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Management of chickpea wilt by chemicals and bioagents

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Abstract
Chickpea (*Cicer arietinum*) is one of the most important pulse crops and belongs to the family Leguminaceae. Though the area under this crop is more in Maharashtra, the average yield per hectare is low because of several biotic and abiotic factors. Among, them the wilt caused by *Fusarium oxysporum* f.sp. *ciceri* is most destructive, both seed and soil borne disease which threatens successful cultivation of chickpea and causes severe losses in chickpea growing areas. The experiment was carried out during 2012-2013 at Department of Plant Pathology, Dr. P.D.K.V. Akola. The fungicides *viz*. Carbendazim, Benomyl and Fosetyl AL screening gave the highest per cent growth inhibition 100%, 100%, 93.7% of *Fusarium oxysporum* f.sp. *ciceri* respectively. *Trichoderma viride* showed maximum per cent growth inhibition of *Fusarium oxysporum* f.sp. *ciceri*, by Dual culture method 77.37%. Among the herbicides Pendimethalin was found effective in *Fusarium oxysporum* f.sp. *ciceri*. In *fusarium* the highest germination per cent observed in the treatment of T_8 Carbendazim at 30 days after sowing. The per cent wilt incidence is less in T_8 Carbendazim 1gm per kg seed and more in T_6 (Fosetyl Al 0.1g per kg seed + *Bacillus subtilis* 10g per kg seed). In control the per cent fusarial wilt incidence was 88.8%. The growth parameters like plant dry weight, root dry weight, shoot dry weight, shoot and root length were observed and was found maximum in treatment T_{11} Carbendazim 1g per kg seed + *Trichoderma viride* 4g per kg seed + *Bacillus subtilis* 10g per kg seed.

Keywords: Wilt, *Fusarium oxysporum* f. sp *ciceri*, *Fusarium*, wilt management

Introduction
Chickpea (*Cicer arietinum*) is one of the most important legumes grown in Asia. In Asia, India is the largest producer of chickpea, contributing more than 70 per cent of the total world production. It is the 3rd most important pulse crop of the world and ranks first in the Indian subcontinent. The centre of origin is in Eastern Mediterranean, it is a self-pollinated, diploid (2n=16) with genome size 1C = 740Mbp. Chickpea is a source of human food and animal feed, it fixes atmospheric nitrogen in soils and thus improves soil fertility and saves fertilizer costs in subsequent crops, particularly in dry lands and conserve natural resources which are essential for sustainable agriculture. It is an excellent source of protein, fiber, complex carbohydrates, vitamins, and minerals, hence referred as "Poor Man's Meat". The crop can be grown as a second crop using residual moisture. The growing demand in both the domestic and export markets provides a source of cash for small holder producers. It increases livestock productivity as the residue is rich in digestible crude protein content compared to cereals. In India, wilt of chickpea was first observed in 1918 from North West Frontier of undivided India (Butler, 1918) [37, 6], and subsequently it is reported from Bihar, Maharashtra (Uppal *et al.* 1935) and Rajasthan (Singh *et al.* 1985) [34]. The chickpea wilt caused by *Fusarium oxysporum* f.sp. *ciceri* is also widely distributed in 32 countries. (Haware 1988 and Nene *et al.*, 1996) [14, 23]. Chickpea wilt caused by *Fusarium oxysporum* Schlecht emend. Synd. and Hans f.sp. *ciceri* (Padwick) Synd. and Hans., was first described by Padwick in 1940 [25] is one of the major diseases in North Africa, South Africa and Southern Europe and causes upto 10% losses in yield. The pathogen is both seed and soil borne, survives in the soil for more than six years in the absence of host plants (Haware *et al.* 1986) [16]. Natural population of this pathogen is diverse in terms of pathogenic variability and can be characterized into pathotypes or races.

The *Fusarium oxysporum* f.sp. *ciceri* causing chickpea wilt is seed borne as well as soil borne, the pathogen survive in the soil in the form of chlamydospore. Since the pathogen is a

soil inhabitant and can survive in the soil for a long time it is important to eliminate the chances of introducing it through seeds. (Haware *et al.* 1978) [15].

Material and Methods

The experiment on "Management of chickpea wilt by chemicals and bioagents" were conducted during *Rabi* season 2012-2013 in the laboratory of Department of Plant Pathology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The details of the material used and methods followed are described in this chapter.

a) Methods

1) Preparation of media

Potato Dextrose Agar (PDA) and *Fusarium* specific medium (Snyder and Nash, 1962) [35] were prepared as per their composition for *Fusarium oxysporum.*

2. Sterilization

The glasswares such as petri plates, pipettes, beakers, and test tubes were sterilized in hot air oven at 180^{0}C for 1 hour. The media were sterilized in autoclave at 15 lbs psi for 10 minutes. The sterilized Potato Dextrose Agar (PDA) medium was used for experimentation.

3. Isolation of *Fusarium oxisporum* f.sp. *ciceri*

Chickpea plant showing typical wilt symptoms were collected from the field of Department of Plant Pathology. Dr. PDKV. Akola (M.S). The repeated isolations were made to isolate pathogen from wilted plants. The roots and stem of infected plants were washed in running tap water to remove soil before isolation to avoid contamination. The roots were cut into small bits of the size 2.5 mm, with sterilized blade.

These bits were then surface sterilized with 0.1 per cent mercuric chloride for two minutes and washed with three changes of sterilized water to remove traces of mercuric chloride. Each bit was blot dried and four bits each placed on the prepoured solidified potato dextrose agar (PDA) plates. These plates were then incubated at 27±1 ^{0}C for seven days. The fungal growth was transferred to the plates of PDA.

4. Purification and maintanance of pathogen

The cultures of *Fusarium oxysporum* f. sp. *ciceri* obtained were purified from single spore method and identified as *Fusarium oxysporum* f.sp. *ciceri* as per (Booth. C 1977) [4]. The pathogen was subcultured on PDA slants and allowed to grow at 27±1 ^{0}C temperature for 10 days. The culture so obtained was stored in refrigerator at 4 ^{0}C and were sub cultured periodically once in a month.

5. Mass Multiplication of culture

The sorghum grains were soaked partially for one hour in warm water (40 ^{0}C to 45 ^{0}C) and then spread on the clean blotting paper for air drying. About 300 g moistened grains were filled in each 1000 ml flask with 10 ml water and autoclaved for 30 minutes at 15 lbs psi pressure. The mycelial bits of pure culture of *Fusarium oxysporum* f.sp. *ciceri* were inoculated under aseptic condition in those flask containing grains and incubated at 28±2 ^{0}C for 10 days. Meanwhile flasks were shaken to avoid clumping of grains and to facilitate early growth of the fungus. The grains turn whitish due to mycelial growth of the test fungus. These mass inoculums were spread in the experimental sick plot before two weeks of sowing.

6. Preparation of sick soil and pathogenicity test

Soil was put in gunny bags and sterilized in autoclave at 1.05 kg/cm^2 for 1 hour consequently for 3 days. The mass multiplied inoculum was added in 1:10 proportion to soil and thoroughly mixed. Thus soil was made sick. The plastic pots of size 15 cm diameter were taken and surface sterilized with 0.1% Mercuric chloride. The sick soil was filled in sterilized pots 1/4th of its capacity. The pots were watered lightly and incubated for 4 days. Chickpea seeds of JG-62 were sown (10 seeds per pot). The pot monitored for seedling mortality. The wilting symptoms were recorded with an interval of 10 days after sowing. Similarly, four pots without inoculation which served as control. Re-isolation of fungus was done from roots of wilted seedlings on PDA media.

7. *In vitro* assay of fungicides, insecticide and weedicides against chickpea wilt

To evaluate the effect of fungicide, insecticide and weedicides against *Fusarium oxysporum* f.sp *ciceri* the "Poison Food Technique" was used. The requisite amount of each fungicide based on active ingradient was added to an autoclaved potato dextrose agar to obtain the desired concentrations, i.e. 0.1 per cent, 0.2 per cent, 0.3 per cent, 0.4 per cent and 0.5 per cent of all fungicides. The same medium without the fungicide served as control. The medium was poured into 90 mm petriplates in 3 replicates and after solidification, each plate was inoculated with a 6 mm mycelial disc of test fungus. The inoculated petriplates were incubated for 7 days at 27±2 ^{0}C. After incubation, radial growth was measured. Per cent inhibition in growth was calculated from the mean diameter after petriplates in control were fully covered with mycelial growth of pathogen as per following formula.

$$\text{Per cent inhibition} = \frac{\text{C-T}}{\text{C}} \text{ x } 100$$

Where;

- C = Growth of test fungus in control in mm.
- T = Growth of test fungus in treatment in mm.

