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In vitro evaluation of fungicides and bioagents against *Fusarium Solani* inciting wilt disease of patchouli

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Abstract

Patchouli (*Pogostemon patchouli*) is an economically important aromatic plant that is affected by several diseases, among which *Fusarium solani* (Mart.) Sacc. is an important soil-borne pathogen causing considerable damage to the crop. The present study evaluated the *in vitro* efficacy of nine fungicides and six bioagents against *F. solani*. Tebuconazole 25.9% EC, Mancozeb 75% WP, Carbendazim 12% + Mancozeb 63% WP, and Carboxin 37.5% + Thiram 37.5% WS completely inhibited mycelial growth. Carbendazim 50% WP recorded 83.15% inhibition, followed by Tebuconazole 50% + Trifloxystrobin 25% WG and Captan 50% WP. Hexaconazole 4% + Zineb 68% WP showed the lowest inhibition among the fungicides tested. Among the bioagents, *Trichoderma longibrachiatum* was most effective, with 79.63% inhibition, followed by *T. harzianum* with 74.26% inhibition. The results indicated considerable variation in the efficacy of the tested treatments, with selected fungicides and *T. longibrachiatum* showing strong antifungal activity against *F. solani*.

Keywords: Patchouli, wilt, *Fusarium solani*, fungicides, bioagents

Introduction

Patchouli (*Pogostemon patchouli* Pellet.), also known as *Pogostemon cablin* Benth., is a member of the mint or Lamiaceae family and is the source of commercial patchouli oil. It appears that the word "patchouli" is derived from the Sanskrit word "Pacholi," which means aromatic herb. Since patchouli oil cannot yet be replaced by a synthetic chemical, it is one of the most significant aromatic crops in the perfume business. Originating in the Philippines, it can be found growing wild in China, India, Malaysia, Indonesia and Singapore. The cultivation of Patchouli is reported to have started first in Java in 1895 with planting material from Singapore, though the identity of the species was uncertain (Ahmed, 2002) [1].

Pogostemon cablin (Blanco) Benth. (patchouli), a pharmacologically significant plant, has been traditionally utilized for the treatment of colds, fevers, headaches, inflammation, digestive disorders, insect and snake bites. Phytochemical investigations have identified key bioactive constituents in patchouli leaves, including patchouli alcohol, β -patchoulene, pogostone, α -bulnesene and β -caryophyllene, which collectively underpin its diverse biological activities. Recent pharmacological studies have validated its antioxidant, anti-inflammatory, antimicrobial, antidepressant and anticancer properties. (Mrisho *et al.*, 2025) [5]. The name "Patchouli" has its roots in the Tamil language, derived from the words *patchai* (or *pacchai*), meaning 'green,' and *ilai*, meaning 'leaf.' Together, they evoke the image of "green leaves," aptly describing the plant's lush, vibrant foliage. Across India, the plant is recognized by a rich array of vernacular names such as *Pachi* in Sanskrit, *Pachauli* in Hindi, *Pachapat* in Bengali, *Pachila* in Malayalam, *Pachetene* in Kannada, *Pacha* in Gujarati and *Panch* in Marathi. These diverse local names underscore its deep cultural integration and longstanding traditional importance in various regions of the country. (Yadav *et al.*, 2017; Magar *et al.*, 2024) [4, 10].

Patchouli oil was iso from shade dried leaves of patchouli through hydro distillation employing a Clevenger distillation apparatus, yielding an oil percentage of 3.5%. Physicochemical parameters, including specific gravity, refractive index, optical rotation, acid value and ester value, were subsequently determined to characterize the extracted oil. Quantitative compositional analysis was carried out using Gas Chromatography-Mass

Spectrometry (GC-MS), which revealed the presence of several principal constituents, namely alpha-guaiene (9.95%), seychellene (7.14%), alpha-patchoulene (7.08%), alpha-bulnesene (13.16%) and patchouli alcohol (32.54%), with the latter representing the most abundantly occurring compound in the oil fraction. (Yadav *et al.* 2017) ^[10].

Patchouli is generally cultivated on dry lands under rain-fed conditions, with fertilization applied according to the specific nutritional requirements of the crop. For optimal growth and yield, the plant requires an annual rainfall ranging between 2,500 and 3,000 mm. (Nasruddin *et al.* 2015) ^[6].

Patchouli (*Pogostemon patchouli*) is vulnerable to various diseases that significantly reduce its planting value. Among those pathogens, *Fusarium solani* (Mart.) Sacc. stands out as the most predominant fungal pathogen, responsible for considerable yield losses. This pathogen causes wilt in seedlings and, during later stages of plant growth, induces root rot that ultimately results in wilting of the affected plants (Pareek and Varma, 2014) ^[7].

The initial external symptom observed was the yellowing of older leaves, which gradually progressed to the middle and younger leaves. The leaves then exhibited a characteristic drying appearance similar to drought stress, despite adequate soil moisture. Brown to black discoloration was

noticed on the stem and roots, accompanied by dark brown to reddish discoloration of the vascular tissues. Severe degradation and disintegration of the secondary root surface were also evident. Affected plants showed complete wilting and could be easily uprooted from the soil. Eventually, the entire plant dried up, resulting in premature death (Chavan, 2007) ^[2].

