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In-vitro Efficacy of Different Fungicides and Bioagents for Management Wilt of Watermelon [*Citrullus lanatus*] Incited by *Fusarium oxysporum* f. sp. *niveum*

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Fusarium wilt of watermelon caused by *Fusarium oxysporum* f. sp. *niveum* has been emerged as one of the major threats to the profitable cultivation of watermelon crops. In present investigation, seven fungicides *viz.,* namely Carbendazim 50% WP, Copper Oxychloride 50% WP, Tebuconazole 50% + Trifloxystrobin 25% WG, Carbendazim 12% + Mancozeb 63% (75% WP), Chlorothalonil 75% WP, Azoxystrobin 23% SC and Tebuconazole 25.9% EC along with four bioagents namely, *Trichoderma viride*, *Trichoderma harzianum, Trichoderma koningii* and *Trichoderma longibrachiatum* were evaluated the *in vitro* at two different concentrations for their efficacy against the pathogen causing wilt in of watermelon. Among the different fungicides evaluated, Carbendazim 50% WP (0.1% and 0.2% concentration) and Carbendazim 12% +Mancozeb 63% (0.1% and 0.2% concentration) were completely inhabited the mycelial growth of *F. oxysporum* f.sp. *niveum* completely. Among the different bioagents evaluated, *Trichoderma harzianum* was found to be the most effective, exhibiting significantly the least mycelial growth (22.50 mm) and the highest mycelial growth inhibition (75.00%) of the test pathogen.

Keywords: Watermelon; Fusarium oxysporum; wilt; bioagents; fungicides.

1. INTRODUCTION

"Watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai] is one of the most widely grown vegetable crops in the warmer parts of the world**.** It is a well-liked summer vegetable fruit belonging to the Cucurbitaceae family of gourds and has a chromosomal number of 2n=2x=22" (Paris, 2015). "It is known by various names in different regions of India such as kalingad, kalindi, and tarbuj. The arid areas of Africa, especially the Kalahari Desert, are believed to be the origin of watermelon" (Strauss, 2015). "Among the various fungal diseases, *Fusarium* wilt caused by *Fusarium oxysporum* f. sp. *niveum* is the most severe soil borne disease and is considered as the most important disease in watermelon. The yield loss is around 30–80% or even more, and is presently a major hindrance to watermelon cultivation worldwide" (Rahman et al., 2021). "Initial symptoms often include a dull, gray green appearance of leaves that precedes a loss of turgor pressure and wilting. Wilting is followed by a yellowing of the leaves and finally necrosis. The wilting generally starts with the older leaves and progresses to the younger foliage. Initial symptoms often occur as the plant begins to vine and wilting may occur in only one runner leaving the rest of the plant apparently unaffected" (Egel and Martyn, 2024). Under conditions of sufficiently high inoculum density or a very susceptible host, the entire plant may wilt and die within a short time. Affected plants that do not die are often stunted and have considerably reduced yields. Under high inoculum pressure, seedlings may damp off as they emerge from the soil.

2. MATERIALS AND METHODS

The present study was conducted at the Department of Plant Pathology, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during the year 2023-2024. Seven fungicides namely, Carbendazim 50% WP, Copper Oxychloride 50% WP, Tebuconazole 50% + Trifloxystrobin 25% WG, Carbendazim 12% + Mancozeb 63% (75% WP), Chlorothalonil 75% WP, Azoxystrobin 23% SC and Tebuconazole 25.9% EC were tested *in vitro* against the pathogen at two different concentrations by applying the "Poisoned Food Technique" (Nene and Thapliyal, 1993) with three replications in Completely Randomized Design. Four bioagents *viz., Trichoderma viride*, *Trichoderma harzianum, Trichoderma koningii* and *Trichoderma longibrachiatum* were evaluated *in vitro* for their efficacy against *Fusarium oxysporum* f. sp. *niveum* by applying "Dual Culture Technique" (Dennis and Webster, 1971) with four replications in a Completely Randomized Design (CRD). The efficacy of bioagents and fungicides against the test fungus was expressed as the percentage inhibition of

mycelial growth over control and the percentage inhibition was calculated by using the formula given by Vincent (1947).