8. *In vitro* antagonism test against chickpea wilt

Trichoderma viride, *Bacillus subtilis* and *Pseudomonas fluorescens* were tested for their biocontrol properties against *Fusarium oxysporum* f.sp. *ciceri*, by dual culture method. The mycelial disc of 6 mm diameter cut from the margin of 5 days old cultures of both test pathogen and antagonists were placed opposite to each other on PDA in Petriplates (90 mm). The distance between inoculum blocks was 6 cm. The petriplates with disc of *Fusarium oxysporum* f.sp. *ciceri* served as the control. The inoculated petriplates were incubated at 27±2 ^{0}C in BOD incubator for 7 days. The growth of *Fusarium oxysporum* f.sp *ciceri* was measured and the per cent growth inhibition of intersecting colonies was calculated as per following formula.

$$\text{Per cent growth inhibition} = \frac{\text{(Colony growth Inter secting plate)} - \text{(Colony growth in control plate)}}{\text{Colony growth in control plate}} \text{ x } 100$$

9. Screening of bioagents with fungicide (by tilted plate method): For screening of bioagents (*Pseudomonas fluroscence, Bacillus subtilis*) with fungicide (Bavistin, Benlate, and Fosetyl AL), firstly, pour petriplates with PDA as a control in half portion of plate and solidify. Then pour PDA mixing with different fungicide at particular concentration in remaining half portion of plate and solidified. After that these plates were streaking of bacterial culture on media and incubate plate for 2-3 days and observed the growth of inhibition of bacteria. Whether they compatible or non compatible.

10. *In vivo* management of *Fusarium* wilt of chickpea

A pot culture experiment was conducted in green house conditions in Completely Randomized Design (CRD) with additional treatment as control with 3 replications and 17 treatments by using chickpea variety JG-62. The inoculum of test pathogen *Fusarium oxysporum* f.sp *ciceri* were mass cultured on crushed sorghum seeds and were added to the soil @ 100 g per kg of soil. Prior to use, the earthen pots were disinfected with 0.1% Mercuric chloride solution. The seeds of JG-62 variety were treated with Fosetyl AL, Carbendazim, *Trichoderma viride, Bacillus subtilis* and Pendimethalin. Then the seeds were sown, 5 seeds per pot and the pots were watered lightly. The pots were kept in cage house and the seedling mortality was recorded at 30 and 60 days after sowing. The details of the treatment in pot experiment are given below:

The details of layout and plan for pot experiment

1. Year, season: *Rabi*, 2012.
2. Design: CRD
3. Number of replications: 3
4. Number of treatments: 17
5. Total number of pots: 51
6. Number of plants per pot: 5
7. Variety: JG-62
8. Date of sowing: Oct 25 (25.10.2012)
9. Date of observations: Nov 25, Dec 25

Treatment details

Sr.no	Treatments	Treatment details
1.	T_1	*Trichoderma viride*
2.	T_2	*Bacillus subtilis*
3.	T_3	*Trichoderma viride* + *Bacillus subtilis*
4.	T_4	Fosetyl AL
5.	T_5	Fosetyl AL + *Trichoderma viride*
6.	T_6	Fosetyl AL + *Bacillus subtilis*
7.	T_7	Fosetyl AL +*Trichoderma viride* + *Bacillus subtilis*
8.	T_8	Carbendazim
9.	T_9	Carbendazim + *Trichoderma viride*
10.	T_{10}	Carbendazim + *Bacillus subtilis*
11.	T_{11}	Carbendazim + *Trichoderma viride* + *Bacillus subtilis*
12.	T_{12}	Pendimethalin
13.	T_{13}	Pendimethalin + *Trichoderma viride*
14.	T_{14}	Pendimethalin + *Bacillus subtilis*
15.	T_{15}	Pendimethalin + *Trichoderma viride* + *Bacillus subtilis*
16	T_{16}	Control with pathogen
17	T_{17}	Control without pathogen
		Fosetyl AL - 0.1g/kg seed
		Trichoderma viride - 4g/kg seed
		Pendimethalin - 1 kg a.i/ha

b) Observations Recorded

1. Germination of seeds

For estimation of per cent germination total no. of germinated seeds were selected from three replications and per cent germination was calculated as per treatment.

2. Shoot and root length

For estimation shoot and root length of plant, five plants (Total 5 of 3 replications) were selected randomly and uprooted from each pot as per treatment at the interval of 30 and 60 DAS. These uprooted plants were used for recording shoot and root length. The shoot length was measured from collar region upto apical shoot and root length was measured from collar region upto central root.

3. Plant dry weight

For estimation of dry weight of plant, five plants (Total 5 of 3 replications) were selected randomly and uprooted from each pot as per treatment at the interval of 30 and 60 DAS. These uprooted plants were kept in properly labelled brown paper bags for drying and then oven dried at 60 ^{0}C till the constant weight was recorded. The oven dry samples were weighed on electronic balance.

4. Shoot and root dry weight: The same plants which are used for recording plant dry weight were used for recording shoot and root dry weight. The oven dried plant after recording plant dry weight were cut from collar region and shoot and root dry weight were measured on electronic balance.

5. Measurement of disease incidence

In the pots, diseased plants observed at 30 DAS and number of diseased plants recorded as per treatments and the total number of plants in pots also calculated for estimation the per cent wilt.

c) Statistical Analysis: Statistical analysis was done by using method of analysis of variance means were tested for significance and critical difference was used for comparison the differences were found to be significant as indicated in 'f' test. (Panse and Sukhatme, 1967) [28].

Results and Discussion

1. Isolation of *Fusarium oxysporum* f.sp. *ciceri*

Fusarium oxysporum f.sp. *ciceri* was isolated from infected roots of chickpea showing typical wilt symptoms on plate 1.

The *Fusarium oxysporum* f.sp. *ciceri*, was identified on the basis of morphological characters as described cultural and vegetative structure by Booth (1977) [4]. Haware *et al.* (1986) [16] reported that chickpea wilt caused by *Fusarium oxysporum* f.sp. *ciceri* can also be seed borne, often the pathogen was carried in hilum region of seeds. Seed borne infection was observed in seeds from plant which wilted after pod formation.

2. Morphology of *Fusarium oxysporum* f.sp. *ciceri*

The *Fusarium oxysporum* f.sp.*ciceri* culture in Plate 1, was observed under the microscope, hyphae were hyaline, septate and profusely branched. It produces both micro and macro-conidia. Micro -conidia were borne on simple short phialids arising laterally on the hyphae, oval to cylindrical, straight to curved measuring, 2.5 - 3.5 µm x 5 - 5.11 µm. Macro-conidia were lesser in number than micro-conidia, septate, fusoid, pointed at both ends with typical foot cell and measuring 3.5 - 4.5 µm x 25 - 65 µm. Chlamydospores were the resting spores, which varied in shape and size. They were round to oval in shape, while their size varies from 7 to 35 µm and they were either apical or intercalary in nature.

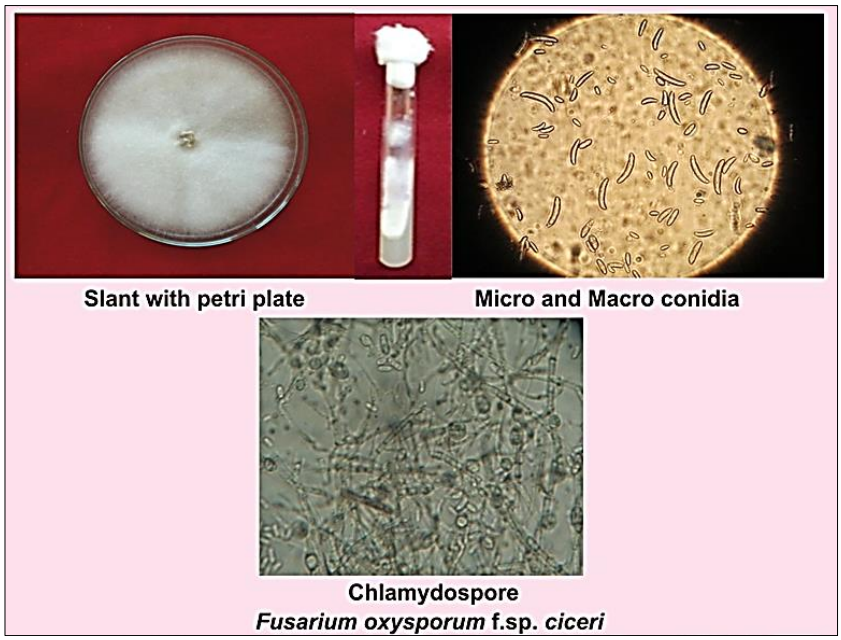

Plate 1: Pure culture and microscopic images of *Fusarium oxysporum* f.sp. *ciceri*.

3. Pathogenicity test of *Fusarium oxysporum* f.sp. *ciceri*

The data presented in Table 1, revealed that in sick soil *Fusarium oxysporum* f.sp. *ciceri*, caused (100%) wilting on JG-62 in 30 DAS. The typical wilting symptoms were observed in Plate 2, within 30 DAS as compared to control where no wilting was observed. The pathogen from the infected plants was reisolated and compared with original culture and found identical, thus Koch's Postulate was proved. Grewal *et al.* (1974) [12] proved that the *Fusarium oxysporum* f.sp. *ciceri* and *Rhizoctonia solani* were most virulent fungi causing 82 to 100 per cent mortality within 20 days. Biswas and Sen Gupta (1981) [3] proved the pathogenicity test with *Fusarium oxysporum* f.sp. *ciceri*, *Sclerotium rolfsii* and *Macrophomina phaseolina* which cause wilt, collar rot and dry root of gram, respectively.

