrol agents with fungicides on radial growth of *M. phaseolina*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Copper Oxy Chloride				
Pseudomonas fluorescens (Sun Agro Monus Pf)	85.00 (67.21)**	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
Pseudomonas fluorescens (Vermigreen Pf)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
				Mancozeb				
Pseudomonas fluorescens (Sun Agro Monus Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
Pseudomonas fluorescens (Vermigreen Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
				Carbendazim				
Pseudomonas fluorescens (Sun Agro Monus Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
Pseudomonas fluorescens (Vermigreen Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
				Hexaconazole				
Pseudomonas fluorescens (Sun Agro Monus Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
Pseudomonas fluorescens (Vermigreen Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.0063		0.0044		0.0126		
	CD(P=0.05)	0.0123		0.0087		0.0246		

* = Mean of four replications; ** = Figures in parentheses are angular transformed values.

Table 81: Combined effect of bacterial biocontrol agents with herbicides on radial growth of *P. aphanidermatum*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Pendimethalin				
Pseudomonas fluorescens (Sun Agro Monus Pf)	21.00 (27.25)**	59.45	14.25 (22.19)	67.01	10.25 (18.63)	72.28	7.75 (16.11)	76.03
Pseudomonas fluorescens (Vermigreen Pf)	22.00 (27.79)	58.65	14.75 (22.57)	66.41	9.25 (17.66)	73.72	7.25 (15.56)	76.84
				Fluchloralin				
Pseudomonas fluorescens (Sun Agro Monus Pf)	23.75 (29.35)	56.71	14.25 (22.17)	67.01	9.75 (18.15)	72.99	8.75 (17.15)	74.48
Pseudomonas fluorescens (Vermigreen Pf)	24.75 (29.77)	55.70	14.75 (22.50)	66.52	9.50 (17.95)	73.29	8.00 (16.43)	75.55
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.5208		0.3187		1.1628		
	CD(P=0.05)	1.1428		0.5627		1.2893		

* Mean of four replications

** Figures in parentheses are angular transformed values.

Table 76: Combined effect of bacterial biocontrol agents with insecticides on radial growth of *M. phaseolina*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Imidacloprid				
Pseudomonas fluorescens (Sun Agro Monus Pf)	42.50 (40.68)**	39.47	38.25 (38.20)	43.16	31.75 (34.28)	48.99	27.25 (31.44)	53.22
Pseudomonas fluorescens (Vermigreen Pf)	43.25 (41.11)	38.83	40.75 (39.65)	41.00	31.25 (33.95)	49.48	26.25 (30.81)	54.15
				Chlorpyriphos				
Pseudomonas fluorescens (Sun Agro Monus Pf)	28.50 (32.22)	52.06	15.75 (23.36)	65.24	14.00 (21.95)	67.34	9.00 (17.44)	74.05
Pseudomonas fluorescens (Vermigreen Pf)	25.75 (30.46)	54.67	18.00 (25.10)	64.65	13.00 (21.08)	68.63	8.50 (16.91)	74.84
				Carbosulfan				
Pseudomonas fluorescens (Sun Agro Monus Pf)	37.00 (37.46)	44.26	26.75 (31.14)	53.66	21.75 (27.78)	58.66	14.75 (22.57)	66.41
Pseudomonas fluorescens (Vermigreen Pf)	36.00 (36.83)	45.20	26.00 (30.63)	54.42	20.25 (26.73)	60.22	15.75 (23.36)	65.24
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.5231		0.2148		1.1941		
	CD(P=0.05)	0.8931		0.2728		1.8971		

* Mean of four replications

** Figures in parentheses are angular transformed values.

Table 79: Combined effect of bacterial biocontrol agents with fertilizers on radial growth of *M. phaseolina*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Calcium Ammonium Nitrate				
Pseudomonas fluorescens (Sun Agro Monus Pf)	61.00 (51.35)**	23.59	43.75 (41.40)	38.40	30.00 (33.20)	50.60	24.50 (29.64)	55.89
Pseudomonas fluorescens (Vermigreen Pf)	59.75 (50.62)	24.68	44.25 (41.69)	39.97	31.25 (33.98)	49.44	25.75 (30.48)	54.64
				Diammonium Phosphate				
Pseudomonas fluorescens (Sun Agro Monus Pf)	50.50 (45.28)	32.62	43.00 (40.99)	39.04	35.25 (35.18)	47.65	21.75 (27.77)	58.68
Pseudomonas fluorescens (Vermigreen Pf)	53.75 (47.15)	29.48	42.00 (40.39)	39.90	32.75 (34.89)	48.08	23.00 (28.64)	57.38
				Single Super Phosphate				
Pseudomonas fluorescens (Sun Agro Monus Pf)	81.50 (64.55)	3.95	81.50 (64.34)	4.27	82.25 (65.10)	3.13	82.25 (65.08)	3.16
Pseudomonas fluorescens (Vermigreen Pf)	81.25 (64.36)	4.24	82.25 (65.09)	3.15	82.50 (65.28)	2.87	81.75 (64.71)	3.71
				Muriate of Potash				
Pseudomonas fluorescens (Sun Agro Monus Pf)	82.25 (65.10)	3.13	81.75 (6472)	3.70	81.75 (64.71)	3.71	82.50 (65.28)	2.87
Pseudomonas fluorescens (Vermigreen Pf)	82.00 (64.89)	3.45	81.50 (64.53)	3.98	82.00 (64.89)	3.45	82.50 (65.28)	2.87
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.3128		0.1427		0.9428		
	CD(P=0.05)	0.4938		0.2242		1.0019		

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 74: Combined effect of bacterial biocontrol agents with fungicides on radial growth of *S. rolfsii*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Copper Oxy Cloride				
Pseudomonas fluorescens (Sun Agro Monus Pf)	85.00 (67.21)**	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
Pseudomonas fluorescens (Vermigreen Pf)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
				Mancozeb				
Pseudomonas fluorescens (Sun Agro Monus Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
Pseudomonas fluorescens (Vermigreen Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
				Carbendazim				
Pseudomonas fluorescens (Sun Agro Monus Pf)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
Pseudomonas fluorescens (Vermigreen Pf)	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00	85.00 (67.21)	0.00
				Hexaconazole				
Pseudomonas fluorescens (Sun Agro Monus Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
Pseudomonas fluorescens (Vermigreen Pf)	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00	0.00 (0.00)	100.00
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.0063		0.0044		0.0126		
	CD(P=0.05)	0.0123		0.0087		0.0246		

* = Mean of four replications; ** = Figures in parentheses are angular transformed values.

Table 82: Combined effect of bacterial biocontrol agents with herbicides on radial growth of *M. phaseolina*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Pendimethalin				
Pseudomonas fluorescens (Sun Agro Monus Pf)	26.25 (30.80)**	54.17	16.25 (23.75)	64.66	12.25 (20.45)	69.57	4.00 (11.49)	82.90
Pseudomonas fluorescens (Vermigreen Pf)	29.00 (32.58)	51.52	16.00 (23.57)	64.93	13.75 (21.75)	67.63	4.25 (11.88)	82.83
				Fluchloralin				
Pseudomonas fluorescens (Sun Agro Monus Pf)	28.25 (32.09)	52.25	20.50 (26.91)	59.96	12.00 (20.22)	69.91	5.00 (12.88)	80.83
Pseudomonas fluorescens (Vermigreen Pf)	32.50 (34.75)	48.29	21.75 (27.75)	58.71	13.50 (17.66)	68.14	5.25 (13.20)	80.36
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.8341		0.3342		1.4734		
	CD(P=0.05)	1.0241		0.4028		2.5181		

* Mean of four replications

** Figures in parentheses are angular transformed values.

Table 77: Combined effect of bacterial biocontrol agents with insecticides on radial growth of *S. rolfsii*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Imidacloprid				
Pseudomonas fluorescens (Sun Agro Monus Pf)	58.50 (49.92)**	25.72	55.00 (47.87)	28.77	39.25 (38.78)	42.30	31.00 (33.82)	49.68
Pseudomonas fluorescens (Vermigreen Pf)	63.00 (52.55)	21.89	55.50 (48.16)	28.34	38.50 (38.34)	42.95	30.25 (33.36)	50.36
				Chlorpyriphos				
Pseudomonas fluorescens (Sun Agro Monus Pf)	32.25 (34.58)	48.54	24.75 (29.78)	55.69	22.50 (28.30)	57.89	18.50 (25.47)	61.79
Pseudomonas fluorescens (Vermigreen Pf)	34.50 (35.94)	46.52	26.00 (30.60)	54.47	24.00 (29.33)	56.36	19.50 (26.19)	61.03
				Carbosulfan				
Pseudomonas fluorescens (Sun Agro Monus Pf)	48.50 (44.13)	34.34	36.25 (37.01)	44.73	28.25 (32.09)	52.85	22.00 (27.91)	58.47
Pseudomonas fluorescens (Vermigreen Pf)	48.00 (43.85)	34.75	36.50 (37.15)	44.72	29.25 (32.72)	51.31	22.25 (28.11)	59.10
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.5138		0.2031		1.0081		
	CD(P=0.05)	0.8841		0.4138		1.8525		

* Mean of four replications

** Figures in parentheses are angular transformed values.

Table 80: Combined effect of bacterial biocontrol agents with fertilizers on radial growth of *S. rolfsii*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Calcium Ammonium nitrate				
Pseudomonas fluorescens (Sun Agro Monus Pf)	78.50 (62.37)	7.20	76.50 (61.00)	9.23	74.25 (59.51)	11.45	72.50 958.37)	13.15
Pseudomonas fluorescens (Vermigreen Pf)	77.75 (61.86)	7.96	76.50 (61.01)	9.22	68.25 (55.80)	10.97	72.50 (58.40)	13.10
				Diammonium Phosphate				
Pseudomonas fluorescens (Sun Agro Monus Pf)	28.75 (62.57)	6.90	73.50 (59.05)	12.14	65.00 (53.75)	20.02	53.25 (46.86)	30.27
Pseudomonas fluorescens (Vermigreen Pf)	30.25 (63.62)	5.34	75.25 (60.18)	10.45	64.75 (53.38)	20.27	52.25 (46.29)	31.12
				Single Super Phosphate				
Pseudomonas fluorescens (Sun Agro Monus Pf)	79.50 (63.08)	6.14	73.00 (58.69)	12.67	64.00 (53.14)	20.93	52.50 (46.43)	30.91
Pseudomonas fluorescens (Vermigreen Pf)	80.00 (68.45)	5.59	74.00 (59.39)	11.70	66.00 (54.33)	19.16	53.00 (46.72)	30.48
				Muriate of Potash				
Pseudomonas fluorescens (Sun Agro Monus Pf)	78.50 (62.38)	7.18	74.50 (59.67)	11.21	64.25 (53.29)	20.71	58.50 (49.90)	48.12
Pseudomonas fluorescens (Vermigreen Pf)	79.25 (62.90)	6.41	75.00 (60.00)	10.72	64.75 (53.58)	20.27	58.50 (49.84)	25.78
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.2821		0.1321		0.9428		
	CD(P=0.05)	0.5038		0.2348		0.9728		

* Mean of four replications; ** Figures in parentheses are angular transformed values.

Table 83: Combined effect of bacterial biocontrol agents with herbicides on radial growth of *S. rolfsii*

Bacterial biocontrol agents	Concentrations (ppm)							
	100		500		1000		2000	
	Radial growth (mm)*	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control	Radial growth (mm)	% growth inhibition over control
				Pendimethalin				
Pseudomonas fluorescens (Sun Agro Monus Pf)	73.50 (59.02)**	12.18	65.00 (53.73)	20.05	50.00 (44.99)	33.06	33.50 (36.56)	43.60
Pseudomonas fluorescens (Vermigreen Pf)	73.75 (59.19)	11.93	62.25 (53.89)	19.81	49.25 (44.50)	33.70	34.75 (36.11)	46.23
				Fluchloralin				
Pseudomonas fluorescens (Sun Agro Monus Pf)	74.50 (59.68)	11.20	62.00 (51.94)	22.71	50.50 (45.28)	32.62	28.50 (32.25)	52.01
Pseudomonas fluorescens (Vermigreen Pf)	75.00 (60.33)	10.68	62.75 (52.40)	22.03	56.25 (48.60)	27.68	35.75 (36.68)	45.42
		Biocontrol agent (B)		Concentrations (C)		B x C		
	SEm±	0.7731		0.3048		1.3021		
	CD(P=0.05)	1.8834		0.3848		2.3018		

* Mean of four replications

** Figures in parentheses are angular transformed values.

Table 67: Combined effect of fungal biocontrol agents with fluchloralin against *P. aphanidermatum* at different concentrations

Sl. No	Fungal biocontrol agents	Concentrations (ppm)							
		100		500		1000		2000	
		Diameter of growth (mm)*	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control
1	*Trichoderma viride* (BCL Tv)	9.50 (17.92)**	70.29	7.50 (15.88)	73.67	6.25 (14.46)	76.03	4.75 (12.57)	79.16
2	*T. viride* (DOR 1 Tv)	7.75 (16.15)	73.23	6.50 (14.76)	76.19	4.25 (11.88)	80.30	2.25 (8.59)	85.96
3	*T. viride* (Sun Agro Derma Tv)	9.50 (17.92)	70.29	7.00 (15.32)	74.60	5.75 (13.86)	77.02	3.75 (11.03)	81.71
4	*T. viride* (NCC-58 Tv)	9.25 (17.66)	70.72	6.50 (14.76)	76.19	5.75 (13.80)	77.12	4.00 (11.49)	80.95
5	*Trichoderma harzianum* (Sun Agro Derma Th)	9.50 (17.62)	70.79	7.00 (15.32)	74.60	4.25 (11.88)	80.30	2.75 (9.44)	84.35
6	*T. harzianum* (DOR 2 Th)	9.25 (17.66)	70.72	6.75 (15.02)	75.10	4.50 (12.22)	79.74	3.25 (10.36)	82.87
7	*T. harzianum* (NCC-57 Th)	9.25 (17.66)	70.72	7.25 (15.61)	74.12	5.00 (12.92)	78.58	3.50 (10.75)	82.18
8	*T. harzianum* (Vermigreen Th)	9.00 (17.39)	71.17	7.75 (6.15)	73.23	4.25 (11.88)	80.30	3.75 (11.10)	81.60
			Biocontrol agent (B)		Concentrations (C)		B x C		
		SEm+	0.38		0.27		0.77		
		CD(P=0.05)	0.76		0.53		1.52		

* Mean of four replications

** Figures in parentheses are angular transformed values

Table 69: Combined effect of fungal biocontrol agents with fluchloralin against *M. phaseolina* at different concentrations

Sl. No	Fungal biocontrol agents	Concentrations (ppm)							
		100		500		1000		2000	
		Diameter of growth (mm)*	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control
1	*Trichoderma viride* (BCL Tv)	4.75 (12.57)**	81.29	7.00 (15.32)	77.20	19.50 (26.19)	61.03	11.50 (19.80)	70.54
2	*T. viride* (DOR 1 Tv)	6.50 (14.71)	78.11	14.00 (21.96)	67.32	19.50 (26.19)	61.03	14.00 (21.96)	67.32
3	*T. viride* (Sun Agro Derma Tv)	4.50 (12.22)	81.81	14.50 (22.36)	78.42	19.50 (26.19)	61.03	14.50 (22.36)	78.42
4	*T. viride* (NCC-58 Tv)	9.00 (17.44)	74.05	12.50 (20.68)	69.23	6.25 (14.44)	78.51	10.50 (18.90)	71.87
5	*Trichoderma harzianum* (Sun Agro Derma Th)	9.75 (18.18)	72.95	11.25 (18.96)	71.78	30.00 (33.20)	50.60	14.25 (22.17)	67.01
6	*T. harzianum* (DOR 2 Th)	8.75 (17.14)	74.49	10.00 (18.42)	72.59	20.00 (26.56)	60.48	19.75 (26.37)	60.76
7	*T. harzianum* (NCC-57 Th)	10.75 (19.13)	71.53	14.25 (22.17)	67.01	19.25 (26.01)	61.30	19.00 (25.83)	61.56
8	*T. harzianum* (Vermigreen Th)	9.00 (17.44)	74.05	14.25 (22.17)	167.01	19.25 (26.01)	61.30	19.00 (25.83	61.56
			Biocontrol agent (B)		Concentrations (C)		B x C		
		SEm+	0.49		0.35		0.99		
		CD(P=0.05)	0.97		0.69		1.95		

* Mean of four replications

** Figures in parentheses are angular transformed values

Table 71: Combined effect of fungal biocontrol agents with fluchloralin against *S. rolfsii* at different concentrations

Sl. No	Fungal biocontrol agents	Concentrations (ppm)							
		100		500		1000		2000	
		Diameter of growth (mm)*	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control	Diameter of growth (mm)	Per cent inhibition over control
1	*Trichoderma viride* (BCL Tv)	2.25 (8.59)**	87.12	1.50 (6.93)	89.68	1.00 (5.73)	91.47	0.25 (1.43)	97.87
2	*T. viride* (DOR 1 Tv)	7.50 (15.88)	76.37	1.50 (6.93)	89.68	1.25 (6.33)	90.58	0.50 (2.86)	95.74
3	*T. viride* (Sun Agro Derma Tv)	3.50 (10.64)	84.16	1.75 (7.53)	88.79	1.00 (5.73)	91.47	0.25 (1.43)	97.87
4	*T. viride* (NCC-58 Tv)	2.75 (9.44)	85.95	1.50 (6.93)	89.68	1.25 (6.33)	90.58	0.25 (1.43)	97.87
5	*Trichoderma harzianum* (Sun Agro Derma Th)	2.50 (9.05)	86.53	1.25 (6.33)	90.58	1.25 (6.33)	90.58	0.25 (1.43)	97.87
6	*T. harzianum* (DOR 2 Th)	2.75 (9.51)	85.85	1.25 (6.33)	90.58	1.25 (6.33)	90.58	0.25 (1.43)	97.87
7	*T. harzianum* (NCC-57 Th)	3.25 (10.36)	84.58	1.25 (6.33)	90.58	1.25 (6.33)	90.58	0.00 (0.00)	100.00
8	*T. harzianum* (Vermigreen Th)	3.50 (10.64)	84.16	1.00 (5.73)	91.47	1.00 (15.73)	91.47	0.00 (0.00)	100.00
			Biocontrol agent (B)		Concentrations (C)		B x C		
		SEm+	0.39		0.32		0.95		
		CD(P=0.05)	0.77		0.65		1.92		

* Mean of four replications

** Figures in parentheses are angular transformed values

Table 84: Combined effect of biocontrol agents and agrochemicals on *P. aphanidermatum* infection and seedling parameters of tomato cv. Pusa Ruby

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	89.00 (70.64) **	10.32 (18.72)	73.75	3.86	6.73	931.83	1.03 (5.84)**	42.78
T_2	86.00 (68.08)	12.64 (20.79)	67.82	3.86	6.73	910.74	0.93 (5.54)	35.45
T_3	68.00 (55.56)	11.31 (19.64)	71.23	3.57	5.96	648.04	0.96 (5.62)	37.40
T_4	75.66 (60.46)	16.65 (24.04)	57.65	3.64	6.33	754.33	1.03 (5.84)	42.78
T_5	67.66 (55.35)	18.98 (25.77)	51.72	3.21	6.40	650.21	1.03 (5.84)	42.78
T_6	72.00 (58.12)	20.65 (26.99)	47.48	3.54	6.10	694.08	1.01 (5.75)	40.58
T_7	70.66 (57.21)	18.98 (25.77)	51.72	3.53	6.13	682.57	0.88 (5.36)	31.05
T_8	74.66 (59.82)	19.65 (26.28)	50.02	3.68	6.10	730.17	0.87 (5.31)	29.82
T_9	65.33 (53.97)	19.97 (26.49)	49.21	3.43	6.10	622.59	0.83 (5.20)	27.13
T_{10}	62.66 (52.39)	20.99 (27.20)	46.66	3.20	5.93	572.08	0.87 (5.33)	30.80
T_{11}	56.13 (64.71)	20.97 (27.18)	46.66	3.45	5.93	765.97	0.86 (5.30)	29.58
T_{12}	46.24 (64.19)	22.31 (28.18)	43.26	3.48	6.03	770.31	0.81 (5.27)	28.85
T_{13} (Pathogen check)	36.00 (36.86)	39.52 (38.32)		2.60	4.50	155.6	0.51 (4.09)	
SEm±	1.79	1.24	0.12	0.23	0.44			
CD (P = 0.05)	3.70	2.23	0.24	0.46	0.91			

* Mean of three replications ** Figures in parentheses are angular transformed values

Table 85: Combined effect of biocontrol agents and agrochemicals on *P. aphanidermatum* infection and seedling parameters of brinjal cv. Shyamala

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	82.66 (65.04)**	10.31 (18.72)**	78.05	1.80	2.90	388.50	0.41 (3.67)**	78.15
T_2	60.00 (50.78)	13.66 (21.64)	70.92	1.72	2.80	283.2	0.30 (3.10)	50.48
T_3	67.00 (54.74)	13.98 (21.89)	78.05	1.74	2.40	277.38	0.24 (2.78)	34.95
T_4	62.33 (52.17)	26.65 (31.05)	43.27	1.81	2.53	270.51	0.19 (2.49)	20.87
T_5	56.33 (48.63)	25.99 (30.59)	44.67	1.19	2.66	216.87	0.21 (2.64)	28.15
T_6	58.00 (49.60)	27.98 (31.88)	40.44	1.44	2.63	236.06	0.20 (2.54)	23.30
T_7	61.00 (51.39)	27.85 (31.82)	40.71	1.54	2.53	248.27	0.19 (2.51)	21.84
T_8	59.00 (50.24)	31.31 (34.02)	33.35	1.66	2.70	257.24	0.21 (2.64)	28.15
T_9	62.33 (52.17)	31.98 (34.39)	31.92	1.72	2.60	269.26	0.21 (2.62)	27.18
T_{10}	59.00 (50.18)	27.32 (31.50)	41.84	1.61	2.60	248.39	0.18 (2.45)	18.93
T_{11}	44.33 (53.34)	26.65 (31.05)	43.27	1.21	2.46	236.09	0.23 (2.74)	33.49
T_{12}	44.00 (53.19)	36.33 (30.85)	22.66	1.31	2.40	237.44	0.20 (2.63)	23.78
T_{13} (Pathogen check)	33.00 (35.06)	46.98 (43.22)	-	0.8	1.60	79.2	0.13 (2.06)	
SEm±	2.34	0.94	0.18	0.36	0.28			
CD (P = 0.05)	4.84	1.85	0.38	0.71	0.58			

* Mean of three replications ** Figures in parentheses are angular transformed values

Table 86: Combined effect of biocontrol agents and agrochemicals on *P. aphanidermatum* infection and seedling parameters of bhendi cv. Parbhani kranthi

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	100.00 (90.00)**	1.65 (7.27)**	89.84	3.48	9.73	1321.21	4.15 (11.73)**	32.24
T_2	98.3 (82.51)	1.65 (7.27)	88.84	3.68	9.80	1325.08	4.17 (11.78)	32.80
T_3	98.3 (82.51)	2.31 (8.72)	85.84	3.80	10.03	1359.48	3.78 (11.21)	26.38
T_4	98.3 (82.51)	2.31 (8.72)	85.84	3.41	9.33	1252.34	3.77 (11.19)	26.15
T_5	98.3 (82.51)	2.31 (8.72)	85.84	3.50	9.63	1290.67	3.77 (11.19)	26.15
T_6	98.3 (82.51)	2.64 (9.28)	83.82	3.48	9.26	1252.34	3.53 (10.82)	21.98
T_7	98.3 (82.51)	2.64 (9.28)	83.82	3.21	9.50	1249.39	3.68 (11.05)	24.57
T_8	98.3 (82.51)	2.64 (9.28)	83.82	3.33	9.56	1267.08	3.42 (10.64)	19.95
T_9	98.3 (82.51)	2.64 (9.28)	83.82	3.59	9.40	1276.91	3.66 (11.03)	24.35
T_{10}	98.3 (82.51)	2.97 (9.80)	81.80	3.39	9.70	1296.31	3.85 (11.31)	27.50
T_{11}	90.3 (71.85)	4.96 (12.79)	69.60	3.72	9.90	1236.57	3.59 (10.92)	23.11
T_{12}	90.3 (71.85)	4.96 (12.79)	69.60	3.68	9.43	1268.71	3.62 (10.95)	23.44
T_{13} (Pathogen check)	88.3 (70.00)	16.32 (23.81)	-	2.67	6.70	827.37	2.38 (8.87)	-
SEm±	0.32	2.36	0.10	0.21	0.21	0.35		
CD (P = 0.05)	0.67	4.85	0.23	0.42	0.42	0.73		

* Mean of three replications ** Figures in parentheses are angular transformed values

Table 87: Combined effect of biocontrol agents and agrochemicals on *M. phaseolina* infection and seedling parameters of tomato cv. Pusa Ruby

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	84.66 (67.01)**	22.99 (28.59)**	41.63	3.66	6.80	885.54	1.00 (5.68)**	38.87
T_2	87.00 (69.03)	21.65 (27.69)	44.93	3.79	6.92	931.77	0.87 (5.30)	29.58
T_3	70.73 (57.01)	24.97 (27.90)	34.12	3.56	6.72	727.10	1.02 (5.76)	40.83
T_4	79.66 (63.23)	30.32 (33.40)	22.88	3.40	6.66	806.95	0.89 (5.30)	29.58
T_5	77.00 (61.34)	26.65 (31.05)	32.22	3.51	6.77	791.56	1.02 (5.80)	41.80
T_6	66.33 (54.33)	28.64 (32.33)	27.16	3.38	6.56	659.32	0.98 (5.64)	37.89
T_7	72.33 (58.30)	28.65 (32.64)	27.13	3.46	6.41	713.89	0.84 (5.26)	28.60
T_8	72.00 (58.03)	29.32 (29.53)	25.43	3.56	6.38	715.68	0.91 (5.39)	31.78
T_9	82.00 (65.40)	29.98 (26.28)	24.12	3.21	6.49	801.80	0.91 (5.32)	30.07
T_{10}	81.00 (64.26)	31.65 (34.20)	19.5	3.28	6.73	810.81	0.83 (5.22)	27.62
T_{11}	76.00 (60.66)	28.98 (27.20)	26.64	3.47	6.58	763.8	0.72 (4.84)	18.33
T_{12}	77.33 (61.57)	28.99 (35.52)	26.27	3.28	6.61	764.79	0.71 (4.79)	17.11
T_{13}	62.33 (52.17)	29.98 (33.15)	23.75	3.61	6.73	644.49	0.73 (4.86)	18.82
T_{14} (Pathogen check)	36.00 (36.86)	39.32 (32.77)	-	2.60	4.50	255.6	0.51 (4.09)	-
SEm±	1.52	1.24	0.13	0.21	1.80			
CD (P = 0.05)	3.13	2.43	0.26	0.13	3.71			

* Mean of three replications ** Figures in parentheses are angular transformed values

Table 88: Combined effect of biocontrol agents and agrochemicals on *M. phaseolina* infection and seedling parameters of brinjal cv. Shyamala

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	80.83 (63.67)**	10.98 (19.28)**	76.62	1.78	2.70	359.89	0.61 (4.48)**	98.23
T_2	81.66 (64.67)	11.31 (19.64)	76.13	1.83	3.00	394.41	0.57 (4.35)	92.47
T_3	75.33 (60.22)	11.97 (20.18)	74.52	1.66	2.70	328.43	0.54 (4.22)	86.72
T_4	73.00 (58.71)	22.65 (28.39)	51.78	1.72	2.86	334.34	0.54 (4.20)	85.89
T_5	67.66 (55.35)	25.32 (30.20)	46.10	1.67	3.03	318.00	0.48 (3.98)	76.10
T_6	68.00 (55.56)	25.64 (30.40)	45.42	1.58	2.86	301.92	0.52 (4.16)	84.07
T_7	69.33 (56.46)	24.98 (29.93)	46.82	1.56	2.96	313.37	0.50 (4.06)	79.64
T_8	68.33 (55.78)	24.32 (29.53)	48.23	1.59	2.60	286.30	0.53 (4.15)	83.62
T_9	69.66 (65.97)	11.98 (20.18)	74.49	1.63	2.80	308.59	0.54 (4.21)	86.28
T_{10}	60.00 (54.97)	23.98 (29.27)	48.95	1.64	2.86	270.00	0.51 (4.10)	81.41
T_{11}	63.66 (52.94)	10.31 (18.72)	73.05	1.40	2.66	258.45	0.49 (4.02)	77.89
T_{12}	78.33 (62.24)	26.32 (30.85)	43.97	1.38	2.76	324.28	0.50 (4.04)	78.76
T_{13}	74.81 (59.87)	27.65 (31.65)	41.41	1.36	2.71	304.47	0.49 (4.02)	77.87
T_{14} (Pathogen check)	33.00 (35.06)	46.98 (43.22)	-	0.8	1.60	79.2	0.33 (2.26)	-
SEm±	1.80	1.33	0.60	0.13	0.26			
CD (P = 0.05)	3.71	2.62	0.12	0.27	0.54			

* Mean of three replications ** Figures in parentheses are angular transformed values

Table 89: Combined effect of biocontrol agents and agrochemicals on *M. phaseolina* infection and seedling parameters of bhendi cv. Parbhani Kranthi

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	98.3 (82.51)**	1.32 (6.55)**	72.49	3.63	9.40	1280.84	4.20 (11.82)**	37.60
T_2	100.00 (90.00	0.99 (5.44)	77.15	3.70	9.76	1346.00	4.27 (11.92)	38.76
T_3	98.3 (82.51)	1.65 (7.27)	69.46	3.59	9.46	1282.8	4.07 (11.64)	35.50
T_4	98.3 (82.51)	2.31 (8.72)	63.37	3.34	9.50	1262.17	3.98 (11.51)	33.99
T_5	98.3 (82.51)	1.98 (7.92)	63.73	3.46	9.33	1257.25	4.01 (11.55)	34.45
T_6	98.3 (82.51)	2.31 (8.72)	63.37	3.40	9.00	1218.92	3.87 (11.35)	32.13
T_7	98.3 (82.51)	2.31 (8.72)	63.37	3.28	9.53	1259.23	3.71 (11.10)	29.22
T_8	98.3 (82.51)	2.31 (8.72)	63.37	3.36	9.43	1257.25	3.71 (11.10)	29.22
T_9	100.00 (90.00)	1.32 (6.55)	72.49	3.38	9.30	1268.00	3.72 (11.12)	29.45
T_{10}	98.3 (82.51)	1.98 (7.92)	63.73	3.22	9.20	1220.88	3.53 (10.82)	25.96
T_{11}	100.00 (90.00)	1.98 (7.92)	63.73	3.28	9.16	1244.00	3.74 (11.15)	29.80
T_{12}	98.3 (82.51)	1.98 (7.92)	63.73	3.40	9.43	1261.18	3.34 (10.52)	22.46
T_{13}	98.3 (90.00)	2.60 (9.28)	61.02	3.19	9.28	1225.80	3.66 (11.02)	28.28
T_{14} (Pathogen check)	88.3 (70.00)	16.32 (23.81)	-	2.67	6.70	827.37	2.25 (8.59)	-
SEm±	0.29	2.54	0.12	0.26	0.32			
CD (P = 0.05)	0.60	4.97	0.24	0.51	0.66			

* Mean of three replications ** Figures in parentheses are angular transformed values

Table 90: Combined effect of biocontrol agents and agrochemicals on *S. rolfsii* and seedling parameters of tomato cv. Pusa Ruby

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	77.33 (61.53)**	12.32 (20.53)**	68.66	3.80	5.00	680.50	1.00 (5.70)**	39.36
T_2	81.00 (64.66)	8.98 (17.36)	77.16	3.88	6.60	848.88	0.90 (5.41)	32.27
T_3	70.33 (57.01)	17.65 (24.80)	55.11	3.67	6.50	715.25	0.93 (5.51)	34.71
T_4	71.53 (57.63)	22.98 (28.59)	41.55	3.57	6.16	727.46	0.85 (5.26)	28.60
T_5	71.00 (57.46)	22.65 (28.39)	42.39	3.50	6.23	712.13	0.86 (5.32)	30.07
T_6	81.38 (64.46)	8.98 (17.36)	77.16	3.42	6.60	814.92	0.84 (5.21)	27.38
T_7	64.00 (53.13)	22.98 (28.59)	41.55	3.48	6.13	647.04	1.02 (5.8)	41.32
T_8	81.33 (64.54)	24.98 (29.93)	36.36	3.40	6.53	807.60	0.89 (5.41)	32.27
T_9	69.33 (56.40)	14.32 (22.22)	65.38	3.49	6.50	692.60	0.73 (4.87)	19.07
T_{10}	73.66 (59.15)	25.98 (30.59)	33.92	3.28	6.03	737.33	0.83 (5.21)	27.38
T_{11}	77.00 (61.34)	26.99 (31.24)	31.35	3.21	6.36	752.29	0.99 (5.67)	38.63
T_{12}	77.33 (61.57)	26.64 (31.05)	32.24	3.27	6.13	773.30	0.82 (5.16)	26.16
T_{13}	73.66 (59.15)	27.99 (31.56)	28.81	3.38	6.17	740.28	0.77 (4.97)	21.51
T_{14} (Pathogen check)	36.0 (36.86)	39.32 (38.82)	-	2.60	4.50	255.60	0.51 (4.09)	-
SEm±	1.53	1.49	0.22	0.42	0.52			
CD (P = 0.05)	3.17	2.92	0.45	0.84	1.08			

* Mean of three replications ** Figures in parentheses are angular transformed values

Table 91: Combined effect of potential biocontrol agents and agrochemicals on *S. rolfsii* infection and seedling parameters of brinjal cv. Shyamala

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	84.00 (66.42)**	9.65 (18.05)**	79.45	1.78	2.70	389.71	0.50 (4.06)**	79.64
T_2	87.66 (69.46)	9.31 (17.76)	80.18	1.84	2.80	392.71	0.56 (4.27)	88.93
T_3	72.33 (58.30)	22.31 (28.18)	52.51	1.38	2.16	306.67	0.49 (4.03)	78.31
T_4	69.66 (56.64)	23.32 (28.86)	50.36	1.40	2.76	289.78	0.43 (3.76)	66.37
T_5	69.33 (56.37)	24.99 (29.93)	46.80	1.38	2.63	278.01	0.40 (3.61)	59.73
T_6	83.66 (66.17)	22.32 (28.18)	52.49	1.33	2.76	342.16	0.55 (4.26)	88.49
T_7	7.66 (57.22)	24.31 (29.53)	48.25	1.22	2.63	272.04	0.35 (3.36)	48.67
T_8	79.33 (62.98)	23.66 (29.06)	49.63	1.32	2.66	315.73	0.41 (3.60)	59.29
T_9	73.66 (59.17)	1.31 (18.72)	78.05	1.40	2.53	289.48	0.42 (3.74)	65.48
T_{10}	73.08 (58.75)	22.31 (28.18)	52.51	1.27	2.73	292.00	0.55 (4.23)	87.16
T_{11}	74.33 (59.62)	23.98 (29.27)	48.95	1.33	2.56	289.14	0.35 (3.34)	47.78
T_{12}	73.02 (58.74)	24.99 (29.93)	46.80	1.29	2.60	283.97	0.37 (3.42)	51.32
T_{13}	75.66 (60.51)	26.98 (31.24)	42.57	1.23	2.46	279.18	0.46 (3.90)	72.56
T_{14} (Pathogen check)	33.00 (35.06)	46.98 (43.22)	-	0.8	1.60	121.77	0.13 (2.06)	-
SEm±		1.94	1.48	0.27	1.38	0.41		
CD (P = 0.05)		3.99	2.90	0.48	2.77	0.85		

* Mean of three replications ** Figures in parentheses are angular transformed values

Table 92: Combined effect of potential biocontrol agents and agrochemicals on *S. rolfsii* infection and seedling parameters of bhendi cv. Parbhani Kranthi

Treatments	Seed germination (%)	Seedling mortality at 40DAS	Mortality decrease over control (%)	Seedling root length (cm) *	Seedling shoot length (cm) *	Seedling vigour index	Seedling dry weight (g) *	Dry weight increase over control (%)
T_1	100.00 (90.00)	1.32 (6.55)	72.49	3.62	8.83	1245.00	4.27 (11.92)	38.76
T_2	100.00 (90.00)	1.32 (6.55)	72.49	3850	8.90	1270.00	4.28 (11.94)	38.99
T_3	98.3 (82.51)	2.97 (9.80)	58.84	3.72	9.13	1263.54	3.70 (11.09)	29.10
T_4	98.3 (82.51)	2.97 (9.80)	58.84	3.57	8.90	1225.80	3.63 (10.98)	27.82
T_5	98.3 (82.51)	2.31 (8.72)	63.37	3.56	9.16	1250.37	3.59 (10.92)	27.12
T_6	98.3 (82.51)	1.32 (6.55)	72.49	3.48	8.90	1216.95	3.92 (11.41)	32.82
T_7	98.3 (82.51)	2.64 (9.28)	61.02	3.01	8.86	1225.80	3.50 (10.77)	25.37
T_8	98.3 (82.51)	1.98 (7.92)	66.73	3.62	9.30	1270.03	3.42 (10.64)	23.86
T_9	98.3 (82.51)	0.99 (5.44)	77.15	3.82	8.93	1253.32	3.48 (10.74)	25.02
T_{10}	98.3 (82.51)	1.98 (7.92)	66.73	3.59	89.03	1240.54	3.45 (10.69)	24.47
T_{11}	98.3 (82.51)	2.98 (9.81)	58.79	3.62	9.00	1240.54	3.70 (11.08)	28.98
T_{12}	98.3 (82.51)	2.31 (8.72)	63.37	3.60	9.16	1254.30	3.71 (11.10)	29.22
T_{13}	96.65 (82.51)	2.31 (8.72)	63.37	3.48	8.96	1202.32	3.37 (10.57)	23.05
T_{14} (Pathogen check)	88.3 (70.00)	16.32 (23.81)	-	2.67	6.70	827.37	2.25 (8.59)	-
SEm±	0.32	2.48	0.10	0.23	0.33			
CD (P = 0.05)	0.66	4.86	0.20	0.45	0.69			

* Mean of three replications ** Figures in parentheses are angular transformed values

Treatments

P. aphanidermatum

T_1 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with copper oxychloride (COC) @ 100 ppm

T_2 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with mancozeb @ 100 ppm

T_3 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with mancozeb @ 100 ppm

T_4 - Seed treatment with *T. harzianum* (Vermigreen Th) + Soil drenching with imidacloprid @ 100 ppm

T_5 - Seed treatment with *T. viride* (NCC-58 Tv) + Soil drenching with chlorpyriphos @ 100 ppm

T_6 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with carbosulfan @ 500 ppm

T_7 - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Soil drenching with calcium ammonium nitrate (CAN) @ 2000 ppm

T_8 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with diammonium phosphate (DAP) @ 2000 ppm

T_9 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with single superphosphate @ 500 ppm

T_{10} - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with muriate of potash (MOP) @ 2000 ppm

T_{11} - Seed treatment with *T. viride* (BCL Tv) + Pre-emergence soil drenching with pendimethalin @ 100 ppm

T_{12} - Seed treatment with (DOR 1 Tv) + Pre-plant soil drenching with fluchloralin @ 100 ppm

T_{13} - Pathogen check.