$$\text{Per cent Inhibition (I)} = \frac{C - T}{C} \times 100$$

Where,

C = Growth (mm) of the test fungus in untreated control plate
T = Growth (mm) of the test fungus in treated plate

3. RESULTS AND DISCUSSION

3.1 *In vitro* Efficacy of Fungicides against Pathogen of Wilt of Watermelon

Results from the Table 1, Plate 1 (a and b) and Fig. 1 revealed that all the fungicides evaluated *in vitro* were significantly effective against *Fusarium oxysporum* f. sp. *niveum,* a causal organism of wilt of watermelon wilt.

3.1.1 Effect on colony growth

At lower concentrations, the fungicides observed radial mycelial growth of the test pathogen ranging from 0.00 mm (Carbendazim 50% WP and Carbendazim 12% + Mancozeb 63% WP) to 34.00 mm (Azoxystrobin 23% EC) compared to 90.00 mm in the untreated control. However, Carbendazim 50% WP and Carbendazim 12% + Mancozeb 63% WP were the most effective, exhibiting the least of the mycelial growth (0.00 mm) followed by Tebuconazole 25.9% EC (10.00 mm), Tebuconazole 50% WG + Trifloxystrobin 25% WG (15.50 mm), Copper Oxychloride 50% WP (24.00 mm) and Chlorothalonil 75% WP (28.00 mm). Azoxystrobin 23% EC was found comparatively less effective with a maximum mycelial growth of 34.00 mm.

At higher concentrations, (Table 1, Fig. 1 and Plate 1) the fungicides observed radial mycelial growth of the test pathogen was ranged from 0.00 mm (Carbendazim 50% WP, Tebuconazole 25.9% EC, Carbendazim 12% + Mancozeb 63% WP) to 28.50 mm (Azoxystrobin 23% EC), compared to 90.00 mm in the untreated control. Carbendazim 50% WP, Carbendazim 12% + Mancozeb 63% WP and Tebuconazole 25% EC was found most effective with the least mycelial growth (0.00 mm) followed by Tebuconazole 50% + Trifloxystrobin 25% WG (12.50 mm), Copper Oxychloride 50% WP (19.50 mm) and Chlorothalonil 75% WP (23.00 mm). Azoxystrobin 23% EC was shown to be less effective, with the maximum mycelial growth of 28.50 mm.

3.1.2 Effect on mycelial growth inhibition

At lower concentrations, the percentage of mycelial growth inhibition of the test pathogen ranged from 62.22% (Azoxystrobin23% EC) to 100% (Carbendazim 50% WP and Carbendazim 12% + Mancozeb 63% (75% WP). However, the fungicides Carbendazim 50% and Carbendazim 12% + Mancozeb 63% WP were found to be the most effective which was inhibiting 100.00% of mycelial growth, followed by fungicide Tebuconazole 25.9% EC (94.44%), Tebuconazole 50% + Trifloxystrobin 25% WG (82.77%), Copper Oxychloride 50% WP (73.33%), Chlorothalonil 75% WP (68.88%). Azoxystrobin 23% EC was found to be comparatively less effective with minimum mycelial inhibition percentage of 62.22%.

At higher concentrations, the percentage of mycelial growth inhibition of the test pathogen ranged from 73.88% (Azoxystrobin 23% EC) to 100% (Carbendazim 50% WP, Tebuconazole 25% EC and Carbendazim 12% + Mancozeb 63% (75% WP). However, the fungicides Carbendazim 50% WP, Tebuconazole 25.9% EC and Carbendazim 12% + Mancozeb 63% WP were found to be the most effective which was inhibited 100.00% mycelial growth followed by fungicide Tebuconazole 50% + Trifloxystrobin 25% WG (86.11%), Copper Oxychloride 50% WP (78.33%) and Chlorothalonil 75% WP (73.88%). Azoxystrobin 23% EC was found comparatively less effective with minimum mycelial inhibition percentage of 68.33%.