Plate 2: Pathogenicity test of *Fusarium oxysporum* f.sp. *ciceri*.

Table 1: Pathogenicity test of *Fusarium oxysporum f.sp. ciceri* on variety JG-62.

Pathogen	*Fusarium oxysporum f. sp. Ciceri*
Variety	JG-62
No. of seeds sown	5
No. of seed germinated	3
Per cent seed germinated	60
Wilted plant	3
Per cent wilt	100

4. Bio-efficacy of fungicides, insecticides, herbicides, and bioagents against *Fusarium oxysporum* f.sp. *ciceri in vitro*.

4.1 *In vitro* effect of fungicides on growth of *Fusarium oxysporum* f.sp. *ciceri*

The data presented in Table 2 showed that 100 per cent growth inhibition of *Fusarium oxysporum* f.sp *ciceri* was observed in Plate 3, with Carbendazim, and Benomyl at all the concentrations used followed by Fosetyl AL at 0.4% and 0.5% (100%), The lowest per cent growth inhibition was observed in Fosetyl AL at 0.3% (93.7%). Similar results were observed by Fenn and Coffey (1984) [9] who reported that that fosetyl AL prevented *in vitro* fungal growth only at concentrations of 1,000 pg per ml or greater. Since Fosetyl AL was found to have low activity against mycelial growth *in vitro*, it has been proposed that rather than exerting a direct effect on the pathogen it may act indirectly by triggering a host resistance response. Sugha *et al.* (1995) [36] evaluated twelve fungicides against *Fusarium oxysporum* f.sp. *ciceri* which causes chickpea wilt under *in vitro*. Carbendazim and Thiram alone and in combination were found highly effective in inhibiting the mycelial growth. Gupta *et al.* (2005) [13] screened 6 fungicides in bioassay against *Fusarium oxysporum* f.sp. *ciceri*. of them, Carbendazim 100 µg/ml was the most effective in inhibiting the growth of fungus. Mukhtar (2007) [21] found that chemical treatment with Benomyl (50 WP) and Carbendazim (50 WP) were proved to be the most effective against *Fusarium oxysporum* f.sp *ciceri.*

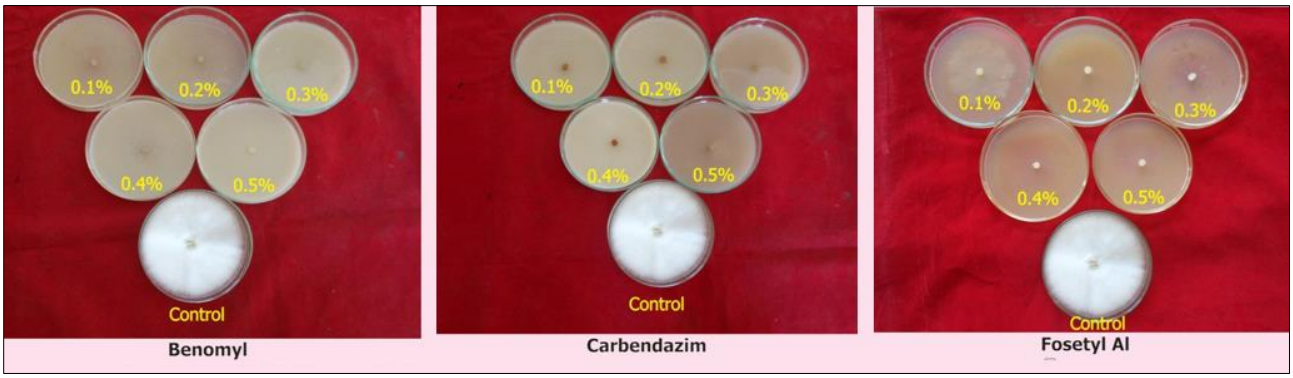

Plate 3: Efficacy of fungicides against *Fusarium oxysporum* f.sp. *ciceri.*

Table 2: Efficacy of fungicides on growth of *Fusarium oxysporum f.sp. ciceri*

Treatments	Fungicides	Concentration	*Fusarium oxysporum* f.sp. *ciceri*	
			Mean colony diameter in mm	Per cent Growth Inhibition
T_1	Carbendazim 50% WP	0.1	0	100
T_2		0.2	0	100
T_3		0.3	0	100
T_4		0.4	0	100
T_5		0.5	0	100
T_6	Fosetyl Al 80%WP	0.1	62.33	30.74
T_7		0.2	7.89	91.23
T_8		0.3	5.67	93.7
T_9		0.4	0	100
T_{10}		0.5	0	100
T_{11}	Benomyl 50% WP	0.1	0	100
T_{12}		0.2	0	100
T_{13}		0.3	0	100
T_{14}		0.4	0	100
T_{15}		0.5	0	100
T_{16}	Control		90	0
F test				Sig.
SE(m)±				0.7
CD(P=0.01)				2.73

4.2 *In vitro* effect of fungicides on growth of bioagents *Trichoderma viride, Pseudomonas fluorescens, and Bacillus subtilis*

4.2.1 Effect of fungicides on *Pseudomonas fluorescens* and *Bacillus subtilis:* The fungicides *viz.*, Fosetyl AL 80% WP, Benomyl 50% WP and Carbendazim 50% WP were used in five concentrations (0.1%, 0.2%, 0.3%, 0.4% and 0.5%) against *Pseudomonas fluroscens*, *Bacillus subtilis* for compatibility test. The results are presented in plate 4 and Table 3 *Bacillus subtilis* (0.1%, 0.2%, 0.3%, 0.4% and

0.5%) was found compatible with Benomyl and Carbendazim and non-compatible with Fosetyl AL. The results are presented in plate 7 and Table 3 *Pseudomonas fluroscense* (0.1%, 0.2%, 0.3%, 0.4% and 0.5%) was found compatible with Benomyl, Carbendazim and Fosetyl AL at 0.1%, 0.2% concentration and non-compatible at 0.3%, 0.4%, 0.5% concentration.