Treatments

M. phaseolina

T_1 - Seed treatment with *T. harzianum* (Sun Agro Derma Th) + Soil drenching with copper oxychloride (COC) @ 100 ppm

T_2 - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Soil drenching with mancozeb @ 100 ppm

T_3 - Seed treatment with *T. viride* (NCC-58 Tv) + Soil drenching with imidacloprid @ 100 ppm

T_4 - Seed treatment with *T. harzianum* (Sun Agro Derma Th) + Soil drenching with imidacloprid @ 100 ppm

T_5 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with imidacloprid @ 100 ppm

T_6 - Seed treatment with *T. harzianum* (Vermigreen Th) + Soil drenching with chlorpyriphos @ 100 ppm

T_7 - Seed treatment with *T. harzianum* (Vermigreen Th) + Soil drenching with carbosulfan @ 100 ppm

T_8 - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with calcium ammonium nitrate (CAN) @ 500 ppm

T_9 - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with diammonium phosphate @ 2000 ppm

T_{10} - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with single superphosphate @ 2000 ppm

T_{11} - Seed treatment with *T. viride* (NCC-58 Tv) + Soil drenching with muriate of potash @ 2000 ppm

T_{12} - Seed treatment with *T. harzianum* (Sun Agro Derma Th) + Pre-emergence soil drenching with pendimethalin @ 100 ppm

T_{13} - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Pre-plant soil drenching with fluchloralin @ 100 ppm.

T_{14} - Pathogen check.

Treatments

S. rolfsii

T_1 - Seed treatment with *T. harzianum* (NCC-57Th) + Soil drenching with copper oxychloride (COC) @ 100 ppm

T_2 - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with mancozeb @ 500 ppm

T_3 - Seed treatment with *T. viride* (DOR 1 Tv) + Soil drenching with imidacloprid @ 100 ppm

T_4 - Seed treatment with *T. viride* (NCC-58 Tv) + Soil drenching with chlorpyriphos @ 100 ppm

T_5 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with carbosulfan @ 2000 ppm

T_6 - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Soil drenching with calcium ammonium nitrate @ 2000 ppm

T_7 - Seed treatment with *T. harzianum* (NCC-57 Th) + Soil drenching with diammonium phosphate @ 2000 ppm

T_8 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with single superphosphate @ 2000 ppm

T_9 - Seed treatment with *T. harzianum* (DOR 2 Th) + Soil drenching with muriate of potash @ 500 ppm

T_{10} - Seed treatment with *T. viride* (Sun Agro Derma Tv) + Soil drenching with muriate of potash @ 2000 ppm

T_{11} - Seed treatment with *T. viride* (NCC-58 Tv) + Pre-emergence soil drenching with pendimethalin @ 100 ppm

T_{12} - Seed treatment with *T. harzianum* (Vermigreen Th) + Pre-emergence soil drenching with pendimethalin @ 100 ppm

T_{13} - Seed treatment with *T. viride* (BCL Tv) + Pre-plant soil drenching with fluchloralin @ 100 ppm.

T_{14} - Pathogen check.

CHAPTER – IV

RESULTS

The results pertaining to the present investigation are presented hereunder the following sections.

4.1 ISOLATION AND IDENTIFICATION OF PATHOGENS

4.1.1 *Pythium aphanidermatum* (Edson) Fitzp.

Isolation of the pathogen was made from the diseased mustard seedlings showing typical damping-off symptoms. On microscopic examination presence of abundant non-septate fungus mycelium was observed in discoloured cortical tissues. The fungus associated with the disease was isolated and purified by single hyphal tip method and maintained on potato dextrose agar medium (PDA) (Plate 1).

To determine the identity of the species, its cultural and morphological characters were studied. A fluppy, aerial growth was formed on PDA (Plate 1). The mycelium was irregularly branched, coenocytic when young, the filaments being full of granular protoplasm (Plate 2). In older cultures, the filaments were hyaline and aseptate. The fungus was found to produce lobulate sporangia. The fungus grew well between 26 to 37°C. On the basis of morphological and cultural characters, growth habit and temperature relations, the fungus was identified as *Pythium aphanidermatum*.

4.1.2 *Macrophomina phaseolina* (Tassi) Goid

The pathogen was isolated by plating the root and stem bits consisting sclerotia of infected castor plants (cv. Aruna) and was purified by hyphal tip method and maintained on PDA medium.

The fungus rapidly formed spherical, hyaline colonies on the medium finally becoming intense carbonaceous black showing concentric zonations covering entire petriplate within a span of four days (Plate 3), few sclerotia were developed on the edge of colonies and later numerous sclerotia formed on the entire colony.

Mycelium consists of broad septate and branched hyphae which frequently run parallel to each other (Plate 5). Hyphae constricted at the point of union and septem separating the lateral and parental hyphae. The sclerotia were black and smooth varied from spherical to oblong to irregular in shape and formed on PDA after four days of incubation (Plate 4).

Based on morphological and cultural characters, the fungus was identified as *M. phaseolina* and the morphological characters tallied with CMI descriptions of *M. phaseolina*.

4.1.3 *Sclerotium rolfsii* Sacc.

The pathogen, *S. rolfsii* was isolated from the collar region of infected sunflower (cv. Morden) showing typical wilt symptoms. The fungus was purified by hyphal tip method and maintained on PDA medium.

At first the fungus formed silky white colonies on the medium, which gradually lost their lustre and become dull in appearance. The mycelium was radiating and fast growing (Plate 6). Hyphae were hyaline, profusely branched, thin

walled and septate (Plate 8). Small mycelial masses were formed when fungus completely covered the surface of medium in petriplates. The mycelial masses appeared like white tiny, knots initially whose size gradually increased and colour changed from light brown to dark brown. The sclerotia were smooth, shiny and hard with spherical to irregular in shape (Plate 7).

Based on colony characters and morphology the fungus was identified as *S. rolfsii* and the morphological characters tallied with the CMI descriptions of *S. rolfsii.*

4.2 PATHOGENICITY TESTS

Pathogenicity tests were conducted by soil inoculation method for all the three pathogens.

4.2.1 *P. aphanidermatum*

Pathogenicity was proved using susceptible tomato cv. Pusa Ruby and soil inoculation method as mentioned in 3.8.1 of Materials and Methods. Poor per cent of seed germination was noted in inoculated trays compared to the control. The affected seedlings were pale green and a brownish water soaked lesion was seen at the basl portion of the stem (collar region). Profuse white mycelial growth was observed on collar region of the seedlings in the inoculated trays resulting in collapse of seedlings. The pathogen was reisolated from the diseased seedlings and fungus obtained resembled original isolates in all aspects.

4.2.2 *M. phaseolina*

Pathogenicity test was carried out on castor seedlings of cv. Aruna by soil inoculation method as mentioned in 3.8.2 of Materials and Methods. Rotting of

germinating seeds was noted initially in the inoculated pots followed by seedling necrosis and mortality of the germinated castor seeds. The pathogen was reisolated from the diseased plants and the fungus obtained resembled original isolate in all respects.

4.2.3 *S. rolfsii*

Pathogenicity was tested on young sunflower (cv. Morden) seedlings by adopting soil inoculation method as mentioned in 3.8.3 of Materials and Methods.

Profuse white mycelial growth was found on the soil surface after 24 h of inoculation. White cottony growth at collar region and root zone was observed in wilted plants. Numerous round brown and mustard seed like sclerotia were seen on soil surface and root region of the infected plants nine days after inoculation. The pathogen was reisolated from the diseased plants and fungus obtained resembled the original isolate in all respects.

4.3 GROWTH AND MORPHOLOGICAL CHARACTERS OF THE ISOLATES OF BIOCONTROL AGENTS

4.3.1 Isolates of *Trichoderma viride*

Colonies of the different *T. viride* isolates on PDA medium were white and cottony during initial stages but later turned bluish green to green in colour (Plates 9,11,13 and 15). In all the isolates the phialospores were hyaline and arose from the tips of phialide in chains. Phialospores were rough, sub-hyaline and mostly sub-globose (Plates 10,12,14 and 16).

4.3.2 Isolates of *T. harzianum*

Colonies of the different isolates of *T. harzianum* were white and cottony initially and later turned light yellowish green in colour on PDA medium (Plates 17,19,21 and 23). Phialospores smooth, green and sub-globose (Plates 18,20,22and 24). The growth of all the isolates was rapid on PDA and covered the entire petriplate (9 cm) within 4-5 days.

4.3.3 Isolates of *P. fluorescens*

Colonies of the bacterial isolates were first dull white and later turned to creamy white with irregularly spreading nature on the Pseudomonas agar medium. The isolates exhibited fluorescence under UV light (Plate 25 and 26).

4.4 IN VITRO EFFICACY OF COMMERCIAL AND NATIVE ISOLATES OF THE BIOCONTROL AGENTS AGAINST SOIL BORNE PATHOGENS

The fungal and bacterial antagonists were screened for their antagonistic activity against the three soil borne test pathogens viz., *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* by dual culture technique and the results are presented in Tables 3, 4 and 5.

4.4.1 Effect of biocontrol agents on the growth of *P. aphanidermatum*

It is evident from the data Table 3 that all the antagonists studied significantly reduced the fungal growth. The per cent growth reduction of *P. aphanidermatum* was maximum (68.46) by the commercial isolate of *T. viride* (NCC-58 Tv) followed by native isolate of *T. harzianum* (DOR 2 Th) while it was

minimum (53.7 %) in case of commercial isolate of *T. harzianum* (Vermigreen Th) (Plate 27 and 28).

Initially all the isolates grew together in dual culture without showing any demarcation (or) zone of inhibition. After the colonies met growth of the pathogen ceased and all the isolates exhibited zone of inhibition after 7-8 days.

Of the two commercial isolates of *Pseudomonas fluorescens* (Sun Agromonus *P. fluroescens* and Vermigreen *P. fluorescens*) tested inhibited the radial growth of pathogen to an extent of 36.20 and 34.32 per cent respectively compared to control. However, the per cent growth inhibition of *P. aphanidermatum* by these bacterial antagonists was less than all the fungal antagonists tested (Table 3 and Plates 33 and 34).

4.4.2 Effect of biocontrol agents on growth of *M. phaseolina*

The perusal of the data presented in Table 4 revealed that the commercial isolate of *T. viride* (BCL Tv) had maximum (76.37%) inhibition of the pathogen followed by native isolate (DOR 1 Tv) of *T. viride* (72.93%) and commercial isolate (Sun Agro Derma) of *T. viride* (72.59%). Although other isolates showed antagonistic activity but it was significantly inferior to these isolates. All the isolates of *Trichoderma* spp. formed inhibition zone after 5-7 days. The minimum growth inhibition (67.93%) of the pathogen was observed in case of commercial isolate (Vermigreen Th) (Plate 29 and 30). The two commercial isolates of *P. fluorescens* tested were least effective in inhibiting the radial growth of pathogen *M. phaseolina* compared to all the fungal antagonists tested (Table 4 and Plates 35 and 36).

4.4.3 Effect of biocontrol agents on the growth of *S. rolfsii*

The results Table 5 showed that among all the fungal antagonists tested, commercial and isolates of *Trichoderma* spp. were found to be significantly superior to commercial isolate of *T. harzianum* (Vermigreen Th) and two other bacterial isolates in arresting the mycelial growth of *S. rolfsii* (Plates 31 and 32). Inhibition was minimum (27.06%) in commercial isolate of *T. harzianum* (Vermigreen Th). Inhibition zone was also observed with all the isolates tested with slight difference. The growth of *S. rolfsii* was inhibited to an extent of 33.47 and 36.88 per cent by the two commercial bacterial antagonists viz., Sun Agromonus *P. fluorescens* and Vermigreen *P. fluorescens* respectively (Plates 37 and 38). However, the bacterial antagonists were inferior to the fungal antagonists tested in inhibiting the growth of the test pathogen.

4.5 SENSITIVITY OF BIOCONTROL AGENTS AGAINST AGROCHEMICALS

4.5.1 Sensitivity of fungal antagonists against agrochemicals

4.5.1.1 Sensitivity of fungal antagonists against fungicides

Four fungicides viz., copper oxychloride (Blitox), mancozeb (Dithane M-45), carbendazim (Bavistin) and hexaconazole (Contaf) were evaluated against commercial formulations and exotic isolates of *Trichoderma* spp, at a concentration of 100, 500, 1000 and 2000 ppm following poisoned food technique. The results of effect of fungicides on the radial growth of *Trichoderma* spp. are presented in Tables 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 and 18.

Copper oxychloride (COC)

The data on growth inhibition in different treatments found to be significant when compared to control. However, there is no significant difference among the different isolates of *Trichoderma* spp. at a concentration of 100 ppm. Cent per cent inhibition of growth of either *T. viride* or *T. harzianum* isolates recorded with all the concentrations of COC tested. Significantly highest per cent inhibition of the growth was observed between the *T. viride* and *T. harzianum* isolates. Among the *Trichoderma* spp. the commercial isolate of *T. viride* (NCC-58 Tv) was least sensitive to all the concentrations of COC tested. The per cent growth inhibition over control of the isolates was 3.42, 5.07, 8.70 and 8.70 at 100, 500, 1000 and 2000 ppm concentration respectively. The native isolate of *T. harzianum* (DOR 2 Th) was highly sensitive to copper oxychloride fungicide at higher concentrations (1000 and 2000 ppm) which recorded more than 50 per cent reduction in growth. Among the isolates of *T. harzianum*, the commercial isolate of Sun Agro Derma Th was least sensitive as it recorded 3.42, 11.65, 12.18 and 21.47 per cent growth inhibition over control at a concentration of 100, 500, 1000 and 2000 ppm respectively. Irrespective of biocontrol agents with the increase concentration of fungicide, there was decrease in growth of the fungal antagonistic isolates was observed (Table 6 and Plate 39).

Mancozeb

It is clear from the Table 7 that all the concentrations of the fungicide mancozeb tested significantly reduced the growth of different isolates of *Trichoderma* spp. Inhibitory effect of mancozeb showed increased trend with increase in the concentration. The commercial isolate of *T. harzianum* (Sun Agro

Derma Th) was least sensitive among *Trichoderma* spp. tested at all the concentrations of mancozeb followed by commercial isolate of *T. harzianum* (NCC-57 Th) (Plate 40).

Per cent growth inhibition was 50 per cent at a concentration of 2000 ppm with the commercial isolate of *T. viride* (BCL Tv) and native isolate of *T. viride* (DOR 1 Tv), whereas, maximum (52.98%) growth inhibition was recorded with the commercial isolate of *T. harzianum* (Vermigreen Th) at a concentration of 2000 ppm.

Carbendazim and Hexaconazole

Cent per cent inhibition of radial growth of all the isolates of *Trichoderma* spp. was recorded at all the concentrations of the two systemic fungicides viz., carbendazim and hexaconazole tested (Tables 8 and 9, and Plates 41 and 42).

4.5.1.2 Sensitivity of antagonistic mycoflora against insecticides

Imidacloprid

The radial growth of all the *T. viride* and *T. harzianum* isolates was not inhibited by the insecticide imidacloprid at all the concentrations (100, 500, 1000 and 2000 ppm) tested as luxuriant growth of the antagonists was found in all the petriplates containing poisoned medium with the insecticide. Growth rate of all the antagonists was similar to that of control in all aspects (Table 10 and Plate 43).

Chlorpyriphos

The per cent growth inhibition of various isolates of *Trichoderma* spp. ranged from zero to 56.86% in different test concentrations of the insecticide.

Inhibition range was zero to 23.8% at 100 ppm, 18.71 to 39.26% at 500 ppm, from 24.90 to 43.70% at 1000 ppm and 21.82 to 56.86% at 2000 ppm concentration.

With the increase in concentration of chlorpyriphos there was decrease in radial growth of *Trichoderma* isolates tested. The native isolate of *T. harzianum* (DOR 2 Th) was more sensitive to the organophosphorus insecticide chlorpyriphos recording 56.86% growth inhibition at 2000 ppm concentration (Table 11 and Plate 44). Whereas, least per cent growth inhibition (21.82%) was observed with commercial isolate *T. harzianum* (Vermigreen Th) followed by commercial isolate *T. viride* (Sun Agro Derma Tv) which recorded 30.9% growth inhibition over control at a concentration of 2000 ppm. In the commercial isolates of *T. viride* (NCC-58 Tv) and *T. harzianum* (Sun Agro Derma Th), the per cent growth inhibition was 55.34 and 51.06% respectively at 2000 ppm concentration of the insecticide.

Carbosulfan

Of the eight isolates of *Trichoderma* spp. tested for their sensitivity against the insecticide carbosulfan at different concentrations (100, 500, 1000 and 2000 ppm), the commercial isolate of *T. viride* (NCC 58 Tv) was least sensitive to the insecticide concentrations tested. Per cent growth inhibition of the isolate was 22.71 at 2000 ppm concentration as against 56.61 and 51.06 per cent growth inhibition of commercial isolate of *T. viride* (Sun Agro Derma Tv) and *T. harzianum* (Sun Agro Derma Th) respectively (Table 12). The growth reduction was maximum at higher concentration in all the isolates of fungal antagonists tested. The per cent growth reduction of various isolates of *Trichoderma* spp. was more in

case of carbosulfan compared to the chlorpyriphos at 100 ppm concentration (Table 12 and Plate 45).

4.5.1.3 Sensitivity of antagonistic mycoflora against fertilizers

The effect of four fertilizers viz., calcium ammonium nitrate (CAN), diammonium phosphate (DAP), single superphosphate (SSP) and muriate of potash (MOP) was evaluated at 100, 500, 1000 and 2000 ppm concentration on growth of antagonistic isolates of *Trichoderma* spp. and the results are presented in Tables 13, 14, 15 and 16.

All the fertilizers supported good growth and development of all the eight isolates of *Trichoderma* spp. at all the concentrations tested. The rate of growth and colour of the colony of the various isolates of *Trichoderma* spp. observed in different treatments were similar to that of control (Plates 46 to 50).

4.5.1.4 Sensitivity antagonistic mycoflora against herbicides

Pendimethalin

Significantly least growth inhibition was recorded with the eight antagonistic isolates of *Trichoderma* spp. at 100 ppm concentration of the weedicide pendimethalin. The commercial isolate of *T. viride* (NCC-58 Tv) and *T. harzianum* (NCC-57 Th and Vermigreen Th) showed no inhibition of the growth at 100 ppm concentration. With the increase in the concentration of weedicide pendimethalin there was decrease in the radial growth of various isolates *Trichoderma* spp. was observed (Table 17). At 2000 ppm concentration of the weedicide, the per cent growth inhibition of various isolates of *Trichoderma* spp. ranged between 56.61 to 84.58 (Table 17 and Plate 51).

Fluchloralin

Compared to the weedicide pendimethalin, fluchloralin found to be superior in inhibiting the growth of various isolates of *Trichoderma* spp. The weedicide was more inhibitory to the growth of various isolates of *Trichoderma* spp even at a lowest concentration of 100 ppm. The per cent growth inhibition of various isolates ranged from 4.52 (NCC-58 Tv) to 30.48 (BCL Tv) at 100 ppm concentration. All the isolates showed more than 50% growth reduction in fluchloralin amended medium at 500 ppm concentration. The range of inhibition was between 58.13 and 80.31 per cent at this concentration. At 2000 ppm concentration, the inhibition range was from 77.20 to 93. 82 per cent (Table 18 and Plate 52).

4.5.2 Sensitivity of bacterial antagonists against agrochemicls

4.5.2.1 Sensitivity of bacterial antagonists against fungicides

Sensitivity of commercial formulations of *Pseudomonas fluorescens* (Sun Agromonus Pf and Vermigreen Pf) with fungicides viz., copper oxychloride, mancozeb, carbendazim and hexaconazole was tested at four concentrations viz., 100, 500, 1000 and 2000 ppm by using inhibition zone technique and the results are presented in Tables 19 and 20. At 100 ppm concentration all the fungicides found to be compatible with bacterial antagonists as there was no growth inhibition was observed at this concentration. With increase in the concentration of each fungicide there was decrease in the growth of the bacterial antagonists. Of the four fungicides tested carbendazim was found to be highly inhibitory to *P. fluorescens* (Vermigreen Pf) at 500, 1000 and 2000 ppm concentrations. Hexaconazole were found to be next

inhibitory fungicide. Mancozeb was found to be least inhibitory fungicide at all the concentrations (Table 19).

Of the four fungicides tested for their efficacy on commercial bacterial antagonist of *P. fluorescens* (Sun Agromonus Pf), hexaconazole was found to be inhibitory to the bacterial antagonist at higher concentrations (Table 20). At 100 ppm concentration all the fungicides were found compatible with bacterial antagonists as there was no growth inhibition at this concentration. Carbendazim was found to be the next inhibitory fungicide followed by copper oxychloride at 500, 1000 and 2000 pm concentrations. Mancozeb was less inhibitory to the bacterial antagonist compared to the other fungicides.

4.5.2.2 Sensitivity of bacterial antagonists against insecticides

By using zone of inhibition technique, the sensitivity of commercial bacterial antagonists (Sun Agromonus Pf and Vermigreen Pf) with insecticides viz., imidacloprid, chlorpyriphos and carbosulfan are tested at 100, 500, 1000 and 2000 ppm concentrations and results were presented in Tables 21 and 22. It is evident from the Table 21 that the overall inhibition of the growth of the commercial isolates of *P. flourescens* (Sun Agromonus Pf) with carbosulfan was least (1.68%) even at 2000 ppm concentration. Whereas, insecticides imidacloprid, chlorpyriphos were inhibitory to bacterial antagonists at higher concentrations which were statistically at par (Table 21).

There was no growth inhibition of bacterial antagonist *P. fluorescens* (Vermigreen Pf) at lower concentrations of 100, 500 ppm with all the insecticides tested. Of the three insecticides tested, chlorpyriphos was found to be more inhibitory at 1000 and 2000 ppm concentration compared to other insecticides. The

insecticide imidacloprid was least inhibitory to the growth of *P. fluorescens* (Vermigreen Pf) when compared to other insecticides (Table 22).

4.5.2.3 Sensitivity of bacterial antagonists against fertilizers

Sensitivity of two bacterial antagonists viz., Sun Agromonus *P. fluorescens* and Vermigreen *P. fluorescens* was tested with fertilizers viz., calcium ammonium nitrate, diammonium phosphate, single super phosphate and muriate of potash at 100, 500, 1000and 2000 ppm concentrations and the data presented in Tables 23 and 24.

All the fertilizers tested were found to be compatible with two bacterial antagonistic isolates as there was no growth inhibition were recorded at all the concentrations (100, 500, 1000 and 2000 ppm) tested.

4.5.2.4 Sensitivity of bacterial antagonists against herbicides

Of the two herbicides tested for their efficacy against the two bacterial antagonists (Sun Agromonus pf and Vermigreen pf) fluchloralin was found to be highly inhibitory to the growth of both bacterial antagonist isolates at 1000 and 2000 ppm concentrations. The per cent growth reduction was 19.13 and 21 in case of Sun Agromonus *P. fluorescens* and Vermigreen *P. fluorescens* respectively in fluchloralin amended medium at 2000 ppm concentration. However, there was no growth inhibition of either of the bacterial antagonistic isolates at 100 ppm concentration of both the herbicides tested (Tables 25 and 26). With the increase in concentration of herbicide, there was increase in growth reduction of both bacterial antagonistic isolates at 500 ppm concentration of both the herbicides tested.

4.6 EFFICACY OF AGROCHEMICALS AGAINST THE TEST PATHOGENS

4.6.1.1 *In vitro* efficacy of fungicides against *P. aphanidermatum*

Four fungicides viz., copper oxychloride (Blitox), mancozeb (Dithane M-45), carbendazim (Bavistin) and hexaconazole (Contaf) were tested for their efficacy against *P. aphanidermatum in vitro* by poisoned food technique at 100, 500, 1000 and 2000 ppm concentration. Radial growth of *P. aphanidermatum* was measured in petriplates and per cent inhibition of growth was calculated and data is presented in Table 27.

It is evident from the data presented (Table 27) that all the chemicals tested at all the concentrations inhibited the growth of *P. aphanidermatum*. Per cent growth reduction of the test fungus was maximum at all the concentrations of copper oxychloride (COC) compared to the other fungicides tested. Cent per cent reduction in radial growth of *P. aphanidermatum* was recorded with the fungicide COC at 500, 1000 and 2000 ppm, while at 1000 and 2000 ppm concentration in respect of mancozeb and hexaconazole. Of the four fungicides tested for their efficacy on growth of *P. aphanidermatum* at all concentrations, COC was superior followed by hexaconazole compared to the other fungicides in inhibiting the growth of test fungus. Carbendazim was comparatively less effective in inhibiting the growth of the test fungus and showed 57.83 and 72.79% growth inhibition at 1000 and 2000 ppm concentrations respectively. Whereas, cent per cent inhibition of the growth of test fungus was recorded at these concentrations in respect of COC, mancozeb and hexaconazole (Plates 53,56,59 and 62).

4.6.1.2 *In vitro* efficacy of fungicides against *M. phaseolina*

It is evident from the data presented in Table 28 that the three fungicides viz., mancozeb, carbendazim and hexaconazole were found to be completely inhibitory (cent per cent) to the growth of *M. phaseolina* at all the concentrations (100, 500, 1000 and 2000 ppm) tested. COC was least effective in inhibiting the growth of test fungus. The growth reduction was least (4.8%) even at a concentration of 2000 ppm in respect of COC (Plates 54,57,60 and 63).

4.6.1.3 *In vitro* efficacy of fungicides against *S. rolfsii*

Of the four fungicides tested Table 29 cent per cent inhibition of the radial growth of the pathogen *S. rolfsii* was recorded in respect of mancozeb and hexaconazole at all the concentrations (100, 500, 1000 and 2000 ppm) tested. However, no inhibition of growth of the pathogen was observed with carbendazim at all the concentrations tested. Whereas, no inhibition of *S. rolfsii* was observed in COC amended medium at a concentration of 100 ppm and the per cent growth inhibition was 6.41 at a concentration of 2000 ppm. The results also indicate the superiority of mancozeb and hexaconazole in inhibiting growth of the pathogen at a lower concentration of 100 ppm (Table 29 and Plates 55,58,61 and 64).

4.6.2 Efficacy of insecticides against test pathogens

The effect of certain insecticides on the growth of three soil borne test pathogens viz., *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* were studied at 100, 500, 1000 and 2000 ppm concentrations by using poisoned food technique and the results are presented hereunder.

4.6.2.1 *In vitro* efficacy of insecticides against *P. aphanidermatum*

Of the four insecticides tested (Table 30), the organophosphorus insecticide, chlorpyriphos significantly inhibited radial growth of the test fungus at all the concentrations compared to the other insecticides. The per cent growth inhibition of *P. aphanidermatum* was 33.05 at 2000 ppm concentration of chlorpyriphos as against 13.65, 15.86 and 17.78 per cent growth inhibition of the fungus at 2000 ppm concentration of thiomethoxam, imidacloprid and carbosulfan respectively. Chloripyriphos found to be more toxic to *Pythium aphanidermatum* compared to the other insecticides tested at all the concentrations. Significant differences in radial growth of the pathogen was observed between concentrations and between insecticides tested (Table 30), Irrespective of the insecticides tested, per cent growth inhibition of the test pathogen was increased with the increase in concentration of the insecticides (Table 30 and Plates 64,65,68 and 71).

4.6.2.2 *In vitro* efficacy of insecticides against *M. phaseolina*

Of the four insecticides tested for their efficacy on growth of *M. phaseolina*, the insecticide carbosulfan found to be superior in inhibiting the growth of *M. phaseolina* followed by thiomethoxam at all the concentrations tested (Table 31). However, the per cent growth inhibition of the test fungus was 60.22 and 51.06 in thiomethoxam and carbosulfan at a concentration of 2000 ppm respectively. However, no inhibition of *M. phaseolina* observed with insecticide imidacloprid at all the concentrations. The per cent growth reduction of *M. phaseolina* was least (2.32 to 32.62) in chlorpyriphos amended medium at all the concentrations tested (Table 31 and Plates 66,69,72 and 75).

4.6.2.3 *In vitro* efficacy of insecticides against *S. rolfsii*

It is evident from the data presented Table 32 that the organophosphorus insecticide chlorpyriphos was found to be superior in inhibiting the radial growth of pathogen *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations (Plates 67,70,73 and 76). Significant difference was observed in per cent inhibition of growth of the pathogen with regard to all the insecticides tested. The imidacloprid was inhibitory to the growth of the pathogen at all the concentrations tested. Least per ent growth inhibition of the test pathogen was recorded with the insecticides thiomithoxam and carbosulfan at all the test concentrations (Table 32 and Plates 67,70,73 and 76).

4.6.3 Efficacy of fertilizers against test pathogens

The efficacy of four fertilizers viz., calcium ammonium nitrate, diammonium phosphate, single superphosphate and muriate of potash (MOP) against three soil borne pathogen was tested by poisoned food method at different concentrations and results are presented hereunder.

All the fertilizers at all the concentrations tested were not inhibitory to the growth of the test pthogens *P. aphanidermatum* and *M. phaseolina*. Whereas, the fertilizer, CAN inhibited the radial growth of *S. rolfsii* and the per cent growth inhibition was 0.59, 4.27, 12.64 and 22.49 at 100, 500, 1000 and 2000 ppm concentrations respectively (Tables 33, 34, 35 and Plates 77 to 88).

4.6.4 *In vitro* efficacy of herbicides against soil borne pathogens

P. aphanidermatum

From the Table 36 it is evident that the per cent growth reduction of *P. aphanidermatum* was maximum in case of both the herbicides tested at 2000 ppm

concentration. Fluchloralin at a concentration of 2000 ppm followed by 1000 ppm concentration was superior in inhibiting the growth of *P. aphanidermatum*. Of the two herbicides tested against *P. aphanidermatum*, fluchloralin was the best in inhibiting the test fungus growth at all the concentrations compared to pendimethalin. However, with the increase in concentration of either of the herbicides tested there was decrease in growth of the fungus was observed (Plates 89 and 92).

M. phaseolina

From the Table 37 it is clear that the per cent growth reduction of the test fungus was maximum (84.0%) in case of the herbicide, fluchloralin at 2000 ppm concentration followed by 1000 ppm concentration (81.8%).

Of the two herbicides tested for their efficacy on growth of *M. phaseolina* at all concentrations, fluchloralin was superior over pendimethalin in inhibiting the growth of *M. phaseolina*. Growth reduction of the test fungus was found maximum at higher concentrations then at lower concentrations (Plate 90 and 93).

S. rolfsii

Cent per cent reduction in radial growth of *S. rolfsii* was recorded with the herbicide, fluchloralin at all the concentrations (100, 500, 1000 and 2000 ppm) tested (Table 38) Maximum (93.6%) growth reduction of the test fungus was observed with pendimethalin at 2000 ppm concentration. With the increase in concentration of pendimethalin, there was decrease in growth of the test fungus was observed (Plates 91 and 94).

4.7 SYNERGISTIC EFFECT OF BIOCONTROL AGENTS AND AGROCHEMICALS AGAINST TEST PATHOGENS

The agrochemicals which were completely inhibitory to the growth of either to the test pathogens or to any of the test antagonistic fungal isolates were not included in study pertaining to the combined effect of *Trichoderma* isolates with the agrochemicals against the test pathogens.

In the present study, the fungicides viz., mancozeb and hexaconazole were completely inhibitory to the growth of *M. phaseolina* and *S. rolfsii* at all the concentrations tested. Whereas, the fungicides viz., carbendazim, hexaconazole and the herbicide fluchloralin were completely inhibitory to the growth of all the test isolates of *Trichoderma* spp. at 100, 500, 1000 and 2000 ppm concentrations. Hence, these chemicals were not included in the experiments to study the combined effect of biocontrol agents with the agrochemicals on the growth of the test pathogens.

4.7.1.1 Combined effect of fungicides and biocontrol agents against test pathogens *in vitro*

P. aphanidermatum

Combined effect of the fungicide copper oxychloride (COC) and mancozeb with the test isolates of *Trichoderma* spp. against the test pathogen *P. aphanidermatum* was studied by dual culture method in poisoned food medium at 100, 500, 1000 and 2000 ppm concentrations. The results are presented in Tables 39 and 40.