Similarly, Parmar (2014) studied the efficacy of six different combination fungicides at different concentrations against *Fusarium oxysporum* f. sp. *niveum* using the poisoned food technique. The results revealed that carbendazim 12% + mancozeb 63% WP inhibited the growth of *Fusarium oxysporum* f. sp. *niveum* (100%). Gurjar and Shekhawat (2012) also evaluated the *in vitro* efficacy of five fungicides against *Fusarium oxysporum Schlecht* and reported that, carbendazim 50% WP was the most effective fungicide in checking mycelial growth.

Table 1. *In vitro* efficacy of fungicides against pathogen of wilt of watermelon

Tr. No.	Treatment	Conc. (%)	Mean colony dia. (mm)	(%) Inhibition over control	Conc. (%)	Mean colony dia. (mm)	(%) Inhibition over control
T_1	Carbendazim 50% WP	0.1%	0.00	100.00	0.2%	0.00	100.00
T_2	Copper Oxychloride 50% WP	0.1%	24.00	73.33	0.2%	19.50	78.33
T_3	Tebuconazole 50% + Trifloxystrobin 25% WG	0.1%	15.50	82.77	0.2%	12.50	86.11
T_4	Carbendazim 12% + Mancozeb 63% (75% WP)	0.25%	0.00	100.00	0.3%	0.00	100.00
T_5	Chlorothalonil 75% WP	0.1%	28.00	68.88	0.2%	23.00	73.88
T_6	Azoxystrobin 23% SC	0.2%	34.00	62.22	0.3%	28.50	68.33
T_7	Tebuconazole 25.9% EC	0.05%	10.00	94.44	0.1%	0.00	100.00
T_8	Control (Untreated)	-	90.00	0.00	-	90.00	0.00
	S.E. (m) ±		**0.38**			**0.27**	
	C.D. at 1%		**1.57**			**1.11**	