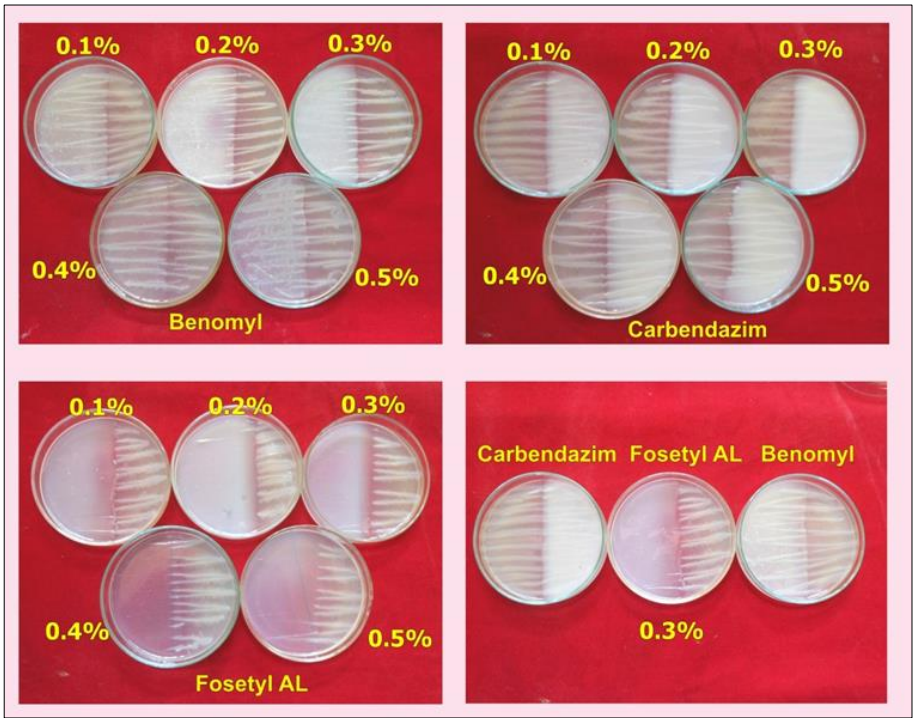

Plate 4a: Effect of fungicides on *Basilis subtilis.*

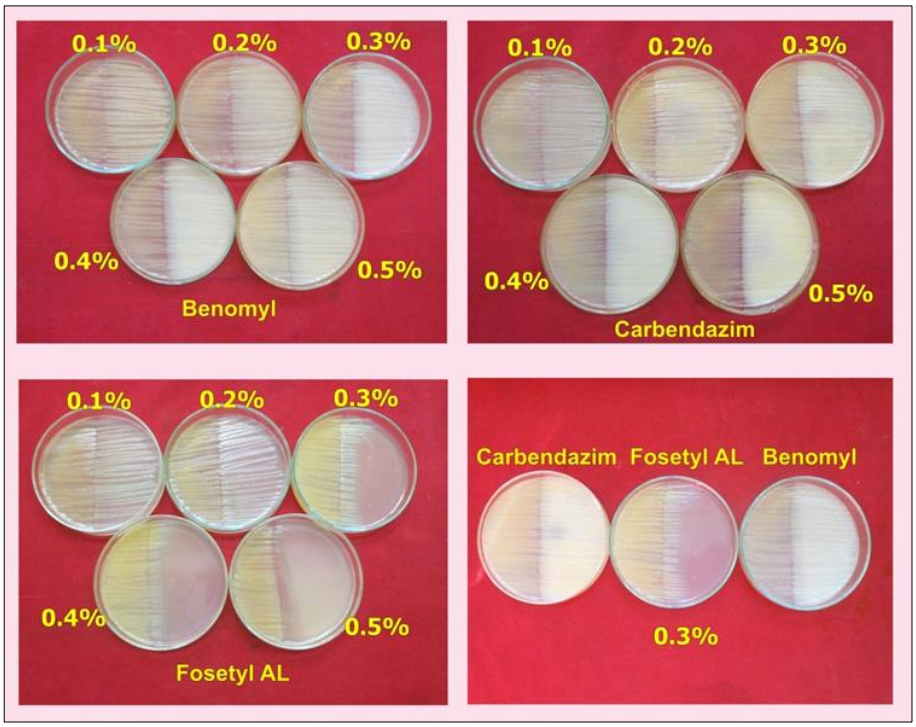

Plate 4b: Effect of fungicides on *Psedomonas fluorescens.*

Table 3: Effect of fungicides on Pseudomonas fluorescens and Bacillus subtilis.

Fungicides / Bioagents	**Fosetyl AL**					**Carbendazim**					**Benomyl**				
	0.1%	0.2%	0.3%	0.4%	0.5%	0.1%	0.2%	0.3%	0.4%	0.5%	0.1%	0.2%	0.3%	0.4%	0.5%
Bacillus subtilis	-ve	-ve	-ve	-ve	-ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Pseudomonas fluorescens	+ve	+ve	-ve	-ve	-ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve

4.2.2 Effect of fungicides on growth of *Trichoderma viride:* The fungicides *viz.*, Fosetyl AL 80% WP, Benomyl 30% WP and Carbendazim 50% WP were used in five concentrations (0.1%, 0.2%, 0.3%, 0.4% and 0.5%) against *Trichoderma viride*. The "Poison Food Technique." was followed. The radial growth was measured in mm after 7 days of incubation at 27±2 ^{0}C. The data presented in Table 4 and Plate 5 showed that 100 per cent growth inhibition of *Trichoderma viride* was observed with Carbendazim, and Benomyl at all the concentrations used. The lowest per cent growth inhibition was observed in Fosetyl AL at 0.1 and 0.2% (0% and 14.44% concentration).

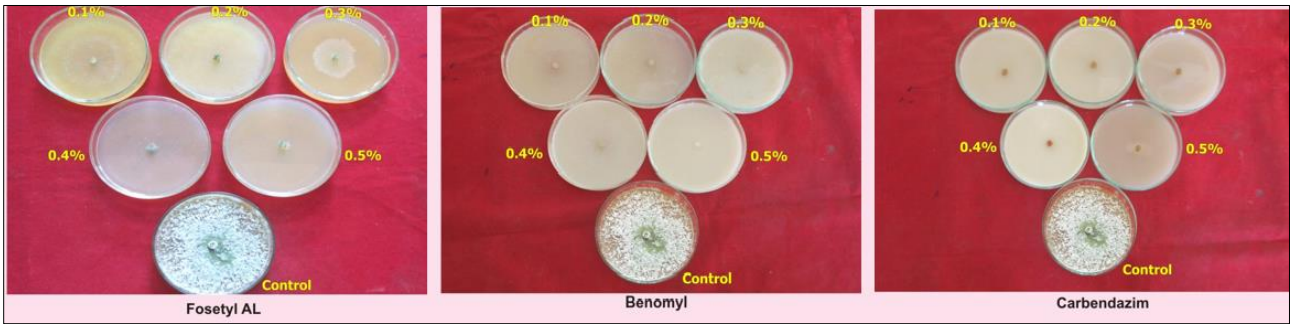

Plate 5: Efficacy of fungicides against *Trichoderma viride.*

Table 4: Effect of fungicides on growth of *Trichoderma viride*

Treatments	Fungicides	Concentration	*Trichoderma viride*	
			Mean colony diameter (mm)	Per cent growth inhibition
T_1	Carbendazim	0.1	0	100
T_2		0.2	0	100
T_3		0.3	0	100
T_4		0.4	0	100
T_5		0.5	0	100
T_6	Fosetyl AL	0.1	90	0
T_7		0.2	77	14.44
T_8		0.3	34.11	62.1
T_9		0.4	9.77	89.14
T_{10}		0.5	9.55	89.38
T_{11}	Benomyl	0.1	0	100
T_{12}		0.2	0	100
T_{13}		0.3	0	100
T_{14}		0.4	0	100
T_{15}		0.5	0	100
T_{16}	Control		90	0
F test				Sig.
SE(m)±				1.23
CD(P=0.01)				4.78

4.3 *In vitro* effect of insecticides on growth of *Fusarium oxysporum* f.sp. *cicero:* The data presented in Table 5 and Plate 6 showed that percent growth inhibition of *Fusarium oxysporum* f.sp. *ciceri* was observed in Imidacloprid 0.1g, 0.2g and 0.3g.

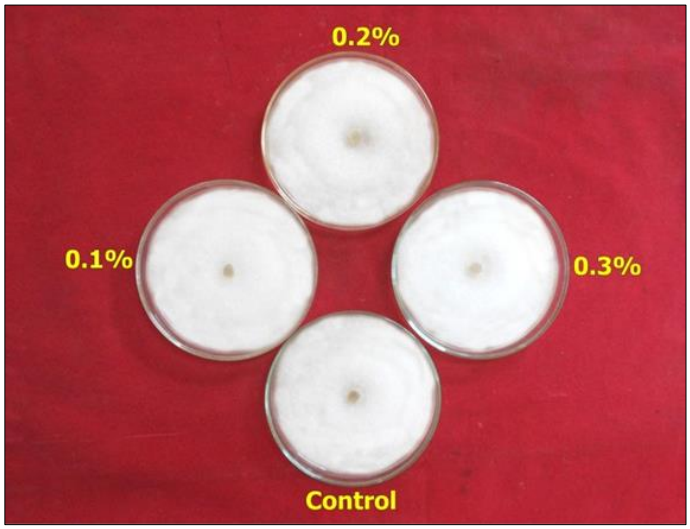

Plate 6: Efficacy of insecticides against *Fusarium oxysporum* f.sp. *ciceri*.

Table 5: Effect of insecticides on growth of *Fusarium oxysporum* f.sp. *ciceri*

Insecticides	Treatments	*Fusarium oxysporum* f. sp. *ciceri*	
		Mean colony Diameter (mm)	Per cent Growth inhibition
Imidacloprid 17.8% SL	T_1-0.1g	90	0
	T_2-0.2g	90	0
	T_3-0.3g	90	0
	T_4-Control	90	0

4.4 *In vitro* effect of herbicides on growth of *Fusarium oxysporum* f.sp. *ciceri*

The herbicides *viz.*, Pendimethalin 30% EC, Imazathaphyr 10% SL, Targa super, Whip super, Oxadiargyl and Oxyflourfen, were used in three different concentrations. The data presented in Table 6 and Plate 7 showed that highest per cent growth inhibition of *Fusarium oxysporum* f.sp. *ciceri* was observed in Pendimethalin 0.1, 0.2, 0.3% (100%), followed by Oxadiargyl 0.3ml (100%), Whip super 0.3 ml(100%) and Oxyflorfen 0.3ml(100%). The lowest growth inhibition was observed in Imazathapyr 0.1ml (10.62%). The results recorded in present studies are found in consences with, Patel and Patel (1993) [29] concluded that *in vitro* studies to screen a number of herbicides (Alachlor, Atrazine, Diuron, 2,4-D ethyl ester, Fluchloralin, Isoproturon, Metribuzin, Oxyfluorfen, Pendimethalin and Trifluralin) at their respective recommended concentration and at 0.5 and 1.5 times these concentration for their activity against *F. oxysporum* f.sp. *cumini* a disease causing organism in cumin [*Cuminum cyminum*]. It was found that the herbicides considerably inhibited the mycelial growth of*F. oxysporum* f. sp. *cumini*. With all herbicides inhibition of the fungus increased with increasing herbicide concentration. Khan *et al.* (2010) [19] studied Five herbicides Pendimethalin, s-metolachlor, Fenoxaprop-p-ethyl, MCPA and isoproturon with four doses were studied in the trials. Best seed yield (1164 and 1150 kg ha^{-1}) was recorded in pre-emergence herbicides at high dose as compared to Fenoxaprop- p-ethyl (1088 kg ha^{-1}). Kathiresan *et al.* (2004) [17] conducted an experiment during the *rabi* seasons of 2000 and 2001 in Annamalainagar, Tamil Nadu, India to investigate the bioefficacy of Oxadiargyl on weeds and onion (*A. cepa* var. aggregatum) cv. CO-2 under irrigated conditions.