Materials and Methods

The present investigation was carried out at the Department of Plant Pathology, College of Agriculture, Dapoli, Dist. Ratnagiri. To evaluate the *in vitro* efficacy of different fungicides and bioagents against *Fusarium solani*.

The efficacy of fungicides against *Fusarium solani* was evaluated under *in vitro* conditions using the poisoned food technique (Sinclair and Dhingra, 1985) ^[8]. Fungicides belonging to different chemical groups viz., Tebuconazole 25.9% EC, Carbendazim 50% WP, Captan 50% WP, Mancozeb 75% WP, Copper oxychloride 50% WP, Hexaconazole 4% + Zineb 68% WP, Carbendazim 12% + Mancozeb 63% WP, Carboxin 37.5% + Thiram 37.5% WS and Tebuconazole 50% + Trifloxystrobin 25% WG were evaluated. The experiment was conducted in a Completely Randomized Design (CRD) with three replications.

Table 1: List of Fungicides

Sr. No.	Name of fungicides	Concentration (%)
1.	Tebuconazole 25.9 % EC	0.1
2.	Carbendazim 50% WP	0.1
3.	Captan 50% WP	0.2
4.	Mancozeb 75% WP	0.2
5.	Copper oxychloride 50 % WP	0.3
6.	Hexaconazole 4% + Zineb 68% WP	0.2
7.	Carbendazim 12% + Mancozeb 63%WP	0.2
8.	Carboxin 37.5 % + Thiram 37.5% WS	0.2
9.	Tebuconazole 50 % + Trifloxystobin 25 % WG	0.1

An *in vitro* study was conducted to evaluate the antagonistic potential of different biocontrol agents against *Fusarium solani* using the dual culture technique (Dennis and Webster, 1971) ^[3]. The bioagents used were four fungal species viz. *Trichoderma viride*, *T. harzianum*, *T. longibrachiatum* and *T. koningii*, and two bacterial species viz. *Pseudomonas fluorescens* and *Bacillus subtilis*.

After seven days of inoculation, observations were recorded on the radial mycelial growth or colony diameter of the pathogen. Per cent mycelial growth inhibition of the

pathogen with the fungicides and bioagents over the untreated control was calculated using the formula given by Vincent (1947) ^[19].

C - T

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

Where,

C = Growth of test fungus in control plate (mm).

T = Growth of test fungus in respective treatment plate (mm).

Table 2: List of Bioagents

Sr. No.	Name of Bio-agent
1	<i>Trichoderma viride</i>
2	<i>Trichoderma harzianum</i>
3	<i>Trichoderma longibrachiatum</i>
4	<i>Trichoderma koningii</i>
5	<i>Pseudomonas fluorescens</i>
6	<i>Bacillus subtilis</i>

Results and Discussion

In vitro efficacy of fungicides against *fusarium solani*

The results indicated that all fungicides tested significantly suppressed the growth of *Fusarium solani*. Among the nine fungicides evaluated, Tebuconazole 25.9% EC, Mancozeb 75 %WP, Carbendazim 12% + Mancozeb 63% WP and

Carboxin 37.5% + Thiram 37.5% WS exhibited complete (100%) inhibition of mycelial growth. Carbendazim 50% WP recorded a colony growth of 15.16 mm with 83.15 per cent inhibition over the control, followed by Tebuconazole 50 % + Trifloxystobin 25 % WG, Captan 50% WP and Copper oxychloride 50 % WP, which resulted in 81.29,

77.22 and 68.52 per cent inhibition over the control, respectively. The lowest inhibition (49.26%) was observed with Hexaconazole 4% + Zineb 68% WP.

The present findings were in accordance with those reported by Naik *et al.* (2007), who assessed the inhibitory effect of fungicides against *F. solani*. Their study revealed that Captan was the most effective fungicide, producing 87.9 per cent inhibition of fungal growth, whereas Chlorothalonil and Mancozeb recorded 43.86 and 42.53 per cent inhibition,

respectively, at 2000 ppm. Comparable results were obtained by Chavan *et al.* (2009), who reported that carbendazim completely inhibited the mycelial growth of *F. solani*, resulting in 100 per cent inhibition at a concentration of 0.1 per cent. Furthermore, Tatarwal and Trivedi (2011) observed complete suppression of *F. solani* mycelial growth by Carbendazim and Tebuconazole, both of which achieved 100 per cent inhibition at 500 and 1000 ppm, respectively, demonstrating their effectiveness against the pathogen.

Table 3: *In vitro* efficacy of fungicides against *Fusarium solani*.