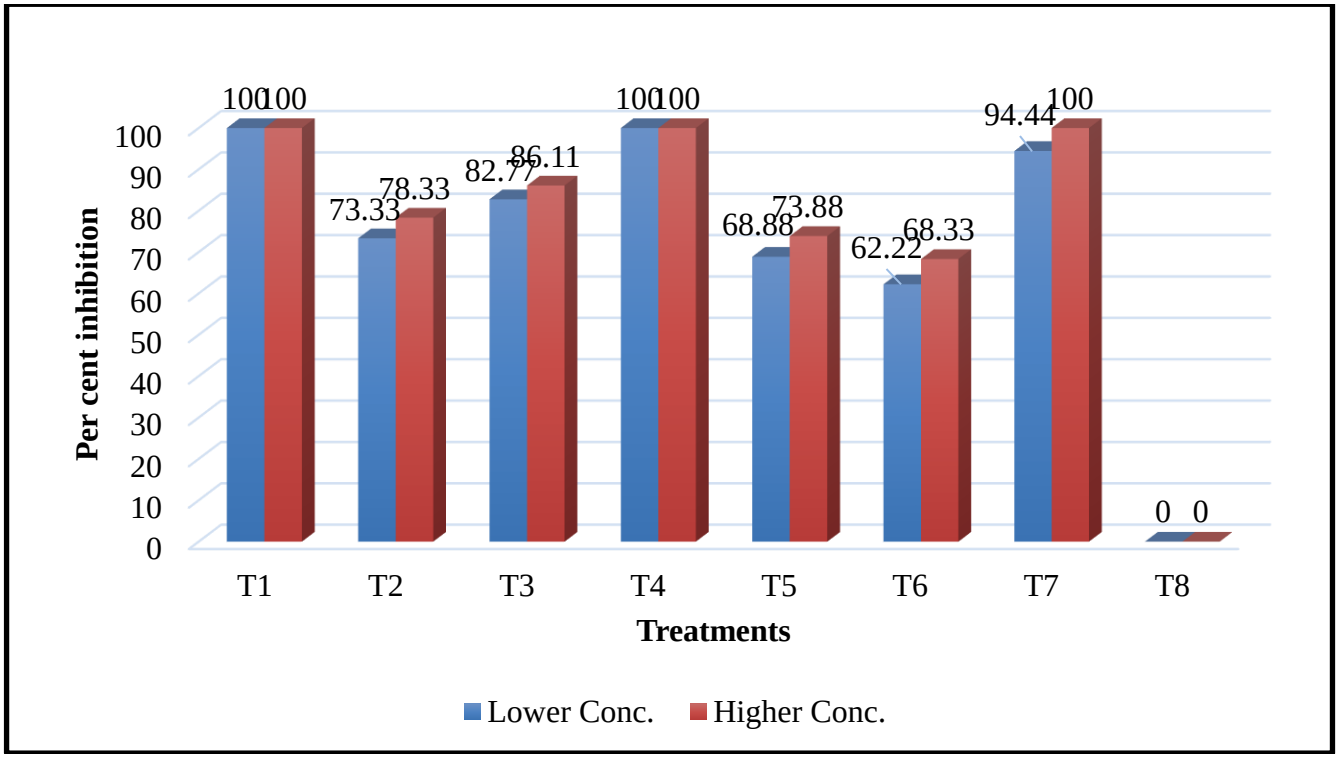

Fig. 1. *In vitro* efficacy of fungicides against the *F. oxysporum* f. sp. niveum

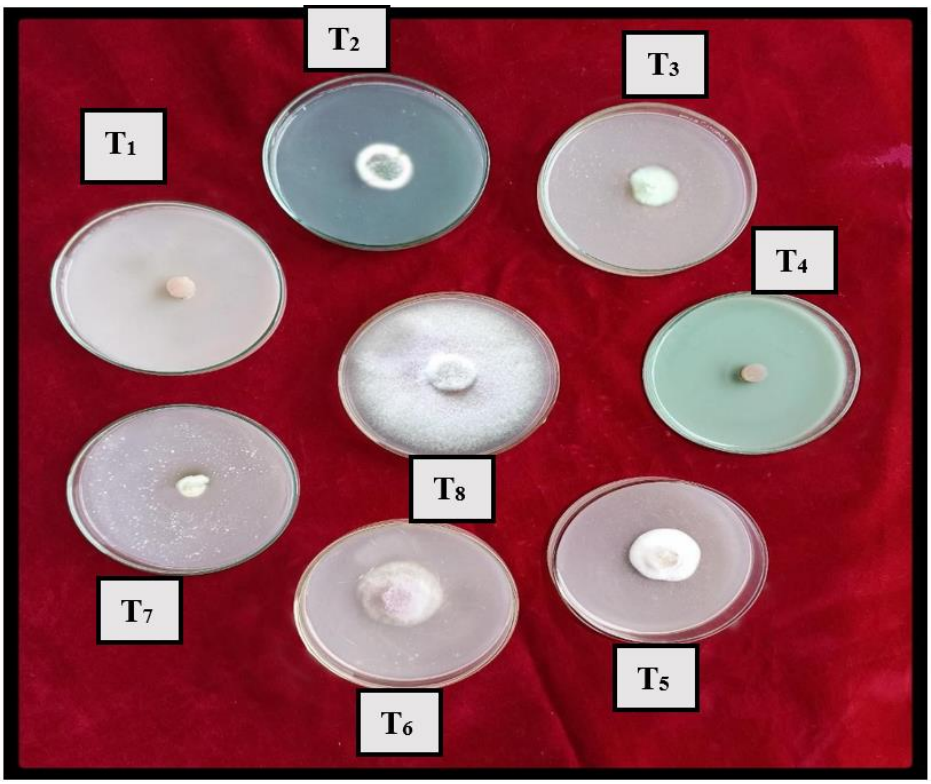

Plate 1 (a). *In vitro* efficacy of fungicides against *F. oxysporum* f. sp. *niveum* at lower concentration