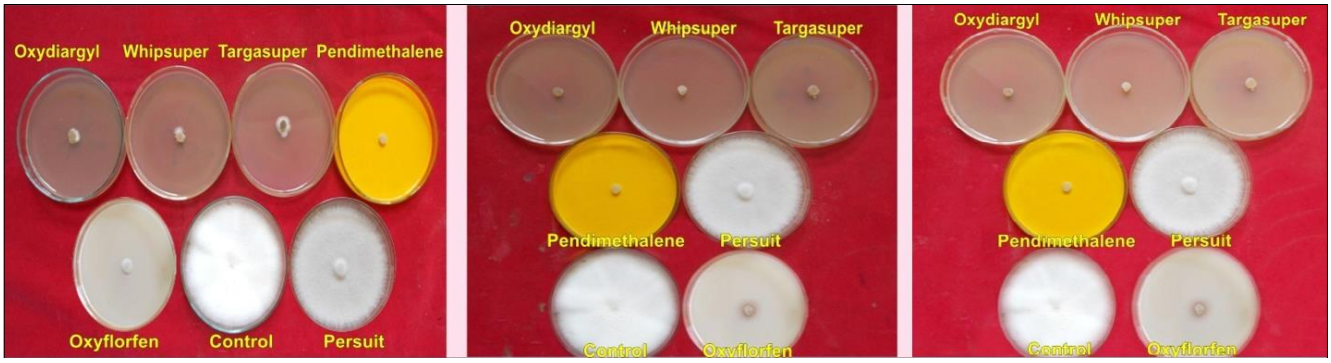

Plate 7: Efficacy of herbicides against *Fusarium oxysporum* f.sp. *ciceri.*

Table 6: Efficacy of herbicides on growth of *Fusarium oxysporum f.sp. ciceri.*

Herbicides	Treatments	Concentration	*Fusarium oxysporum* f.sp. *ciceri*	
			Mean colony Diameter (mm)	Per cent Growth inhibition
Targa super	T_1	0.1g	14.55	83.83
	T_2	0.2g	11.55	87.16
	T_3	0.3g	8.33	90.74
Oxadiargyl	T_4	0.1g	9.89	89.01
	T_5	0.2g	7	92.22
	T_6	0.3g	0	100
Whip super	T_7	0.1g	11	87.78
	T_8	0.2g	8.55	90.5
	T_9	0.3g	0	100
Pendimethylene	T_{10}	0.1g	0	100
	T_{11}	0.2g	0	100
	T_{12}	0.3g	0	100
Oxyfluorfen	T_{13}	0.1g	14.44	83.95
	T_{14}	0.2g	6.77	92.47
	T_{15}	0.3g	0	100
Imazathypyr	T_{16}	0.1g	80.44	10.62
	T_{17}	0.2g	76.11	15.43

	T_{18}	0.3g	75.88	15.68
Control	T_{19}	-	90	0
F test	Sig.			
SE(m)±	0.43			
CD(P=0.01)	1.68			

4.5 *In vitro* effect of bioagents on growth of *Fusarium oxysporum* f.sp. *ciceri*

The bioagents *viz., Bacillus subtilis, Pseudomonas fluorescens, Trichoderma viride* were used. The effect on radial growth of mycelium of *Fusarium oxysporum* f.sp. *ciceri* was studied by dual culture method, The data presented in Table 7 and Plate 8 showed that highest per cent growth inhibition was observed in *Trichoderma viride* (77.37%) followed by *Bacillus subtilis* (75.76%). The growth inhibition was observed in *Pseudomonas fluorescens* (63.38%). Deepashri and Raut (2005) [8] studied the bio-control efficacy of antagonistic organism in managing the chickpea wilt and root rot pathogens. Twelve isolates of *Trichoderma* inhibited pathogen to varying degrees. Maximum efficiency was recorded in APDRC (Tricho) 82.26% against *Fusarium oxysporum* f.sp. *ciceri.* Pandey *et al.* (2005) [27] mentioned that the mechanism involved in antagonism behind *Trichoderma viride* might be biochemical and antibiosis effect rather than physical and chemical. The mode of parasitism was examined between *Trichoderma, Fusarium* and *Rhizoctonia* under a microscope. Prameela *et al.* (2005) [30] showed that *Trichoderma viride* and *Trichoderma harzianum* exhibited maximum inhibition of 62% and 39%, respectively against *Fusarium oxysporum* f.sp. *carthami* causing safflower wilt, whereas, *Pseudomonas fluorescens* showed 36% inhibition.

Table 7: Antagonistic effect of bioagents on growth of *Fusarium oxysporum f.sp. ciceri.*

Treatments	Bio agents	*Fusarium oxysporum* f. sp *ciceri*	
		Mean Colony diameter (mm)	Per cent Growth inhibition
T_1	*Bacillus subtilis*	21.81	75.76
T_2	*Pseudomonas fluorescens*	32.95	63.38
T_3	*Trichoderma viride*	20.36	77.37
T_4	Control	90	0
'F test	Sig.		
SE(m)±	0.62		
CD (P=0.01)	3.25		

5: *In vivo* effect of fungicides, insecticides, herbicides, bioagents on chickpea wilt incited by *Fusarium oxysporum* f.sp.*ciceri*

5.1 Effect of combinations on germination per cent

The highest per cent germination i.e. 80% was observed in Table 8. Treatment T_8 i.e. Carbendazim 80% followed by T_{11} Carbendazim + *Trichoderma viride* + *Bacillus subtilis* i.e. 60% means T_{16} as against control 26.6%. These results are in support of findings of Bunker and Mathur (2001) [5] who was found that seed treatment with *T.viride, T.harzianum* and *T.aureoviride* was as effective as Bavistin seed treatment. It resulted in higher germination and reduced mortality. Murugesan *et al.* (2009) [22] reported that Imidacloprid, Monocrotophos and *P. fluorescens* improved germination and increased shoot length. Whereas neem oil had adverse effect on shoot length. Chaitra *et al.* (2010) [7] reported that seed treatment with Bavistin, Mancozeb and zineb significantly increased seedling emergence over untreated control in pot culture study where soil is artificially inoculated with *Fusarium oxysporum.* Govindappa *et al.* (2011) [11] showed that bioagents formulations *viz., Trichoderma harzianum, Bacillus subtilis* and *Pseudomonas fluorescens* reduced the wilt incidence both under greenhouse and field conditions, thereby enhancing the growth of the seedlings. These antagonists significantly reduced the population of *Fusarium oxysporum* f.sp. *carthami,* which increased the seed germination and seedling vigour.

5.2 Effect of combinations on Plant Dry weight

The effect of treatments found to be significant at 30 and 60 DAS. The data presented in Table 8 showed that highest plant dry weight 4.8 g and 8.96 g respectively at 30 DAS and 60 DAS was observed in T_{11} i.e. Carbendazim + *Trichoderma viride* + *Bacillus subtilis* followed by 4.43 g and 8.26 g at 30 and 60 DAS respectively in T_9 i.e. Carbendazim + *Trichoderma viride*. The lowest plant dry weight was observed in T_6 i.e. Fosetyl AL + *Bacillus subtilis* 2.43 g and 4.26 g at 30 and 60 DAS whereas in control it was 2.44g and 4.03 g at 30 and 60 DAS respectively. The above findings are in conformity with Saxena *et al.* (1994) [32] who showed that all the fungicides Bavistin, Triforine, Metalaxyl, Captafol, Captan and Thiram increased the total dry matter per plant as compared to Triadimefon.

5.3 Effect of combinations on root length (cm)

The data presented in Table 8 in respects of root length at 30 and 60 DAS revealed that the maximum root length was observed in T_{11} at 30 and 60 DAS i.e. 15.35 cm and 26.35 cm respectively. The effect of treatments found significant at 30 and 60 DAS. The data presented in Table 8, fig 7 showed that highest root length at 30 DAS and 60 DAS was 15.35 cm and 26.35 cm respectively, observed in T_{11} i.e. Carbendazim + *Trichoderma viride* + *Bacillus subtilis* followed by 15.26 cm and 26.91 cm respectively in treatment T_9 i.e. Carbendazim+ *Trichoderma viride*. The lowest root length was observed in T_6 i.e. Fosetyl Al+ *Bacillus subtilis* 8.37 cm, 11.44 cm at 30 and 60 DAS whereas in control it was 9.25cm and 12.58 cm at 30 and 60 DAS respectively. The above findings are in conformity with, Pahwa and Prakash (1996) [26] reported that length of root reduced significantly by application of Fluchloralin and Pendimethalin. Ali Khan *et al.* (2005) [1] showed that *Trichoderma harzianum* was examined for its effects on

emergence and vigour of rice seedlings through seed or soil treatments. All doses of *T. harzianum* in both the experiments significantly increased seedling emergence, root and shoot length, fresh and dry weight of root of rice seedlings, as compared to check. Maximum increase in seedling emergence (44.67%) was observed when bioagent was applied as soil treatment with the bioagent @ 8 gm per kg soil. There was similar trend of increase in root and shoot length, root and shoot weight from soil and seed treatments. Higher doses of the antagonist exhibited maximum increase in seed germination and seedling vigour.