Copper oxychloride (COC)

The data presented in Table 39 indicate significant differences in radial growth of the pathogen *P. aphanidermatum* among the antagonistic fungi studied in COC ammended medium at all the concentrations. At 100 ppm concentration of COC per cent growth inhibition of *P. aphanidermatum* was 75.53 with the native isolate of *T. harzianum* (DOR 2 Th) followed by the native isolate of *T. viride* (DOR 1 Tv) in which the per cent growth inhibition was 74.12 was observed. At 100 and 500 ppm concentrations of COC all the isolates of antagonistic fungi over grew the pathogen (Plate 95), whereas the growth of both the antagonists and pathogen was restricted at higher concentrations (1000 and 2000 ppm) of COC. The range of growth inhibition of *P. aphanidermatum* ranged from 63.93 to 75.53 at 100 ppm concentration with all the isolates antagonistic fungi tested. With the increase in concentration of fungicide COC there was decrease in per cent growth inhibition of the pathogen in various treatments which ranged between 31.17 (Vemigreen Th) and 66.79 (DOR 2 Th) (Table 39)

Mancozeb

All the isolates of *Trichoderma* spp. in mancozeb amended medium showed significant differences in inhibiting the growth of *P. aphanidermatum* (Table 40) Maximum (88.51) per cent growth inhibition of the test pathogen was recorded with exotic isolate of *T. harzianum* (DOR 2 Th) and commercial formulation of *T. harzianum* (NCC-57 Th) while the growth inhibition was 39.39 per cent in respect of commercial formulation *T. harzianum* (Vermigreen Th) at 100 ppm concentration. The native isolate of *T. viride* (DOR 1 Tv) and commercial formulation of *T. viride* (Sun Agro Derma Tv) were at par in inhibiting the growth

of *P. aphanidermatum* in mancozeb amended medium at a concentration of 100 ppm (Table 40) The efficacy of different isolates of *Trichoderma* spp. was reduced at higher concentration of the fungicide as the growth of the *Trichoderma* spp. suppressed in mancozeb amended medium at higher concentrations (Plate 98). All the *Trichoderma* spp. over grew the pathogen in mancozeb amended medium at 100, 500 ppm concentrations while the growth of the antagonistic fungi was suppressed in mancozeb amended medium at higher concentrations (Plates 98).

M. phaseolina

Combined efficacy of the fungicides viz., COC and mancozeb with native and commercial isolates of *Trichoderma* spp., against *M. phaseolina* were studied at a concentration of 100, 500, 1000 and 2000 ppm and the results are presented in Table 41 and 42.

Copper oxychloride

Significant differences in the radial growth of the pathogen *M. phaseolina* were observed with all *Trichoderma* isolates tested in COC amended medium at a concentration of 100 ppm. The commercial isolate of *T. harzianum* (Sun Agro Derma Th) was found to be superior in inhibiting the radial growth of the test pathogen followed by native isolate of *T. harzianum* (DOR 2 Th) in COC amended medium at a concentration of 100 ppm (Table 41). With increase in the concentration of fungicide COC there was decrease in the efficacy of the various isolates of *Trichoderma* spp. indicating inhibitory effect of the fungicide on the growth of various isolates of *Trichoderma* (Table 41). The synergistic effect of the fungicide and biocontrol agents is not observed at higher concentrations of the fungicide. In fungicide amended medium all isolates of *Trichoderma* spp. overgrew

the pathogen at lower concentrations of 100 and 500 ppm, while the growth of antagonistic fungi suppressed at higher concentration (1000 and 2000 pm) resulting in less per cent growth inhibition of the test pathogen (Tables 41 and Plate 96).

Mancozeb

The data presented in Table 42 showed that there was significant difference between isolates of *Trichoderma* spp. in inhibiting the growth of *M. phaseolina* in mancozeb amended medium at different concentrations. Maximum reduction in radial growth of *M. phaseolina* was recorded with commercial formulation of *T. viride* (Sun Agro Derma Tv) which was on par with the commercial isolate of *T. viride* (NCC-58 Tv). With the increase in concentration of mancozeb, the growth of the individual isolates of *Trichoderma* spp. was also suppressed. However, at lower concentrations of the fungicide all the antagonistic fungi tested overgrew the pathogen. Higher per cent growth inhibition of test pathogen was observed in mancozeb amended medium at higher concentrations (1000 and 2000 ppm) indicating the efficacy of the fungicide mancozeb only (Table 42 and Plate 99).

S. rolfsii

Copper oxychloride (COC)

Significant differences in per cent growth inhibition of the pathogen *S. rolfsii* were observed between the various isolates of *Trichoderma* spp. in COC amended medium at all the concentrations tested. Among the *Trichoderma* isolates tested commercial isolate of *T. harzianum* (NCC-57 Th) found to be superior in inhibiting the growth of *S. rolfsii* at all concentrations of COC. Per cent growth inhibition of the pathogen was 78.11, 78.58, 70.62 and 61.03 at 100, 500, 1000 and

2000 ppm concentrations respectively with the commercial isolate of *T. harzianum* (NCC-57 Th). With the increase in concentration of the fungicide there was decrease in per cent growth inhibition of the pathogen was observed with all the isolates of *Trichoderma* spp. tested. Combined effect of biocontrol agent with fungicide was observed at lower concentration only. Overgrowth of the biocontrol agent on the pathogen was observed only with commercial isolate of *T. harzianum* (NCC-57 Th) and with most of other isolates of *Trichoderma*, a clear narrow zone of inhibition observed whenever biocontrol agent and *S. rolfsii* in contact with each other (Plate 97). The growth of the various isolates of *Trichoderma* spp. was suppressed at higher concentrations of the fungicide COC. While at lower concentrations, the synergistic effect of the fungicide and biocontrol agents was clearly observed in suppressing the growth of the test pathogen *S. rolfsii* (Table 43).

Mancozeb

The data presented in Table 44 showed that there was significant difference between the isolates of *Trichoderma* spp. in inhibiting the growth of *M. phaseolina* in mancozeb amended medium at different concentrations. Maximum inhibition of *M. phaseolina* was recorded with commercial formulation of *T. viride* (Sun Agro Derma Tv) which is on par with the commercial isolate of *T. viride* (NCC-58 Tv). With the increase in concentration of mancozeb, the growth of the individual isolates of *Trichoderma* spp was also suppressed. However, at lower concentrations of the fungicide all the antagonistic fungi tested overgrew the pathogen. Higher per cent growh inhibition of test pathogen was observed in mancozeb amended medium at higher concentrations at 1000 and 2000 ppm indicating the efficacy of the fungicide mancozeb only (Table 44 and Plate 100).

4.7.1.2 Combined effect of insecticides and biocontrol agents against test pathogens *in vitro*

P. aphanidermatum

Imidacloprid

All test isolates of *Trichoderma* spp. significantly reduced the growth of *P. aphanidermatum* in imidacloprid amended medium at all the concentrations tested (Table 45). The commercial isolate of *T. harzianum* (Vermigreen Th) found to be superior in inhibiting the radial growth of the pathogen with the insecticide imidacloprid at 100ppm concentration followed by commercial isolate of *T. harzianum* (NCC-57 Th). At lower concentrations of the insecticide the isolates overgrew the pathogen while at higher concentrations the growth of potential biocontrol agents was suppressed resulting in decreased combined efficacy of biocontrol agents with the insecticide. It is interesting to note that the colony colour of commercial isolate *T. viride* (Sun Agro Derma Tv) was changed to green in imidacloprid amended medium at 100, 500 ppm while no change in the colour of colony was observed at 1000 and 2000 ppm concentrations (Plate 101). The colour of the culture of commercial isolate of *T. viride* isolate *T. harzianum* (NCC-57 Th) was white even after 7 days of incubation in imidacloprid amended medium at 1000 and 2000 ppm concentrations indicating less sporulation of these isolates (Plate 101).

Chlorpyriphos

The data presented in Table 46 indicates the significant differences in the inhibitory effect on the growth of test pathogen *P. aphanidermatum* among all the test isolates of *Trichoderma* spp. in chlorpyriphos amended medium at all the

concentrations tested. Maximum growth inhibition (75.73%) of the test pathogen was observed with commercial isolate of *T. harzianum* (Vermigreen Th) followed by native isolate of *T. harzianum* (DOR 2 Th), in chlorpyriphos amended medium at 1000 ppm concentration. The per cent growth inhibition of the *P. aphanidermatum* was maximum (81.93) with commercial isolate of *T. harzianum* (Vermigreen Th) in chlorpyriphos amended medium at 2000 ppm concentration. The colour of the culture of various test isolates of *Trichoderma* were white even after seven days of incubation in chlorpyriphos amended medium. Irrespective of isolates of *Trichoderma* spp. the sporulation was sparse in chlorpyriphos amended medium at all concentrations. However, the sporulation was less at higher concentration of chlorpyriphos than at lower concentration (Plate 104).

Carbosulfan

The perusal of the data Table 47 indicates significant differences in the efficacy of various isolates *Trichoderma* spp., in inhibiting the growth of *P. aphanidermatum* in carbosulfan amended medium at all the concentrations tested. Maximum (67.9%) inhibition of the growth of *P. aphanidermatum* was observed with commercial isolate of *T. viride* (BCL Tv) followed by commercial isolate of *T. harzianum* (NCC-57 Th). All the isolates of *Trichoderma* spp. overgrew the pathogen in carbosulfan amended medium at all the concentrations tested (Table 47 and Plate 107).

M. phaseolina

Imidacloprid

Significant differences between the isolates of *Trichoderma* spp. and different concentrations of the insecticide imidacloprid were found in respect of

growth inhibition of the test pathogen *M. phaseolina* (Table 48). Maximum growth reduction (91.47%) was recorded with the commercial isolates of *T. viride* (NCC-58 Tv) and *T. harzianum* (Sun Agro Derma Th, NCC-57 Th and Vermigreen Th) and with native isolate of *T. harzianum* (DOR 2 Th) in imidacloprid amended medium at 100 ppm concentration. At higher concentration of imidachloprid, a decrease in growth inhibition of the test pathogen was recorded. However, at 2000 ppm concentration the per cent growth inhibition of the pathogen ranged between 39.47 and 71.58. The efficacy of various isolates of *T. viride* was more at lower concentrations than at higher concentrations of imidacloprid. The isolates of *Trichoderma* spp. overgrew the pathogen in imidacloprid amended medium at 100 and 500 ppm concentrations, while at higher concentrations of imidacloprid the growth of various isolates of *Trichoderma* spp. was also suppressed (Plate 102).

Chlorpyriphos

Significant differences were observed in radial growth of *M. phaseolina* with all the isolates of *Trichoderma* spp. at all the concentrations of chlorpyriphos tested. Efficacy of various isolates of *Trichoderma* spp. was more in chlorpyriophos amended at 100 ppm concentration compared to the other test concentrations (Table 49). Maximum growth reduction (93.6 %) was observed with the commercial isolate of *T. harzianum* (Vermigreen Th) in chloripyriphos amended medium at 100ppm followed by the commercial isolate of *T. viride* (BCL Tv). In chlorpyriphos amended medium, the growth of all the isolates of the *Trichoderma* spp. was abundant compared to the test pathogen. Whereas, growth of the test pathogen and isolates of *Trichoderma* spp. was suppressed at higher concentrations of chlorpyriphos. Overgrowth of the pathogen by any of the test isolates of

Trichoderma spp. was not observed in chlorpyriphos amended medium at higher concentrations (Plate 105).

Carbosulfan

The commercial isolate of *T. harzianum* (Vermigreen Th) significantly reduced the radial growth of test pathogen compared to the other isolates of *Trichoderma* spp. in carbosulfan amended medium at 100 ppm concentration (Table 50). All the other isolates of *Trichoderma* spp. were at par as the per cent growth inhibition of the pathogen was 91.47 at 100 ppm concentration of carbosulfan. All the test isolates of *Trichoderma* spp. overgrew the pathogen at all the concentrations of carbosulfan tested. There was gradual decrease in per cent growth inhibition of the pathogen with increase in concentration of the insecticide carbosulfan was observed (Plate 108).

S. rolfsii

Imidacloprid

The combined effect of the insecticide imidacloprid with various isolates of *Trichoderma* spp. on the growth of *S. rolfsii* was studied on PDA amended with imidacloprid at 100, 500, 1000 and 2000 ppm concentrations and the results are presented in Table 51. The perusal of the data furnished in Table 51 shows significant difference between the isolates of *Trichoderma* spp. with regard to inhibition of the growth of the pathogen in imidacloprid amended medium at all the concentrations. Highest inhibition (95.74%) of the pathogen was recorded with the native isolate of *T. viride* (DOR 1 Tv) followed by exotic isolate of *T. harzianum* (DOR 2 Th). In other isolates, the per cent growth inhibition varied between 93.60 per cent and 84.16% at 100 ppm concentration (Table 51 and Plate 103). At higher

concentrations (500, 1000 and 2000 pm) of imidacloprid, there was corresponding increase in radial growth of the test pathogen was observed with all the isolates of *Trichoderma* spp. (Table 51). At 1000 and 2000 ppm concentration of imidacloprid, the pathogen *S. rolfsii* overgrew the commercial isolate of *T. harzianum* (Vermigreen Th) (Plate 103). In addition, a narrow clear zone of inhibition was observed with commercial isolate of *T. viride* (BCL Tv) and *T. harzianum* (Sun Agro Derma Th, DOR 2 Th and NCC-57 Th in imidacloprid amended medium at 1000 and 2000 ppm concentrations.

Chlorpyriphos

The results mentioned in Table 52 revealed that all the isolates of *Trichoderma* spp. significantly inhibited the growth of the test pathogen *S. rolfsii* in chlorpyriphos amended medium at 100, 500, 1000 and 2000 ppm concentrations. The maximum inhibition (95.74%) of the pathogen was recorded with native and commercial isolate of *T. viride* (DOR 1 Tv and NCC-58 Tv) followed by commercial isolate of *T. viride* (Sun Agro Derma Tv) in chlorpyriphos amended medium at 100 ppm concentration. In other isolates of *Trichoderma* spp., the per cent growth inhibition varied between 73.67 and 91.47 in chlorpyriphos amended medium at 100 ppm concentration (Table 52). At any concentration of the chlorpyriphos none of the isolates of *Trichoderma* spp. overgrew the pathogen. With the increase in concentration of chlorpyriphos there was decrease in growth of the various isolates of *Trichoderma* spp. was observed (Plate 105).

Carbosulfan

All the isolates of *Trichoderma* spp. significantly reduced the radial growth of the pathogen *S. rolfsii* in carbosulfan amended medium at all

concentrations tested (Table 53). At 100 ppm concentration of carbosulfan the per cent growth inhibition (80.77 %) of *S. rolfsii* was ranged from 61.01 to 73.76 per cent with all the fungal antagonistic isolates tested. However, maximum growth inhibition of the pathogen was recorded with the commercial isolate of *T. harzianum* (Sun Agro Derma Th) at 2000 ppm concentration compare to other isolates. In all the isolates of *Trichoderma* spp. radial growth of the pathogen decreased with increase in concentration of carbosulfan. The growth of the various isolates of *Trichoderma* spp. was not affected in carbosulfan amended medium at lower concentration and at higher concentration, the growth of the isolates of *Trichoderma* spp. was suppressed (Plate 109).

4.7.1.3 Combined effect of fertilizers and biocontrol agents against test pathogens *in vitro*

P. aphanidermatum

Calcium Ammonium Nitrate (CAN)

The results Table 54 indicated that the per cent growth reduction of the pathogen, *P. aphanidermatum* differed significantly between the *Trichoderma* isolates and concentrations of the fertilizer CAN. In CAN amended medium all the isolates of *Trichoderma* spp. reduced the growth of the pathogen *P. aphanidermatum* more than 50 per cent at all the concentrations tested. Maximum growth (72.35%) reduction of *P aphanidermatum* was observed with the commercial isolate of *T. viride* (Sun Agro Derma Tv) followed by commercial isolate of *T. harzianum* (NCC-57 Th) at 2000 ppm concentration. In other isolates growth reduction was ranged between 51.11 to 68.29 per cent irrespective of the concentration of CAN tested. A narrow zone of inhibition was observed between

the antagonist and the pathogen with all the isolates of *Trichoderma* spp. in CAN amended medium at all concentrations (Plate 110).

Diammonium phosphate (DAP)

It is evident from the data Table 55 that the commercial isolate of *T. harzianum* (NCC-57 Th) inhibited the growth of pathogen to an extent of 82.81 per cent in DAP amended medium at 2000 ppm concentration. Significant differences in the growth of the pathogen was observed with other isolates of *Trichoderma* spp. in DAP amended medium at 100, 500, 1000 and 2000 ppm concentration. Almost all isolates of *Trichoderma* spp. tested arrested the growth of test pathogen *P. aphanidermatum* more than 50% (Table 55). The commercial isolate of *T. harzianum* (NCC-57 Th) overgrew the pathogen at all the concentrations of DAP, while a narrow zone of inhibition was formed between the pathogen and biocontrol agent in respect of the commercial isolate of *T. viride* (BCL Tv) and native isolate of *T. viride* (DOR 1 Tv) and *T. harzianum* (Sun Agro Derma Th) at all the concentrations tested (Plate 113).

Single super phosphate (SSP)

Of the eight isolates of *Trichoderma* spp. tested on the growth of *P. aphanidermatum* maximum growth inhibition (80.39%) of the pathogen was observed with the commercial isolate of *T. harzianum* (NCC-57 Th) followed by commercial isolate of *T. viride* (NCC-58 Tv) in SSP amended medium at 2000 ppm the concentration (Table 56). The commercial isolate of *T. harzianum* overgrew the test pathogen at all concentrations while a narrow zone of inhibition was formed between the pathogen and biocontrol agent in respect of the commercial isolates of *T. viride* (BCL Tv) and exotic isolate of *T. viride* (DOR 1 Tv) and commercial

isolate of *T. harzianum*, Sun Agro Derma Th, DOR Th and Vermigreen Th (Plate 116).

Muriate of Potash (MOP)

It is evident from the data Table 57 radial growth of the pathogen was significantly reduced in MOP amended medium at all concentrations with all the test isolates of *Trichoderma* spp. However, per cent growth inhibition of the pathogen ranged between 80.3 to 95.25 at 2000 ppm concentration compared to the per cent growth inhibition which ranged between 67.16 to 78.08 at 100 ppm concentration with all the isolates of *Trichoderma* spp. tested (Table 57). However, maximum growth inhibition (95.25 %) of the pathogen was observed with the native isolate of *T. viride* (DOR 1 Tv) in MOP amended medium at 2000 ppm concentration. Narrow zone of inhibition formed between the *P. aphanidermatum* and biocontrol agents in respect of commercial isolate of Tv (BCL Tv), native isolate *T. viride* (DOR 1 Tv), commercial isolate of *T. harzianum* (Sun Agro Derma Th) and native isolate of *T. harzianum* (DOR 2 Th) (Plate 119).

M. phaseolina

Calcium Ammonium Nitrate (CAN)

Significant differences in the radial growth of the pathogen *M. phaseolina* were observed in CAN amended medium at all the concentrations and among the isolates of *Trichoderma* spp. tested. Irrespective of the concentration of CAN almost all the isolates of *Trichoderma* spp. inhibited growth of the pathogen (Table 58). The native isolate of *T.viride* (DOR 1 Tv) was found superior in inhibiting the radial growth of *M. phaseolina* in CAN amended medium at all the concentrations. However, the least per cent growth inhibition of the pathogen

observed in CAN amended medium with the commercial isolate of *T. harzianum* (Vermigreen Th) at all concentrations and the growth reduction varied between 57.37 and 61.01 (Table 58). A narrow zone of inhibition was observed between the pathogen *M. phaseolina* and with the isolates of *Trichoderma* spp. (BCL Tv, DOR 1 Tv and Vermigreen Th). Whereas, the isolates of *Trichoderma* spp., viz., Sun Agro Derma Th, Sun Agro Derma Tv, DOR 2 Th, and NCC-57 Th overgrew the pathogen (Plates 111).

Diammonium Phosphate (DAP)

In DAP amended medium the radial growth of the pathogen *M. phaseolina* reduced significantly with all the isolates of *Trichoderma* spp. at all concentrations (Table 59). Irrespective of the antagonistic fungal isolates and concentrations of DAP per cent growth inhibition of the pathogen *M. phaseolina* ranged between 64.25 and 79.85 (Table 59). Compared to all other fungal antagonistic isolates, the native isolate of *T.viride* (DOR 1 Tv) significantly inhibited the growth of *M. phaseolina* in DAP amended medium at all the concentrations tested. A narrow zone of inhibition was observed with the commercial isolates of *Trichoderma* spp. (BCL Tv and Vermigreen Th). While, the antagonistic fungal isolates viz., DOR 1 Tv, NCC-58 Tv, Sun Agro Derma Th, DOR 2 Th and NCC-57 Th overgrew the pathogen (Plate 114). Of all the isolates of *Trichoderma* spp. tested for their efficacy in DAP amended medium, commercial isolate of *T. harzianum* (Vermigreen Th) was least effective in inhibiting the test pathogen at all concentrations tested (Table 59).

Single Superphosphate (SSP)

Significant differences were observed in the growth reduction of test pathogen *M. phaseolina* with all the isolates of *Trichoderma* spp. in SSP amended medium at all concentrations tested (Table 60). The native isolate of *T. viride* (DOR 1 Tv) significantly inhibited the growth of *M. Phaseolina* in SSP amended medium at all test concentrations, compared to other fungal antagonistic isolates. The per cent growth inhibition of the pathogen ranged between 41.29 and 84.49 irrespective of the isolates of *Trichoderma* spp and concentrations of SSP tested. The commercial isolate of *T.harzianum* (Vermigreen Th) was least effective in inhibiting the growth of test pathogen compared to the other isolates of *Trichoderma* spp. in SSP amended medium at all concentrations (Table 60). A narrow zone of inhibition was observed with antagonistic fungal isolates of *Trichoderma* spp. (BCL Tv, DOR 1 Tv, Sun Agro Derma Th and Vermigreen Th). Whereas the antagonistic fungal isolates viz., NCC-58 Tv, DOR 2 Th and NCC-57 Th overgrew the pathogen (Plate 116).

Muriate of Potash (MOP)

The per cent growth inhibition of the pathogen *M. phaseolina* in MOP amended medium significantly differed with the isolates of *Trichoderma* spp. at all concentrations tested. All the isolates of *T. viride* were found to be superior in inhibiting the growth of the pathogen *M. phaseolina* compared to all the isolates of *T. harzianum* in MOP amended medium at all the concentrations tested. The per cent growth inhibition of the pathogen ranged between 74.12 and 86.53 with all the isolates of *T. viride* tested. Whereas, it was between 46.71 to 67.93 in respect of all the isolates of *T. harzianum*. Among the isolates of *T. viride*, the commercial isolate

(NCC 58 Tv) was found to be superior which inhibited *M. phaseolina* to an extent of 86.53 per cent in MOP amended medium at 2000 ppm concentration. While, the commercial isolate of *T. harzianum* (Sun Agro Derma Th) inhibited the pathogen to an extent of 67.93 per cent in MOP amended medium at 2000 ppm concentration. However, the commercial isolate of *T. harzianum* (Vermigreen Th) was least effective in inhibiting the pathogen compared to the other antagonistic fungal isolates tested (Table 61). However, no clear zone of inhibition was observed with any of the isolates *Trichoderma* spp. tested in MOP amended medium at all concentrations (Plate 120).

S. rolfsii

Calcium ammonium nitrate (CAN)

Significant differences in radial growth of the pathogen *S. rolfsii* were observed with all the isolates of *Trichoderma* spp. in CAN amended medium at all the concentrations tested (Table 62). Significant difference in the growth of the pathogen with increase in the concentration of the CAN was observed with all the isolates of *Trichoderma* tested. Of all the isolates of *Trichoderma* spp. tested, commercial isolate of *T. harzianum* (Vermigreen Th) was least effective in inhibiting the pathogen at all concentrations of CAN tested (Table 62). Of the eight *Trichocderma* isolates tested, the commercial isolate of *T. viride* (Sun Agro Derma Th) and commercial isolate of *T. harzianum* (NCC 57 Th) found to be inhibiting the radial growth of *S. rolfsii* at different concentrations. With increase in concentration of CAN there was corresponding decrease in the radial growth of the pathogen was observed indicating the efficacy of CAN against *S.rolfsii.* A clear narrow zone of inhibition was observed between pathogen and antagonistic isolate in respect of

BCL Tv, DOR 1 Tv, NCC-58 Tv, Sun Agro Derma Th and DOR 2 Th, whereas, the pathogen *S. rolfsii* overgrew the antagonistic fungus in case of vermigreen Th (Plate 112).

Diammonium Phosphate (DAP)

It is obvious from the Table 63 that out of eight *Trichoderma* spp. tested against *S. rolfsii* in DAP amended medium, all of them significantly inhibited the radial growth of test pathogen. The range of inhibition of the pathogen with all the isolates of *Trichoderma* spp. was between 8.75 and 61.74 in DAP amended medium at all concentrations. The commercial isolate of *T. harzianum* (Vermigreen Th) was least effective in inhibiting the growth of the pathogen with 8.75, 10.25, 15.96 and 21.39 per cent growth inhibition in DAP amended medium at 100, 500, 1000 and 2000 ppm concentrations respectively (Table 63). Of the eight antagonistic isolates tested against *S. rolfsii*, commercial isolate of *T. viride* (Sun Agro Derma Th) was found to be superior in inhibiting the radial growth of the pathogen compared to all other isolates in DAP amended medium at all concentrations.

A narrow zone of inhibition was observed between the pathogen and biocontrol agent in respect of BCL Tv, DOR 1 Tv, NCC-58 Tv, DOR 2 Th and NCC-57 Th, whereas the pathogen overgrew the biocontrol agent in case of Vermigreen Th at 100, 500 and 1000 pm concentrations of DAP (Plate 115).

Single Superphosphate (SSP)

Significant differences in the radial growth of the pathogen *S. rolfsi* were observed with all the isolates of *Trichoderma* spp. and at all the concentrations of the SSP tested (Table 64). The commercial isolate of *T. harzianum* (Sun Agro

Derma Th) significantly inhibited the radial growth of *S. rolfsii* compared to all other isolates. Sun Agro Derma Th inhibited the radial growth of *S. rolfsii* to an extent of 69.17, 62.23 and 67.23 per cent in SSP amended medium at 100, 500, 1000 and 2000 ppm concentrations respectively. The commercial isolate of *T. harzianum* (Vermigreen Th) found to be least effective in inhibiting the growth of the test pathogen in SSP amended medium at all the concentrations tested.

A narrow clear zone of inhibition was found between the test pathogen and biocontrol agent in respect of BCL Tv, DOR 1 Tv, Sun Agro Derma Th, DOR 2 Th and NCC-57 Th. Whereas the pathogen *S. rolfsii* overgrew the antagonistic isolate Vermigreen Th in SSP amended medium at all concentrations tested (Plate 118).

Muriate of Potash (MOP)

In MOP amended medium significant differences were observed in radial growth of the pathogen, *S. rolfsii* with all the isolates of *Trichoderma* spp. at 100, 500, 1000 and 2000 ppm concentrations (Table 65). Maximum per cent growth inhibition of the pathogen was recorded with commercial isolate of *T. viride* (NCC-58 Tv) at 100, 500, 1000 and 2000 ppm concentrations compared to all other isolates. While, least inhibition of the pathogen was recorded with commercial isolate of *T. harzianum* (Vermigreen Th) which inhibited the pathogen to an extent of 33 per cent at 2000 ppm concentration ppm concentrations (Table 65 and Plate 121).

A clear zone of inhibition was observed between the test pathogen and biocontrol isolate in respect of BCL Tv, DOR 1 Tv, Sun Agro Derma Tv, NCC-58 Tv, Suin Agro Derma Th, DOR 2 Th. The pathogen overgrew the vermigreen Th

in MOP amended medium at 100, 500, 1000 and 2000 ppm concentrations (Plate 121).

4.7.1.4 Combined effect of herbicides and biocontrol agents against test pathogen *in vitro*

P. aphanidermatum

Pendimethalin

Significant differences in the radial growth of pathogen in pendimethalin amended medium were observed with all the isolates of *Trichoderma* spp. at all concentrations of the weedicide tested. Per cent growth inhibition was ranged between 65.34 and 89.50 at 100 ppm concentration and at 500 ppm the inhibition of the pathogen ranged between 65.34 and 88.51 per cent, while the per cent growth inhibition of the pathogen ranged between 51.69 and 80.39 at 100 ppm concentration and between 57.59 and 78.65 at 2000 ppm concentration irrespective of the *Trichoderma* isolates tested (Table 66). Among the eight isolates of *Trichoderma* spp. tested for their efficacy in combination with the pendimethalin, the commercial isolate of *T. viride* (BCL Tv) was found to be superior in inhibiting the growth of *P. aphanidermatum* at 100 ppm concentrations.

It is interesting to note that the combined efficacy of pendimethalin with *Trichoderma* spp. was found to be highly effective in inhibiting the test pathogen at low concentrations viz., 100 and 500 compared to higher concentrations (1000 and 2000 ppm). At 2000 ppm concentration pendimethalin was inhibitory to the growth of the test pathogen and various isolates of *Trichoderma* spp. (Table 66 and Plate 122). Further, the radial growth of *P. aphanidermatum* decreased in all the combinations of fungal isolate in pendimethalin amended medium at 1000 and 2000

ppm concentrations indicating decreased antagonistic potential of the fungal biocontrol agents studied.

Fluchloralin

Significant differences in the radial growth of pathogen in fluchloralin amended medium were observed with all the isolates of *Trichoderma* spp. at all the concentrations of the herbicides tested. Per cent growth inihibition was ranged between 70.29 and 72.23 at 100 ppm concentration and at 500 ppm the inhibition of the pathogen ranged between 73.23 and 74.60. While the per cent growth inihibition of the pathogen ranged between 77.02 and 80.30 at 1000 ppm concentration. And between 79.16 and 85.96 at 2000 ppm concentration irrespective of the *Trichoderma* isolates tested (Table 67). Among the eight isolates of *Trichoderma* spp. tested for their efficacy in combination with fluchloralin, the native isolate of *T. viride* (DOR-1 Tv) was found to be superior inhibiting the radial growth of *P. aphanidermatum* at 100 ppm concentration.

M. phaseolina

Pendimethalin

In pendimethalin amended medium, of the eight isolates of *Trichoderma* spp. tested for their efficacy against *M. phaseolina*, the commercial isolate of *T. harzianum* (Sun Agro Derma Th) significantly inhibited the radial growth of the pathogen compared to all other *Trichoderma* isolates at 100 ppm concentration. With the increase in concentration of pendimethalin, there was an increase in growth of the test pathogen was observed with all the isolates of *Trichoderma* spp. at 500 and 1000 ppm concentrations. With further increase in

concentration of pendimethalin (2000 ppm) there was decrease in growth of the test pathogen and all the antagonistic fungal isolates tested (Table 68and Plate 123).

Fluchloralin

In fluchloralin amended medium, of the eight isolates of *Trichoderma* spp. tested for their efficacy against *M. phaseolina*, the commercial isolates of *T. viride* (Sun Agro Derma Tv) significantly inihibited the radial growth of the pathogen compared to all other *Trichoderma* isolates at 100 ppm concentrations. With the increase in concentration of fluchloralin, there was decrease in the growth of the test pathogen was observed with all the isolates of *Trichoderma* spp. At higher concentration of fluchloralin (2000 ppm) there was decrease in growth of the test pathogen and all the antagonistic fungal isolates tested (Table 69).

S. rolfsii

Pendimethalin

Significant differences in radial growth of the pathogen *S. rolfsii* were found in pendimethalin amended medium with all the test isolates of *Trichoderma* spp. At lower concentrations (100, 500 ppm) of pendimethalin the growth of all test isolates of *Trichoderma* spp. was faster than the test pathogen. However, at higher concentrations (1000, 2000ppm) the weedicide pendimethalin was inhibitory to the growth of test pathogen as well as to the test isolates of *Trichoderma* spp. (Plate 124). The per cent growth inhibition of the test pathogen at higher concentrations of pendimethalin is due to the effect of the chemical rather than due to antagonistic fungal isolates (Table 70).

CHAPTER – V

DISCUSSION

Biological control of plant pathogens by the addition of antagonistic microorganisms to the soil or seed or both, has become a powerful tool in recent years because of fast development resistance in fungal pathogens against site specific fungicides and advancement in fermentation and genetic manipulation technologies. Soil borne plant pathogens are very difficult to control by using any single method of control. Therefore, Integrated Disease Management (IDM) is an acceptable approach in control of the diseases caused by various soil borne plant pathogens and as biological control has became one of the important components in IDM. It is inevitable that biocontrol agents are often applied along with fungicides, insecticides, weedicides and fertilizers either to seed or soil or both which may result in either in synergism or antagonism between them. As most of the commonly used agrochemicals exert either positive, negative or neutral effects on biocontrol agents, the present studies on compatibility of biocontrol agents with various agrochemicals and the combined effect of biocontrol agents with compatible agrochemicals were taken up and results obtained in the investigation are discussed in detail in this chapter under the following sections.

5.1 ISOLATION AND IDENTIFICATION OF PATHOGENS

5.1.1 *P. aphanidermatum*

The fungus associated with the damping-off disease could be easily isolated from the infected mustard seedlings in the present study. The fungus was isolated by single hyphal tip method and the pure culture of the pathogen maintained

on PDA medium. The growth of the fungus was on PDA was dull white and the mycelium was irregularly branched, aseptate, the sporangia were lobulate.

Morphology of the pathogen observed was in accordance with the description given by Edson (Fitz) Patrick (1923) for *P. aphanidermatum*.

5.1.2 *M. phaseolina*

The fungus associated with the root rot disease in castor could be utilized by plating root and stem bits consisting of sclerotia on PDA medium. The fungus was further purified by mono hyphal tip method and pure culture of the fungus was maintained on PDA medium. At first the fungus produced spherical, hyaline colonies on the medium which later turned carbonaceous black, with concentric zonations covering entire petriplate within four days of incubation. The fungus produced fewer sclerotia on edges of colonies and after four days later numerous sclerotia developed on the entire colony. The mycelium was septate, the sclerotia were black and smooth varied from spherical to irregular in shape. The morphology and cultural characters of the pathogen observed were in accordance with the descriptions given by Holliday and Punithalingam (1970), Sarwar (1974), Maiti and Raoof (1984), Moses and Ranga Reddy (1987) and Kanakamahalaxmi (1995) for castor isolate of *M. phaseolina*. Similar observations of the fungus also recorded by Phillip *et al*. (1969), Jain *et al*. (1973), Gupta and Kolte (1982), Singh and Singh (1982), Sharma *et al*. (1987), Hooda and Grover (1988), Basu Chaudary and Pal (1982), Verma *et al*. (1992), Muthukrishnan *et al*. (1995), Rajeswari (1997), Chandrasekhar *et al*. (2000), Humayun (2001), Mallaiah (2002), Padmalatha (2002) and Durai (2004) irrespective of the host from which *M. phaseolina* was isolated.

5.1.3 *S. rolfsii*

The fungus could be isolated easily from infected sunflower plants (cv. Morden) showing collar rot symptoms. The fungus was further purified by hyphal tip method and pure culture of the fungus was maintained on PDA medium. Similarly, several workers maintained the pure culture of *S. rolfsii* on PDA medium irrespective of the host from which the pathogen was isolated (Ramakrishnan and Damodaran, 1955; Amin, 1976; Kamal and Singh, 1976; Bhargava and Shukla, 1979; Bandara, 1980; Das *et al*., 1987; Srivastava *et al*., 1987; Anitha Chowdary, 1997; Harinarayana, 1999 and Biswas and Sen, 2000; Arunasri 2003; Rajani, 2003). In early stages of growth, the fungus was silky white and later it becomes dull white. Mycelium was radiating with aerial thin walled septate hyphae. Sclerotia developed seven days after incubation which were round, oval in shape and hard and brown in colour, the mature sclerotia resembled mustard seed. The morphology of the pathogen was similar to those recorded by Taubenhaus (1919), Ramakrishnan (1930), Subramanian (1964), Barnett and Hunter (1972), Mahmood *et al*. (1976), Singh (1987), Mirza and Aslam (19930, Harinath Naidu (2000), Mohan *et al*. (2000) and Rajyalakshmi (2002), irrespective of the host from which *S. rolfsii* was isolated.

5.2 PATHOGENICITY TEST

Pathogenicity was established by inoculation and reisolation of the pathogen from infected plants. Soil inoculation method was followed to prove the pathogenicity of the three test pathogens. Soil inoculation of *P. aphanidermatum*, was also proved to be best in inducing the disease (Vijayakrishna Kumar, 1997; Haritha, 2002). Similarly, soil inoculation of *M. phaseolina* was also followed by Vidyasekharan and Arjunan (1978) in mung bean, Amar Singh and Bhowmik (1979)

in sunflower, Goswami and Dutta (1981) in sunflower, Grover and Sakhuja (1981) and Hooda and Grover (1983) in mungbean to prove the pathogenicity. Among the five inoculation techniques followed to prove the pathogenicity of *S. rolfsii* in sunflower, Chakravarthy and Bhowmik (1983) reported that soil inoculation method was the best in inducing the disease (94.2%). Soil inoculation of *S. rolfsii* was also proved to be the best in inducing the disease by Mishra and Bais (1987) in barley, Muthamilan and Jeyarajan (1992) in groundnut, Anahosur (2001) in brinjal and potato.