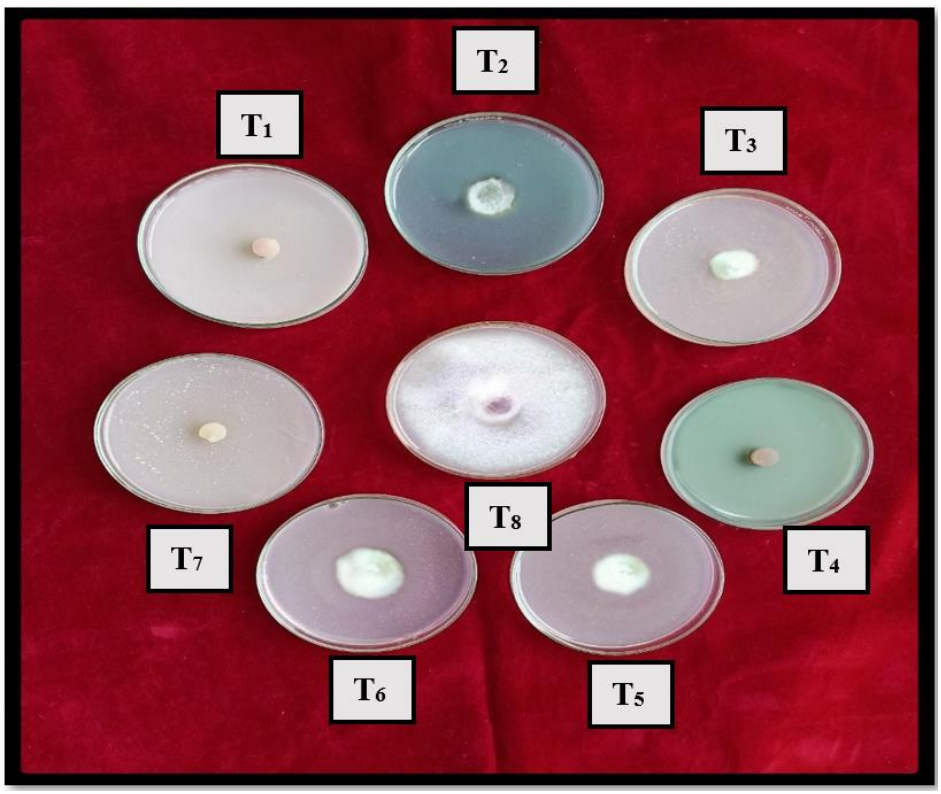

Plate 1 (b). *In vitro* efficacy of fungicides against *F. oxysporum* f. sp. *niveum* at higher concentration

Madhavi & Bhattiprolu (2011) were carried out similar study on the *in vitro* efficacy of six fungicides against *Fusarium solani* using the poisoned food technique, which showed that a combination of carbendazim 12% +mancozeb 63% was effective in inhibiting mycelial growth, followed by carbendazim alone.

3.2 *In vitro* Efficacy of Bioagents against Pathogen of Wilt of Watermelon

The results from Table 2, Plate 2 and Fig. 2 showed that all the bioagents studied *in vitro* were significantly effective in inhibiting the mycelial growth of *Fusarium oxysporum* f. sp. *niveum.* Among the four bioagents *Trichoderma harzianum* was found to be the most effective exhibiting the least mycelial growth (22.50 mm) and the highest mycelial growth inhibition (75.00%) of the test pathogen followed by *Trichoderma longibrachiatum* (23.75 mm and 73.61% respectively), *Trichoderma viride* (27.50 mm and 69.44%, respectively) and *Trichoderma koningii* (35.00 mm and 61.11%, respectively). *Trichoderma koningii* was found to be comparatively less effective with the maximum mycelial growth (35.00 mm) and the minimum mycelial growth inhibition (61.11%).