5.4 Effect of combination on root dry weight (g)

The data presented in Table 8 in respects of root dry weight at 30 and 60 DAS. The effect of treatments found to be significant at 30 and 60 DAS. The data presented in Table 8 showed that highest root dry weight at 30 DAS and 60 DAS was 0.24g and 0.41 g respectively observed in T_{11} i.e. Carbendazim + *Trichoderma viride* + *Bacillus subtilis.* The lowest plant dry weight was 0.17 g and 0.27 g at 30 and 60 DAS respectively observed in T_6 i.e. Fosetyl AL + *Bacillus subtilis* whereas in control it was 0.15 g and 0.23 g at 30 and 60 DAS respectively. The results were in confirmation with Anderson *et al.* (2002) [2] reported that Chlorsulfuron significantly reduces the biomass of roots of chickpea plants. Singh and Wright (2002) [33] showed that Terbutryn/terbuthylazir, bentazone decreased root dry weight. Ali khan *et al.* (2005) [1] found that *Trichoderma harzianum* had its effects on emergence and vigour of rice seedlings through seed or soil treatments. All doses of *T. harzianum* in both the experiments significantly increased seedling emergence, root and shoot length, fresh and dry weight of root of rice seedlings, as compared to check. Maximum increase in seedling emergence (44.67%) was observed when bioagent was applied as soil treatment with the bioagent @ 8 gm per kg soil. There was similar trend of increase in root and shoot length, root and shoot weight from soil and seed treatments. Higher doses of the antagonist exhibited maximum increase in seed germination and seedling vigour. Yadav *et. al.* (2006) [38] reported the effects of pendimethalin, Fluchloralin and Metolachlor, applied at 1, 1.5 or 2 kg per ha at pre-emergence (Pendimethalin and Metolachlor) or pre-plant incorporation in the soil (Fluchloralin), on the growth and nodulation of chickpeas cv. Avarothi. Application of Fluchloralin, Pendimethalin and Metolachlor did not affect the germination of chickpea. In general, various characters *viz*., number of branches per plant, dry weight per plant, number of nodules and dry weight per plant were significantly affected by the herbicides at all the tested rates. Fluchloralin applied at 1.0 kg per ha promoted the growth and significantly increased the number of branches per plant, dry weight per plant, number of nodules per plant and dry weight of the nodules. All the herbicides applied at 1.5 or 2.0 kg per ha had inhibitory effects on the number of branches per plant, dry weight per plant, number of nodules, and dry weight per plant and either significantly reduced the values of the growth parameters or gave values on a par with the untreated control. The herbicides at all the tested rates reduced the leaf area per plant except Fluchloralin which increased the leaf area when applied at 1.0 kg per ha.

5.5 Effect of combinations on shoot length (cm)

The effect of treatments found significant at 30 and 60 DAS. The data presented in Table 8 and fig 8 showed that highest shoot length at 30 DAS and 60 DAS was 22.48 cm and 30.91 cm respectively observed in T_{11} i.e. Carbendazim + *Trichoderma viride* + *Bacillus subtilis* followed by 21.21 cm and 29.00 cm in T_9 i.e. Carbendazim + *Trichoderma viride*. The lowest shoot length was observed in T_6 Pendimethalene 13.69 cm and 19.81 cm at 30 and 60 DAS whereas in control it was 15.89 cm and 21.25 cm at 30 and 60 DAS respectively. The findings of the present study are in agreement with, Pahwa and Prakash (1996) [26] who reported that length of shoot reduced significantly with the application of Fluchloralin and Pendimethalin irrespective of concentration in mungbean. Govindappa *et al.* (2011) [11] showed that in safflower Anucop, Captan and Mancozeb M-45 were found extremely effective in reducing *Fusarium oxysporum* f.sp. *carthami* wilt. The seed treatments improved seed germination, seedling vigour and plant stand. Due to these treatments many of the seed-borne fungi failed to express in the normal way. Bioagents formulations *viz., Trichoderma harzianum, Bacillus subtilis* and *Pseudomonas fluorescens* reduced the wilt incidence both under greenhouse and field conditions, thereby enhancing the growth of the seedlings. These antagonists significantly reduced the population of *Fusarium oxysporum* f.sp. *carthami*, increased the seed germination and seedling vigour. Leaf extracts of *Becopa monniera* and *Adathoda vasica* were found effective in the control of safflower wilt. Comparatively *B. monniera* enhanced the seed germination and quality parameters of plants both under greenhouse and field conditions and also effectively suppressed the wilt up to flowering.

5.6 Effect of combination on shoot dry weight (g)

The effect of treatments found significant at 30 and 60 DAS. The data presented in Table 8 showed that highest shoot dry weight at 30 DAS and 60 DAS was 2.22 cm and 3.22cm respectively observed in T_{11} i.e. Carbendazim + *Trichoderma viride* + *Bacillus subtilis*. The lowest shoot length was observed in T_6 Fosetyl Al + *Bacillus subtilis* 1.53 cm and 2.36 cm at 30 and 60 DAS whereas in control it was 0.95 cm and 1.62 cm at 30 and 60 DAS respectively. The findings of the present study are in agreement with, (Yadav *et al.* 2006; Saxena *et al.* 1994) [38, 32] showed that all the fungicides (Bavistin, Triforine, Metalaxyl, Captafol, Captan, Thiram) increased the total dry matter per plant as compared to Triadimefon. Gade *et al.* (2007) [10] A field experiment was conducted on pigeon pea cultivars BSMR-736, BDN-2 and ICP-2376 during 2000/01 and 2001/02 in Akola, Maharashtra, India, under wilt sick soil conditions. The delay in wilting was clearly observed in soil solarization (16.31%) and its combination with seed treatment of Thiram (1.5 g per kg) + Benomyl (1.5 g per kg). The stimulating effect of solarization was also observed in the form of shoot length (161.76 cm) and shoot dry weight (53.58 g per plant) and also in yield (14.58 q per ha). However, response of BSMR-736 was more to soil solarization compared to the other 2 cultivars.

Table 8: Effect of germination per cent, plant dry weight, root length, root dry weight, shoot length, and shoot dry weight.

Treatments	No of seeds sown	*Fusarium oxysporum* f sp *ciceri*											
		Germination per cent		Plant Dry weight (g)		Root Length (cm)		Root Dry weight (g)		Shoot Length (cm)		Shoot Dry Weight (g)	
		Total No. of germinated seeds	Percent seed germination	Plant dry wt. at 30 DAS (g)	Plant dry wt. at 60 DAS (g)	Root length at 30 DAS (cm)	Root length at 60 DAS (cm)	Root dry wt at 30 DAS (g)	Root dry wt at 60 DAS (g)	Shoot Length at 30 DAS (cm)	Shoot length at 60 DAS (cm)	Shoot dry wt at 30 DAS (g)	Shoot dry wt at 60 DAS (g)
T_1 *Trichoderma viride*	15	9	60 (50.77)*	4.33	7.86	14.13	24.13	0.43	0.63	20.31	24.98	2.14	3.14
T_2 *Bacillus subtilis*	15	7	46.6 (43.05)*	4.16	7.46	13.43	23.43	0.42	0.66	19.55	24.72	1.94	2.94
T_3 *Trichoderma viride+Bacillus subtilis*	15	8	53.2 (46.83)*	3.8	7.23	14.12	24.1	0.48	0.65	19.55	24.76	2.07	3.08
T_4 Fosetyl Al	15	4	26.6 (31.05)*	2.8	4.8	9.17	15.17	0.19	0.29	14.97	21.3	1.63	2.63
T_5 Fosetyl Al+ *Trichoderma viride*	15	6	40 (39.23)*	2.96	4.66	8.97	14.97	0.19	0.29	14.5	21.22	1.53	2.36
T_6 Fosetyl Al+ *Bacillus subtilis*	15	10	66.6 (54.70)*	2.43	4.26	8.37	11.44	0.17	0.27	14.15	20.23	1.54	2.41
T_7 Fosetyl Al+ *Trichoderma viride+Bacillus subtilis*	15	9	60 (50.77)*	2.66	4.3	8.98	14.98	0.19	0.29	14.63	20.16	1.56	2.57
T_8 Carbendazim	15	12	80 (63.43)*	3.33	8.23	14.92	25.01	0.22	0.4	20.62	28.7	1.7	2.56
T_9 Carbendazim+ *Trichoderma viride*	15	10	66.6 (54.70)*	4.43	8.26	15.26	26.91	0.22	0.41	21.21	29	1.73	2.67
T_{10} Carbendazim+ *Bacillus subtilis*	15	8	53.2 (46.83)*	4.2	7.43	15.01	25.6	0.22	0.4	20.46	28.83	1.37	2.38
T_{11} Carbendazim+ *Trichoderma viride+Bacillus subtilis*	15	11	73.2 (58.82)*	4.8	8.96	15.35	26.35	0.24	0.41	22.48	30.91	2.22	3.22
T_{12} Pendimethylene	15	7	46.6 (43.05)*	2.96	4.56	8.51	14.37	0.2	0.31	13.59	20.1	1.5	2.47
T_{13} Pendimethylene+ *Trichoderma viride*	15	7	46.6 (43.05)*	3.13	4.4	8.72	11.72	0.19	0.3	13.71	20.38	1.54	2.5
T_{14} Pendimethylene+ *Bacillus subtilis*	15	4	26.6 (31.05)*	2.5	4.36	8.55	11.55	0.19	0.3	13.69	19.81	1.63	2.67
T_{15} Pendimethylene+ *Trichoderma viride+Bacillus subtilis*	15	6	40 (39.23)*	2.9	4.53	8.78	12.11	0.19	0.29	13.77	20.63	1.59	2.59
T_{16} Control inoculated	15	4	26.6 (31.05)*	2.44	4.03	9.25	12.58	0.15	0.23	15.89	21.25	0.95	1.62
T_{17} Control without inoculated	15	8	53.2 (46.83)*	2.46	4.23	14.18	25.85	0.23	0.34	17.34	20.34	1.82	1.92
F test			Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)±			6.24	0.26	0.24	0.2	0.25	0.012	0.012	0.24	0.29	0.096	0.11
CD(P=0.01)			24.12	1.02	0.92	0.78	0.98	0.048	0.050	0.94	1.12	0.37	0.45