5.3 GROWTH AND MORPHOLOGICAL CHARACTERS OF BIOCONTROL AGENTS

5.3.1 Isolates of *Trichoderma viride* Pers

Like the earlier findings of Barnet and Hunter (1972), Anitha Chowdary (1997), Rajeswari (1997), Harinarayana (1999), Chowdhary and Prathibha Sharma (2002), all the isolates of *T. viride* used in the present study produced white cottony colonies on PDA medium, which gradually changed bluish to green in colour. Phialospores were hyaline, catenulate and subglobose with spiny surface.

5.3.2 Isolates of *T. harzianum* Rifai

All the isolates of *T. harzianum* used in present study produced white cottony colonies initially, which later turned to light yellowish green in colour on PDA medium. Similar observations on morphology of native and commercial isolates of *T. harzianum* were also recorded by Prathibha Sharma and Singh (2001).

5.3.3 Isolates of *P. fluorescens*

The two commercial isolates of *P. fluorescens* used in present study produced dull white colonies which later turned to creamy white on King's "B" agar medium and the isolates exhibited fluorescens under UV light. Similar observations were also reported by Rangeswaran and Prasad (2000); Holt *et al*. (2000) in respect of various isolates of *P. fluorescens* irrespective of their source of isolation.

5.4 *IN VITRO* EFFICACY OF COMMERCIAL AND NATIVE ISOLATES OF BIOCONTROL AGENTS AGAINST SOIL BORNE PLANT PATHOGENS

5.4.1 Effect of biocontrol agents on the growth of *P. aphanidermatum*

In vitro evaluation of fungal and bacterial antagonists against *P. aphanidermatum* revealed that the species of *Trichoderma* and *Pseudomonas* inhibited the growth of test pathogen, *P. aphanidermatum* (Table 3, Plates 27 and 28). The commercial isolate of *T. viride* (NCC-58 Tv) exhibited maximum antagonistic activity against the pathogen followed by native isolate of *T. harzianum* (DOR 2 Th). Among the fungal isolates, minimum inhibition of the pathogen was by the commercial isolate of *T. harzianum* (Vermigreen Th). Two commercial isolates of *Pseudomonas fluorescens* (Sun Agro Monas *P. fluorescens* and Vermigreen *P. fluorescens*) exhibited the least inhibition of the *P. aphanidermatum* compared to the fungal antagonists tested (Table 3, Plates 33 and 34) Sanjay Arya and Kaushik (2001) studied efficacy of *Trichoderma* spp. and *Gliocladium virens* against the forest nursery tree damping off fungi *viz., Fusarium oxysporum, P.aphanidermatum, Rhizoctonia solani,* in *in vitro* and reported that *T. viride* caused maximum inhibition of *P. aphanidermatum* followed by *G.virens, T. harzianum, T.*

hamatum and T. longibrachiatum. Vijaya Krishna Kumar (1997) also reported the superiority native isolate of *T. harzianum* as a potential antagonist against *P. aphanidermatum* compared with other exotic isolates of *T. harzianum* and *T. viride* and *G. virens*.

In the present study, a clear zone of inhibition between the antagonist and test pathogen *P. aphanidermatum* was noticed with the both commercial and native isolates of *Trichoderma* spp., (BCL Tv, NCC-58 Tv, Sun Agro Derma Th, DOR 1 Tv and DOR 2 Th), and this could be attributed to the fact that the antagonist might had released antibiotics which were inhibitory to the growth of *P. aphanidermatum*. A similar observation was made by Devaki *et al.* (1992) and Deepak Kumar and Dubey (2001), who reported that the volatile and non-volatile metabolites produced by *T. harzianum* were both fungistatic and fungicidal to the *P. aphanidermatum*. Some of the commercial isolates of *Trichoderma* spp. (NCC-57 Th and Vermigreen Th) overgrew the pathogen which was suggested as a mechanism of biocontrol by *Trichoderma* spp. by many workers. Antibiosis, lysis, competition and mycoparasitism were suggested as mechanisms of biocontrol by *Trichoderma* spp.

In the present study, two types of mechanisms viz., competition and antibiosis were observed with *P. aphanidermatum*, which are in agreement with the works of Fajola and Alasoudura (1975); Papavizas and Lumsden (1980); Bell *et al*. (1982); Chet *et al*. (1981); Elad *et al*. (1982a); Lifshitz *et al*. (1984a); Mukhopadyay *et al*. (1986); Mukerjee *et al*. (1989); Sawant and Mukhopadyay (1990); Vijaya Krishna Kumar (1997); Haritha (2002) and Prathibha Sharma and Prem Dureja (2004).

In the present study, the low biocontrol activity of two isolates of *P. fluorescens* may be attributed to the non-production of antibiotics, siderophores, ammonia, cyanide and hydrolytic enzymes (Baker, 1987). Antibiotics like phenazine-1-carboxylic acid, pyoluteorin and the acetyl-phloroglucinols produced by strains of *P. fluorescens* were the main causes of antagonistic activity of bacteria as reported by Singh and Reddy (1979); Howel and Stipanovic (1980); Hadar *et al*. (1983); Nelson *et al*. (1984); Weller and Graham (1984); Charmswamy and Cook (1985); Elad and Chet (1987); Homma (1991); Vincent *et al*. (1991) and Thomashou *et al*. (1991).

5.4.2 Effect of biocontrol agents on the growth of *M. phaseolina*

The antagonistic ability of ten bioagents were tested against *M. phaseolina*. Of these, commercial isolate of *T. viride* (BCL Tv) was found to be effective in arresting the mycelial growth of *M. phaseolina* (Table 4 and Plates 29 and 30). Hyperparasitism between bioagents and *M. phaseolina* has been reported by several workers while working with various isolates of *T. viride*. Hyper-parasitism potential within *Trichoderma* spp. has already been established and documented by Dennis and Webster (1971b); Vasudeva and Sikka (1941); Elad *et al*. (1986); Ikotun and Adenkunles (1990); Bikkar Singh *et al*. (1991); Deshmukh and Raut (1992); Ram Singh *et al*. (1993); Rukmani and Mariappan (1994); Mahabeer Singh and Majumdar (1995); Alice (1996); Majumdar *et al*. (1996); Rajendran and Ranganathan (1996) and Indra and Thirubhuvanamala (2002). Whereas, the efficacy of *T. harzianum* against *M. phaseolina* isolates of various host plants has also been reported by Elad *et al*. (1986); Parakhia and Vaishnav (1986); Dubey and Dwivedi (1988); Majumdar (1986); Ikotun and Adenkunle (1990); Angappan (1992); Ram Singh *et al*. (1993); Sankar (1994); Srivastava *et al*. (1996);

Selvarajan and Jeyarajan (1996); Calistru *et al*. (1997); Rajeswari *et al*. (1998); Kanakamahalaxmi *et al*. (1998); Biswas and Sen (2000); Kajal Kumar and Chitreswaran (2000); Humayun (2001); Padmalatha (2002); Sindhan *et al*. (2002) and Durai (2004) in dual culture technique. In the present study, inhibition zones were observed between the isolates of *Trichoderma* spp. and the pathogen after 5 days of incubation in dual culture plates (Plates 29 and 30). Among them, the commercial isolate of *T. viride* (NCC-58 Tv) exhibited a clear zone of inhibition compared to other antagonistic isolates. Campbell (1989), Indra and Thirubhuvanamala (2002) opined that such an inhibition zone could be taken as a clue for production of antibiotics and there by useful for screening and selecting antagonists. Similarly, zone of inhibition was also observed by Selvarajan and Jeyarajan (1996) between *G. virens* and *M. phaseolina*. Some of the antagonistic isolates of *Trichoderma* spp. viz., native commercial isolates of *T. harzianum* (DOR 2 Th, Sun Agro Derma Th, NCC-57 Th and Vermigreen Th) overgrew the pathogen. Patel and Anahosur (2001) also showed that *M. phaseolina* grew normally towards the antagonist until it made contact without showing apparent inhibition zone and on contact, *T. harzianum* overgrew and suppressed the growth of the pathogen, which showed its mycoparasitic property.

The two isolates of bacterial biocontrol agents were least effective against the test pathogen and degree of inhibition was less as compared to fungal biocontrol isolates (Table 4 and Plates 35 and 36). This may be attributed to the fact that *P. fluorescens* isolates might have produced less amount of antibiotics in the medium. Similar reports were also given by Paramjit Singh and Mehrotra (1980); Ray *et al*. (1990); Dilip Kumar and Dubey (1992); Muthamilan (1994); Sanhez *et al*. (1994); Jayasree *et al*. (2000) and Durai (2004), while working with various isolates

of *P. fluorescens*. The differences found in the efficacy of the various isolates of *Trichoderma* spp. may be due to their genetic makeup and as these were isolated from different ecological regions.

5.4.3 Effect of biocontrol agents on the growth of *S. rolfsii*

The efficacy of the fungal antagonists, the commercial isolate of *T. harzianum* (NCC-57 Th) was found to be superior in inhibiting the mycelial growth under *in vitro* conditions compared to the commercial isolate of *T. harzianum* (Vermigreen Th) and the two commercial isolates of *P. fluorescens*. In the present study, a clear zone of inhibition was observed with all the isolates tested against *S. rolfsii* (Plates 31 and 32). Similar observations were made with various isolates of *T. viride* by Rajendra *et al*. (1998) and *T. harzianum* by Anitha *et al*. (2000). The supremacy of the fungal biocontrol agents may be effective due to the production of fungistatic substances. These results are an agreement with several works related to biological control of soil borne plant pathogens demonstrated all over the world [Mathur and Sarbhoy (1978); Agarwal *et al*. (1978); Elad *et al*. (1981); Elad *et al*. (1983); Upadyay and Mukhopadyay (1986); Davet (1987); Sundheim and Tronsmo (1988); Zeppa *et al*. (1990); Kwee and Keng (1990); Montealegre and Henriquez (1990); Roy (1991); Dickman and Mitra (1992); Kulkarni (1992); Amar Singh and Dhanbir Singh (1994); Bhuyan *et al*. (1994); Mannina *et al*. (1997); Dickman and Chet (1998); Biswas *et al*. (2000); Kajal Kumar and Chitreswar Sen (2000); Sathri Saralamma (2000); Rajeev and Mukhopadyay (2001); Rajyalakshmi (2002) and Rajani *et al*. (2004)].

The degree of inhibition of the pathogen by the two isolates of *P. fluorescens* was less as compared to different isolates of antagonistic

Trichoderma spp. except of commercial isolates of *T. harzianum* (Vermigreen Th). Differences in the antagonistic potential of various isolates of *P. fluorescens* against *S. rolfsii* were also reported and well documented by Ganeshan and Scher (1985), Gnanamanickam (1987); Weller (1988); Elangovan and Gnanamanickam (1992); Laha *et al*. (1992); Vidyasekaran and Muthamilan (1995); Laha *et al*. (1996); Rabindran and Vidyasekharan (1996); Vidyasekharan *et al*. (1997); Harinarayana (1999); Thirubhuvanamala *et al*. (1999); Dube (2001) and Umamaheswari *et al*. (2002).

In the present study, different isolates of *Trichoderma* spp. showed differential antagonistic potentiality against *S. rolfsii* (Table 5, Plates 31 and 32). This type of variation in hyper parasitic potential within the different isolates of *Trichoderma* spp. has already been well established and documented by Morton and Stroube (1955); Dennis and Webster (1971); Elad *et al*. (1980) and Almedia and Landin (1981).

5.5 SENSITIVITY OF BIOCONTROL AGENTS AGAINST AGROCEMICALS

5.5.1 Sensitivity of fungal antagonists against agrochemicals

5.5.1.1 Sensitivity of fungal antagonists against fungicides

Of the four fungicides tested, carbendazim (Bavistin) and hexaconazole (Contaf) completely inhibited the growth of the various isolates of *T. viride* and *T. harzianum*. However, copper oxychloride (Blitox) and mancozeb (Dithane M-45) had no inhibitory effect on these fungal antagonists tested at 100 ppm concentration. With the increase in concentration of either of the

fungicides a decrease in growth of fungal antagonists was observed (Tables 5 to 9 and Plates 39 to 42).

Of the eight isolates of *Trichoderma* spp. tested, commercial isolate of *T. viride* (NCC-58 Tv) was least sensitive to copper oxychloride at all the concentrations tested. Whereas, these fungicides had no inhibitory effect on isolates of *P. fluorescens* at 100 ppm concentration and slightly incompatible with test fungicides at higher concentrations (Tables 19 and 20).

Singh *et al*. (1995) also reported that the growth of the isolates of *T. viride* was not inhibited at 500 ppm concentration with captafol and mancozeb. Ramarethinam *et al*. (2001) reported that the fungicides like carbendazim (50% WP), hexaconazole (5% EC) completely inhibited the growth of *T. viride* even at 100 ppm concentration *in vitro*. Desai *et al*. (2002) also reported that mancozeb at 500 ppm recorded a lower inhibition of hyphae (5.70%) and sporulation (11.02%) of *T. harzianum*. Whereas, Haritha (2003) and Narayana Bhat and Srivastava (2003) reported that mancozeb and COC inhibited the radial growth of *Trichoderma* spp. by 76.66 and 44.44% at 1000 ppm and complete inhibition of growth at 100 ppm concentration of hexaconazole. The results are also in agreement with the works of Mukhopadyay *et al*. (1986); Sawant and Mukhopadyay (1990); Sharma and Mishra (1995); Rajan and Sharma (1996); Karpagavlli (1997); Abha Agarwal and Tripathi (1994); Gupta *et al*. (1999); Sharma *et al*. (1999); Whipps *et al*. (2001); Budge and Whipps (2001); Sharma *et al*. (2001); Karpagavalli and Ramabhadram (2001); Deepak Kumar and Dubey (2001); Anitha *et al*. (2001); Bhat and Sabalpara (2001); Sitansu *et al*. (2001); McLean *et al*. (2001); Batista *et al*. (2002); Srinivasulu *et al*. (2002); Durai (2004); Desai *et al*. (2004); Prathibha Sharma and Prem Dureja (2004) who also found good growth of *Trichoderma* isolates at low and medium

concentrations of various fungicides. The differential response of various isolates of *Trichoderma* spp. and *P. fluorescens* to various fungicides in the present study might be due to their inherent resistance to the fungicides and their ability to degrade these chemicals.

5.5.1.2 Sensitivity of fungal biocontrol agents against insecticides

In the present study, an attempt was made to evaluate the compatibility of both native and commercial isolates of *Trichoderma* spp. with three insecticides (imidacloprid, chlorpyriphos and carbosulfan) at four concentrations (100, 500, 1000 and 2000 ppm). Of these, imidacloprid at all the concentrations was compatible with all the fungal antagonistic isolates as luxuriant growth of these was observed (Plates 43, 44 and 45) which was similar to that of control in all aspects. The results clearly indicated the compatibility between potential *Trichoderma* isolates and the insecticide (imidacloprid) and also the mycotonic effect of the insecticide. Tiwari *et al.* (2004) studied non target effect of insecticide on mycelial growth of *T. harzianum* and reported that chlorpyriphos and carbosulfan was highly inhibitory to the growth of *T. harzianum* while imidacloprid was found to be highly compatible at 500 and 1000 ppm concentrations. Chlorpyriphos and carbosulfan insecticides inhibited the growth of *Trichoderma* isolates at higher concentrations indicating the sensitivity of the antagonistic mycoflora against test insecticides. The per cent growth inhibition of these isolates ranged between 0 to 56.86 in different test concentrations of chlorpyriphos, while, the per cent growth inhibition of various *Trichoderma* isolates ranged between 5.62 to 56.61 with carbosulfan. On the contrary, cent per cent inhibition of native isolate of *T. harzianum* was reported by Desai and Kulkarni (2004) by chlorpyriphos at 500, 1000 and 2000 ppm concentrations and Desai and Kulkarni (2002) also reported cent per cent inhibition

of native isolate of *T. viride* by chlorpyriphos at 500, 1000 and 2000 ppm concentrations. Kumar (1998) reported that there was significant reduction in the radial growth and sporulation of *T. viride* when tested at 7000 ppm of imidacloprid. The differential sensitivity of the various isolates of *Trichoderma* spp. under study may be due to the species and isolates specificity and the source of origin. Martinez and Toledo *et al*. (1992) also reported cent per cent inhibition of both hyphae and sporulation of native isolate of *T. viride* with chlorpyriphos in addition to methyl pyrinofos. Similar results were also obtained by Bhat and Sabalpara, (2001); Prasanna *et al*., (2002); Desai *et al*. (2002 and 2004).

5.5.1.3 Sensitivity of fungal biocontrol agents against fertilizers

All the fertilizers (calcium ammonium nitrate, diammonium phosphate, single superphosphate and muriate of potash) tested have supported good growth and development of all the isolates of *Trichoderma* spp. at all the concentrations (Plates 46 to 50). The insensitivity of these isolates against the fertilizers under laboratory conditions reveals that the species of *Trichoderma* might have utilized these fertilizers as a food base and multiplied rapidly on the medium containing these fertilizers. As these fertilizers are rich sources of Ca, Mg, Mn and others which might have helped the good growth of *Trichoderma* isolates. Compatibility of various isolates of *Trichoderma* spp. with fertilizers was also reported by Desai *et al*. (2002) and Desai and Srikant Kulkarni (2002).

5.5.1.4 Sensitivity of fungal biocontrol agents against herbicides

In the present investigation of the two herbicides tested fluchloralin was found to be relatively more toxic to all the isolates of *Trichoderma* spp. at all the concentrations (Tables 17 and 18). However, both the herbicides tested were

found to be highly toxic at higher concentration (2000 ppm). In case of commercial isolate of *T. viride* (NCC-58 Tv) more or less complete growth was obtained at lower concentrations of both the herbicides tested. From the results it can be concluded that the inhibition of growth of the antagonistic fungi found to be minimum at lower concentrations and fluchloralin was found to be more toxic than pendimethalin to the antagonistic isolates tested (Tables 17 and 18; Plates 51 and 52). Precise references regarding the tolerance of herbicides are very few. Domsch *et al*. (1980) reported that *T. harzianum* was able to grow in the presence of herbicide diallate, whereas, Sharma and Mishra (1995) observed better tolerance of a strain of *T. harzianum* to 2,4-D as compared to fluchloralin and pendimethalin. The tolerance of *Trichoderma* spp. to certain herbicides may be attributed to the gradual utilization of herbicide as carbon or nitrogen source by the biocontrol agents. This fact was supported by Domsch *et al*. (1980) who observed that a strain of *T. viride* could grow on simazine and atrazine as sole carbon source. The differential tolerance levels of the isolates of *Trichoderma* spp. studied in the present investigation may be due to the presence or absence of enzyme system to disintegrate the toxic residues to basic non-toxic moeties. From the results it can be concluded that those highly toxic and inhibitory herbicides may be avoided while using *Trichoderma*. However, the less inhibitory herbicides may be used in combination where *Trichoderma* used as a biocontrol agent. Jayaraj and Radhakrishnan (2000) studied tolerance of *T. harzianum* to certain herbicides *in vitro* and in soil and reported that the herbicide alachlor was found to be relatively less toxic at lower concentrations compared to pendimethalin, butachlor, oxyfluorfen and 2,4-D *in vitro* conditions. Whereas, pendimethalin application caused maximum reduction in the growth and survival in soil when compared to alachlor. Similar

results were obtained by Jaworska *et al*. (2002), as Pendimethalin strongly inhibited the growth rate of tested fungi and *T. viride* was more sensitive to herbicides than *T. harzianum*.

5.5.2 Sensitivity of bacterial antagonists against agrochemicals

5.5.2.1 Sensitivity of bacterial antagonists against fungicides

The two commercial isolates of *P. fluorescens* tested were highly compatible with all the fungicides (COC, mancozeb, carbendazim and hexaconazole) tested at lower concentration (100 ppm) and was slightly incompatible with these fungicides at higher concentrations (500, 1000 and 2000 ppm) (Tables 19 and 20). Of the two isolates of *P. fluorescens* tested for their sensitivity against fungicides, the commercial formulation of *P. fluorescens* (Sun Agro Monus Pf) was found to be highly compatible. Whereas, carbendazim was found to be highly inhibitory to the commercial isolate of *P. fluorescens* (Vermigreen Pf). Among all the fungicides tested mancozeb was found to be less toxic and compatible with *P. flourescens* isolates as it inhibited bacterial growth by minimum. The results are in agreement with Fernando and Linderman (1994) who reported that mancozeb (as Manzate-200) could be applied at low concentration in combination with bacterial biocontrol agents to control root rot of cowpea caused by *Phytophthora vignae* under *in vitro* conditions. Parakhia *et al*. (1998) also found that mancozeb (3 g/kg of seed) was compatible with bacterial antagonists including *P. fluorescens* for the control of collar rot of groundnut caused by *Aspergillus niger*.

Thiram was found to be compatible with *P. fluorescens* under *in vitro* conditions (Vyas, 1987; Vidyasekaran and Mithamilan, 1995). Whereas, Harinarayana (1999) also found that hexaconazole at 0.1% concentration inhibited *P. fluorescens* by 9.62 and chlorpyriphos by 7.77 per cent.

Arunasri (2003) reported that at lower concentrations of 50 and 100 ppm all the fungicides were found to be compatible with *Pseudomonas* sp. as there was no growth inhibition at these concentrations. Malathi *et al*. (2002) studied the effect of carbendazim and thiophanate-methyl on the growth of *P. fluorescens*, and reported that carbendazim and thiophanate-methyl at 100 ppm enhanced the growth of *P. fluorescens* isolates. The antagonistic bacteria multiplied even when the fungicide rate increased to 500 ppm.

Durai (2004) reported that thiram at 1000 ppm shown the highest inhibition (4.7%) of *P. flourescens*. Mancozeb was found to be compatible with *P. fluorescens* (B1) even at 50 ppm concentration as the growth inhibition was nil. The inhibition was only 0.7 per cent even at 1000 ppm concentration. The differences in the sensitivity of the two test isolates of *P. fluorescens* against the test fungicides may be attributed to their ability to detoxify or disintegrate the toxicants.

5.5.2.2 Sensitivity of bacterial antagonists against insecticides

In the present study, the two bacterial antagonists studied differed in their sensitivity against the test insecticides (carbosulfan, imidacloprid and chlorpyriphos) (Tables 21 and 22). Of these, carbosulfan was found to be less toxic even at higher concentration of 2000 ppm to the commercial isolate of *P. fluorescens* (Sun Agro Monus Pf), whereas, imidacloprid was least inhibitory to the growth of commercial isolate *P. fluorescens* (Vermigreen Pf). However, the insecticide chlorpyriphos found to be highly toxic to both the bacterial antagonists at higher concentrations. The relative tolerance to test insecticides by bacterial antagonists may be due to their isolate specificity.

5.5.2.3 Sensitivity of bacterial antagonists against fertilizers

Of the four fertilizers tested, none of them were inhibitory to the growth of test two commercial bacterial isolates (Sun Agro Monus Pf and Vermigereen Pf) at all the concentrations (Tables 23 and 24). The insensitivity of both the isolates of *P. fluorescens* against the test fertilizers may be due to utilization of the fertilizers as food as these fertilizers contain carbon, nitrogen and other nutrients.

5.5.2.4 Sensitivity of bacterial antagonists against herbicides

The insensitivity of two bacterial antagonists against two herbicides (pendimethalin and fluchloralin) was observed at lower concentrations. The increase in sensitivity of both the isolates of *P. fluorescens* against the test herbicides due to toxic effect with increase in concentration (Tables 25 and 26). However, further studies are required.

5.6 EFFICACY OF AGROCHEMICALS AGAINST TEST PATHOGENS

5.6.1 *In vitro* efficacy of fungicides against test pathogens

5.6.1.1 *In vitro* efficacy of fungicides against *P. aphanidermatum*

Of the four fungicides tested, COC was highly inhibitory (68 to 100%) against *P. aphanidermatum* at various concentrations. While, cent per cent growth inhibition of the test pathogen was observed with hexaconazole and mancozeb at 1000 and 2000 ppm concentrations carbendazim showed comparatively low rate of inhibition of the test pathogen (Table 27). Similarly, Narayana Bhat and Srivastava (2003) reported complete inhibition of *P. aphanidermatum* by COC at

500 and 1000 ppm concentrations. While, Haritha *et al*. (2003) reported complete inhibition of *P. aphanidermatum* from 250 ppm concentration by COC. The inhibitory (88.9 to 95.2%) nature of a triazole fungicide hexaconazole was also reported by Narayana Bhat and Srivastava (2003) at 250, 500 and 1000 ppm concentrations. The results are also in agreement with those reported by Narayana Bhat and Srivastava (2003) who, also reported ineffectiveness of carbendazim in inhibiting the radial growth of pathogen under *in vitro* conditions. Cent per cent inhibition by mancozeb also reported by Haritha (2003) and Narayana Bhat and Srivastava (2003) at 250, 500 and 1000 ppm concentrations. Similar observations on the efficacy of various fungicides on the growth of *P. aphanidermatum* were also made by Sahni *et al*. (1967); Sonoda (1972); Grover and Dutt (1972); Tripathi and Grover (1977); Nagarajan and Reddy (1980); Sadhu and Gill (1982); Ohep *et al*. (1984); Patel *et al*. (1988); Dharam Vir *et al*. (1989) and Gunasekharan *et al*. (1994).

5.6.1.2 *In vitro* efficacy of fungicides against *M. phaseolina*

It is obvious from the results (Table 28) that the fungicides mancozeb, carbendazim and hexaconazole were found to be completely inhibitory to the growth of*M. phaseolina* at 100, 500, 1000 and 2000 ppm concentrations. While COC was least effective in inhibiting the growth of the pathogen and per cent growth reduction was least (4.8%) even at higher concentration of COC (2000 ppm). Several workers reported efficacy of different fungicides on the growth of *M. phaseolina*. Kirkpatrick and Sinclair (1973) showed that carbendazim and thiophanate methyl were found effective at 50 ppm against soybean isolate of *M. phaseolina*. Ilyas *et al*. (1975) reported that thiophanate-methyl was more effective in inhibiting the colony diameter as well as mycelial growth of *M. phaseolina* at 50 ppm. Taneja and Grover (1982) reported the effectiveness of

carbendazim and thiophanate methyl at EC 0.01 and 5.9 μm ml^{-1} respectively against the mungbean isolate of *M. phaseolina*.

Patel and Patel (1990) obtained complete inhibition of the pathogen with benomyl (0.05%), while copper oxychloride gave minimum growth inhibition (57.70%). Peshney *et al*. (1992) observed that thiram, captan and mancozeb were effective in inhibiting the growth of *M. phaseolina* at 200 ppm. Padmalatha (2002) reported complete inhibition of fungal growth with mancozeb at 100 ppm concentration which was contrary to the complete inhibition of pathogen observed at 500 ppm. Chattopadyay and Kalpanasastry (2002) reported by *in vitro* tests that carbendazim could cause 100% inhibition of mycelial growth of *M. phaseolina* even at 25 ppm concentration. Durai (2004) observed that of the two systemic fungicides, hexaconazole was found to be highly effective as it inhibited the pathogen cent per cent at 50 ppm concentration. Among non-systemic fungicides tested, captan and mancozeb completely inhibited the growth of the pathogen at 1000 ppm and 100 ppm respectively. Similar observations on efficacy of various fungicides on the growth of *M. phaseolina* were made by Shukla and Singh (1973); Tripathi *et al*. (1977); Gupta and Bharadwaj (1980); Chattopadyay *et al*. (1981); Chauhan (1986); Jadeja and patel (1988); Patel and Patel (1990); Singh and Kaiser (1995); Rajpurohit (1997); Ebenezer and Wesley (2000) and Anitha *et al*. (2001).

5.6.1.3 *In vitro* efficacy of fungicides against *S. rolfsii*

Four fungicides were evaluated *in vitro* against *S. rolfsii* at different concentrations, the fungicides mancozeb, hexaconazole were found to be completely inhibitory to the growth of *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations. Similar results were also obtained by Narayana Bhat and Srivastava (2003) with

mancozeb and hexaconazole who reported cent per cent inhibition of *S. rolfsii* at 250, 500 and 1000 ppm concentrations. However no inhibition of growth of the pathogen was observed with carbendazim at all the concentrations tested. COC was found to be least effective against test pathogen even at higher concentration of 2000 ppm (Table 29 and Plates 55, 58, 61 and 64). On the contrary Narayana Bhat and Srivastava (2003) also reported no inhibition of *S. rolfsii* at 250 ppm concentration and 64.4 and 68 per cent inhibition at 500 and 1000 ppm concentrations of COC. Carbendazim inhibited the radial growth of *S. rolfsii* to an extent of 36.7 per cent at 1000 ppm which is contrary to our observations. Efficacy of these fungicides against *S. rolfsii* was also studied by Subramanian (1964); Srikant Kulkarni *et al*. (1986); Singh and Dwivedi (1988); Narain and Kar (1990); Kamna *et al*. (1992); Tiwari (1995); Girija Ganeshan (1997); Anitha Chowdhary (1997); Bag and Sinha (1997); Das and Panda (1997); Pushpavathi *et al*. (1998); Johnson and Subramanian (2000); Mukerjee and Tripathi (2001); Pranab Dutta and Das (2002) and Thakur *et al*. (2002).

5.6.2 *In vitro* efficacy of insecticides against test pathogens

Four insecticides viz., thiomethoxam, chlorpyriphos, imidacloprid and carbosulfan were evaluated *in vitro* against the three test pathogens. Of these chlorpyriphos found to be superior in inhibiting the growth of *P. aphanidermatum* and *S. rolfsii*. While, thiomethoxam and carbosulfan was highly inhibitory to the growth of *M. phaseolina*. The insecticide imidacloprid did not inhibit the mycelial growth of *M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations (Tables 30, 31 and 32 Plates 65 to 76).

Mukhopadhyay and Thakur (1977) evaluated the effectiveness of soil insecticides, and reported that a mixture of carbaryl and gamma-BHC and phorate, gamma-BHC and quinalphos alone at 50 and 100 ppm were more effective than the other treatments in inhibiting the fungal growth and sclerotial formation of *S. rolfsii* on PDA at 28°C.

Backman and Hammond (1981) reported that in field tests, chlorpyriphos at insecticidal rates reduced *S. rolfsii* stem rot in groundnut *in vivo*. Synergism between the active and the inert ingredients of the emulsifiable concentrate formulation suppress the fungus.

Hagan *et al*. (1989) reported that the insecticide chlorpyriphos suppressed southern stem rot caused by *S. rolfsii* on groundnut as effectively as the fungicide terrachlor. While, Kucharek and Edmondson (1991) reported that the chlorpyriphos at 500 ppm suppressed the growth of two isolates of *S. rolfsii in vitro* by 63 and 43 per cent.

Chapin and Thomas (1993) showed that chlorpyriphos (Lorsban 15G) reduced incidence of southern stem rot of groundnut caused by *S. rolfsii* along with injury caused by the insects belonging to lepidoptera.

Lal and Nagarajan (1988) studied *in vitro* evaluation of pesticides against *S. rolfsii* causing collar rot of tobacco at 125, 250, 500, 1000 ppm. Out of five insecticides, carbaryl and endosulfan at all the concentrations gave 71.48 to 100% inhibition while, diethoate @ 250 ppm, methyl demeton and monocrotophos @ 500 ppm exhibited 51.86 to100% inhibition.

Desai and Srikant Kulkarni (2002) reported the effect of urea on the growth and sporulation of *Macrophomina phaseolina*. Mycelial and sclerotial

formation inhibition of *M. phaseolina* ranged from 4.24 to 100 and 12.00 to 100 per cent. Cent per cent inhibition was recorded at 1000 ppm concentration of urea.

5.6.3 Efficacy of fertilizers against test pathogens

All the fertilizers tested were found not inhibitory to the growth of *P. aphanidermatum* and *M. phaseolina* at all the concentrations tested (Tables 33 to 36). However, CAN was found to be inhibitory to the growth of *S. rolfsii* at all the concentrations tested.

Jenkins and Averee (1986) reported that ammonia released by ammonium fertilizers may directly inhibit sclerotial germination and retard mycelial growth of *S. rolfsii*. Prasad *et al*. (1986) reported that urea completely suppressed the formation of sclerotia of *R. solani*. Fang and Liu (1998) reported significant reduction of germination and viability of sclerotia of *S. rolfsii* with nitrogenous compounds (urea, ammonium sulphate, ammonium nitrate, ammonium chloride, sodium nitrate and potassium nitrate). Brenneman *et al*. (1990) investigated that ammonium bicarbonate did effectively inhibit the formation of sclerotia of *S. rolfsii in vitro*.

Henis and Chet (1967) demonstrated loss of germinability in sclerotia of *S. rolfsii* at pH values of 9.8 or higher, either with or without ammonia. Calcium ammonium nitrate had no effect on the survival of sclerotia of *S. rolfsii* 30 days after incubation (Henis and Chet, 1968).

In the present study, the fertilizers (diammonium phosphate, single super phosphate and muriate of potash) were supportive and stimulatory to the growth of all the test pathogens *viz., P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* (Tables 33 to 36). The results also indicate, the potentiality of these

pathogens to utilize a wide sources of NPK and other micronutrients. However, the insensitivity of the test pathogens against these fertilizers (DAP, SSP and MOP) has not been reported yet. Walia *et al*. (1992) reported that the influence of nutrients on pathogenic behaviour of *Rhizoctonia solani* on cowpea. All the sources of N and P increased the seedling mortality but ammonium sulphate and calcium monophosphate had more pronounced effect. Increased pathogenesis in the presence of P may be attributed to enhanced aggressiveness of inoculum as reported by Monga and Grover (1985) in case of *Fusarium solani*.

Walia *et al*. (1992) reported that both the potassium chloride and potassium sulphate abate the disease (*R. solani*). Higher dose i.e., 60 μg k g^{-1} soil was more effective in reducing seedling mortality. Reduced seedling infection caused by *R. solani* by addition of K on medium or soil have been reported by Kataria *et al*. (1981) and Monga and Grover (1985). Potassium salts are known to lower the micro pH of the soil (Teuscher and Alder, 1960) and infection by *R. solani* is reduced at lower and higher pH. Sunder (1982) also observed increased seedling mortality of cowpea with *R. solani* on amendment of NPK to nutrient deficient soil. Amendment of soil with secondary nutrients had varied effects on pathogenic behaviour of fungus.

In the present investigation, the major and micronutrients present in CAN, DAP, SSP and MOP also influenced radial growth of the test pathogens. The lower level of all the nutrients had no effect on seedling mortality while higher dose of Ca decreased the seedling infection and those of Mg increased it (Walia *et al*., 1992).

5.6.4 Efficacy of herbicides against test pathogens

Out of the two herbicides tested fluchloralin was found to be relatively more toxic to all the test pathogens viz., *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* at 100, 500, 1000 and 2000 ppm concentrations (Tables 36 to 38 and Plates 89 to 92). However, both the herbicides were found to be highly toxic at higher concentrations. Grinstein *et al*. (1979) in groundnut; Wilfest and Weltzien (1980) in sugarbeet, Vyas *et al*. (1986) in soybean observed toxicity of pendimethalin and fluchloralin against *P. debaryanum*, *M. phaseolina* and *S. rolfsii*. References on fungistatic / fungitoxic effect of herbicides on the growth of *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* are very few. Anahosur *et al*. (1984) reported ametoyne, terbutryne, prometryne, 2,4-D and Atrazine inhibited the radial growth of the pathogen *S. rolfsii*. Parmjit Singh Bagga and Vineet kumar (2000) reported *in vitro* effect of herbicides, pendimethalin and fluchloralin amended medium, the average mycelial growth was 67.6, 71.8,53.8 and 71.3 mm recorded with the pathogens like *Fusarium nivale*, *Helminthosporium sativum, Alternaria* spp., respectively at 0.15 g / 100 ml concentration.

Bhorania *et al*. (2002) also reported that the herbicides fluchloralin and pendimethalin inhibited sclerotial germination of *S. rolfsii* and recorded 94.02 and 14.25 per cent at a concentration of 0.90 and 1 litre ha^{-1} respectively.