Gurjar and Shekhawat (2012) were carried out a similar study on the *in vitro* efficacy of four bioagents against *Fusarium oxysporum Schlecht* and reported that, *Trichoderma harzianum* was the most effective treatment in checking the mycelial growth of the pathogen. Similarly, Patel et al. (2023) evaluated the *in vitro* efficacy of six different bioagents using the dual culture method against *F. solani*, and reported that, *Trichoderma harzianum* was the most effective treatment in inhibiting the mycelial growth of the pathogen.

Table 2. *In vitro* efficacy of bioagents against pathogen of wilt of watermelon

Tr. No.	Bioagents	Mean colony dia. (mm)	(%) Inhibition over control
T_1	*Trichoderma viride*	27.50	69.44
T_2	*Trichoderma harzianum*	22.50	75.00
T_3	*Trichoderma koningii*	35.00	61.11
T_4	*Trichoderma longibrachiatum*	23.75	73.61
T_5	Control	90.00	0.00
	SE(m) ±	**0.47**	
	C.D (P=0.01)	**1.97**	

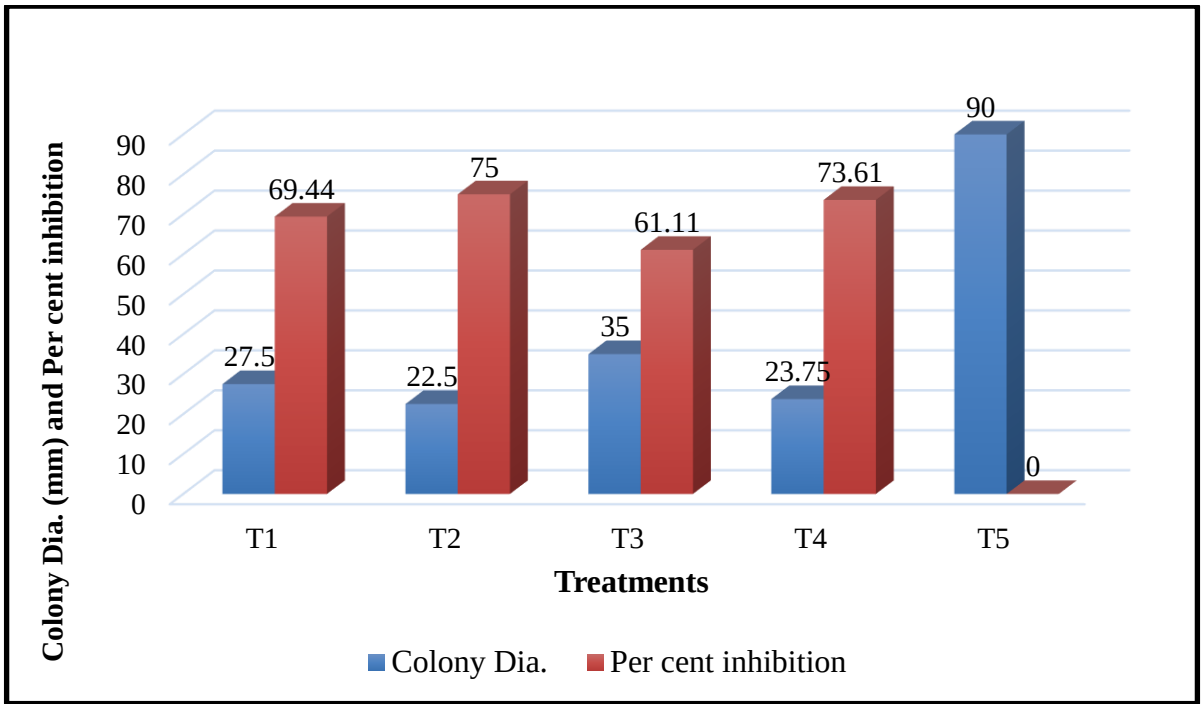

Fig. 2. *In vitro* efficacy of bioagent against the *F. oxysporum* f. sp. *niveum*