5.7 Combine effect of bioagents and fungicides on per cent wilt

An interaction effect of treatments found to be significant. The data presented in Table 9 and fig 9 showed that highest per cent wilt over control was 75.6% observed in T_8 i.e. Carbendazim followed by 73.4% in T_9 i.e. Carbendazim + *Trichoderma viride*. The lowest per cent wilt over control was observed in T_6 i.e, Fosetyl Al + *Bacillus subtilis* 29.00 followed by T_5 i.e, Fosetyl Al + *Trichoderma viride* 29.00%. Whereas in control it is 11.2%. The above results are in conformity with findings, Mukhopadhyay and Mukherjee (1991) [20] reported that *Trichoderma viride* + *Pseudomonas fluorescens* + Vitavax showed 13.4 per cent disease as compared with 53.9 per cent in untreated control and gave additional yield of 105 kg per ha in chickpea. Reddy (1991) [31] reported integrated control of *Fusarium* wilt of chickpea by utilizing host plant resistance combined with other control practices such as seed treatment with Benlate (0.15%). Kaur and Mukhopadhyay (1992) [18] reported that the wilt complex of chickpea caused by *Fusarium oxysporum* f.sp. *ciceri*, *Rhizoctonia solani* and *Sclerotium rolfsii* were effectively controlled by *Trichoderma* alone and in combination with fungicides. Fungicidal seed treatment significantly reduced the incidence of wilt complex and increased the crop yield. They also reported that seed treatment with Vitavax-200 (Carboxin + Thiram) and Zirum resulted 29.9 per cent disease control. Nikam *et al.* (2007) [24] proved that chemical seed treatment with Thiram (0.15%) + Carbendazim (0.1%) was most effective against *Fusarium oxysporium* f.sp. *ciceri*. *In vitro* evaluation of *Trichoderma sp*. Against *F. oxysporium* f.sp. *ciceri* showed maximum growth inhibition and *F. oxysporium* f.sp. *ciceri* being soil borne disease could be managed by the integration of various practices like using resistant varieties, seed treatment with chemicals, seed and soil application of bioagents and amendment of soils with oilseeds cakes. Gade *et al.* (2007) [10], the delay in wilting was clearly observed in soil solarization (16.31%) and its combination with seed treatment of Thiram (1.5 g/kg) + Benomyl (1.5 g per kg). The stimulating effect of solarization was also observed in the form of shoot length (161.76 cm) and shoot dry weight (53.58 g/plant) and also in yield (14.58 q/ha). However, response of BSMR-736 was more to soil solarization compared to the other 2 cultivars.

Table 9: Combine effect of bioagents and fungicides on per cent wilting caused by *Fusarium oxysporum f. sp. ciceri.*

Sr. No	Treatments	*Fusarium oxysporum* f.sp. *ciceri*	
		Mean Percent wilt incidence	Percent wilt over control
1	T_1- *Trichoderma viride*	28.8 (32.46)*	71.2
2	T_2-*Bacillus subtilis*	31 (33.83)*	69
3	T_3-*Trichoderma viride*+*Bacillus subtilis*	28.8 (32.46)*	71.2
4	T_4-Fosetyl Al	64.4 (53.37)*	35.6
5	T_5-Fosetyl Al+ *Trichoderma viride*	71 (57.42)*	29
6	T_6-Fosetyl Al+ *Bacillus subtilis*	71 (57.42)*	29
7	T_7-Fosetyl Al+ *Trichoderma viride* + *Bacillus subtilis*	57.6 (49.37)*	42.4
8	T_8-Carbendazim	24.4 (29.60)*	75.6
9	T_9- Carbendazim+ *Trichoderma viride*	26.6 (31.05)*	73.4
10	T_{10}- Carbendazim+ *Bacillus subtilis*	31.09 (33.27)*	69
11	T_{11}- Carbendazim+ *Trichoderma viride*+*Bacillus subtilis*	26.6 (31.05)*	73.4
12	T_{12}-Pendimethylene	48.8 (44.31)*	51.2
13	T_{13}- Pendimethylene+ *Trichoderma viride*	44.4 (41.78)*	55.6
14	T_{14}- Pendimethylene+ *Bacillus subtilis*	39.8 (39.11)*	60.2
15	T_{15}- Pendimethylene+ *Trichoderma viride*+*Bacillus subtilis*	46.6 (43.05)*	53.4
16	T_{16}-Control inoculated	88.8 (70.45)*	11.2
17	T_{17}-Control without inoculated	0.00 (0.00)*	100
F test		Sig.	
SE(m) ±		2.32	
CD at 0.01%		4.51	

Summary and Conclusions

Evaluation of fungicides, insecticides, herbicides, and bioagents against *Fusarium oxysporum* f. sp. *ciceri*

The effect of three fungicides was evaluated *in vitro* against *Fusarium oxysporum* f.sp. *ciceri* by employing poison food technique. Among the fungicides tested, Carbendazim, Benomyl and Fosetyl Al were found effective in inhibiting mycelial growth of *Fusarium oxysporum* f. sp. *ciceri.* Among herbicides Pendimethalin is effective; Antagonist effect of *Trichoderma viride* was more effective.

Per cent germination

The germination per cent was observed significantly superior in treatment T_8 Carbendazim i.e. 80% followed by T_{11} Carbendazim + *Trichoderma viride* + *Bacillus subtilis* i.e. 73.2%, whereas in control it is 26.6 per cent.

Plant dry weight

The plant dry weight was found maximum in treatment T_{11} Carbendazim + *Trichoderma viride* + *Bacillus subtilis* at every growth stage showed significant differences, it is 4.8 g and 8.96 g at 30 and 60 DAS over other treatments. Whereas in control it is 2.44 g and 4.03 g at 30 and 60 DAS respectively.

Root length: The treatment differences found significant at every stage of growth having maximum root length in treatment T_{11} Carbendazim + *Trichoderma viride* + *Bacillus subtilis*. It is 15.35 cm and 26.35 cm at 30 and 60 DAS.

Whereas in control it is 9.25 cm and 12.58 cm at 30 and 60 DAS respectively.

Root dry weight

The root dry weight was found maximum in treatment T_{11} Carbendazim + *Trichoderma viride* + *Bacillus subtilis* at every growth stage showed significant differences it was 0.24 g and 0.41 g at 30 and 60 DAS over other treatments, whereas in control it was 0.15 g and 0.23 g at 30 and 60 DAS respectively.

Shoot length

The highest shoot length at 30 DAS and 60 DAS was 22.48 cm and 30.91 cm respectively observed in T_{11} i.e. Carbendazim + *Trichoderma viride* + *Bacillus subtilis* followed by 21.21 cm and 29.00 cm in T_9 i.e. Carbendazim + *Trichoderma viride*, whereas in control it was 15.89 cm and 21.25cm at 30 and 60 DAS respectively.

Shoot dry weight

The highest shoot dry weight at 30 DAS and 60 DAS was 2.22 cm and 3.22 cm respectively observed in T_{11} i.e. Carbendazim + *Trichoderma viride* + *Bacillus subtilis*,.whereas in control it was 0.95 cm and 1.62 cm at 30 and 60 DAS respectively.