Jadeja (2003) evaluated nine herbicides (oxadiazon, oxyfluorfen, Alachlor, Fluazifop-p-butyl, butachlor, fluchloralin, glyphosate, pendimethalin and paraquat) against damping-off, leaf blight, stem canker, collar rot pathogen of brinjal. Maximum mean radial growth inhibition of 92.22 per cent was observed in oxadiazon followed by oxyfluorfen (88.32) and alachlor (82.59).

5.7 SYNERGISTIC EFFECT OF BIOCONTROL AGENTS AND AGROCHEMICALS AGAINST TEST PATHOGENS

5.7.1 Combined effect of agrochemicals and antagonistic fungal isolates against test pathogens

5.7.1.1 Combined effect of fungicides and fungal biocontrol agents against test pathogens *in vitro*

In the present study, it was observed that all the compatible combinations of fungicides with various potential antagonistic isolates reduced radial growth of the test pathogens. However, the combined effect of various antagonistic fungal isolates with the fungicides was observed at lower concentration (100 ppm) compared to the higher concentrations. The native isolate of *T. harzianum* (DOR 2 Th) was found superior in reducing the radial growth of *P. aphanidermatum* in COC amended medium at 100 ppm concentration. Whereas, the commercial isolate of *T. harzianum* (NCC-57 Th) and native isolate of *T. harzianum* (DOR 2 Th) was the best in inhibiting the growth of *P. aphanidermatum* in mancozeb amended medium at 100 ppm concentration compared to other treatments (Tables 39, 40 and Plates 95, 98).

The radial growth of *M. phaseolina* was least with commercial isolate of *T. harzianum* (Sun Agro Derma Th) in COC amended medium at 100 ppm concentration. While, the commercial isolate of *T. viride* (Sun Agro Derma Tv) in mancozeb amended medium was highly inhibitory to *M. phaseolina* compared to other fungal antagonistic isolates. However, with the increase in concentration of mancozeb, maximum inhibition of *M. phaseolina* was observed with all fungal antagonistic isolates combinations indicating the inhibitory effect of the fungicide

mancozeb rather than the combined effect of fungicide and biocontrol agent (Tables 41, 42 and Plates 96, 99).

The effect of integration of *Trichoderma* with chemicals was also reported by several workers (Ohr *et al*., 1973; Papavizas *et al*., 1982; Papavizas and Lewis, 1983). The control of *Armillaria mellea* (Vohl ex. Fr) Kummer with a combination of methyl bromide and *Trichoderma* was found to be a classical example of integrated pest management involving the use of a pesticide with a biocontrol agent (Papavizas *et al*., 1982). The benefit of antagonists in the suppression of disease symptoms has been widely reported (Baker and Cook, 1974; Papavizas and Lumsden, 1980). Bhaskaran and Seetharaman (1986) reported that seed treatment with *T. harzianum* effectively inhibited the growth of *M. phaseolina* in petriplates besides enhancing the germination rate in pots from 40 to 72 per cent. Ramadoss and Sivaprakasam (1986) reported effective control of *M. phaseolina* infection in cowpea with carbendazim. The effect of integration of *Trichoderma* with chemicals was also reported by several workers (Ohr *et al*., 1973; Papavizas *et al*., 1982 and Papavizas and Lewis, 1983).

Alagarsamy and Sivaprakasam (1988) reported the *in vitro* effect of antagonists in combination with carbendazim against cowpea isolate of *M. phaseolina, T. viride* reduced the growth of *M. phaseolina* in the petriplates on the 3rd, 6th days inoculation and recorded 36.9 and 76.5 per cent reduction over control.

Among the eight isolates of *Trichoderma* spp. tested for their efficacy in combination with the fungicide COC, the commercial isolate of *T. harzianum* (NCC-57 Th) was found to be superior in inhibiting the radial growth of *S. rolfsii* at

all the concentrations of COC tested. However, with increase in the concentration of the fungicide, the synergistic effect of fungicide and bioagents was not observed as the growth of various fungal antagonistic isolates was also suppressed. Compared to the other fungal antagonistic isolates, the native isolate of *T. viride* (DOR 1 Tv) performed better in inhibiting the radial growth of *S. rolfsii* in mancozeb amended medium at different concentrations tested (Tables 43, 44, Plates 97, 100).

Goudar and Srikant Kulkarni (1999) evaluated the inhibition of *Fusarium udum* by antagonists in combination with chemicals viz., carbendazim and captan on PDA plates. The treatment combination of carbendazim (@ 0.05%) + *Trichoderma viride* (4 g/kg of seeds) inhibited the pathogen to 63 per cent over other treatments.

The results clearly indicated that the synergistic effect of the fungicide and potential antagonistic isolates is more pronounced at lower concentrations compared to the higher concentrations of the fungicide. However, increased concentration of the fungicide showed adverse effect on the growth of the fungal antagonists.

5.7.1.2 Combined effect of insecticides and fungal biocontrol agents against test pathogens *in vitro*

In the present study, the commercial isolate of *T. harzianum* (Vermigreen Th) and imidacloprid and chlorpyriphos combinations was effective in inhibiting the growth of *P. aphanidermatum* at lower concentration than at higher concentration. Whereas, the commercial isolate of *T. viride* (BCL Tv) and carbosulfan combination was effective against *P. aphanidermatum* at 100 ppm concentration (Tables 45, 46, 47 and Plates 101, 104, 107).

The results revealed that imidacloprid and commercial isolate of *T. viride* (NCC-58 Tv) combination was effective in inhibiting the radial growth of *M. phaseolina* at 100, 500, 1000 and 2000 ppm concentrations compared to the other treatments. However, in chlorpyriphos and carbosulfan amended medium the commercial isolate of *T. harzianum* (Vermigreen Th) was found superior in inhibiting the growth of *M. phaseolina* compared to the other isolates of *T. harzianum* spp. at 100 ppm concentration (Tables 48, 49, 50 and Plates 102, 105, 108).

Maximum inhibition of *S. rolfsii* was recorded with the native isolate of *T. viride* (DOR 1 Tv) in imidacloprid, chlorpyriphos and carbosulfan amended medium at 100 ppm concentration. With the increase in concentration of either of the insecticides, decrease in growth of various isolates of *Trichoderma* spp. was observed indicating the fungistatic effect of these insecticides on the growth of the isolates of *Trichoderma* spp. In chlorpyriphos amended medium all the fungal antagonistic isolates significantly inhibited *S. rolfsii* at 100 ppm concentration. However, at higher concentrations of chlorpyriphos, the growth of both the pathogens and fungal antagonistic isolates was suppressed (Tables 51, 52, 63 and Plates 103, 106, 109). The results are in agreement with Kucharek and Edmondson (1991) who also reported the suppression of the growth of the two isolates of *S. rolfsii in vitro* conditions by 63 and 49 per cent with chlorpyriphos at 500 ppm concentration. The difference in antagonistic potential of various isolates of *Trichoderma* spp. might be attributed to gradual utilization of insecticides as a source of nutrition by the isolate. From the results it can be concluded that the fungal antagonistic isolates under study were highly competitive compared to the pathogen in utilizing the insecticide as food for their growth and development. It is

interesting to note that although all the test pathogens under study were not inhibited by any of the test insecticides, the combination of the insecticides with the potential fungal antagonistic isolates, inhibited growth of the pathogens indicating the synergistic effect of biocontrol agent and insecticide combination. The results also indicate the high competitive nature of the fungal antagonistic isolates and their ability to disintegrate and detoxify the insecticides more efficiently than the pathogens. Kumar (1998) reported that the imidacloprid and *Trichoderma* combination was effective against *M. phaseolina* a root rot causing pathogen in cotton.

Prasanna *et al*. (2002) investigated the effect of thiomethoxam 70 WS and *T. harzianum* on *Rhizoctonia solani* in *in vitro* conditions. Seeds treated with thiomethoxam at 2.85, 4.28 and 10 g/kg seed in combination with *T. harzianum* at 4 g/kg inhibited 37.30, 35.95 and 32.40 per cent respectively. The studies conducted have clearly indicated that thiomethoxam showed lesser effect on *T. harzianum*. Hence, it is possible that *T. harzianum* can be used along with thiomethoxam as seed treatment as one of the tools for the management in integrated pest and disease management against *R. solani*.

However, further studies are required to study the precise mechanisms involved pertaining to the interactions between the pathogen and the biocontrol agent in insecticide amended media.

5.7.1.3 Combined effect of fertilizers and fungal biocontrol agents against test pathogens *in vitro*

Combined effect of the four fertilizers (CAN, DAP, SSP and MOP) with potential antagonistic isolates was tested against the test pathogens viz.,

P. aphanidermatum, *M. phaseolina* and *S. rolfsii* in inhibiting radial growth of the pathogens in fertilizers amended medium at 100, 500,1000 and 2000 ppm concentrations. Maximum growth reduction of the pathogen *P. aphanidermatum*, with commercial isolate of *T. viride* (Sun Agro Derma Tv) in CAN amended medium was observed at 2000 ppm concentration. While the commercial isolate of *T. harzianum* (NCC-57 Th) inhibited the growth of pathogen to an extent of 82.81 and 80.93 per cent in DAP and SSP amended medium respectively at 200 ppm concentration. The per cent growth reduction of the pathogen was obtained in MOP amended medium with the native isolate of *T. viride* (DOR 1 Tv) at 2000ppm concentration (Tables 54 to 57 and Plates 110, 113, 116 and 119). Of the four fertilizers and different potential antagonistic fungal isolates, the native isolate of *T. viride* (DOR 1 Tv) was found to be superior in inhibiting the radial growth of *M. phaseolina* in CAN, DAP and SSP amended medium at all the concentrations. However, the commercial isolate of *T. viride* was found to be superior in inhibiting *M. phaseolina* to an extent of 86.53 per cent in MOP amended medium at 2000 ppm concentration (Tables 58 to 61, Plates 111, 114, 117 and 120). Among the various antagonistic fungal isolates, the commercial isolate of *T. viride* (Sun Agro Derma Th) was found superior in inhibiting the radial growth of *S. rolfsii* to an extent of 77.63 and 65.46 per cent in CAN and DAP amended medium respectively at 2000 ppm concentrations compared to other *Trichoderma* isolates. However, the native isolate of *T. harzianum* (DOR 2 Th) was found to be superior in inhibiting the radial growth of *S. rolfsii* in SSP and MOP amended medium at 2000 ppm concentration (Tables 62 to 65, Plates 112, 115, 118 and 121). In the present study the effective utilization of macro and microelements present in the fertilizers by native and commercial antagonistic isolates of *Trichoderma* spp.

5.7.1.4 Combined effect of herbicides and fungal biocontrol agents against test pathogens *in vitro*

Combined effect of herbicides and antagonistic fungal isolates was studied in *in vitro* at different concentrations against three test pathogens viz., *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii*. Maximum growth reduction of *P. aphanidermatum* by the commercial isolate of *T. viride* (BCL Tv) was observed in pendimethalin amended medium at 100 ppm concentration (Tables 66 and 67, Plate 122). While, the native isolate of *T. viride* (DOR 1 Tv) inhibited radial growth of the pathogen to an extent of 72.33 per cent in fluchloralin amended medium at 100 ppm concentration. The commercial isolate of *T. harzianum* (Sun Agro Derma Th) was found to be superior in inhibiting the radial growth of *M. phaseolina* in pendimethalin amended medium at 100 ppm concentration. While, the radial growth of *M. phaseolina* inhibited by the commercial isolate of *T. viride* (BCL Tv) combination with fluchloralin at 100 ppm concentrations compared to other combinations (Tables 68 and 69, Plate 123). Among different native and commercial isolates of *Trichoderma* spp. the commercial isolates of *T. viride* (NCC-58 Tv and BCL Tv) inhibited the radial growth of *S. rolfsii* in pendimethalin and fluchloralin amended medium at 100 ppm concentration to an extent of 78.03 and 87.12 per cent respectively (Tables 70, 71, Plate 124).

5.7.2 Combined effect of bacterial biocontrol agents and agrochemicals against test pathogens

Combined effect of bacterial biocontrol agents with agrochemicals (fungicides, insecticides, fertilizers and herbicides) was studied against the three test pathogens under *in vitro* conditions. The synergistic effect of bacterial biocontrol

agents and the agrochemicals was seen at lower concentrations. However, there was no significant difference in inhibition of the radial growth of the pathogens between the two commercial isolates of *P. fluorescens* (Sun Agro Monus Pf and Vermi Green Pf) in combination with the fungicides. In chemicals amended medium the efficacy of the bacterial biocontrol agents increased with the increase in concentrations. The growth of the test pathogens was inhibited at higher concentrations (500, 1000 and 2000 ppm) of the chemicals indicating the effect of the individual chemicals only (Tables 72 to 83 and Plates 122 to 146). In contrast the combined effect of fertilizers and bacterial biocontrol agents was not observed at all the concentrations of the fertilizers as growth of the test pathogens was not affected.

Fernando and Linderman (1994) reported that mancozeb (as Manzate 200) could be applied at lower concentration in combination with biocontrol agents to control root rot of cowpea caused by *Phytophthora vignae* under *in vitro* conditions).

Parakhia *et al*. (1998) found that mancozeb (3g per kg of seed) was compatible with bacterial antagonists (*P. flourescens*) to control collar rot of ground nut caused by *Aspergillus niger*.

Tripathi and Johri (2002) investigated in vitro integrated use of fungicides and fluorescent pseudomonads recovered from rhizoplane (PEn-4) and rhizosphere of pea (PRS-1) and wheat (WRS-24) were enhanced the inhibitory potential against *Colletotrichum dematium, Rhizoctonia solani* and *Sclerotium rolfsii*.

5.8 COMBINED EFFECT OF BIOCONTROL AGENTS AND AGROCHEMICALS ON TEST PATHOGENS UNDER GLASSHOUSE CONDITIONS

Although it is a well established fact that certain diseases can be controlled either completely or partially by the use of biocontrol agents, it is understood that the best method to control disease is through integrated disease management, where in a biological control component would be significant. It is a general experience that with antagonists as the only component in biological control programmes has not been encouraging (Upadyay and Bharat Rai, 1993).

Integrated biological and chemical control seems to be a very promising way of controlling pathogens with minimal interference with biological equilibrium (Baker and Cook, 1982; Henis and Chet, 1975 and Papavizas, 1973). One of the most attractive way of reducing the amount of fungicide is the integration of sublethal doses of chemicals with *Trichoderma* spp. which is resistant to relatively high doses of chemicals (Munnecke, 1972; Elad *et al*., 1981).

In the present study, combination of antagonistic fungal biocontrol agents and selected agrochemicals was undertaken to study their effect on three soil borne plant pathogens viz., *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* under glasshouse conditions in pot culture. In the present investigation, an attempt was made to observe whether the treatments imposed have any effect on disease incidence and also any stimulatory or inhibitory effect on the seed germination, root and shoot lengths and on dry weight of seedlings of the test cultivars under high soil inoculum pressure.

5.8.1 Combined effect of biocontrol agents and agrochemicals on *P. aphanidermatum* under glasshouse conditions

In all 13 treatments were tested against *P. aphanidermatum*. Of these T_1 [a combination of seed treatment with *T. harzianum* (DOR 2 Th) and soil drenching with COC @ 100 ppm] was found to be superior over the other treatments which not only reduced the seedling mortality caused by the pathogen but also resulted in higher population stand of tomato, brinjal and bhendi crops. The treatments T_1 and T_2 [a combination of seed treatment with *T. harzianum* (DOR 2 Th) and soil drenching with mancozeb @ 100 ppm] were also found superior over other treatments in promoting root and shoot lengths, seedling vigour index and dry weight of seedlings of tomato cultivar Pusa Ruby, brinjal cv. Shyamala and bhendi cv. Parbhani Kranthi (Tables 84 to 86 and Plates 152, 155 and 158).

In the present investigation, *T. harzianum* (DOR 2 Th) antagonistic to *P. aphanidermatum* showed profound influence on damping-off incidence, root and shoot lengths and dry matter production of tomato, brinjal and bhendi seedlings in combination with COC at 100 ppm concentration. This may be due to the production of hydrolytic enzymes secreted by biocontrol agents which help in entry of antagonists to pathogens through penetration with direct lysis and degradation of cell walls as reported by Chet and Baker (1981). Similarly Elad *et al*. (1982a) also reported that the ability of *Trichoderma* isolates to control *P. aphanidermatum*, *S. rolfsii* in soil was achieved through hydrolytic enzyme production. It is evident from the results that the application of antagonists along with fungicides did not affect the enzyme production but also the fungicides COC and mancozeb enhanced the enzyme production. The use of *Trichoderma* spp. as a potential biocontrol agent

in the integrated biological control of plant pathogens along with other disease management practices has been discussed by Chet and Henis (1985) and Papavizas (1985). It has been pointed out that since *Trichoderma* dominates in soil treated with a sublethal dosage of pesticides, proliferates easily to produce antibiotics, competes for nutrients, and acts as a mycoparasite, its role in integrated control may be of practical significance. These results are in accordance with Grienstein *et al*. (1979); Hadar *et al*. (1977); Sivan *et al*. (1984); who also reported that the integration of lower doses of fungicides like PCNB, Prothiocarb with *Trichoderma* spp. improved the disease control. Fungicides might have weakened the pathogen and made it vulnerable, thus allowing *G. virens* to become more virulent on a weak pathogen (Upadyay and Mukhopadyay, 1986). Integration of metalaxyl with *T. harzianum* for control of damping-off caused by *P. aphanidermatum* of sugarbeet was reported by Sawant and Mukhopadyay (1990).

Gliocladium virens was applied in combination with seed dressing fungicides like Apron, Captaf and Thiram over their individual applications in controlling the tomato damping-off caused by *P. aphanidermatum* was reported by De and Mukhopadyay (1994).

Kumar and Mukhopadyay (1994) reported that the combination of *G. virens* and thiram produced highest disease control (100%) followed by *G. virens* + Captaf (88.75%), *G. virens* + Apron (82.49%), *G. virens* + Cobose L (71.25%) and *G. virens* + Fytolan (56.24%) against *P. aphanidermatum*. This juxtaposition of fungicides and *G. virens* improved the biocontrol efficacy and the result of integration was additive to thiram.

Jeyaraj and Ramabhadran (1998) studied the effect of combined application of *T. harzianum* along with the damping-off fungus *P. aphanidermatum* in potassium incorporated soil. The results demonstrated enhanced survival and population level of *T. harzianum* and reduced populations of the pathogen.

Seed treatment with carbendazim followed by soil application of *T. viride* Pers was proved effective as disease incidence recorded was 5 and 18.33 per cent in Varsha Upahar and Pusa Sawani varieties of bhendi as compared to 45 and 62 per cent incidence observed in control, respectively (Anitha and Tripathi, 2000).

Kaushik *et al*. (2002) reported that the soil solarization coupled with biocontrol agents, *T. viride*, *T. harzianum*, *T. longibrachiatum* and *P. fluorescens* and sub-lethal doses of captan and carbendazim exhibited higher seed germination and seedling survival of *A. nilotica, Albizia lebbeck, Azadirachta indica* and *Dalbergia sisso* against damping-off fungus *P. aphanidermatum*.

Integration with metalaxyl and bioagent *T. harzianum* reduced damping-off of cauliflower by over 40.1 per cent (Deepa and Chaube, 2002).

Lakra (2003) reported that the incidence of post-emergence damping-off caused by *P. aphanidermatum* was minimum (13.5%) when seed and soil treatment with *T. viride* @ 4 g kg^{-1} and 5 g/m^2 were undertaken in brinjal crop.

It is evident from the results that the increased efficacy of fungal biocontrol agents and fungicide combinations were the best compared to the other combinations viz., biocontrol agent + insecticide, biocontrol agent + weedicide and biocontrol agent + fertilizers.

From the results, it is clear that the potential fungal biocontrol agents and compatible fungicide combinations at lower doses are the best compared to the other combinations.

5.8.2 Combined effect of biocontrol agents and agrochemicals on *M. phaseolina* under glasshouse conditions

Although the two systemic fungicides, carbendazim and hexaconazole were found very effective against *M. phaseolina* under *in vitro* conditions owing to their high toxicity to *Trichoderma* isolates, their use in integrated control was not considered and the next best fungicides i.e., COC and mancozeb having compatibility with *Trichoderma* isolates were studied.

The efficacy of combination of fungal antagonists and agrochemicals was tested in pot culture against the pathogen and observations on seed germination, plant disease mortality and growth parameters viz., root and shoot lengths, dry weight of root and shoot and seedling vigour index of tomato, brinjal and bhendi were recorded in each treatment. Of the 14 treatments evaluated, T_1 [a combination of seed treatment with *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC @ 100 ppm] was found to be superior in reducing seedling mortality and increasing seed germination, root and shoot lengths and seedling vigour index. While, dry weight of seedlings increased significantly over control in T_5 [a combination of seed treatment with *T. harzianum* (NCC-57 Th) and soil drenching with imidacloprid @ 100 ppm] compared to all other treatments. The germination percentage, reduction in seedling mortality, root and shoot lengths and seedling vigour index and dry weight of seedlings significantly higher in T_2 treatment compared to all other treatments in brinjal cv. Shyamala. Cent per cent seed

germination in T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm], T_9 [a combination of seed treatment with *T. viride* (DOR 1 Tv) and soil drenching with DAP @ 2000 ppm] and T_{11} [a combination of seed treatment with *T. viride* (NCC-58 Tv) and soil drenching with MOP @ 2000 ppm]. While, all the parameters like, the reduction in seedling mortality, root and shoot lengths, seedling vigour index and dry weight of seedlings were significantly higher in T_2 treatment of bhendi cv. Parbhani Kranthi compared to pathogen check (Tables 87 to 89 and Plates 153, 156, 157).

Seed treatment with *Trichoderma* spp. and soil drenching with mancozeb @ 100 ppm showed that mancozeb and antagonists positively affected plant height. It is attributed that mancozeb could arrest the pathogen and antagonists could parasitise the pathogen and promote growth of the host plant by secreting growth promoting metabolites. Two mechanisms have been advanced most frequently to explain the increased growth response induced by certain microflora. The first hypothesis was that enhanced growth might be due to biological control of plant pathogens in the soil. The other hypothesis so far not demonstrated clearly for any biological system was that a microbial agent produces growth regulatory metabolites (Kloepper and Schroth, 1981). Since, *Trichoderma* spp. when applied in the soil can survive for longer periods and propagate in soil (Harman *et al*., 1981) a combination with chemicals achieve a long term controlling effect on soil borne pathogenic fungi. In the present study also *Trichoderma* spp. might have acted as a mycoparasite and dominated in soil when added with a sublethal dose of mancozeb.

Seeds treated with carbendazim at 2 g kg^{-1} of seed with the spore suspension of *T. viride* (N) containing 106 spores ml^{-1} showed maximum germination of 91.8%, shoot length (38.6 cm), root length (7.2 cm) and dry matter

production (2.35 g plant^{-1}) against *M. phaseolina* infection in cowpea (Alagarsamy and Sivaprakasam, 1988).

Venkateswar Rao (19980 reported that an integration of soil solarization (six weeks), *T. viride* (native) and mancozeb (0.3%) effectively (82.8%) controlled the stem and root rot of sesame caused by *M. phaseolina* under field conditions.

Rajeswari *et al*. (1999) reported that the integration of *T. harzianum* as soil application (5 g kg^{-1}) + seed treatment (10^8 conidia/ml) with sub-lethal dose of carbendazim (0.02%) significantly reduced dry root rot incidence (95.3%) over soil treatment (91.5%) and seed treatment alone (86.5%) in mungbean dry root rot incited by *M. phaseolina*.

Datta *et al*. (2000) reported that the higher groundnut seed germination (74.94%) and yield (11.48 g plant^{-1}) and lower disease index (1-6) was recorded in combined seed treatment with *T. harzianum* + thiram (0.05%) followed by *T. harzianum* + thiram (0.01%) in pot culture experiment against *Rhizoctonia solani* causing soybean stem rot.

Latha and Narasimhan (2001) studied the combined effect of *Pseudomonas fluorescens* as seed treatment (ST) @ 10 g kg^{-1}, carbofuran as soil application SA @ 3.3 kg ha^{-1} + carbendazim as ST @ 2 g kg^{-1} and *Trichoderma viride* as ST @ 4 g kg^{-1} + *P. fluorescens* as ST @ 10 g kg^{-1} + *Paecilomyces lilacinus* as ST @ 1 g mycelium kg^{-1} and recorded the minimum root rot incidence for management of the root rot complex of blackgram, caused by the fungus *Macrophomina phaseolina* and cyst nematode.

Soil application of *T. harzianum* + *T. viride* in integration with Bavistin seed treatment had the minimum mortality upto 45 days (Bunker and Kusum Mathur, 2001).

Dubey and Patel (2001) reported that the carboxin and captan were integrated with *G. virens* and carboxin and thiophanate-methyl with *T. viride* as they inhibited the growth of *T. cucumeris*, the causal agent of web blight of urd and mung bean.

Integration of carbendazim (0.1% a.i.) and *T. viride* mutant on seed with soil application of P (@ 20 kg ha^{-1}) and K (@ 15 kg ha^{-1}) caused highest (71.7%) reduction in sesame stem root rot incidence over control besides significantly ($P < 0.05$) reducing pathogen population in soil and enhancing plant growth. Satisfactory disease reduction 40%, 26.7% and 14%, 32.6% increase in shoot length respectively (Chattopadyay and Kalpanasastry, 2002).

Suriachandraselvan and Seetharaman (2002) studied the efficacy of *T. viride* in combination with fungicides against *M. phaseolina* infection in black gram. Seeds treated with carbendazim (2 g/kg) + *T.viride* (4 g/ kg) recorded the minimum disease incidence of 7.9 per cent as against 42.6 per cent in control. This treatment also recorded maximum germination of 97.7 per cent, root length of 9.6 cm, shoot length of 7.9 cm and seedling vigor of 1679 as against 77.7 per cent, 5.1 cm, 4.2 cm, and 737 respectively in control.

5.8.3 Combined effect of biocontrol agents and agrochemicals on *S. rolfsii* under glasshouse conditions

Of the 14 treatments, maximum seed germination recorded in tomato (cv. Pusa Ruby) in T_6 [a combination of seed treatment with *T. viride* (Sun Agro

Derma Tv) and soil drenching with CAN @ 2000 ppm)] was found to be superior followed by T_9 [a combination of seed treatment with *T. harzianum* (DOR 2 Th) and soil drenching with MOP @ 500 ppm] (Tables 90, 91, 92, Plates 154, 157, 160). The maximum per cent decrease in seedling mortality and maximum increase in root and shoot lengths, seedling vigour index was recorded in T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm]. While, maximum dry weight of tomato seedlings was recorded in T_7 [a combination of seed treatment with *T. harzianum* (NCC-57 Th) and soil drenching with DAP @ 2000 ppm] in brinjal cv. Shyamala (Tables 90, 91, 92, Plates 154, 157, 160). Seed germination, per cent decrease in seedling mortality, root and shoot lengths and seedling vigour index was recorded in T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm] was found to be superior compared with all other treatments. T_7 [a combination of seed treatment with *T. harzianum* (NCC-57 Th) and soil drenching of DAP @ 2000 ppm] was superior in increasing the dry weight of brinjal seedlings (Tables 90, 91, 92, Plates 154, 157, 160). Highest seed germination and least seedling mortality was recorded in T_1 [a combination of seed treatment with *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC @ 100 ppm] and T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm]. While, maximum root and shoot lengths were recorded in T_3 [a combination of seed treatment with *T. viride* (NCC-58 Tv) and soil drenching with imidacloprid @ 100 ppm] followed by T_1 treatment. Maximum seedling vigour index and dry weight of seedlings was recorded in T_2 treatment (Tables 90, 91, 92, Plates 154, 157, 160).

Different fungicides, insecticides, fertilizers, herbicides and soil fumigants are widely used for controlling soil borne diseases. Because of concern regarding the toxicity of these compounds, there is a general trend to reduce the amounts applied to soil. One of the most attractive ways of reducing the amounts of fungicide is the integration of sublethal doses of chemicals with *Trichoderma* spp. which is resistant to relatively high doses of methyl bromide (Munnecke, 1973) and PCNB (Elad *et al*., 1981). Devat *et al*. (1981) found that benomyl inhibited *Trichoderma* growth while thiram enhanced it. Papavizas *et al*. (1982) found mutants to benomyl. These indicate the possibility of combining some appropriate chemicals with this biocontrol agent. In the present study, it was found that the application of *Trichoderma* spp. to the soil in combination with soil drenching by fungicides, insecticides, herbicides and soil application of fertilizers, had an additive effect providing good control of the disease. *Trichoderma* spp. are known to have greater tolerance for broad spectrum fungicides than many other soil biota and to colonise the treated soil more rapidly than other competitors (Munnecke, 1973).

Integrating bioagents with sublethal doses of fungicide not only improves the efficiency but also reduces dependence on agrochemicals (Mukhopadyaya, 1995). Many workers have obtained successful control of soil borne diseases in various crops by integrating bioagents with sublethal doses of fungicides. Introduction of *Trichoderma* with sublethal doses of fumigant such as methyl bromide has shown better results than use of *Trichoderma* alone for management of soil borne pathogens (Strashov *et al*., 1985). Maiti and Sen (1985) reported that, a combination of calcium ammonium nitrate + *T. harzianum* was more effective in reducing stem blight of groundnut caused by *S. rolfsii* than urea + *T. harzianum*. Punja *et al*. (1986) stated that combining deep ploughing and

application of calcium fertilizers and ammonium bicarbonate provided effective and economical control of carrot rot caused by *S. rolfsii*. Papavizas and Lewis (1983) found that *T. viride* and carbendazim (100 ppm) controlled *S. rolfsii* in beans. Upadyay and Mukhopadyay (1986) also reported that integration of PCNB (5 mg kg^{-1} soil) and *T. harzianum* (6 g kg^{-1} soil) significantly reduced the incidence of sclerotium root rot of sugarbeet caused by *S. rolfsii* and increased the yield. Kuruvilla Jacob (1989) reported that, integration of carbendazim seed treatment and soil drench with *T. harzianum* was inferior than either of the methods used alone in reducing root rot of urd bean. Wokocha (1990) reported that the combined applications of fungicides with *T. viride* significantly enhanced the disease control, giving maximum control of the disease in which DSI of 0.0% (*T. viride* + PCNB), 16.4% (*T. viride* + Captan) and 19.0% (*T. viride* + Aldrex T) was recorded. Asghari and Mayee (1991) reported that onion and garlic crop rotation with groundnut, application of *T. harzianum* and carbendazim drenching (0.2%) reduced the population of *S. rolfsii* in the soil and increased population of the antagonist *T. harzianum*.

Olives and Mont (1993) conducted glasshouse experiments and reported that the combination of *T. viride* and quintozene gave the best control of *S. rolfsii* in barley and beans.

Integration of seed treatment with *T. harzianum*, *Rhizobium* and *T. harzianum* added to soil on 6 days after sowing plus carbendazim (0.1%) as soil drenching on 30 DAS was more efficient in reducing root rot of groundnut caused by *S. rolfsii* than other treatments when tested under glasshouse conditions (Muthamilan and Jeyarajan, 1996).

Anitha Chowdhary (1997) reported that the combined soil application of *T. viride*, cheshnut compound and neem cake completely controlled sclerotial wilt disease in bell pepper.

Uma Singh and Thapliyal (1998) investigated that the both pre- and post-emergence seedling rots in soybean were effectively managed by seed treatment with vitavax 200 plus *T. harzianum* (or) *G. virens*.

Seedling root dip in *T. viride* + soil drenching with chlorpyriphos + basal application of calcium ammonium nitrate (CAN) effectively controlled *S. rolfsii* in bell pepper (Hari Narayana, 1994).

Pathak *et al*. (2001) reported that the combination of *Gliocladium virens* and carbendazim 50 WP (or) mancozeb increased per cent seed germination, plant height, 82.12 cm or 87.87 cm and dry weight (2.897 g) (or) 2.258 g respectively, against *S. sclerotium* in mustard crop.

Integration of contaf + *G. virens* (0.05% + 0.1%) exhibited 100 per cent seed germination, but also 100 per cent reduction in wilt incidence and increase in plant height of 47.49 per cent at 40 DAS against the wilt complex of French bean (*Phaseolus vulgaris*) caused by *Sclerotium rolfsii, Rhizoctonia solani* and *Fusarium oxysporum* f.sp. *phaseoli* under field conditions (Mukerjee *et al*., 2001).

Patibanda *et al*. (2002) reported synergistic effect of thiram (seed coating @ 0.1%) and soil application of *T. harzianum* in reducing wilt pathogen *S. rolfsii* of groundnut. They opined that synergistic effect might be due to effective occupation of rhizosphere zone by antagonists as thiram on seeds could reduce other competitive microflora of the soil.

Seed treatment with *T. viride, P. fluorescens*, combined with commercial neem product Niwaar and thiram effectively controlled soil microflora of groundnut including *S. rolfsii* (Rama Yella Reddy, 2002).

Saralamma and Vittal Reddy (2003) also reported that the combined application of bioagent, *T. harzianum*, captan and neem cake effectively suppressed the *S. rolfsii*, incitant of groundnut stem rot.

Arunasri (2003) imposed nine treatments in pot culture of which, seedling root dip in thiram @ 0.1% + seedling root dip in effective antagonists + soil application of effective antagonists (*Trichoderma* isolate^{-1} and *Pseudomonas* sp.) was found to be superior and recorded least PDI (6.66%), maximum plant height (16.17 cm) dry weight of shoot (113.67 mg) and root (53 mg) against *S. rolfsii* of crossandra.

Critical observation of the data also reveals the effectiveness of the combination of potential biocontrol agents with the compatible fungicides over the combination of the fungal antagonists with other compatible insecticides, herbicides and fertilizers in reducing the seedling mortality caused by the test pathogens and increasing the various growth parameters of the seedlings of test crops.

CHAPTER – VI

SUMMARY

In plant protection schedules, very often it becomes necessary to combine the application of biocontrol agents with other chemicals. Combined application of biocontrol agents with other agrochemicals especially fungicides, insecticides, weedicides and fertilizers may result either in synergism or antagonism between them. As agrochemicals exert positive, negative or neutral effects on biocontrol agents and lack of sufficient information on the compatibility of biocontrol agents with other commonly used agrochemicals prompted taking up of investigations reported in the present study and the results of these investigations are summarized hereunder.

P. aphanidermatum, M. phaseolina and *S. rolfsii* were isolated from diseased mustard (cv. Local) seedlings, castor plants (cv. Aruna) and sunflower plants (cv. Morden) respectively by tissue segment method. The pathogens were purified by single hyphal tip method and maintained on potato dextrose agar medium. The pathogens were identified based on their colony and morphological characters. Pathogenicity of the fungi was proved by soil inoculation method and the reisolated fungi from diseased plants resembled the original ones.

In vitro screening of various commercial and native isolates of *Trichoderma* spp. and *P. fluorescens* against the three test pathogens was conducted in dual culture tests. Of the eight isolates of *Trichoderma* spp. screened against *P. aphanidermatum*, the efficacy of commercial isolate of *T. viride* (NCC-58 Tv) was superior when compared with other potential antagonistic *Trichoderma* isolates. The growth reduction of the pathogen was 68.46% by this isolate followed by native

isolate of *T. harzianum* (DOR 2 Th). In all other *Trichoderma* isolates the per cent growth reduction of the pathogen varied between 53.7 and 60.95. The growth reduction of the pathogen was between 34.32 and 36.24% by the two commercial isolates of *P. fluorescens*.

All the isolates of *Trichoderma* spp. in the present study significantly inhibited the growth of *M. phaseolina* than the two *P. fluorescens* isolates tested. Maximum (76.37%) inhibition of growth of the pathogen was recorded with the commercial isolate of *T. viride* (BCL Tv). Whereas, commercial isolate of *T. harzianum* (NCC-57 Th) significantly arrested the radial growth of *S. rolfsii* and growth reduction of the pathogen was 60.22 per cent by this isolate. The commercial isolate of *T. harzianum* (Vermigreen Th) was least effective in inhibiting the growth of *S. rolfsii*. The two isolates of *P. fluorescens* tested inhibited the growth of *S. rolfsii* to an extent of 36.88 per cent.