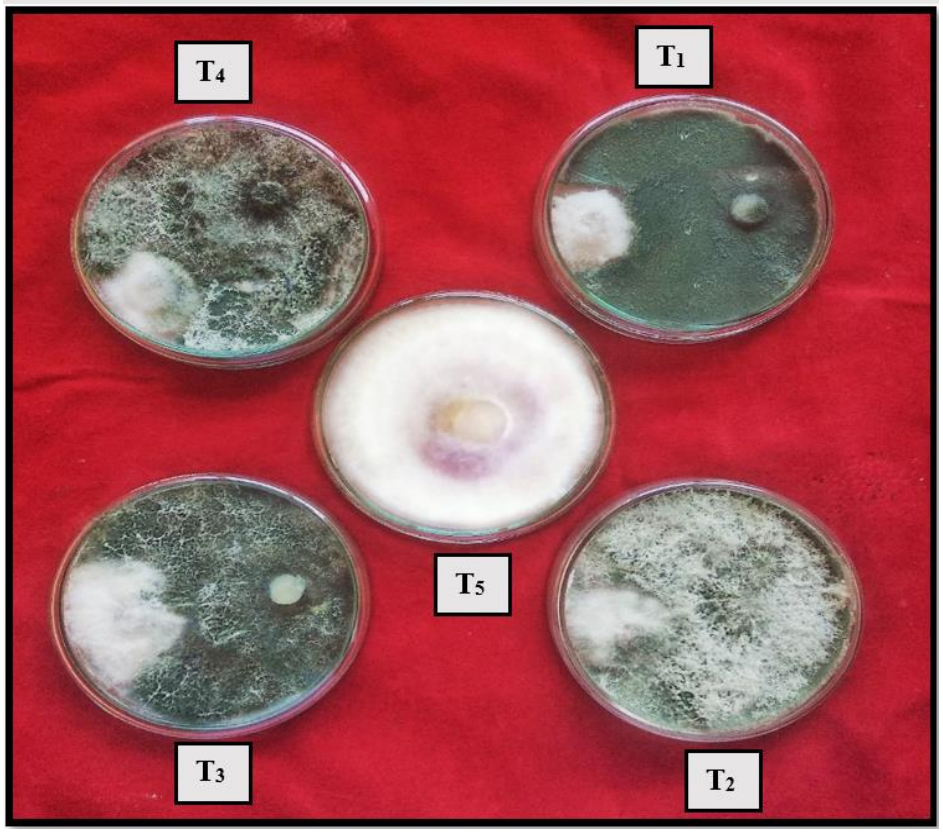

Plate 2. *In vitro* efficacy of bioagents against *Fusarium oxysporum* f. sp*. niveum*

Sharma et al. (2022) also evaluated the *in vitro* efficacy of bioagents against *Fusarium* wilt of cucumber using the dual culture technique and reported that, *Trichoderma harzianum* was the most effective with 61.08% inhibition of mycelial growth.

4. CONCLUSION

Among the different fungicides evaluated *in vitro*, Carbendazim 50% WP (0.1% and 0.2% concentration) and Carbendazim 12% + Mancozeb 63% (0.1% and 0.2% concentration) completly inhibited the mycelial growth of *Fusarium oxysporum* f. sp*. niveum* completely. Similarly, among the bioagents *T. harzianum* was the most effective in inhibiting *Fusarium oxysporum* f. sp*. niveum* with 75.00% inhibition followed by *T. longibrachiatum* at 69.44%.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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