Per cent wilt incidence

Per cent wilt incidence is minimum in treatment T_8 Carbendazim i.e. 24.4% and the per cent wilt over control is 75.6%, whereas in inoculated control per cent wilt was 88.8% and per cent wilt over control was 11.2%.

Conclusions

On the basis of results obtained from present investigation it was concluded that-

1. Among all the treatments effect of T_{11}- Carbendazim + *Trichoderma viride* + *Bacillus subtilis* was found significantly superior in respect of all growth parameters.
2. Per cent wilt incidence was less in treatment T_8 - Carbendazim.
3. Seed treatment with Carbendazim + *Trichoderma viride* + *Bacillus subtilis* i.e. T_{11} is significantly superior among root length, shoot length, shoot dry weight and root dry weight etc.
4. Germination per cent of treatment T_8 Carbendazim and T_1-*Trichoderma viride* @ 4g per kg seed was more as compared to other treatments.
5. It has been observed that one method alone cannot control the wilt to the desired level. It was, therefore, concluded that integrated management of *Fusarium* wilt could be possible through fungicidal seed treatment combined with the application of bio control agents to seed and soil and use of resistant varieties.
6. However, more efforts are needed to develop wilt management modules involving resistant/tolerant cultivars of chickpea, judicious use of fungicides and bio control agents for the management of *Fusarium* wilt of chickpea.

References

1. Ali K, Sinha AP, Rathi YPS. Plant growth promoting activity of *Trichoderma harzianum* on rice seed germination and seedling vigour. Indian Journal of Agricultural Research. 2005;39(4):265-262.
2. Anderson A, Baldock J, Rogers S, Gill G, Bellott B. The effect of chlorusulfuron on the ability of *Rhizobium* to infect chickpea (*Cicer arietinum*) roots. Current Plant Science and Biotechnology in Agriculture. 2002;38(1):548.
3. Biswas P, Sen Gupta PK. Competitive saprophytic activity of three fungal pathogens of Bengal gram in soil. Indian Phytopathology. 1981;34(1):99-100.
4. Booth C. Fusarium: Laboratory guide to the identification of the major species. Kew, Surrey (UK): Commonwealth Mycological Institute; 1977. 58 p.
5. Bunker RN, Mathur K. Integration of biocontrol agents and fungicide for suppression of dry root rot of *Capsicum frutescens*. Journal of Mycology and Plant Pathology. 2001;31(3):330-334.
6. Butler EJ. Fungi and diseases in plants. Calcutta (India): Thacker Spink and Company; 1918. 547 p.
7. Chaitra M, Rao MSL, Ashtaputre SA, Mesta RK. Evaluation of seed dressing fungicides for the integrated management of chickpea wilt. Pestology. 2010;34(5):30-33.
8. Deepashri G, Raut BT. *Trichoderma* as an effective bio-agent against chickpea wilt complex. Journal of Plant Disease Sciences. 2005;1(1):66-69.
9. Fenn ME, Coffey MD. Studies on the *in vitro* and *in vivo* antifungal activity of fosetyl-Al and phosphorous acid. Phytopathology. 1984;74:606-611.
10. Gade RM, Deshmukh VV, Deshmukh RW. Evaluation of integrated disease management practices vis-à-vis growth parameters under wilt sick condition in pigeonpea. Journal of Plant Disease Sciences. 2007;2(2):217-219.
11. Govindappa MV, Ravishankar Rai, Lokesh S. *In vitro* and *in vivo* responses of different treating agents against wilt disease of safflower. Journal of Cereals and Oilseeds. 2011;2(1):16-25.
12. Grewal JS, Pal M, Kulshrestha DD. Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi; 1974.
13. Gupta SK, Upadhyay JB, Ojha KL. Effect of fungicidal seed treatment on the incidence of chickpea wilt complex. Annals of Plant Protection Sciences. 2005;13:184-187.
14. Haware MP. Fusarium wilt and other important diseases of chickpea in the Mediterranean area. In: Proceedings of Seminar on Present Status and Future Prospects of Chickpea Crop Production and Improvement; 1988 Jul 11-13; Spain.
15. Haware MP, Nene YL, Rajeshwari R. Eradication of *Fusarium oxysporum* f. sp. *ciceri* transmitted in chickpea seeds. Phytopathology. 1978;68:1364-1367.
16. Haware MP, Nene YL, Mathur SB. Seed borne diseases of chickpea. Technical Bulletin No. 1. Copenhagen (Denmark): Danish Government Institute of Seed Pathology; 1986. 32 p.
17. Kathiresan RM, Gnanavel I, Jayakanth UV, Arulchezhian MP, Anbhazhagan R, Padmapriya SP. Bio-efficacy and phytotoxicity of oxadiargyl in onion (*Allium cepa* var. *aggregatum*). Indian Journal of Weed Science. 2004;36(3-4):236-238.
18. Kaur MP, Mukhopadhyay AN. Integrated control of chickpea wilt complex by *Trichoderma* and chemical

methods in India. Tropical Pest Management. 1992;38:372-375.
19. Khan MI, Hassan G, Khan I. Herbicides and their dose effects on wild onion (*Asphodelus tenuifolius*) in chickpea. Pakistan Journal of Weed Science Research. 2010;16(3):299-308.
20. Mukhopadhyay AN, Mukherjee PK. Innovative approaches in biological control of soil borne diseases in chickpea. In: Proceedings of Fourth International *Trichoderma* and *Gliocladium* Workshop; 1991 Jul 17-20; Belgirate, Italy. Petria. 1991;1:146.
21. Mukhtar I. Comparison of phytochemical and chemical control of *Fusarium oxysporum* f. sp. *ciceri*. Mycopathologia. 2007;5(2):107-110.
22. Murugesan N, Kavitha A. Seed treatment with *Pseudomonas fluorescens*, plant products and synthetic insecticides against leafhopper *Amrasca devastans* in cotton. Journal of Biopesticides. 2009;2(1):22-25.
23. Nene YL, Sheila VK, Sharma SB. A world list of chickpea and pigeonpea pathogens. 5th ed. Patancheru (India): International Crops Research Institute for the Semi-Arid Tropics; 1996. 27 p.
24. Nikam PS, Jagtap GP, Sontakke PL. Management of chickpea wilt caused by *Fusarium oxysporum* f. sp. *ciceri*. African Journal of Agricultural Research. 2007;2(12):692-697.
25. Padwick GW. Original description of the chickpea wilt pathogen as *Fusarium orthoceras* var. *ciceri* in India; 1940.
26. Pahwa SK, Jai Prakash. Studies on effect of herbicides on growth, nodulation and symbiotic nitrogen fixation in mungbean (*Vigna radiata*). Indian Journal of Weed Science. 1996;28(3-4):160-163.
27. Pandey KK, Pandey PK, Upadhyay JP. Mycoparasitism of *Trichoderma* species on *Fusarium* and *Rhizoctonia*. Journal of Mycology and Plant Pathology. 2005;35(1):174-176.
28. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. 2nd ed. New Delhi (India): Indian Council of Agricultural Research; 1967.
29. Patel SM, Patel BK. Evaluation of herbicidal concentrations against *Fusarium oxysporum* f. sp. *cumini* causing cumin wilt. In: Proceedings of Integrated Weed Management for Sustainable Agriculture Symposium; 1993; Hisar, Haryana. Vol II. p. 131-132.
30. Prameela M, Rajeshwari B, Prasad RD. Bio-efficacy of antagonists against *Fusarium oxysporum* f. sp. *carthami* inciting safflower wilt. Journal of Mycology and Plant Pathology. 2005;35(2):272-274.
31. Reddy MV, Raju TN, Pundir RPS. Evaluation of wild *Cicer* accessions for resistance to wilt and root rots. Indian Phytopathology. 1991;44(3):388-391.
32. Saxena M, Saxena DR, Vyas SC. Effect of fungicidal seed treatment on *Rhizobium* inoculation in soybean. Journal of Mycology and Plant Pathology. 1994;24(2):151-154.
33. Singh G, Wright D. Effect of herbicides on nodulation and growth of two varieties of peas (*Pisum sativum*). Acta Agronomica Hungarica. 2002;50(3):337-348.
34. Singh RD, Bhargava AK, Gaur RB. Some observations on the incidence of chickpea wilt in Sriganganagar district, Rajasthan, India. International Chickpea Newsletter. 1985;13:15-16.
35. Snyder WC, Nash SM. Quantitative estimations by plate counts of propagules of the bean root rot *Fusarium* in field soils. Phytopathology. 1962;52:567-572.
36. Sugha SK, Kapoor SK, Singh BM. Management of chickpea wilt with fungicides. Indian Phytopathology. 1995;48:27-31.
37. Uppal BN, Patel MK, Kamat MN. Fungi of Bombay. Department of Agriculture Bulletin No. 176. 1935. p. 31.
38. Yadav PK, Khan AH, Rammurti RK, Upadhyay. Effect of herbicides on germination, growth and nodulation in chickpea (*Cicer arietinum*). Indian Journal of Agricultural Sciences. 2006;76(11):682-684.