The *in vitro* studies on sensitivity of various antagonistic fungal isolates against four fungicides (copper oxychloride, mancozeb, carbendazim and hexaconazole) revealed incompatibility of carbendazim and hexaconazole (100% inhibition) at 100, 500, 1000 and 2000 ppm concentrations. Whereas, the isolates of *Trichoderma* spp were compatible with copper oxychloride and mancozeb at lower concentrations compared to the higher concentrations. The isolates of *T. harzianum* were more sensitive to copper oxychloride at higher concentrations of 1000 and 2000 ppm. Of the eight isolates of *Trichoderma* spp. tested, commercial isolate of *T. viride* (NCC-58 Tv) was least sensitive to copper oxychloride fungicide at all the concentrations tested. The bacterial antagonistic isolates of *P. fluorescens* were compatible with all the fungicides tested at 100 ppm concentration and slightly incompatible with the test fungicides at 500, 1000 and 2000 ppm concentrations.

Among insecticides, imidacloprid was highly compatible with all the commercial and native isolates of *Trichoderma* spp. at 100, 500, 1000 and 2000 ppm concentrations. Whereas, the antagonistic fungal isolates were slightly incompatible at lower concentration (100 ppm) of both the insecticides, chlorpyriphos and carbosulfan. With the increase in concentration of an insecticide there was decrease in the radial growth of the antagonistic fungal isolates. Of the two commercial bacterial biocontrol isolates tested for their sensitivity against three insecticides (carbosulfan, imidacloprid and chlorpyriphos) in *in vitro* conditions, carbosulfan was found to be relatively less toxic to the commercial isolate of *P. fluorescens* (Sun Agro Monus Pf) even at 1000 and 2000 ppm concentrations. Whereas, imidacloprid was least inhibitory to the growth of commercial isolate of *P. fluorescens* (Vermigreen Pf) than the other insecticides. However, chlorpyriphos found to be highly toxic at higher concentrations to both the bacterial antagonists tested.

None of the fertilizers under study (calcium ammonium nitrate, Diammonium phosphate, Single superphosphate and Muriate of potash) inhibited the growth of all the isolates of *Trichoderma* and *P. fluorescens* at 100, 500, 1000 and 2000 ppm concentrations indicating the compatibility of the biocontrol agents with these fertilizers.

The herbicides, pendimethalin and fluchloralin were inhibitory to the growth of all the antagonistic fungal isolates tested. However, these herbicides were highly inhibitory to the growth of test isolates at higher concentrations compared to the lower concentrations. The two isolates of *P. fluorescens* showed maximum tolerance to the two test herbicides at 100 and 500 ppm concentrations. While, at higher concentrations of the test herbicides, the per cent growth inhibition of the commercial bacterial biocontrol isolates of *P. fluorescens* (Sun Agro Monus Pf and

Vermigreen Pf) was increased. However, fluchloralin was found to be superior compared to pendimethalin in inhibiting the growth of these isolates.

Among the four fungicides (copper oxychloride, mancozeb, carbendazim and hexaconazole) tested for their efficacy against *P. aphanidermatum* under *in vitro* conditions, copper oxychloride was found to be superior in inhibiting the growth of *P. aphanidermatum* compared to other test fungicides. Whereas, mancozeb and hexaconazole completely inhibited the pathogen at higher concentrations (1000 and 2000 ppm). While, carbendazim was least effective in reducing the growth of the pathogen at all test concentrations. Of the four fungicides tested against *M. phaseolina*, mancozeb, carbendazim and hexaconazole were completely inhibitory to the growth of the pathogen at 100, 500, 1000 and 2000 ppm concentrations. Copper oxychloride was least effective in inhibiting the test pathogen at all test concentrations. Of the four fungicides tested, mancozeb and hexaconazole completely inhibited the growth of *S. rolfsii*, at all test concentrations, while, COC and carbendzim were least effective in inhibiting the growth of the pathogen.

The *in vitro* studies on sensitivity of the three test pathogens against the four insecticides (thiomethoxam, carbosulfan, imidacloprid and chlorpyriphos) revealed significant differences among the different insecticides and their concentrations in respect of the inhibition of the growth of the test pathogens. Of the four insecticides tested, chlorpyriphos was found to be superior in inhibiting the growth of *P. aphanidermatum* compared to other insecticides at all the concentrations tested. However, with the increase in concentration of the insecticides there was corresponding in the rapid growth of the pathogen. Whereas, *M. phaseolina* was highly compatible with the insecticide, imidacloprid at all the test

concentrations. While, chlorpyriphos was slightly incompatible with *M. phaseolina*. *M. phaseolina* was highly sensitive to thiomithoxam and carbosulfan at all the test concentrations tested. The per cent inhibition was between 15.5 and 60.22 in case of thiomethoxam, while it ranged between 37.53 and 50.06% in case of carbosulfan. Of the insecticides tested for their efficacy against *S. rolfsi* under *in vitro* conditions, chlorpyriphos found to be inhibitory to the radial growth of the pathogen. With increasing concentration of chlorpyriphos, there was corresponding decrease in the radial growth of the pathogen as the per cent growth inhibition, 21.39 at 100 ppm concentration as against 57.89 per cent at 2000 ppm concentration. However, the insecticides, imidacloprid did not inhibit the mycelial growth of the *S. rolfsi* at 100, 500, 1000 and 2000 ppm. Whereas, least inhibition of the radial growth of the pathogen was recorded in thiomithoxam, and carbosulfan at all the concentrations tested.

Of the four fertilizers (calcium ammonium nitrate, diammonium phosphate, single superphosphate, and muriate of potash) tested for their efficacy against *P. aphanidermatum*, *M. phaseolina* and *S. rolfsii* under *in vitro* conditions, calcium ammonium nitrate was found inhibitory to the growth of *S. rolfsii* at all the concentrations tested. However, no inhibitory effect these fertilizers on radial growth of the test pathogens was observed at all the concentrations tested.

The two herbicides (pendimethalin and fluchloralin) were inhibitory to the growth of the test pathogens at all the concentrations (100, 500, 1000 and 2000 ppm). However, fluchloralin was found to be superior in inhibiting the growth of the test pathogens at all the concentrations tested.

All the compatible combinations of agrochemicals with various potential fungal antagonistic isolates reduced the radial growth of the test pathogens. The combined effect of various biocontrol agents with the fungicides was observed clearly at a lower concentration (100 ppm concentration) than at higher concentrations. Of the eight fungal biocontrol isolates tested for their efficacy against *P. aphanidermatum* in copper oxychloride and mancozeb amended medium, the native isolate of *T. harzianum* (DOR 2 Th) was found to be superior in reducing the radial growth of the pathogen at 100 ppm compared to other treatments. The efficacy of commercial isolate of *T. harzianum* (NCC-57 Th) was at par with native isolate of *T. harzianum* (DOR 2 Th) in inhibiting the growth of *P. aphanidermatum* in mancozeb amended medium at 100 ppm concentration. Among the eight fungal biocontrol isolates tested in copper oxychloride amended medium, the efficacy of the commercial isolate of *T. harzianum* (Sun Agro Derma Th) was found to be superior compared to the other fungal biocontrol isolates at lower concentration (100 ppm) in inhibiting the radial growth of *M. phaseolina*. While, the commercial isolate of *T. viride* (Sun Agro Derma Tv) in mancozeb amended medium was highly inhibitory to *M. phaseolina* compared to the other fungal biocontrol isolates at 100 ppm concentration. However, with the increase in concentration of mancozeb maximum inhibition of *M. phaseolina* was observed with all fungal biocontrol isolates combinations indicating inhibitory effect of the fungicide rather than the combined effect of fungicide and biocontrol agent. The combined effect of various antagonistic biocontrol isolates with the fungicide copper oxychloride was studied at 100, 500, 1000 and 2000 ppm concentrations against *S. rolfsii*. Among the eight isolates of *Trichoderma* spp. tested for their efficacy in combination with the fungicide COC, the commercial isolate of *T. harzianum* (NCC-57 Th) was found to

be superior in inhibiting the growth of *S. rolfsii* at all the concentrations of COC tested. With the increase in concentration of the fungicide, the synergistic effect of the fungicide and biocontrol agents was not observed as the growth of the various fungal biocontrol agents was also suppressed. However, the combined effect of biocontrol agents with the fungicide was observed at lower concentrations only. Of the eight fungal antagonistic isolates tested, native isolate of *T.viride* (DOR-1 Tv) performed better than other isolates in inhibiting the radial growth of *S. rolfsi* in mancozeb amended medium at different concentrations tested. However, at higher concentrations of the mancozeb the synergistic effect of the fungicide and the fungal antagonistic isolates was not observed as the growth of various fungal antagonistic isolates was suppressed at higher concentrations.

In association with imidacloprid and chlorpyriphos (100 ppm), the commercial isolate of *T. harzianum* (Vermigreen Th) inhibited the radial growth of *P. aphanidermatum* of 86.75 and 75.73 per cent respectively. Whereas, the commercial isolate of *T. viride* (BCL Tv) inhibited the radial growth of *P. aphanidermatum* to an extent of 67.90 per cent in association with the insecticide carbosulfan.

Maximum inhibition (91.47 %) of *M. phaseolina* was recorded with the commercial isolate of *T. viride* (NCC-58 Tv) in imidacloprid amended medium at 100 ppm and also at higher concentrations. In chlorpyriphos and carbosulfan amended medium, the commercial isolate of *T. harzianum* (Vermigreen Th) was found superior in inhibiting the radial growth of *M. phaseolina* compared to other isolates of *Trichoderma* spp. at 100 ppm concentration. The radial growth of *S. rolfsii* was inhibited to an extent of 95.74 per cent recorded in imidacloprid amended medium in association with native isolate of *T. viride* (DOR 1 Tv). The

radial growth of *S. rolfsii* was inhibited to an extent of 95.74 per cent in chlorpyriphos amended medium with the native and commercial isolates of *T. viride* (DOR 1 Tv and NCC-58 Tv) at 100 ppm concentration. Whereas, maximum growth inhibition (80.77 %) of the *S. rolfsii* was recorded with commercial isolate of *T. harzianum* (Sun Agro Derma Th) compared to other antagonistic fungal biocontrol isolates in carbosulfan amended medium.

The growth reduction of pathogen, *P. aphanidermatum* was maximum with the commercial isolate of *T. viride* (Sun Agro Derma Tv) in CAN amended medium at 2000 ppm concentration, while the commercial isolate of *T. harzianum* (NCC-57 Th) inhibited growth of the pathogen to an extent of 82.81 and 80.39 per cent in DAP and SSP amended medium respectively at 2000 ppm concentration. In MOP amended medium the growth of *P. aphanidermatum* was inhibited to an extent of 95.25 per cent with native isolate of *T. viride* (DOR 1 Tv) at 2000 ppm concentration. The native isolate of *T. viride* (DOR 1 Tv) was found superior in inhibiting the radial growth of *M. phaseolina* in CAN, DAP and SSP amended medium at all the concentrations compared to other fungal antagonistic isolates. However, the commercial isolate of *T. viride* (NCC-58 Tv) was found to be superior in inhibiting *M. phaseolina* to an extent of 86.53 per cent in MOP amended medium at 2000 ppm concentration. While, the commercial isolate of *T. harzianum* (Sun Agro Derma Th) inhibited the pathogen to an extent of 67.93 per cent in MOP amended medium at 2000 ppm concentration. Among the fungal antagonistic isolates, the commercial isolate of *T. viride* (Sun Agro Derma Tv) was found to be superior in inhibiting the radial growth of *S. rolfsii* in CAN and DAP amended media at 2000 ppm concentration. However, the native isolate of *T. harzianum* (DOR 2 Th) was found superior in inhibiting the radial growth of *S. rolfsii* in SSP,

amended medium at 2000 ppm concentration. While, the native isolate of *T. harzianum* (DOR 2 Th) was found superior in inhibiting the radial growth of *S. rolfsii* in MOP amended medium followed by the commercial isolate of *T. viride* (Sun Agro Derma Tv) at 2000 ppm concentration.

The combined effect of herbicides and antagonistic fungal isolates was studied at various concentrations against the test pathogens. The commercial isolate of *T. viride* (BCL Tv) was found to be superior in inhibiting the radial growth of *P. aphanidermatum* in pendimethalin amended medium at 100 ppm concentration. While, the native isolate of *T. viride* (DOR 1 Tv) inhibited radial growth of the pathogen to an extent of 73.23 per cent in fluchloralin amended medium at 100 ppm concentration. The radial growth of *M. phaseolina* was inhibited by the commercial isolate of *T. harzianum* (Sun Agro Derma Th) in pendimethalin amended medium at 100 ppm concentration compared to other antagonistic *Trichoderma* isolates. While, radial growth of *M. phaseolina* inhibited by the combination of commercial isolate of *T. viride* (BCL Tv) with fluchloralin at 100 ppm concentration compared to other fungal antagonistic isolates. Among different native and commercial isolates of *Trichoderma* spp. the commercial isolates of *T. viride* (NCC-58 Tv and BCL Tv) inhibited the radial growth of *S. rolfsii* in pendimethalin and fluchloralin amended medium at 100 ppm concentration to an extent of 78.03 and 87.12 per cent respectively. However, at higher concentrations (1000 and 2000 ppm) the test herbicides were not only inhibitory to the pathogen but also to the fungal antagonistic isolates.

The combined effect of the two bacterial biocontrol isolates with four fungicides at 100, 500, 1000 and 2000 ppm concentrations against *P. aphanidermatum, M. Phaseolina* and *S. rolfsi* was studied. The inhibitory effect

of the agrochemicals (fungicides, insecticides, fertilizers and herbicides) and bacterial agents (Sun Agro Monus Pf and Vermi Green Pf) combination was observed at a concentration of 100 ppm. With the increase in concentration of the agrochemcals, the synergistic effect of the chemicals and biocontrol agents was not observed. However, cent per cent inhibition of the test pathogen was observed at higher concentrations of the fungicides and herbicides. All the pathogens overgrew the bacterial biocontrol agents in all the media amended with the fertilizers at higher concentrations.

Of the 13 treatments evaluated, T_1 [a combination of seed treatment with native isolate of *T. harzianum* (DOR 2 Th) and soil drenching with COC @ 100 ppm] followed by T_2 [a combination of seed treatment with *T. harzianum* (DOR 2 Th) and soil drenching with mancozeb @ 100 ppm] was found to be best in increasing the germination of seeds of test cultivars viz., tomato, brinjal and bhendi. Whereas, least per cent seed germination was observed in individual treatments involving the two herbicides (pendimethalin and fluchloralin). All the treatments significantly reduced the seedling mortality (post-emergence) as compared to pathogen check. Out of 13 treatments tested for control of the disease caused by *P. aphanidermatum* T_1 (a combination of seed treatment with *T. harzianum* (DOR 2 Th) and soil drenching with COC @ 100 ppm] was found to be superior over other treatments reducing the seedling mortality and resulting in higher population stand. These treatments (T_1 and T_2) were also found superior over other treatments in promoting root and shoot lengths, seedling vigour index and dry weight seedlings of tomato (cv. Pusa Ruby), brinjal (cv. Shyamala) and bhendi (cv. Parbhani Kranthi) crops.

Among the 14 treatments evaluated, T_1 [a combination of seed treatment with *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC at the rate of 100 ppm] followed by T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm] were found to be superior in increasing the germination percentage of seeds of tomato cv. Pusa Ruby. While, minimum seed germination was recorded in the treatments involving the herbicides (pendimethalin and fluchloralin). The seedling mortality caused by *M. phaseolina* was decreased to an extent of 44.93 per cent in T_2 followed by T_1. However, maximum root and shoot lengths and seedling vigour index of tomato seedlings was observed in T_2 treatment. While, dry weight of seedlings was increased significantly over control in T_5 [a combination of seed treatment with *T. harzianum* (NCC-57 Th) and soil drenching with imidacloprid @ 100 ppm]. Significantly higher germination percentage of brinjal seeds was recorded in T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm] followed by T_1 [a combination of seed treatment with *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC @ 100 ppm]. While, T_{10} [a combination of seed treatment with *T. viride* (DOR 1 Th) and soil drenching with SSP @ 2000 ppm] recorded minimum seed germination. Maximum root and shoot lengths and seedling vigour index was recorded with T_2 treatment followed by T_1 treatment. However, dry weight of brinjal seedlings was maximum in T_2 treatment. Among all the treatments T_1 treatment was found to be the best in reducing the seedling mortality caused by *M. phaseolina* followed by T_2 treatment. Cent per cent germination of seeds of bhendi cv. Parbhani Kranti germination was recorded in T_2 treatment followed by T_9 [a combination of seed treatment with *T. viride* (DOR 1 Th) and soil drenching with DAP @ 2000 ppm]. However, seed germination in treatments T_2, T_9 and T_{11} were on par.

Maximum seed germination of seeds of tomato cv. Pusa Ruby was recorded in T_6 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with CAN @ 2000 ppm] followed by T_9 [a combination of seed treatment with *T. harzianum* (DOR 2 Th) and soil drenching with MOP @ 500 ppm]. While, least seedling mortality caused by *S. rolfsii* was recorded in T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm] compared to other treatments. Maximum root and shoot lengths and seedling vigour index was recorded in T_2 treatment. While, maximum dry weight of tomato seedlings was recorded in T_7 [a combination of seed treatment with *T. harzianum* (NCC-57 Th) and soil application of DAP @ 2000 ppm]. While, T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm] treatment recorded maximum seed germination, and least seedling mortality, root and shoot lengths and seedling vigour index compared to other treatments. In treatment, T_7 [a combination of seed treatment with *T. harzianum* (NCC-57 Th) and soil application of DAP @ 2000 ppm] recorded maximum dry weight of brinjal cv. Shyamala seedlings. Highest seed germination and least seedling mortality was recorded in T_1 [a combination of seed treatment with *T. harzianum* (Sun Agro Derma Th) and soil drenching with COC @ 100 ppm) and T_2 [a combination of seed treatment with *T. viride* (Sun Agro Derma Tv) and soil drenching with mancozeb @ 100 ppm] treatments. While, maximum root and shoot lengths were recorded in T_3 [a combination of seed treatment with *T. viride* (NCC-58 Tv) and soil drenching with imidacloprid @ 100 ppm] treatment. Whereas, maximum seedling vigour index and dry weight of seedlings of bhendi cv. Parbhani Kranthi was recorded in T_2 treatment.

LITERATURE CITED

Abdel-El-Moity T H, Papavizas G C and Shatla M N 1982 Isolation of new isolates of *T. harzianum* tolerant to fungicides and their experimental use for control of white rot of onion. Phytopathology 72: 396-400.

Abdul Baki A and Anderson J D 1973 Vigour determination in soybean seed multiple criteria. Crop Science 13: 630-633.

Abeygunawardena D V W and Wood R K S 1957 Factors affecting the germination and mycelial growth of *Sclerotium rolfsii* Sacc. Transactions of British Mycological society 40: 221-231.

Abha Agarwal and Tripathi H S 1999 Biological and chemical control of Botrytis grey mold of chickpea. Journal of Mycology and Plant Pathology 29(1): 52-56.

Abraham Mathew and Gupta S K 1996 Studies on web blight of French bean caused by *Rhizoctonia solani* and its management. Indian Journal of Mycology and Plant Pathology 26: 171-177.

Adiver S S and Anahosur K H 1995 Efficacy of some triazole fungicides against late leaf spot of groundnut and their subsequent effects on *Sclerotium rolfsii*. Indian Phytopathology 48: 459-462.

Agarwal S C, Khare M N and Agarwal P S 1978 Biological control of *Sclerotium rolfsii* causing collar rot of lentil. Indian Phytopathology 30(2): 176-179.

Agarwal S C, Khare M N and Agarwal S 1977 Biological control of *Sclerotium rolfsii* causing collar rot of lentil. Phytopathology 30: 176-179.

Agnihotri V P, Sen C and Srivastava S M 1975 Role of fungitoxicants in the control of *sclerotium* root rot of sugarbeet, *Beta vulgaris* L. Indian Journal of Experimental Biology 13(1): 89-91.

Alagarsamy G and Sivaprakasam K 1988 Effect of antagonists in combination with carbendazim against *Macrophomina phaseolina* infection in cowpea. Journal of Biological Control 2: 123-125.

*Alice D, Ebenzar E G and Sivaprakasam K 1996 Biocontrol of *Macrophomina phaseolina* causing root rot of jasmine. Journal of Ecobiology 8: 17-20.

Almedia R T and Landim C M V 1981 Preliminary studies on the biological control of *Sclerotium rolfsii* Sacc. against sclerotial wilt of cowpea [*Vigna unguiculata* (L.) Walp.]. Fitescanidale 5: 15-20.

Amar Singh and Dhanbir Singh 1994 Biocontrol of *Sclerotium rolfsii* Sacc. causing collar rot of brinjal. Journal of Biological Control 8(2): 105-110.

Amarsingh and Bhomik T P 1979 Occurrence of charcoal rot of sunflower in India. Indian Phytopathology 32: 626-627.

Anahosur K H 2001 Integrated management of potato sclerotium wilt caused by *Sclerotium rolfsii*. Indian Phytopathology 54: 158-166.

Anahosur K H, Patil S H and Hedge R K 1983 Evaluation of PCNB against *Macrophomina phaseolina* causing charcoal rot of sorghum. Pesticides 17: 11-12.

Aneja K R 2001 Laboratory experiments in microbiology, biotechnology, mushroom cultivation and tissue culture. New Old Publications, pp.544.

Angappan K 1992 Biological control of chickpea root rot caused by *Macrophomina phaseolina* (Tassi.) Goid. M Sc (Ag.) Thesis, Tamil nadu Agricultural University, Coimbatore, 114 pp.

Anil Kumar T B and Gowda K T P 1984 Effect of fungicides on the saprophytic survival of *Sclerotium rolfsii*. Pesticides 18: 43-46.

Anil Kumar T B, Sastry M N L and Patil Kulkarni B G 1979 Effect of fungicides on the viability of sclerotia of *Sclerotium rolfsii*. Pesticides 1: 43-46.

Anita Mazinder Buragohain and Islam M 2000 Antagonistic activity of *Trichoderma* spp. against *Sclerotium rolfsii* (Sacc.) Curzi. Pestology, Volume XXIV, no.12.

Anitha Chowdary K 1997 Studies on sclerotial wilt of bell pepper (*Capsicum annuum* L.). M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Anitha K and Tripathi N N 2000 Integrated management of seedling diseases of okra caused by *Rhizoctonia solani* and *Pythium aphanidermatum* (Edson) Fitzp. Indian Journal of Plant Protection 28(2): 127-131.

Arunasri 2003 Management of collar rot disease of crossandra [*Crossandra infundibuliformis* (L.) Nees] incited by *Sclerotium rolfsii* Sacc. M Sc(Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Asghari M A and Mayee C D 1991 Comparative efficacy of management practices on stem and pod rots of groundnut. Indian Phytopathology 44: 328-332.

Avizohar Hershenzon Z and Shacked P 1968 A baiting method for estimating the saprophytic activity of *Sclerotium rolfsii* in soil. Phytopathology 58: 410-413.

Aycock R 1966 Stem rots and other diseases caused by *Sclerotium rolfsii*. North Carolina Agricultural Experiment Station Technical Bulletin No.174, p.202.

Backman P A and Hammond J M 1981 Suppression of peanut stem rot with the insecticide chlorpyriphos. Peanut Science 8(2): 129-130.

Bag T K and Sinha A K 1997 Control of stem rot of soybean incited by *Sclerotium rolfsii* through metal salts. Indian phytopathology 50(3): 350-357.

Baker K F 1987 Evolving concepts of biological control of plant pathogens. Annual review of Phytopathology 25: 67-85.

Barnett H L and Hunter D B 1972 Illustrated genera of imperfecti fungi. Burges Publishing Company, p.241.

*Batista D da C, Oliveira S M A de, Taveres S C C H, Laranjeira D, Neves R A F das Silva R L X da C Batista D, de Oliveiera S M A and das Neves R A F 2002 Effect of fungicides inhibiting the *in vitro* growth of *Fusarium oxysporum* f. sp. *Passiflorae* and interference with *Trichoderma* spp. Summa Phytopathologica 28(4): 305-310.

Beena N and Sharma YR 2000 Effect of *Trichoderma* and fluorescent pseudomonads and their combination on disease suppression of rhizome rot of ginger. Indian Phytopathology 53(3): 372.

Bell D K, Wells H D and Markham C R 1982 *In vitro* antagonism of *Trichoderma* species against six fungal plant pathogens. Phytopathology 72: 379-382.

Bhargava S N and Shukla D N 1979 A new root rot of sesame (*Sesamum indicum*). Indian Journal of Mycology and Plant Pathology 9: 244.

Bhaskaran R and Seetharaman K 1986 Biological control of pre-emergence damping-off of blackgram caused by *Macrophomina phaseolina*. Abastracts of papers presented in Seminar on management of soil borne diseases of crop plants. Pp.31-32. Tamil Nadu Agricultural University, Coimbatore.

Bhat T K and Sabhalpara A N 2001 Sensitivity of some bio-inoculants to pesticides. Journal of Mycology and Plant Pathology 31(2): 267.

Bhoraniya M F, Khandar R R and Khunti J P 2002 Evaluation of pesticides against *Sclerotium rolfsii* on chilli by soil plate technique. Plant Disease Research 17(1): 145-146.

Bhoraniya M F, Khandar R R and Khunti J P 2002 Evaluation of pesticides against Sclerotium rolfsii in chilli by soil plate technique. Plant Disease Research 17(1): 145-146.

Bhuyan S A, Das B C and Borah L C 1994 Antagonist effect of *Trichoderma harzianum* and *Aspergillus ferreus* on *Rhizoctonia solani* causing sheath blight of rice. JASS 7(1): 125-127.

Bicci M, Cinar O and Erkilic A 1994 Cultural, chemical, physical and biological methods to control stem rot, *Sclerotium rolfsii* in peanut. Turkish journal of Agriculture and Forestry 18(5): 423-435.

Bikker Singh Khara H S and Singh B 1991 Root zone mycoflora of okra as influenced by some physical factors. Journal of Research, Punjab Agricultural University 28: 515-520.

Bikker Singh Khara H S and Singh B 1991 Root zone mycoflora of okra as influenced by some physical factors. Journal of Research, Punjab Agricultural University 28: 515-520.

Biswas K K and Sen C 2000a Identification of effective isolate of *Trichoderma harzianum* Rifai for biocontrol of *Macrophomina phaseolina* (Tassi) Goid. Journal of Mycology and Plant Pathology 39: 408-410.

Biswas K K, Chitreswar Sen and Sen C 2000 Management of stem rot of groundnut caused by *Sclerotium rolfsii* through *Trichoderma harzianum*. Indian Phytopathology 53(3): 290-295.

Brenneman T B, Csinos A S and Phipps P M 1990 Evaluation of ammonium bicarbonate four control of soil borne peanut pathogens. Peanut Science 17(1): 28-31.

Brown M C, Shephard M C and Frank J A 1988 Hexaconazole – Useful properties in the control of apple, coffee and peanut diseases. Pests and Diseases 1: 229-234.

Budge S P and Whipps J M 2001 Potential for integrated control of *Sclerotinia sclerotiorum* in glasshouse lettuce using *Coniothyrium minitans* and reduced fungicide application. Phytopathology 91(2): 221-227.

Bunker R N and Mathur K 2001 Antagonism of local biocontrol agents to *Rhizoctonia solani* inciting dry root rot of chilli. Journal of Mycology and Plant Pathology 31(1): 50-53.

Bunker R N and Mathur Kusum 2001 Integration of biocontrol agents and fungicide for suppression of dry root rot of *Capsicum frutescens*. Journal of Mycology and Plant Pathology 31(3): 330-334.

Calistru C, McLean M and Berjak P 1997 *In vitro* studies on the potential for biological control of *Aspergillus flavus* and *Fusarium moniliforme* by *Trichoderma* species. Mycopathologia 137(2): 115-124.

Chahal S S, Thind T S, Sharma S B and Sokhi S S 1990 Determination of action of fosetyl-Al against two phyto-mycotous pathogens through unconventional procedures. Indian Journal of Mycology and Plant Pathology 20: 30-37.

Chakravarthy S and Bhowmik T P 1983 Symptoms and techniques of inducing collar rot of sunflower caused by *Sclerotium rolfsii* Sacc. Indian Journal of Agricultural Sciences 53: 570-573.

Champawat and Sharma R S 2003 Integrated management of nursery diseases in brinjal, chilli, cabbage and onion. Journal of Mycology and Plant Pathology 33(2): 290-291.

Chandrasekhar G, Ayyappan S and Balakrishna Murthy P 2000 Biocontrol of root rot diseases of brinjal (eggplant). Pestology 24(6): 45-47.

Chang Y C, Chang Y H, Baker R, Kleifeld O and Chet I 1986 Increased growth of plants in the presence of biological control agent *Trichoderma harzianum*. Plant Disease 70: 145-148.

Chapin J W and Thomas J S 1993 Effects of chlorpyriphos on pod damage, disease incidence and yield in two peanut fungicide programs. Peanut Science 20(2): 102-106.

Charmswarng C and Cook R J 1985 Identification and comparative pathogenicity of Pythium species from wheat roots and wheat-field soils in the Pacific Northwest. Phytopathology 75: 821-827.

Chatterson S 2002 Biological control of *Pythium* root rot of bell pepper (*Capsicum annuum* L.) in a small-scale hydroponic system. M Sc Thesis, University of Guelph, Ontario, Canada.

Chatterson S, Sutton J C and boland G J 2004 Timing *Pseudomonas chloraphilis* applications to control *Pythium aphanidermatum*, *Pythium dissotocum* and root rot in dydroponic peppers. Biological Control, pp: 360-373.

Chattopadyay C and Bineeta Sen 1996 Integrated management of *Fusarium* wilt of muskmelon caused by *Fusarium oxysporum*. Indian Journal of Mycology and Plant Pathology 26(2): 162-170.

Chattopadyay C and Kalpanasastry R 2002 Combining viable disease controls tools for management of Sesamum stem rot caused by *Macrophomina phaseolina* (Tassi.) Goid. Indian Journal of Plant Protection 30(2): 132-138.

Chattopadyay T K, Pan S and Sen C 1981 Seedling blight of jute caused by *Macrophomina phaseolina* and its control. Indian Journal of Mycology and Plant Pathology 26: 162-170.

Chauhan M S 1986 Comparative efficacy of fungicides for the control of seedling diseases of cotton due to *Rhizoctonia* spp. Indian Journal of Mycology and Plant Pathology 16: 335-337.

Chet I 1987 *Trichoderma* – application, mode of action and potential as a biocontrol agent of soil borne plant pathogenic fungi., pp.137-159. In: Chet I (ed.) Innovative approach to plant disease control. John Wiley & Sons, New York.

Chet I and Henis Y 1985 *Trichoderma* as a biocontrol agent against soil borne root pathogens in Ecology and Management of soil borne pathogens (Parker C A eds). American Phytopathological Society St. Paul Minnesota, USA, p.110-112.

Chet I, Elad Y, Kalfon A, Hadar Y and Katan J 1982 Integrated control of soil borne diseases in potatoes. Phytopathology 72: 418-425.

Chowdhry P, Sharma P and Mathur N 2001 Biology and systemics in identification of *Trichdoerma* species for biocontrol of plant pathogens. Practical Manual on Challenges and Opportunities of Biological Control in Plant Disease Management, pp: 70.

Cook R J and Baker K F 1983 The nature and practice of biological control of plant pathogens. The American Phytopathological Society, St Paul M N, 539 pp.

Corpus E A and paderes D E 1993 Sclerotia of *Sclerotium rolfsii* Sacc. as baiting material in the isolation of *Trichoderma* species. Twenty Fourth Annual Scientific Meeting of the Pest Management Council of the Philippines. Inc. College, Laguna (Philippines). P.66.

Csinos A S 1984 Evaluation of the insecticide chlorpyrifos for activity against southern stem rot of peanut. Peanut Science 11: 98-102.

Csinos A S 1989 Targeting fungicides for control of Southern Stem rot of peanut. Plant Disease 73: 723-726.

Das C M, Mishra S K, harichandran B K and Narain A 1987 Effect of certain soil types on the growth of *Sclerotium rolfsii* causing stem rot of groundnut. Indian Phytopathology 40: 418-419.

Das S R and Panda S N 1997 Evaluation of fungicides against *Sclerotium rolfsii* causing collar rot of tuberose. Orissa Journal of Horticulture 25(1): 46-48.

Datta P, Das B C and Hazarika D K 2000 Integrated management of soybean stem rot. Journal of Biological Control 14(1): 67-69.

Davet P 1987 Criteria for selecting *Trichoderma* clones, antagonistic sclerotial fungi in soil. Bulletin DEPP, 17: 355-540.

Davey A E and Leach L D 1941 Experiments with fungicides for use against *Sclerotium rolfsii* in soils. Hilgardia 13: 523-547.

Deepa Khulbe and Choube H S 2002 Effect of soil solarization and its integration with bioagents and fungicides on incidence of damping-off and plant growth response of vegetable crops in nursery. Journal of Mycology and Plant Pathology 32(3): 413.

Deepak Kumar and Dubey S C 2001 Management of collar rot of pea by the integration of biological and chemical methods. Indian Phytopathology 54(1): 62-66.

Dennis C and Webster J 1971 Antagonistic properties of species-group of *Trichoderma* III hyphal interactions. Transactions of British Mycological Society 57: 363-369.

Desai S A and Srikant Kulkarni 2002a Effect of urea on the growth and sporulation of *Macrophomina phaseolina* (Tassi) Goid and native isolates of *Trichoderma viride* Pers. and *Trichoderma harzianum* Rifai. Karnataka Journal of Agricultural Sciences 15(1): 77-79.

Desai S A and Srikant Kulkarni 2002b Fungistatic effect of chlorpyriphos on the growth of *Trichoderma viride* Pers. Karnataka Journal of Agricultural Sciences 15(2): 384-385.

Desai S A and Srikant Kulkarni 2004 Effect of fungicides, insecticides and weedicides on the growth and sporulation of native *Trichoderma harzianum* Rifai. Karnataka Journal of Agricultural Sciences 17(1): 57-62.

Desai S A, Srikant Kulkarni and Kulkarni S 2002a Evaluation of different grains and seeds for mass multiplication of biocontrol agents. Karnataka Journal of Agricultural Sciences 15(1): 158-160.

Desai S A, Thammaiah M and Suresh Kunkatikar 2002 Fungicidal tolerance by *Trichoderma harzianum* Rifai – A biocontrol agent. Karnataka Journal of Agricultural Sciences 15(2): 397-398.

Deshmukh P P and Raut J G 1992 Antagonism by *Trichoderma* spp. on five plant pathogenic fungi. New Agriculturist 3: 127-130.

Deshpande G D and Bochow H 1986 Enhanced predisposition to seedling damping-off after seed dressing in cucumber. Indian Phytopathology 39: 373-375.

Devaki N S and Shankara Bhat S 1992 French bean as inoculum source for damping-off of tobacco. Indian Phytopathology 45: 124-126.

Devaki N S, Bhat S S, Bhat S G, Manjulatha K R and Shankara Bhat S 1992 Antagonistic activities of *Trichoderma harzianum* on *Pythium aphanidermatum* and *P. myriotylum* on tobacco. Journal of Phytopathology 136: 82-87.

Devat P, Artigues M and Martin C 1981 Production of *Trichoderma harzianum* Rifai. Agronomie: 933-935.

Dhamnikar S V and Peshney N L 1982 Chemical control of *Sclerotium* wilt of groundnut. Pesticides 4: 19-21.

Dharam Singh and Maheswari V K 2001 Biological seed treatment for the control of loose smut of wheat. Indian Phytopathology 54(4): 457-460.

Dharam Singh and Umamaheswari 2001 Biological seed treatment for the control of loose smut of wheat. Indian Phytopathology 54(4): 457-460.

Dharam Vir and Grewal J S 1961 Efficacy of different fungicides. III. Seed disinfection in relation to damping-off of chillies (*Capsicum annum* Linn.). Indian Phytopathology 14: 10-12.

Dharma Singh and Maheswari V K 2001 Biological seed treatment for the control of loose smut of wheat. Indian Phytopathology 54(4): 457-460.

Dharma Singh and Maheswari V K 2001 Biological seed treatment for the control of loose smut of wheat. Indian Phytopathology 54(4): 457-460.

Dharma Vir S and Indra Hooda 1987 Influence of FYM on the efficacy of fungicide in controlling damping-off of tomato and chilli. Vegetable Science 14: 58-64.

Dhingra O D and Sinclair J B 1993 Basic plant pathology methods. CBS Publications and Distribution, New Delhi, p.335.

Dickman M B and Chet I 1998 Biodegradation of oxalic acid; a potential new approach to biological control. Soil Biology and Biochemistry 30: 1195-1197.

Dickman M B and Mitra A 1992 *Arabidopsis thaliana* as a model for studying *Sclerotinia sclerotiorum* pathogenesis. Physiological and Molecular Plant Pathology 41: 255-263.

Dileep Kumar and Dubey H C 1992 Seed bacterization with a fluorescent pseudomonads for enhanced plant growth, yield and disease control. Soil Biology and Biochemistry 24: 539-542.

Dinakaran D and Marimuthu T 1997 Inhibition of *Macrophomina phaseolina* (Tassi) Goid by mutant of *Trichoderma viride* Pers ex fr. Journal of Biological Control 11: 43-47.

Dinakaran D and Ramakrishnan D 1996 Studies on the control of tomato damping-off with *Trichoderma viride*. Plant Disease Research 11(2): 148-149.

Domsch K H, Gams W and Anderson T H 1980 Compendium of soil fungi. Academic, London, pp.794-809.

Dubey S C 1998 Evaluation of fungal antagonists of *Thanetophorus cucumeris* causing web blight of horsegram. Journal of Mycology and Plant Pathology 28(1): 15-18.

Dubey S C 2000 Biological management of web blight of groundnut (*Rhizoctonia solani*). Journal of Mycology and Plant Pathology 30(1): 89-90.

Dubey S C and Patel B 2001 Evaluation of fungal antagonists against *Thanetophorus cucumeris* causing web blight of urd and mung bean. Indian Phytopathology 54(2): 206-209.

Durai M 2004 Management of charcoal rot of sesame (*Sesamum indicum* L.) incited by *Macrophomina phaseolina* (Tassi.) Goid. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Dwivedi R S and Dubey R C 1987 Effect of fungicides on survival of *Macrophomina phaseolina* in soil and in soybean stem on soil. International Journal of Tropical Plant Disease 5: 147-152.

Dwivedi T S and Chaube H S 1985 Effect of fungicides on the emergence and infection of cotton seedlings by *Macrophomina phaseolina* (Tassi.) Goid. Indian Journal of Mycology and Plant Pathology 15: 295-296.

Ebenezar E G and Wesely E G 2000 Effect of fungicides on *Macrophomina phaseolina* causing root rot in greengram. Pestology 24(3): 12-14.

Elad and Chet I 1987 Possible role of competition for nutrients in biocontrol of Pythium damping-off by bacteria. Phytopathology 77: 190-195.

Elad Y and Chet I 1983 Improved selective media for isolation of *Trichoderma* spp., *Fusarium* spp. Phytoparasitica 11: 55-58.

Elad Y, Chet I and Katan J 1980a *Trichoderma harzianum* : A biocontrol agent effective against *Sclerotium rolfsii* and *Rhizoctonia solani*. Phytopathology 70: 119-121.

Elad Y, Chet I, Boyle P and Henis Y 1983a Parasitism of *Trichoderma* spp., *Rhizoctonia solani* and *Sclerotium rolfsii* scanning electron microscopy-flouorescent microscopy. Phytopathology 73: 85-88.

Elad Y, Hadar Y, Chet I and Henis Y 1982 prevention with *Trichoderma harzianum* Rifai. Aggr. of reinfestation by *Sclerotium rolfsii* and *Rhizoctonia solani* of soil fumigated with methyl bromide and improvement of disease control in tomatoes and peanuts. Crop Protection 1: 199-211.

Elad Y, Hadar Y, Hadar E, Chet I and Henis Y 1981 Biological control of *Rhizoctonia solani* by *Trichoderma harzianum* in carnation. Plant Disease 65: 675-677.

Elad Y, Katan J and Chet I 1980b Physical, biological and chemical control integrated for soil borne diseases in potatoes. Phytopathology 70: 418-422.

Elad Y, Sivan A, Zeidam O, Kleifeld O and Chet I 1983a biological and integrated control of soil pathogens as a means for reduction of fungicides. In: Developments in ecology and environmental quality (Shuval H, ed.). Balaban International Science Service, Israel, pp.587-594.

Elad Y, Zvieli Y and Chet I 1986 biological control of *Macrophomina phaseolina* (Tassi) Goid by *Trichoderma harzianum*. Crop Protection 5: 288-292.

Elangovan C and Gnanamanickam S S 1992 Incidence of *Pseudomonas fluorescens* in rhizosphere of rice and their antagonism towards *Sclerotium oryzae*. Indian Phytopathology 45: 358-361.

*Elarosi H, Michali S H and Felga G I 1969 Studies on the control of damping-off of tomato by seed dressing in Egypt (UAE). Phytopath Mediterranean 8: 124-131.

Ercole D N, Nipoli P, Manzali D, Pillo L di and Di Pillo L 1993 *In vitro* and *in vivo* activity of *Trichoderma* sp. against some seedling diseases of horticultural plants. Colture Protette 22: 63-65.

Fajola A O and Alasoudura S O 1975 Antagonistic effects of *Trichoderma harzianum* on *Pythium aphanidermatum* causing damping-off disease of tobacco in Nigeria. Phytopathology 68: 900-907.

Fang H C and Liu T M E 1988 Effect of urea and nitrogenous compounds on the sclerotial germination and viability of the *Sclerotium rolfsii* in soil and its relationship with microorganisms. Plant Protection Bulletin – Taiwan 30(3): 235-244.

Fernando W G D and Linderman R G 1994 Chemical control of stem and root rot of cowpea caused by *Phytophthora vignae*. Plant Disease 78: 967-971.

Gaffar A 1968 Interaction of soil fungi with *Macrophomina phaseolina* (Maubl.) Asby the cause of root rot in cotton. Mycopathological Applied Mycology 34: 196-201.

Gamliel A and Katan J 1993 Suppression of major and minor pathogens by fluorescent pseudomonads in solarized and non-solarized soils. Phytopathology 83: 68-75.

Ganesan P and Gnanmanickam S S 1987 Biological control of *Sclerotium rolfsii* Sacc in peanut by inoculation with *Pseudomonas flourescens*. Soil Biology and Biochemistry 19: 35-38.

Gangopadyay S and Grover R K 1984 Efficacy of fungitoxicants on the control of root rot of cowpea caused by mixed inocula of *Rhizoctonia solani*, *Rhizoictonia bataticola* and *Fusarium solani*. Indian Journal of Mycology and Plant Pathology 14: 57-68.

Gattani M L and Kaul T N 1951 Damping-off of tomato seedlings, its cause and control. Indian Phytopathology 4: 171-180.

Girija Ganeshan 1997 Fungicidal control of Sclerotium basal rot of cluster bean cv. Pusa Naubahar. Indian Phytopathology 50(4): 508-512.

Girija V K and Umamaheswaran 2003 Basal rot of balsam and its management through bioagents. Plant Disease Research 18(1): 52-55.

Gnanavel I and Jayaraj J 2003 Integration of soil solarization and *Trichoderma viride* Pers. Fr to control damping off of tomato (*Lycopersicon esculentum* Mill.). Journal of Biological Control 17(1): 99-102.

Godfrey G H and Young P A 1943 Soil fumigation for plant disease control. Texas Agricultural Experimental Station Bulletin 628, 40 p.

Gopalakrishnan C, Ramanujam B, Prasad R D, Rao N S and Rabindra R J 2003 Screening and selection of potential *Trichoderma* isolates for the control of cotton seed rot and damping-off. Journal of Biological Control 17(2): 161-165.

Goswami B K and Meshram N J 1991 Influence of mustard and karanj oilseed cakes amended soil on soil mycoflora after 3 weeks of decomposition and at harvest of tomato infected with root knot nematode *Meloidogyne incognita*. Indian Journal of Nematology 21: 92-94.

Goudar S B and Srikant Kulakarni 1999 Compatibility effect of antagonists and seed dressers against *Fusarium udum* – the causal agent of pigeonpea wilt. Karnataka Journal of Agricultural Science 12(1-4): 197-199.

Govindappa M M and Grewal J S 1965 Efficacy of different fungicides in controlling damping-off of tomato. Indian Journal of Agricultural Science 25: 210-215.

Grienstein D, Elad Y, Katan J and Chet I 1979 Control of *Sclerotium rolfsii* by means of a herbicide and *Trichoderma harzianum*. Plant Disease Reporter 63: 823-826.

Grover R K and Dutt S 1972 Seed and soil treatment with fungitoxicants for control of damping-off of tomatoes caused by *Pythium aphanidermatum*. Indian Journal of Mycology and Plant Pathology 2: 98-102.

Gunasekharan C R, Vinayagamurthy A and Sundaram R 1994 Management of root knot nematode and damping-off disease in tomato nursery. South Indian Horticulture 42: 346-347.

Gupta R B L 1995 Management of *Macrophomina* stem blight of cowpea through seed dressing and spray fungicides. Indian Journal of Mycology and Plant Pathology 25: 112.

Gupta S K and Bharadwaj S S 1980 Evaluation of some systemic and non-systemic fungicides *in vitro* against *Rhizoctonia bataticola*. Pesticides 14(11): 20-21.

Gupta V P, Sharma D D, Rekha M and Chandrasekhar D S 1999 Integration of *Trichoderma pseudokoningii* with agrochemicals for disease management and plant development in mulberry. Archives of Phytopathology and Plant Protection 32(6): 521-529.

Hadar Y, Harman G E and Taylor A G 1984 Evaluation of *Trichoderma koningii* and *T. harzianum* from New York soils for biological control of seed rot caused by *Pythium* spp. Phytopathology 74:106-110.

Hadar Y, Harman G E, Taylor A G and Norton J M 1983 Effects of pre-germination of pea and cucumber seeds and of seed treatment with *Enterobactor clocae* on rots caused by *Pythium* spp. Phytopathology 73: 1322-1325.

Hader Y, Chet I and Henis Y 1979 Biological control of *Rhizoctonia solani* damping-off with wheat bran culture of *Trichoderma harzianum*. Phytopathology 69: 64-68.

Hagan A K, Weeks J R and Bowen K 1991 Effects of applications, timing and method on control of southern stem rot of peanut with foliar applied fungicides. Peanut Science 18: 47-50.

Hagan A K, Weeks J R and Meguire J A 1988 Comparison of soil insecticides alone and in combination with PCNB for suppression of southern stem rot of peanut. Peanut Science 15: 35-38.

Hagan A K, Weeks J R and Reed R B 1986 Southern stem rot suppression on peanut with the insecticide chlorpyriphos. Peanut Science 13(1): 36-37.

Hagan A K, Weeks J R and Reed R B 1989 Southern stem rot suppression on peanuts with lorsban insecticide. Down to Earth 45(2): 22-24.

Hari Narayana A B 1999 An integrated approach to the management of sclerotial wilt disease in bell pepper caused by *Sclerotium rolfsii* Sacc. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Harinath Naidu 2000 Crossandra – a new host record for *Sclerotium rolfsii*. Indian Phytopathology 54: 335-339.

Haritha V 2003 Studies on the management of damping-off disease incited by *Pythium aphanidermatum* (Edson) Fitzp. in tobacco nurseries. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Haritha V 2004 Studies on the management of damping-off disease incited by *Pythium aphanidermatum* (Edson) Fitzp in tobacco nurseries. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Harman G E, Chet I and Baker R 1981 Factors affecting *Trichoderma hamatum* applied to seeds as a biocontrol agent. Phytopathology 71: 569-572.

Hazarika D K and Das K K 1998 Biological management of root rot of French bean (*Phaseolus vulgaris* L.) caused by *Rhizoctonia solani*. Plant Disease Research 13(2): 101-105.

Hegde S G and Anahosur K H 1998 Integrated management of foot rot of black pepper. Karnataka Journal of Agricultural Sciences 11(1): 78-82.

Henis Y and Chet I 1967 Mode of action of ammonia on *Sclerotium rolfsii*. Phytopathology 57: 425-427.

Henis Y and Chet I 1968 The effect of nitrogenous amendments on the germinability of sclerotia of *Sclerotium rolfsii* and on their accompanying microflora. Phytopathology 58: 209-211.

Henis Y and Papavizas G C 1983a Factors affecting germinability and susceptibility to attack of sclerotia of *Sclerotium rolfsii* by *Trichoderma harzianum* in soil. Phytopathology 73: 1469-1474.

Henis Y, Ghaffar A and Baker R 1978 Integrated control of *Rhizoctonia solani* damping-off of radish. Effect of successive planting, PCMB and *Trichoderma harzianum* on pathogen and disease. Phytopathology 68: 900-909.

HoH J G, Kreeg N R, Sneath P H, Stanley J T and Williams S T 2000 Bergy's manual of determinative bacteriology. Lippincott Williams and Wilkins, Maryland, USA.

Holliday p and Punithalingam E 1970 *Macrophomina phaseolina*. CMI Description of Pathogenic Fungi and Bacteria no.275, pp.2.

Homma Y 1991 Biological control of plant diseases and virus vectors in Japan. The biological control of plant diseases. Proceedings of the International Seminar on "Biological Control of Plant Diseases and Virus Vectors" held in Tsakuba, Japan 1991: 171-180.

Hooda I and Grover R K 1983 Comparative antifungal activity of fungitoxicants against *Rhizoctonia bataticola* causing seedling rot and foliage blight of mungbean. Indian Journal of Plant Pathology 1: 75-82.

Hooda Indra and Grover R K 1988 Effect of age quantity of inoculum and isolates of *Macrophomina phaseolina* on the pathogenesis of mungbean and its control by chemicals. Indian Phytopathology 41: 107-117.

Hornby D (ed.) 1990 Biological control of soil borne plant pathogens. Walling Food Oxon, UAB International, pp.479.

Howell C R and Stipanovic R D 1979 Control of *Rhizoctonia solani* on cotton seedlings with *Pseudomonas fluorescens* and with antibiotic produced by the bacterium. Phytopathology 70: 712-715.

Howell C R and Stipanovic R D 1980 Suppression of *Pythium ultimum*-induced damping-off of cotton seedlings by *Pseudomonas fluorescens* and its antibiotic, pyoluteorin. Phytopathology 70: 712-715.

Howell C R and Stipanovic R D 1983 Gliovirin, a new antibiotic from *Gliocladium virens* and its role in the biological control of *Pythium ultimum*. Canadian Journal of Microbiology 29: 321-324.

Humayun P 2001 Studies on biological control of soil borne plant pathogens. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Ibrahim A N, Fadl F A and Hussein M S 1977 Varietal resistance of peas and effect of fertilizers of certain root rot fungi. Egyptian Journal of Phytopathology 9: 1-7.

Ilyas M B, Illis M A and Sinclair J B 1975 Evaluation of soil fungicides for control of charcoal rot of soybean. Plant Disease Reporter 59; 360-364.

Indra N and Subbaiah G 2003 Management of blackgram root rot caused by *Macrophomina phaseolina* by antagonistic microorganisms. Madras Agricultural Journal 90(7-9): 490-494.

Indra N and Thirubuvanamala G 2002 Antagonism of *Trichoderma* spp. against *Macrophomina phaseolina* causing root rot of blackgram. Plant Disease Research 17(1): 142-144.

Inwang B and Chamswarng C 1986 Control of tomato stem rot (*Sclerotium rolfsii*) in microorganisms isolated from the cultivated soils. Proceedings of the 24th National Conference: Poster Session, Bangkok (Thailand), p: 173-185.

Jackson K and Domicone J 1991 Soil fungicide demonstration on southern blight of peanut. Result of 1990 plant disease control field studies. Research Report, Agricultural Experiment Station, Oklahoma State University No.P920, RP.61-71.

Jacob C 1989 Biological control of root rot of blackgram (*Vigna mungo* L.) Hepper by introduction of antagonists. Ph D Thesis, Tamil Nadu Agricultural University, Coimbatore.

Jain A C, Vyas S C, Verma R K and Asha Arora 1984 Ridomil – a systemic fungicide effective against *Pythium aphanidermatum*. Pesticides 18: 40-41.

Jain N K, Khare N N and Sharma H C 1973 Variation among the isolates of *Rhizoctonia bataticola* from urd plant parts and soil. Mysore Journal of Agricultural Science 6: 461-465.

Jaworska M and Dluzniewska J 2002 Activity *in vitro* of some herbicides on the fungi of *Trichoderma* genus. Progress in Plant Protection 42(2): 633-635.

Jayalakshmi V, Sivaprakasam K and Seetharaman K 2003 Effect of *Pseudomonas fluorescens* on *Rhizoctonia solani* on the growth of rice plant. Journal of Biological Control 17(2): 189-192.

Jayaraj J and Radhakrishnan N V 2000 Tolerance of *Trichoderma harzianum* to certain herbicides *in vitro*. Indian Journal of Weed Science 32(1&2): 74-76.

Jayaraj J and Radhakrishnan N V 2000b Survival of the biocontrol agent *Trichoderma harzianum* in soil as influenced by certain herbicides. Indian Journal of Weed Science 32(1&2): 116-117.

Jayaraj J and Ramabhadran R 1998 Effect of certain nitrogenous sources on the *in vitro* growth, sporulation and production of antifungal substances by *Trichoderma harzianum*. Journal of Mycology and Plant Pathology 28(1): 23-25.

Jayaraj J and Ramabhadran R 1998 Effect of certain nitrogenous sources on the *in vitro* growth, sporulation and production of antifungal substance by *Trichoderma harzianum*. Journal of Mycology and Plant Pathology 28(1): 23-25.

Jayarajan J and Ramabhadran R 1996 Effect of certain soil-insecticides on *in vitro* growth, sporulation and cellulase production by *Trichoderma harzianum* Rifai.

Jayasree K, Shanmugam V, Raghuchander T, Ramanathan A and Samiyappan R 2000 Evaluation of *Pseudomonas fluorescens* (Pf-1) against blackgram and sesame root rot disease. Journal of Biological Control 14(2): 55-61.

Jenkins S F and Averre C W 1986 Problems and progress in integrated control of Southern blight of vegetables. Plant Disease 70: 614-619.

Jeyarajan R, Ramakrishnan G, Dinakaran D and Sridhar R 1994 Development of product of *Trichoderma viride* and *Bacillus subtilis* for biocontrol of root rot disease. Pp: 25-36. In: Dwivedi B K (ed.). Biotechnology in India. Bioved Research Society, Allahabad, India.

Jharia H K and Khare M 1986 Biological control of *Rhizoctonia bataticola* causing disease in soybean. Indian Phytopathology 39: 148.

Johnson M and Subramanyam K 2000 *In vitro* efficacy of fungicides against stem rot pathogen (*Sclerotium rolfsii*) of groundnut. Annals of Plant Protection Sciences 8: 255-257.

Kadir T S and Daradjat A A 1991 Efficacy of fungicides on *Sclerotium rolfsii* and spot blotch *Helminthosporium sativum* in wheat. Media Panelitian Sukumandi Indonesia 10: 38-40.

Kajalkumar B and Chitreswaran 2000 Identification of effective isolates of *Trichoderma harzianum* for bio-control of *Macrophomina phaseolina* (Tassi.) Goid. Indian Journal of Mycology and Plant Pathology 30: 408-410.

Kalappanavar I K and Patil N K 2000 Biological control of *Sclerotium rolfsii* Sacc. a causal agent of foot rot of wheat. Karnataka Journal of Agricultural Sciences 13(2): 478-479.

Kamal and Singh S 1976 Some new hosts for *Sclerotium rolfsii* from India. Indian Phytopathology 29: 188-189.

Kammanna B C, Nirmala K, Hanumantha B T, Govindarajan T S and Kannan N 1992 Soft rot of coffee caused by *Sclerotium rolfsii* and *in vitro* evaluation of fungicides against the fungus. Journal of Coffee Research 22: 1-9.

Kanakamahalakshmi R, Ravindra Babu R, Sarwar H A K and Raoof M A 1998 Yield losses and management of root rot of castor incited by *Macrophomina phaseolina* (Tassi.) Goid. Indian Journal of Plant Protection 26: 159-163.

Kanakamahalaxmi 1995 Role of *Macrophomina phaseolina* (Tassi) Goid in the castor wilt complex. M Sc (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Kandaswamy M and Sundaram N V 1956 Chilli wilt and its control. Madras Agricultural Journal 43: 338-340.

Karpagavalli S 1997 Effect of different fungicides on the growth of *Trichoderma*. Indian Journal of Plant Protection 25(1): 82-83.

Karpagavalli S and Ramabhadran R 2001 Effect of fungicides and *Trichoderma* species on cellulolytic enzyme production, damping-off incidence and seedling vigour of tomato. Plant Disease Research 16(2): 179-185.

Karthikeyan G, Sabitha Doraisamy and Sivakumar C V 2000 Biological and chemical control of *Pythium aphanidermatum – Meloidogyne incognita* disease complex in chilli and brinjal. Madras Agricultural Journal 87(1-3): 105-108.

Karthikeyan G, Sabitha Doraiswamy and Sivakumar C V 2001 Biological control of *Pythium aphanidermatum – Meloidogyne incognita* disease complex in brinjal with organic amendments. Madras Agricultural Journal 88: 1-3.

Kassim N A, Taha K H and Seddy K IAS 1989 Efect of different concentrations of sodium chloride on some fungi causing damping-off of tomato seedlings. Mesopotamia Journal of Agriculture 21: 343-351.

Kataria H R, Yadav J P S and Grover R K 1981 Interaction of chemical fertilizers with seed dressing fungicides in controlling *Rhizoctonia solani* Z. Pflkranth. Pflschutz 88: 641-650.

Kaur N P and Mukhopadyay 1992 Integrated control of chickpea wilt complex by *Trichoderma* and chemical methods in India. Tropical Pest Management 38(4): 372-375.

Kaur N P and Mukhopadyay A N 1992 Integrated control of chickpea wilt complex by *Trichoderma* and chemical methods in India. Tropical Pest Management 38: 372-375.

Kaushik J C, Sanjay Arya and Gupta P P 2002 Management of damping-off disease in forest nurseries by soil solarization and biocontrol agents. Forage Research 28(1): 29-31.

Khare M N, Agarwal S C, Kushwaha L S and Tomar K S 1974 Evaluation of fungicides for the control of wilt of lentil caused by *Sclerotium rolfsii*. Indian Phytopathology 27: 364-366.

Kirpatrick B L and Sinclair J B 1973 Uptake of two systemic fungicides and their breakdown products by soybean seed. Phytopathology 63: 1532-1535.

Kloepper J W and Schroth M N 1981 Plant growth promoting rhizobacteria and plant growth under genobiotic conditions. Phytopathology 71: 642-644.

Kotum T I and Adenkule F 1990 Inhibition of growth of some plant pathogenic fungi by some antagonistic microorganisms isolated from soil. Journal of Basic Microbiology 30: 95-98.

Kousalya G and Jeyarajan R 1991 Efficacy of antagonists on germination and root rot of blackgram. Journal of Biological Control 5: 42-44.

Krishnamoorthy A S and Bhaskaran R 1990 Biological control of damping-off disease of tomato caused by *Pythium indicum* Balakrishnan. Journal of Biological Control 4(1): 52-54.

Kucharek T A and Edmondson G R 1991 Suppression of southern stem rot of peanut caused by *Sclerotium rolfsii* with the insecticide chlorpyriphos (Lorsban 15 G). Proceedings of Soil and Crop Science Society of Florida 50: 41-43.

Kulkarni S 1980 Chemical control of foot rot of wheat in Karnataka. Pesticides 14(5): 29-30.

Kulkarni S A 1992 Studies on collar rot of groundnut caused by *Sclerotium rolfsii*. M Sc Thesis, University of Agricultural Sciences, Dharwad.

Kumar K 1998 Studies on bioefficacy and determination of residues of imidacloprid applied against sucking pests on cotton. Ph D Thesis, Tamil Nadu Agricultural University, Coimbatore, 123 pp.

Kuruvilla Jacob C 1989 Biological control of root rot of blackgram *Vigna mungo* (L.) Hepper by introduction of antagonists. Ph D Thesis, Tamil Nadu Agricultural University, Coimbaotre, pp.214.

Kwee L T and Keng T B 1990 Antagonism of *in vitro* of *Trichoderma* species against several basidiomycetous soil borne pathogens and *Sclerotium rolfsii*. Journal of Plant Disease and Protection 97: 33-41.

Labakha L V and Donadze V Z 1975 The use of *Trichoderma lignorum* Harz. against *Sclerotium rolfsii* Sacc. causing southern root rot of tomato. Trudy Naclchno Issledovatel Skogo Instituta Zashchity Rastenii Gruz-SSR 27(3): 142-146.

Laha G S, Singh R P and Verma J P 1992 Biocontrol of *Rhizoctonia solani* in cotton by fluorescent Pseudomonads. Indian Phytopathology 45(4): 412-415.

Laha G S, Verma J P and Singh R P 1996 Effectiveness of fluorescent Pseudomonas in the management of sclerotial wilt of cotton. Indian Phytopathology 49(1): 5-8.

Laha G S, Verma J P and Singh R P 1998 Effectiveness of fluorescent pseudomonads in the management of sclerotial wilt of cotton. Indian Phytopathology 49(1): 3-8.

Lakra B S 2003 Management of damping off of 'true' potato seedlings by using bioagents and a fungicide. Plant Disease Research 18(1): 73-74.

Lal R and Nagarajan 1993 Effect of biological agents and fungicides on collar rot disease in tobacco. Tobacco Research 19: 54-56.

Lal R and Nagarajan K 1988 *In vitro* evaluation of pesticides against *Sclerotium rolfsii* Sacc. causing collar rot of tobacco. Pestology 11: 8.

Latha T K S and Narasimhan V 2001 Management of root rot and cyst nematode complex in blackgram. Plant Disease Research 16(1): 73-78.

Latha T K S, Rajeswari E and Narasimhan V 2000 Management of root rot disease complex through antagonists and chemicals. Indian Phytopathology 53(2): 216-218.

Latunde Dada A D 1993 Biological control of Southern blight disease of tomato caused by *Sclerotium rolfsii* with simplified mycelial formulations of *Trichoderma koningii*. Plant Pathology 41: 522-529.

Lazzaretti E, Menten Jom and Bettiol W 1994 *Bacillus subtilis* antagonistic to the principal pathogens associated with bean and wheat seeds. Fitopatologia Vanezolna 7(2): 42-46.

Lifshitz R, Sneh B and Baker R 1984a Soil suppressiveness to a pathogenic *Pythium* species. Phytopathology 74: 1054-1061.

Lifshitz R, Windham M T and Baker R 1986 Mechanism of biological control of pre-emergence damping-off of pea seed treatment with *Trichoderma* spp. Phytopathology 76: 723-725.

Lozano T Z E and Pineda Lopez B 1977 Preliminary studies on biological control of *Sclerotium rolfsii* Sacc. in the Cordoba region. Fitopatologia Columbiana 6: 62-72.

Lumsden R D and Locke J C 1989 Biological control of damping-off caused by *Pythium ultimum* and *Rhioctonia solani* with *Gliocladium virens* in soilless mix. Phytopathology 79: 361-366.

Madhumeeta Gupta V K and Meeta M 1995 Evaluation of various fungicides for the control of basal rot (*Sclerotium rolfsii*) of carnation. Plant Disease Research 10(2): 170-173.

Mahabeer Singh and Majumdar V L 1995 Antagonistic activity of *Trichoderma* sp. to *Macrophomina phaseolina* (Tassi) Goid *in vitro*. Environment and Ecology 13: 481-482.

Mahadevamurthy S, Prakash H S and Shetty H S 1990 Effect of fertilizer amendment of soil and antagonist treatment on sclerotial germination of *Claviceps fusiformis*. Plant Disease Research 5(2): 212-215.

Maiti D and Sen C 1985 Integrated biological control of *Sclerotium rolfsii* with nitrogenous fertilizers and *T. harzianum*. Indian Journal of Agricultural Sciences 55: 464-468.

Maiti S and Raoof M A 1984 Areal infection of *Macrophomina phaseolina* on castor. Journal of Oilseeds Research 1: 232-233.

Majumdar V L, Jat J R and Gour H N 1996 Effects of biocontrol agents on the growth of *Macrophomina phaseolina* the incitant of blight of moth bean. Indian Journal of Mycology and Plant Pathology 26: 202-203.

Malathi P, Viswanathan R, Padmanabhan P, Mohanraj D and Sunder A R 2002 Compatibility of biocontrol agents with fungicides against red rot disease of sugarcane. Sugar Technology 4(3-4): 131-136.

Mallaiah B 2002 Evaluation of bio-fungicides in the control of dry root rot of greengram. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Mani M T and Marimuthu J 1994 Effect of decomposed coir pith, fungicides and biocontrol agents on damping-off of chillies and dry root rot of blackgram. Indian Journal of Mycology and Plant Pathology 24: 20-23.

Manisha Tripathi, Johri B N and Tripathi M 2002 *In vitro* antagonistic potential of fluorescent pseudomonads and control of sheath blight of maize caused by *Rhizoctonia solani*. Indian Journal of Microbiology 42(3): 207-214.

Mannina L, Sepre A L, Ritini A, Fogliane V, Vinaole P, Randozzo G, Maddau L and Boltalice A 1997 A new fungal growth inhibitor from *Trichoderma viride*. Tetrahedron 53: 3135-3144.

Manoranjitham S K and Prakasam V 2002 Biological control of damping off disease of tomato. South Indian Horticulture 47(1-6): 302-305.

Manoranjitham S K, Prakasam V and Rajappan K 1999 Effect of antagonists on *Pythium aphanidermatum* (Edson) Fitz and the growth of chilli seedlings. Journal of Biological Control 13: 101-106.

Manoranjitham S K, Prakasam V and Rajappan K 2001 Biocontrol of damping off of tomato caused by *Pythium aphanidermatum*. Indian Phytopathology 54(1): 59-61.

Manoranjitham S K, Prakasam V, Rajappan k and Amutha G 2000 Control of chilli damping-off using bioagents. Journal of Mycology and Plant Pathology 30(2): 225-228.

Maramara M G V and Paningbatan R A 1993 Seed coating with *Trichoderma viride* Pers to control *Sclerotium* wilt in mungbean [*Vigna radiata* (L.) Wilezek] Philippine. Phytopathology 29: 54-66.

Martinez Toledo M V, Salmeron V and Gonzalez Lopez J 1992 Effect of the insecticides methyl pyrimfos and chlorpyrifos on soil microflora in an agricultural loam. Plant and Soil 147: 25-30.

Mathivanan N, Srinivasan K and Chellaiah S 1997 Evaluation of *Trichoderma viride* and carbendazim for integrated management of root diseases in cotton. Indian Journal of Microbiology 37: 107-108.

Mathur S B and Sarbhoy A K 1978 Biological control of *sclerotium* root rot of sugarbeet. Indian Phytopathology 31: 365-367.

McClellan W D, Christic J R and Horn N L 1949 Efficacy of soil fumigants as affected by soil temperature and moisture. Phytopathology 39: 272-283.

McLean K L, Hunt J, Stewart A, Zydenbos S M 2001 Compatibility of the biocontrol agent *Trichoderma harzianum* C52 with selected fungicides. New Zealand Plant Protection Volume 54, 2001. Proceedings of a conference – Quality Hotel – Palmerston North – New Zealand 14-16 August 2001, pp. 84-86.

Mehta R D, patel K , Roy K K and Mehta M H 1995 Biological control of soil borne pathogens with *Trichoderma harzianum*, Department of Microbiology, M.S. University of Baroda, Gujarat, India). Indian Journal of Mycology and Plant Pathology 25(1&2): 128.

Michael S H, Elarosi H and Felga G I 1969 Soil drench as a method for the control of damping off disease of tomato in Egypt (UAE). Phytopath Mediterranea 8: 217-223.

Mirza M S and Aslam M 1993 *Helianthus tuberosus*: a new host of *Sclerotium rolfsii* in Pakistan. Helia 16: 85-88.

Mishra B K and Bias B S 1987 Studies on seedling blight and root rot of barley caused by *Sclerotium rolfsii*. Indian Phytopathology 40: 161-167.

Mishra M K 1997 Chemical control of stem and root rot of jute. Journal of Mycology and Plant Pathology 27(1): 98.

Mohamood M, Abu Mohammad, Gupta S K and Kumar S 1976 Studies on root rot disease of groundnut caused by *Sclerotium rolfsii* Sacc. Proceedings of Bihar Academy of Agricultural Science 13: 157-158.

Mohan L, Paranidharan V and Prema S 2000 New diseases of timla fig (*Ficus auriculalata*) in India. Indian Phytopathology 53: 496.

Mohapatra P D and Dash S C 1990 Efficacy of different methods of controlling *Sclerotium rolfsii* Sacc. in betelvine 3(2): 126-129.

Monga D and Grover R K 1985 Chemical control of *Fusarium solani* altered in pathogenicity by substrate nutrients. Indian Journal of Mycology and Plant Pathology 15: 121 (Abt.).

Montealegre J R and Henriquez J L 1990 Possibilities of integrated control of *Sclerotium rolfsii* Sacc. of *Trichoderma* strains and fungicides. Fitopatologia 25: 68-74.

Morton D J and Stroube W H 1955 Antagonistic and stimulatory effects of soil microorganisms upon *Sclerotium rolfsii*. Phytopathology 45: 417-420.

Mukerjee *et al*. 2001 Integrated management of wilt complex in French bean (*Phaseolus vulgaris* L.). Journal of Mycology and Plant Pathology 31(2): 213-215.

Mukerjee P K and Upadyay J P 1988 Evaluation of *Trichoderma harzianum* for biocontrol of *Pythium* damping-off of cauliflower. Indian Phytopathology 41: 292.

Mukerjee P K, Mukhopadyay A N, Sarmah D K and Shrestha S M 1995 Comparative antagonistic properties of *Gliocladium virens* and *Trichoderma harzianum* on *Sclerotium rolfsii* and *Rhizoctonia solani* its relevance to understanding the mechanism of biocontrol. Journal of Phytopathology 143: 275-279.

Mukerjee S, Tripathi H S and Rathi Y P S 2001 Integrated management of wilt complex in Frenchbean (*Phaseolus vulgaris* L.). Journal of Mycology and Plant Pathology 31(2): 213-215.

Mukerjee S, Tripathi H S and Rathi Y P S 2001 Integrated management of wilt complex in French bean (*Phaseolus vulgaris* L.). Journal of Mycology and Plant Pathology 31(2): 213-215.

Mukherjee P K, Upadyay J P and Mukhopadyay A N 1989 Biological control of *Pythium* damping-off of cauliflower by *Trichoderma harzianum*. Journal of Biological Control 3: 119-124.

Mukhopadyay A N 1995 Exploitation of *Gliocladium virens* and *Trichoderma harzianum* for biological seed treatment against soil borne diseases. Indian Journal of Mycology and Plant Pathology 25(1&2): 124.

Mukhopadyay A N 1987 Biological control of soil borne plant pathogens by *Trichoderma* spp. Presidential address delivered at the 9th Annual meeting of the Society of Mycology and Plant Pathology. Indian Journal of Mycology and Plant Pathology 17: 1-10.

Mukhopadyay A N and Thakur R P 1971 Control of *Sclerotium* root rot of sugarbeet with systemic fungicides. Plant Disease Reporter 55: 630-634.

Mukhopadyay A N and Thakur R P 1977 Efect of some soil insecticides on sclerotium root rot of sugarbeet. Indian Journal of Agricultural Sciences 47(11); 533-536.

Mukhopadyay A N, Birambhatt A and Patel G J 1986 *Trichoderma harzianum* – a potential bio-control agent for tobacco damping-off. Tobacco Research 12(1): 26-35.

Munnecke D E 1972 Factors affecting the efficacy of fungicides in soil. Annual Review of Phytopathology 10: 375-398.

Muthamilan M 1994 Management of diseases of chickpea and rice using fluorescent pseudomonads. Ph D Thesis, Tamil Nadu Agricultural University, Coimbatore.

Muthamilan M and Jayarajan R 1992 Effect of antagonistic fungi on *Sclerotium rolfsii* causing root rot of groundnut. Journal of Biological Control 6(2): 88-92.

Muthamilan M and Jeyarajan R 1996 Integrated management of *Sclerotium* root rot of groundnut involving *Trichoderma harzianum*, Rhizobium and carbendazim. Indian Journal of Mycology and Plant Pathology 26: 204-209.

Nagarajan K and Reddy T S N 1980 Preliminary evaluation of ridomil against damping-off and leaf blight diseases of tobacco in seedbeds. Tobacco Research 6(2): 127-131.

Nagaraju P, Naresh D and Biradar D 2002 Biological control of sheath blight (*Rhizoctonia solani*) in transplanted rice (*Oryza sativa*). Indian Journal of Agricultural Sciences 72(5): 306-307.

Narain and Kar A K 1990 Wilt of groundnut caused by *Sclerotium rolfsii*, *Fusarium* sp. and *Aspergillus niger*. Crop Research 3: 257-262.

Narayana Bhat M and Srivastava L S 2003 Evaluation of some fungicides and neem formulations against six soil borne pathogens and three *Trichoderma* spp. *in vitro*. Plant Disease Research 18(1): 56-59.

Narian and Kar A K 1990 Wilt of groundnut caused by *Sclerotium rolfsii*, *Fusarium* sp and *Aspergillus niger*. Crop Research 3: 257-262.

Neelamegam R and Govindarajalu T 2002 Integrated application of *Trichoderma viride* Pers. Fr. And farmyard manure to control damping off of tomato (*Lycopersicon esculentum* mill.). Journal of Biological Control 16(1): 65-69.

Nelson E B, Harman G E and Nash G T 1988 Enhancement of *Trichoderma*-induced biological control of *Pythium* seed rot and pre-emergence damping-off of peas. Soil Biology and Biochemistry 20: 145-150.

Nelson E B, Mash G T and Harman G E 1984 Lectin mediated attachment of the biocontrol agent *Enterobacter cloacae* to fungal hyphae. II. Role in the biological control of Pythium seed rot. Phytopathology 74: 807.

Nene Y L and Thapliyal P N 1993 Fungicides in plant disease control (3rd ed.). Oxford and IBH Publishing Company Private Limited.

Nortan D C 1954 Antagonism in soil between *Macrophomina phaseolina* and selected soil inhabiting organisms. Phytopathology 44: 522-524.

Ohep J, McMillan R T Jr, Bryan H H and Cantliffe D J 1984 Control of damping-off of tomatoes by incorporation of fungicides in direct-seeding gel. Plant Disease 68: 66-67.

Ohr H D, Munnecke D E and Bricker J L 1973 The integration of *Armillaria mellea* and *Trichoderma* spp. as modified by methyl bromide. Phytopathology 63: 965-973.

Olivos M I and Mint R 1993 Use of fungicides and *Trichoderma viride* for the control of *Sclerotium rolfsii*. Fitopatologia 28: 16-21.

Padmalatha K V 2002 Studies on the management of charcoal rot of sunflower (*Helianthus annuus* L.). M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad (A.P.).

Palakshappa M G, Kulkarni S and Hegde R K 1986 Studies on foot rot of betelvine caused by *Sclerotium rolfsii* Sacc. in Karnataka. Plant Pathology Newsletter 4: 17.

Pandey K K and Upadyay J P 1997 Selection of potential biocontrol agents based on production of volatile and non-volatile antibiotics. Vegetable Science 24: 144-146.

Panes V G and Sukhatme P V 1978 Statistical methods for Agricultural Workers. Indian Council of Agricultural Research, New Delhi, pp: 136.

Paninghatan R A 1994 *Trichoderma* spp. for the biocontrol of stem rot of sweet pepper pest management council of Philippines. Integrated Pest Management: Learning from experience, p.68.

Papavizas G C 1985 *Trichoderma* and *Gliocladium*: Biology, ecology and potential for bio-control. Annual Review of Phytopathology 23: 23-54.

Papavizas G C 1973 Status of applied biological control of soil borne plant pathogens. Soil Biology and biochemistry 5: 708-720.

Papavizas G C 1982 Survival of *Trichoderma harzianum* in soil and in pea and bean rhizospheres. Phytopathology 72: 121-125.

Papavizas G C and Lewis J A 1988 The use of fungi in integrated control of plant diseases. In: Fungi in biological control systems (ed.) Burge M N, Manchester U K. Manchester University Press, pp: 241-275.

Papavizas G C and Lewis J A 1981 Biological control in crop production (ed. Papavizas G C). Totowa N J. Allanheld, Osmum, pp.305-322.

Papavizas G C and Lewis J A 1983 Physiological and biocontrol characteristics of stable mutants of *Trichoderma viride* resistant to MBC fungicides. Phytopathology 73: 407-411.

Papavizas G C and Lumsden R D 1980 Boiological control of soil borne fungal propagules. American Review of Phytopathology 18: 389-413.

Papavizas G C, Lewis J A and Abd-El-Moity T H 1982 Evaluation of new biotypes of *Trichoderma harzianum* for tolerance to benomyl and enhanced biocontrol abilities. Phytopathology 72: 126-132.

Parakhia A M and Vaishnav M U 1986 Biocontrol of *Rhizoctonia bataticola*. Indian Phytopathology 39: 439-440.

Parakhia A M, Akbari L F, Jungnu Antharia, Vaishnav M V and Antharia J 1998 Comparative evaluation of bioagents and seed dressing fungicides against *Aspergillus niger* causing collar rot of groundnut. Gujarat Agricultural University Research Journal 23(2): 61-65.

Paramjit Singh and Mehrotra R S 1980 Biological control of *Rhizoctonia bataticola* on gram by coating seed with *Bacillus* and *Streptomyces* spp. and their influence on plant growth. Plant and Soil 56: 475-483.

Paramjit Singh Bhagga and Vineet kumar 2000 *In vitro* effect ofherbicides on important fungal pathogens of wheat. Indian Phytopathology 53(3): 325-326.

Patel B N, Patel J B, Tilva D G and Patel R C 1988a Efficacy of certain fungicides in management of damping-off in bidi tobacco nursery. Tobacco Research 14: 109-112.

Patel B N, Patel J B, Tilva D G and Patel R C 1988b Efficacy of certain fungicides in management of damping-off in bidi tobacco nursery. Tobacco Research 14: 109-112.

Patel B N, Patel R C and Mukhopadyay A M 1987 Management of damping-off and *Cercospora* leaf spot in tobacco nursery. Tobacco Research 13(1): 80-82.

Patel K K and Patel J J 1990 Control of charcoal rot of sesamum. Indian Journal of Mycology and Plant Pathology 20(1): 62-63.

Patel S T and Anahosur 2001 Potential antagonism of *T. harzianum* against *Fusarium* spp., *Macrophomina phaseolina* and *Sclerotium rolfsii*. Indian Journal of Mycology and Plant Pathology 31: 365.

Pathak *et al* 2001 Effect of antagonistic fungi and seed dressing fungicides on the incidence of stem rot of mustard. Journal of Mycology and Plant Pathology 31(3): 327-329.

Patibanda A K, Upadyay J P and Mukhopadyay A N 2002 Efficacy of *Trichoderma harzianum* Rifai alone or in combination with fungicides against *Sclerotium* wilt of groundnut. Journal of Biological Control 16: 57-63.

Patibanda *et al*. 2002 Efficacy of *Trichoderma harzianum* Rifai alone or in combination with fungicides against Sclerotium wilt of groundnut. Journal of Biological Control 16(1): 57-63.

Patil M B and Rane M S 1982 Incidence and control of *Sclerotium* wilt of groundnut. Pesticides 4: 23-24.

Peshney N L, Gade R M and Thakare K G 1992 Sensitivity and adoptability of *Rhizoctonia bataticola* to different fungicides. Journal of Soils and Crops 2: 35-38.

Pranab Dutta and Das B C 2002 Management of collar rot of tomato by *Trichoderma* spp. and chemicals. Indian Phytopathology 55: 235-237.

Prasad B K, Thakur S P, Sinha and Prasad A 1986 *In vitro* studies on the influence of chemical fertilizers, organic manures and some cations on the growth of *Sclerotium rolfsii* Sacc. isolated from tomato fruits. Indian Journal of Mycology and Plant Pathology 16(2): 215-217.

Prasad R D and Rangeswaran R 2000 Effect of soil application of a granular formulation of *Trichoderma harzianum* on *Rhizoctonia solani* incited by seed rot and damping off of chickpea. Journal of Mycology and Plant Pathology 30(2): 216-220.

Prasanna A R, Nargund V B, Bheemanna M and Patil V 2002 Compatibility of thiomethoxam with *Trichoderma harzianum*. Journal of Biological Control 16(2): 149-152.

Prasanthi S K, Srikant Kulkarni, Anahosur K H and Kulkarni S 2000 management of safflower root rot caused by *Rhizoctonia bataticola* by antagonistic microorganisms. Plant Disease Research 15(2): 146-150.

Prathibha Sharma and Prem Dureja 2004 Evaluation of *Trichoderma harzianum* and *T. viride* isolates at BCA pathogen crop interface. Journal of Mycology and Plant Pathology 34(1): 47-55.

Punja Z K and Grogan R G 1981 *Sclerotium rolfsii* on turf in California. Attempted biological and chemical control. Phytopathology 71: 251.

Punja Z K, Grogan R G and Unruh T 1982 Chemical control of *Sclerotium rolfsii* on golf greens in Northern California. Plant Disease 66: 108-111.

Puspavathi B and Chandrasekhara Rao K 1998 Biological control of *Sclerotium rolfsii*, the incitant of groundnut stem rot. Indian Journal of Plant Protection 26(2): 149-154.

Pyke T R and Dietz A 1996 U2163, a new antibiotic. I. Discovery and biological activity. Applied Microbiology 14: 506-510.

Rabindran R and Vidyasekharan P 1996 Development of a formulation of *Pseudomonas fluorescens* PfALR2 for management of rice sheath blight. Crop Protection 15(8): 715-721.

Raghuchander T, Rajappan K and Samiyappan R 1997 Evaluating methods of application of biocontrol agent in the control of mungbean root rot. Indian Phytopathology 50: 229-234.

Raghuchander T, Samiyappan R and Arjunan G 1993 Biocontrol of *Macrophomina* root rot of mungbean. Indian Phytopathology 46: 379-382.

Rahman M A, Vijaya M and Chiranjeevi Ch 2003 Performance of soil solarization, captan and biocontrol agents in management of damping-off disease in solanaceous vegetable nursery. Indian Journal of Plant Protection 31(2): 7-175.

Rai J N and Srivastava S K 1977 Studies on the chemical control of root and stem rot of *Brassica juncea* caused by *Macrophomina phaseolina*. Indian Journal of Mycology and Plant Pathology 7: 47-51.

Rajan P P and Sharma Y R 1996 Compatibility of potassium phosphate (Akomin 40) with different species of *Trichoderma* and *Gliocladium virens*. Biotechnology of spices, medicinal and aromatic plants. Proceedings of the National Seminar on Biotechnology of Spices and Aromatic Plants, Calicut, India, 24-25 April, 1996, pp.150-155.

Rajani T 2004 Integrated management of *Sclerotium rolfsii* Sacc. the incitant of stem rot of groundnut. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Rajeev Pant and Mukhopadyay A N 2001 Integrated management of seed and seedling rot complex of soybean. Indian Phytopathology 54: 346-350.

Rajendra P, Patil, Jagadeesh K S and Kulkarni J H 1998 Karnataka Journal of Agricultural Sciences 11(1): 45-49.

Rajendran K and Ranganathan K Biological control of onion basal rot (*Fusarium oxysporum* f.sp. *cepae*) by combined application of fungal and bacterial antagonists. Journal of Biological Control 10: 97-102.

Rajeswari B 1997 Studies on biological control of *Macrophomina phaseolina* (Tassi) Goid incitant of dry root rot of mungbean. Ph D Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Rajeswari B, Chandrasekhar Rao K and Pramodchandra Kumar C 1999 Efficacy of antagonists and carbendazim against dry root rot of mungbean [*Vigna radiata* (L.) (Tassi)] Goid under glasshouse conditions. Journal of Biological Control 13: 93-99.

Rajib de R K and Mukhopadyay A N 1994 Biological control of damping-off by *Gliocladium virens*. Journal of Biological Control 8: 34-40.

Rajpurohit T S 1997 Management of *Macrophomina* stem and root rot of sesamum through fungicidal seed treatment and varietal resistance. Journal of Mycology and Plant Pathology 27(1): 98.

Rajyalakshmi 2002 Studies on variability among the isolates of *Sclerotium rolfsii* Sacc. M Sc (Ag.) Thesis submitted to Acharya N G Agricultural University, Hyderabad (A.P.).

Ram Singh M and Kang M S 1993 Rhizosphere mycoflora of mungbean and their interaction with *M. phaseolina*. Plant Disease Research 8: 25-29.

Rama Bhadra Raj M and Raoof M A 2003 Integrated approach for the management of castor wilt (*Fusarium oxysporum* f.sp. *ricini* Nanda and Prasad). Indian Journal of Plant Protection 31(1) 64-67.

Rama Yalla Reddy M 2002 Evaluation of certain bio-fungicides against predominant seed borne fungal disease of groundnut (*Arachis hypogaea* L.). M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad (A.P.).

Ramadoss S and Sivaprakasam K 1986 Effect of fungicides and insecticides on the linear growth of *Macrophomina phaseolina*. In: Management of soil borne diseases (R. Jayarajan, R. Bhaskaran and M. Shanmugam eds.). Tamil Nadu Agricultural University Press, p. 16 (Abst.).

Ramakrishnan G, Jeyarajan R and Divakaran D 1994 Talc based formulation of *Trichoderma viride* for biocontrol of *Macrophomina phaseolina*. Journal of Biological Control 8: 41-44.

Ramamoorthy V and Muthusamy M 1991 Control of seed borne pathogens of groundnut by antagonistic fungi. Journal of Biological Control 5: 39-41.

Ramarethinam S, Murugesan M V and Marimuthu S 2001 Compatibility studies of fungicides with *Trichoderma viride* used in the commercial formulation Bio-Cure-F. Pestology 25(5): 2-6.

Ramarethinam S, Murugesan N V and Marimuthu S 2001 Compatibility studies of fungicides with *Trichoderma viride* used in commercial formulation. Bio-Cure-F. Pestology 25(5): 2-6.

Ramesh Sunder A, Das N D and Krishnaveni D 1995 *In vitro* antagonism of *Trichoderma* spp. against two fungal pathogens of castor. In: Symposium on integrated pest management and environment. Directorate of Plant Protection, Quarantine and Storage, Tamil Nadu.

Rangeswar R and Prasad R D 2000 Biological control of *Sclerotium* rot of sunflower. Indian Phytopathology 53(4): 444-449.

Rangeswaran R and Prasad R D 2000 Biological control of Sclerotium rot of sunflower. Indian Phytopathology 53(4): 444-449.

Rangeswaran R, Prasad R D and Anuroop C P 2001 Field evaluation of two bacterial antagonists, *Pseudomonas putida* PDBCAB(9) and *P. fluorescens* (PDBCAB2) against wilt and root rot of chickpea. Journal of Biological Control 15(2): 165-170.

Rathore B S 1997 Relative efficacy of fungicidal seed treatments in the management of foot rot and seedling blight of moth bean. Plant Disease Research 12(2): 157-159.

Raut J G and Bhombe B B 1984 Longevity of *Macrophomina phaseolina* in sunflower seeds. Indian Phytopathology 37: 333-334.

Ray S K and Mukerjee N 1997 Studies on *in vitro* antagonism of some bacterial isolates against *Sclerotium rolfsii* Sacc. causing root rot of groundnut, sugarbeet. Journal of Mycopathological Research 35(2): 99-105.

Ray S, Ghosh M and Mukerjee N 1990 Fluorescent pseudomonads for plant disease control. Journal of Mycopathological Research 28: 135-140.

Reddy T S N and Nagarajan K 1985 Effect of some systemic and non-systemic fungicides on the control of damping-off of tobacco seedlings. Tobacco Research 11(2): 148-154.

Rettinasababady C, Ramadoss N and Thirumani S 2002 Management of root rot *Macrophomina phaseolina* [(Tassi.) Goid] of rice fallow blackgram by resident isolates of *Trichoderma viride.* Indian Journal of Agricultural Research 36(2): 118-122.

Rifai M A 1969 A revision of genus *Trichoderma*. Mycological Papers, No.116. Trans. Br. Mycol. Soc.

Robert P. Larkin and Deborah R. Frahel 1998 Efficacy of various fungal and bacterial biocontrol organisms for control of *Fusarium* wilt of tomato. Plant Disease 82: 1022-1028.

Roy A K 1991 Antagonistic effect of some fungi on *Rhizoctonia solani* Kuhn causing sheath blight of rice. In: Recent trends in plant disease control. H B Singh (ed.) Today and Tomorrow Publication, New Delhi.

Rudolf R D, Noeggel K A and Rogers W D 1989 Control of diseases of groundnuts with Folicur (R) (tebuconazole) in the USA. Pflanzenschutz Nachrichten Bayer 42: 119-214.

Rukmani S and Mariappan V 1994 Effect of *Trichoderma* spp. on root rot of blckgram caused by *Macrophomina phaseolina*. Pp: 217-220. In: Sivaprakasam K and Seetharaman K (eds.). Crop Diseases – Innovative Techniques and Management. Kalyani Publishers, Ludhiana.

Sadhu K S and Gill S P S 1982 Effect of seed and soil treatments on the damping-off of cauliflower. Pesticides: 17-18.

Sahni M L, Singh R P and Singh R 1967 Efficacy of some new fungicides in controlling damping-off of chillies. Indian Phytopathology 20: 1121-1127.

*Sanchez A, Evhavej B R and Schroder E L 1994 *Pseudomonas cepacia* a potential biofungicide for root rot pathogens of beans. Journal of Agriculture of the University of Puerto Rico 78(1-2): 55-57.

Sanjay Arya and Kauhik J C 2001 Efficacy of *Trichoderma* species and *Gliocladium virens* as biocontrol agents against damping off of forest nurseries. Plant Disease Research 16(1): 46-51.

Saralamma S 2000 Studies on biological control of *Sclerotium rolfsii* (Sacc.) incitant to root rot of groundnut. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Saralamma S and Vittal Reddy T 2004 *In vitro* mycoparasitism of *Trichoderma harzianum* and *Sclerotium rolfsii* Sacc. causing root rot of groundnut. Indian Journal of Plant Protection 32(2): 140-142.

Sarwar H A K 1974 Studies on the root and stem rot disease of castor caused by *Rhizoctonia bataticola* Butl. M Sc (Ag.) Thesis submitted to Andhra Pradesh Agricultural University, Hyderabad.

Sawant I S and Mukhopadyay A N 1990 Integration of metalaxyl with *Trichoderma harzianum* for the control of Pythium damping-off in sugarbeet. Indian Phytopathology 43: 535-541.

Sawant Indu S and Mukhopadyay A N 1990 Integration of metalaxyl with *Trichoderma harzianum* for the control of Pythium damping off in sugarbeet.

Sawant Indu S, Sawant S D and Ganapathy M M 1994 Collar rot of passion fruit caused by *Rhizoctonia solani* and its control. Indian Phytopathology 202-205.

Saxena D R and Saxena M 1995 Evaluation of antagonists against dry root rot pathogen of chickpea. Indian Journal of Mycology and Plant Pathology 25: 130.

Schulties D T 1989 Nu-flow AD Apron / Chloroneb flowable fungicide for cotton seed treatment. In: Proceedings Beltwide Cotton Production Conference Nemphis TN USA. National Cotton Council of America, 81.

Selvarajan R and Jeyarajan R 1996 Inhibition of chickpea root pathogens (*Fusarium solani* and *Macrophomina phaseolina*) by antagonists. Indian Journal of Mycology and Plant Pathology 26: 248-251.

Shahid M A, Mukthar Ahmed and Khan M A 1990 Chemical control of collar rot of lentil caused by *Sclerotium rolfsii* Sacc. Sarhad Journal of Agriculture 6: 503-507.

Shanker P and Jeyarajan R 1996 Biological control of sesamum root rot by seed treatment with *Trichoderma* spp. and *Bacillus subtilis*. Indian Journal of Mycology and Plant Pathology 26(2): 217-220.

Shanmugam V and Verma A S 1998 *In vitro* evaluation of certain fungicides against selected antagonists of *Pythium aphanidermatum* the incitant of rhizome rot of ginger. Ournal of Mycology and Plant Pathology 28(1): 70.

Sharif F M, Okasha A M and Kazen K T 1988 *Pencillium stipitatum* and *Trichoderma harzianum* in the biological control of cucumber damping-off disease caused by *Pythium aphanidermatum*. Journal of University of Kuwait Science 15: 107-113.

Sharma B K and Singh B M 1990 Biological control of white rot of pea caused by *Sclerotinia sclerotiorum* (Lib.) de Bary. Journal of Biological Control 4(2): 132-134.

Sharma D D, Gupta V P and Chandrashekar D S 1999 Compatibility of certain biocontrol agents with chemical pesticides and fertilizers. Indian Journal of Sericulture 38(1): 79-82.

Sharma J and Tripathi H S 2001 Biological and chemical control of web blight disease of urdbean. Indian Phytopathology 54(2): 267-269.

Sharma K B and Sharma N D 1976 Chemical control of root rot of cotton. Indian Journal of Mycology and Plant Pathology 6: 190-191.

Sharma R C and Rai S N 1999 Chemical control of banded leaf and sheath blight of maize. Indian Phytopathology 52: 94-95.

Sharma S D and Ashok Mishra 1995 Tolerance of *Trichoderma harzianum* to agrochemicals. Indian Journal of Mycology and Plant Pathology 25 (1&2): 129.

Sharma S D and Mishra A 1995 Tolerance of *Trichoderma harzianum* to agrochemicals. In: Abst. Global conference on Advances in Research on Plant Diseases and Their Management. February 12-17, 1995. Rajasthan College of Agriculture, India, p.162.

Sharma S D, Mishra A, Pandey R N and Patel S J 2001 Sensitivity of *Trichoderma harzianum* to fungicides. Journal of Mycology and Plant Pathology 31(2): 251-253.

Sharma S R, Verma B R and Sharma B K 1999 Biocontrol of *Sclerotinia sclerotiorum* causing stem rot of chickpea. Indian Phytopathology 52(1): 44-46.

Sharma Y R, Singh B M and Khatri H L 1976 Chemical control of seed and soil borne infection by *Corticium rolfsii* Curzi. in maize. Phytopathologia Mediterranea 15: 2-3.

Shenoi M M and Abdul Wajid S M 1992 Management of damping-off, blight and black shank diseases with ridomil MZ-72 WP in FCV tobacco nurseries of Karnataka. Tobacco Research 18(1&2): 53-58.

Shukla B N and Singh B P 1973 Effect of fungicidal seed treatment on *Macrophomina* root rot of sesame. Indian Journal of Mycology and Plant Pathology 3(2): 208-209.

Siddaramaiah A l and Desai S A 1980 Fungicidal control of foot rot of linseed. Current Research 9(10): 175-176.

Silveira N S S, Michereffi S J, Menezes M and Carmpos T G M 1994 Potentiality of *Trichoderma* spp. isolates on the control of *Sclerotium rolfsii* on bean. Summa Phytopathology 20: 22-25.

Sindhan G S, Indra Hooda and Karwasra S S 2002 Biological control of dry rot of chickpea caused by *Rhizoctonia bataticola*. Plant Disease Research 17(1): 68-71.

Singh and Dwivedi R S 1988 Laboratorye valuation of some pesticides against *Sclerotium rolfsii* Sacc., a foot royt pathogen of barley (*Hordeum vulgare* L.). Pesticides 22(3):20-23.

Singh and NE KG 1987 Effect of soil amendment on *Rhizoctonia bataticola* causing dry root rot of chickpea. International Chickpea Newsletter 17: 23-25.

Singh R D N and Kaiser S A K 1995 Evaluation of some systemic and non-systemic fungicides against the charcoal rot pathogen *Macrophomina phaseolina* (Tassi) Goid of maize. Journal of Tropical Agriculture 33: 54-58.

Singh R K and Dwivedi R S 1987 Studies on biological control of *Sclerotium rolfsii* Sacc causing foot rot of barley. Acta Botanica Indica 15: 160-164.

Singh R S and Reddy C S 1979 Suppression of damping-off tomato and seedling blight of chickpea and sugarbeet by strains by *Streptomyces diastaticus* 32: 374-377.

Singh R S, Jindal A, Singh D and Singh T 1995 Selection of *Trichoderma* isolates against common fungicides for their use in integrated plant disease management. Indian journal of Mycology and Plant Pathology 25(1&2): 127.

Singh T and Singh D 1982 Transmission of *Macrophomina phaseolina* from seed to plant. Proceedings of Indian Academic Science (Plant Science) 91: 357-370.

Siva Prakasam K and Kandaswamy t 1983 Collar rot of sweet potato. Madras Agricultural Journal 70: 205.

Sivakumar G, Sharma R C and Rai S N 2000 Biocontrol of banded leaf and sheath blight of maize by peat based *Pseudomonas fluorescens* formulation. Indian Phytopathology 53(2): 190-192.

Sivan A, Elad Y and Chet I 1984 Biological control effects of a new isolate of *Trichoderma harzianum* on *Pythium aphanidermatum*. Phytopathology 74: 498-501.

Sonoda R M 1972 Control of tomato transplant damping-off. Plant Disease Reporter 56: 840-842.

Sonoda R M 1976 Incorporating fungicides in planting mix to control soil borne seedling diseases of plug-mix seeded tomatoes. Plant Disease Reporter 60: 27-30.

Sreenivasa Prasad S and Manibhushan Rao K 1990 Biocontrol potential of fungal antagonists *Gliocladium virens* and *Trichoderma longibrachiatum*. Zeitschrift-fur-Pflanzenkrankheiten-und-Pflanzenschutz 97: 570-579.

Sreeramulu K R, Onkarappa T and Narayanaswamy H 1998 Biocontrol of damping-off and black shank disease in tobacco nursery. Tobacco Research 24(1): 1-4.

Sridhar R, Ramakrishnan G and Jeyarajan R 1991 Studies on the efficacy of *Bacillus subtilis* isolates against the dry root rot fungus *Macrophomina phaseolina* on urd bean. Journal of Biological Control 5: 59-60.

Srikant Kulkarni, Chattannavar S N and Hedge R K 1986 Laboratory evaluation of fungicides against foot rot of wheat caused by *Sclerotium rolfsii* Sacc. Pesticides 20: 27-31.

Srinivasa Prasad M 1999 Organic solvents as carrier of thiophanate methyl into soybean seeds and control of charcoal rot. Indian Phytopathology 52: 274-277.

Srivastava A K, Arora D K, Gupta B, Pandey R R and Lee M W 1996 Diversity of potential microbial parasites colonizing *sclerotia* of *Macrophomina phaseolina* in soil. Biology and Fertility of Soils 22: 136-140.

Srivastava R K, Prasad R D, Rangeswaran R, Wasnikar A R, Singh S P and Rao M S 2002 A rapid *in vivo* bioassay method for testing and selection of fungal antagonists of plant pathogens. Journal of Biological Control 16(2): 173-176.

Srivastava S N, Agnihotri V P and Singh K 1987 Factors influencing competitive saprophytic ability of *Sclerotium rolfsii* in soil. Indian Phytopathology 40: 495-499.

Strashnov Y, Elad Y, Sivan A and chet I 1985 Integrated control of *R. solani* by methyl bromide and *T. harzianum*. Plant Pathology 34: 146-151.

Subramanian K S 1964 Studies on sclerotial root rot disease of groundnut (*Arachis hypogea* L.) by *Sclerotium rolfsii* Sacc. Madras Agricultural Journal 51: 367-378.

Summer D R and Littrel R H 1989 Effects of chemigation with chlorothalonil and diniconazole on soil fungi and pod, peg and stem diseases of peanut. Plant Disease 73: 642-646.

Summer D R, Brenneman T B and Harrison G W 1991 Populations of fungi in soil after chemigation and chlorothalonil and tebuconazole via centerpilot irrigation. Plant Disease 75: 999-1004.

Sunder S 1982 Influence of organic manures and clay minerals on the efficacy of fungicides against *Rhizoctonia solani*. M Sc Thesis, HAU, Hisar.

Suriachandraselvan and Seetharaman 2002 Efficacy of *Trichoiderma viride* in combination with fungicides against *Macrophomina phaseolina* (Tassi.) Goid infection in blackgram. Madras Agricultural Journal 78(7-9): 512-514.

Taha K H, Kassim N A and Mohammed M N Y 1988 Chemical control of damping-off and root rot disease of tomato plants. Mesopotamia Journal of Agriculture 20: 275-287.

Taneja M and Grover R K 1982 Efficacy of benzimidazole and related fungicides against *Rhizoctonia solani* and *R. bataticola*. Annals of Applied Biology 100: 425-432.

Taubenhaus J J 1919 Recent studies on *Sclerotium rolfsii*. Journal of Agricultural Research 18: 127-138.

Teuscher H and Adler R 1960 The soil and its fertility. Reinhold Publication Company, New York.

Thakur K S, Keshry P K, Tamrakar D K and Sinha A K 2002 Studies of management of collar rot disease (*Sclerotium rolfsii*) of chickpea by use of fungicides. PKV Research Journal 26(1&2): 51-52.

Thompson S S 1978 Control of Southern stem rot of peanuts with PCNB plus fensulfothion. Peanut Science 5: 49-52.

Thribhuvanamala G, Rjeswari E and Sabitha Duraiswamy 1999 Biological control of stem rot of tomato caused by *Sclerotium rolfsii* Sacc. Madras Agricultural Journal 86(1-3): 30-33.

Tiwari 1996 Comparative evaluation of three systemic fungicides against *Sclerotium rolfsii* causing root rot in gram and sunflower. Indian Journal of Mycology and Plant Pathology 25(3): 243-245.

Tiwari R K S, Rajput M L, Ashok Singh and Thakur B S 2004 Non-target effect of insecticides on the mycelial growth of *T. harzianum* (Rifai). Indian Journal of Plant Protection 32(2): 140-141.

Tokeshi H, Valdebenito R M, Souza N L and Deyokoonzio N K S 1980 Biological control of *Sclerotium rolfsii* Sacc. on sugarcane with *Trichoderma* sp. Summa Phytopathologica 73: 660-663.

Tomashow L S, Weller D M, Bonsall R F and Pierson L S 1991 Production of the antibiotic phenazine-1-carboxylic acid by fluorescent pseudomonad species in the rhizosphere of wheat. Applied Environmental Microbiology 56: 908-912.

Tripathi M and Johri B N 2002 In vitro antagonistic potential of fluorescent pseudomonas and control of sheath blight of maize cused by *Rhizoctonia solani*. Indian Journal of Microbiology 42: 207-214.

Tripathi N N and Grover R K 1977 Comparison of fungicides for the control of *Pythium butleri* causing damping-off of tomato in nursery beds. Indian Phytopathology 30: 489-494.

Tripathi N N, Kaushik C D and Yadava T P 1977 Control of charcoal rot of sesamum caused by *Rhizoctonia bataticola*. Pesticides 11: 35-37.

Tripathi S K, Sathie K B and Vyas S C 1988 Chemical control of collar rot of pea. Indian Phytopathology 41(1): 143-144.

Turner J T and Backman P A 1991 Factors relating to peanut yield increase after seed treatment with *Bacillus subtilis*. Plant Disease 75: 347-353.

Uma Singh and Thapliyal P N 1998 Effect of inoculum density, host cultivars and seed treatment on the seed and seedling rot of soybean caused by *Sclerotium rolfsii*. Indian Phytopathology 51(3): 244-246.

Upadyay J P and Mukhopadyay A N 1986 Biological control of *Sclerotium rolfsii* by *Trichoderma harzianum* in sugarbeet. Tropical Pest Management 32: 215-220.

Ushamalini C, Rajappan K and Kousalya Gandadharan 1997 Control of cowpea wilt by non-chemical means. Plant Disease Research 12(2): 122-129.

Vanitha S and Suresh M 2002 Management of collar rot of brinjal (*Sclerotium rolfsii*) by non-chemical methods. South Indian Horticulture 50(4-6): 602-606.

Venkateswar Rao K 1998 An integrated approach for management of sesamum stem and root rot caused by *Macrophomina phaseolina* (Tassi) Goid. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

*Verma R, Singh and Singh D 1992 Incidence and colonization of *Rhizoctonia bataticola* in cowpea seeds. Acta Botanica India 20: 104-107.

Vidyasekaran P and Muthamilan M 1995 Development of formulations of *Pseudomonas fluorescens* for control of chickpea wilt. Plant Disease 79: 782-786.

Vidyasekharan P and Arjunan G 1978 Studies on leaf blight of urd bean caused by *Macrophomina phaseolina*. Indian Phytopathology 31: 361-362.

Vijaya Krishna Kumar K 1997 Integrated approach for management of damping-off disease in tomato caused by *Pythium aphanidermatum* (Edson) Fitzp. M Sc (Ag.) Thesis submitted to Acharya N G Ranga Agricultural University, Hyderabad.

Virupakshaprabhu H and Hiremath P C 2003 Bioefficacy of fungicides against collar rot of cotton caused by *Sclerotium rolfsii* Sacc. Karnataka Journal of Agricultural Sciences 16(4): 576-579.

Vyas S C and Khare M N 1986 Biological control of dry root rot of soybean caused by *R. bataticola* with carbendazim and antagonist. Seminar on management of soil borne diseases of crop plants, January 8-10, Tamil Nadu Agricultural University, Coimbatore, India.

Walia G S, Sunder S and Grover R K 1992 Influence of nutrients of pathogenic behaviour of *Rhizoctonia solani* on cowpea. Indian Journal of Mycology and Plant Pathology 22(2): 170-177.

Weindling R 1932 *Trichoderma lignorum* as a parasite of other soil fungi. Phytopathology 22: 837-845.

Weller D M 1988 biological control of soil borne plant pathogens in the rhizosphere with bacteria. Annual Review of Phytopathology 26: 379-407.

Weller D M and Cook R J 1983 Suppression take-all of wheat by seed treatments with fluorescent Pseudomonads. Phytopathology 73: 463-469.

Weller D M and graham M C 1984 Application of fluorescent pseudomonads to improve the growth of wheat. Phytopathology 74: 806 (Abstract).

Whipps J M, Budge S P, Elad Y (ed.), Freeman S (ed.) and Monte E 2001 Integrated control of *Sclerotinia sclerotiorum* in glasshouse lettuce using the mycoparasite *Coniothyrium minitans*. Bulletin OILB SROP 24(3): 217-220.

Wilde T H, Griggs T D and McClean B T 1989 Propomocarb-HCl a fungicide suitable for integrated pest management tomato and pepper production in the tropics. Proceedings of the International Symposium on late integrated management practices. Tainan, Taiwan: 303-306.

Windham M T, Elad Y and Baker R 1986 A mechanism for increased plant growth induced by *Trichoderma* spp. Phytopathology 76: 518-521.

Wokocha R C 1990 Integrated control of *Sclerotium rolfsii* infection of tomato in the Nigerian Savanna; effect of *Trichoderma viride* and some fungicides. Crop Protection 9(3): 231-234.

Wolf J D E, Jamart J and Kamoen O 1990 A screening and evaluation method for fungicides against *Pythium* spp. Me de delingen van de Faculteit Landbou – wweteSchappen Rij Ksuniversiteit cent 3a: 943-953.

Wolfhechel H and Funck Jensen D 1992 use of *Trichoderma harzianum* and *Gliocladium virens* for the biological control of post-emergence damping-off and root rot of cucumbers caused by *Pythium ultimum*. Journal of Phytopathology 136: 221-230.

Wright J M 1956 Biological control of soil borne *Pythium* infection by seed inoculation. Plant and Soil 8: 132-140.

Wu W S, Liu S D, Chang Y C and Tscchen S 1986 Hyper parasitic relationship between antagonists and *Rhizoctonia solani*. Plant Protection bulletin 28(1): 91-100.

Yan-Sittuang, Liu De Qing, Yang Yuttuan, Yan S H, Lu D Q and Yang Y H 1996 Effects of three fungicides on *Sclerotium rolfsii* and its antagonistic strain of *Trichoderma* spp. and soil microbial population. Chinese Journal of Biological Control 12(1): 29-32.

Zeppa G, Allegrone G, Barbeni M and Guorda P A 1990 Variability in the production of volatile metabolites by *Trichoderma viride*. Annale Microbiologia Entomologia 90: 171-176.

* Originals not seen

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