Tr. No.	Treatments	Concentration (%)	Mean colony diameter (mm)*	Per cent inhibition over control
T ₁	Tebuconazole 25.9 % EC	0.1	00.00	100
T ₂	Carbendazim 50% WP	0.1	15.16	83.15
T ₃	Captan 50% WP	0.2	20.50	77.22
T ₄	Mancozeb 75 %WP	0.2	00.00	100
T ₅	Copper oxychloride 50 % WP	0.3	28.33	68.52
T ₆	Hexaconazole 4% + Zineb 68% WP	0.2	45.66	49.26
T ₇	Carbendazim 12% + Mancozeb 63%WP	0.2	00.00	100
T ₈	Carboxin 37.5 % + Thiram 37.5 % WS	0.2	00.00	100
T ₉	Tebuconazole 50 % + Trifloxystobin 25 % WG	0.1	16.83	81.29
T ₁₀	Control		90.00	
	SE(m)±		0.36	
	CD at 1%		1.45	

(*) = Average of three replications



Plate 1: *In vitro* efficacy of fungicides against *Fusarium solani*

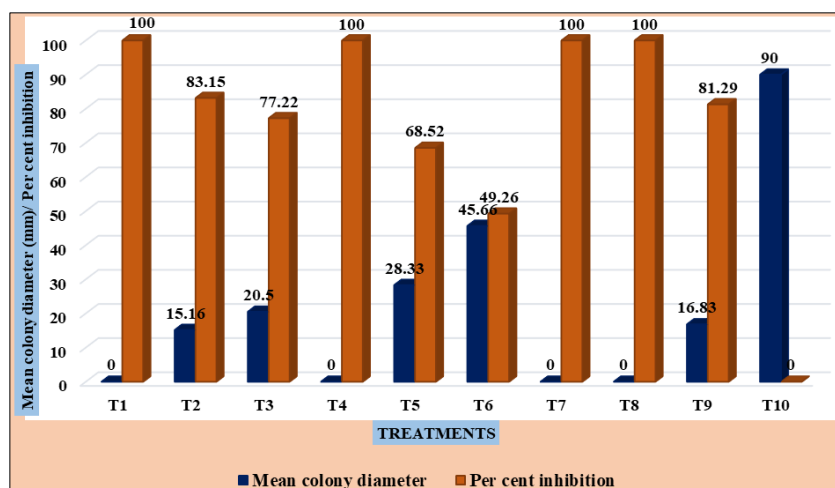


Fig 1: *In vitro* efficacy of fungicides against *Fusarium solani*

In vitro efficacy of bioagents against *Fusarium solani*

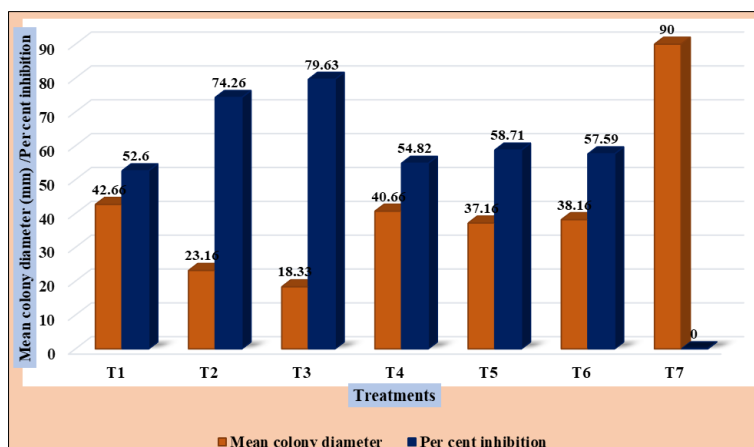
The results depicted in Table 4, indicated that the six bio-agents evaluated all bio-agents effectively inhibited the mycelial growth of *F. solani*. The maximum pathogen growth inhibition was recorded by *T. longibrachiatum* (79.63%) with least colony growth of the test pathogen (18.33 mm) followed by *T. harzianum* which exhibited 74.26% mycelial inhibition and 23.16 mm mycelial growth. *Pseudomonas fluorescens*, *Bacillus subtilis* and *Trichoderma koningii* were showed 37.16 mm, 38.16 mm, 40.66 mm mycelial growth with 58.71%, 57.59%, 54.82% inhibition, respectively. Least inhibition was noticed in *Trichoderma viride* 52.60 %, which showed 42.66 mm mycelial growth.

Similar observations were made by Joshi and Raut (2005) and Chakraborty and Chatterjee (2008), who found that *Trichoderma harzianum* effectively inhibited the growth of *Fusarium solani* under laboratory conditions. Chavan (2007) [2]. evaluated the antagonistic activity of different bioagents against *F. solani* under *in vitro* conditions and reported that *T. harzianum* exhibited the highest inhibition of mycelial growth (78.11%), which was significantly superior to all other bioagents tested. The next most effective bioagent was *T. koningii* (75.63%), followed by *T. viride* (74.92%) and *T. virens* (70.16%). The lowest inhibition was recorded with *B. subtilis* (57.02%), while *Pseudomonas fluorescens* showed 65.10 per cent inhibition of mycelial growth.

Table 4: *In vitro* efficacy of Bio-agents against *F. solani*

Tr. No.	Treatments	Mean colony diameter (mm)*	Per cent inhibition over control
T ₁	<i>Trichoderma viride</i>	42.66	52.60
T ₂	<i>Trichoderma harzianum</i>	23.16	74.26
T ₃	<i>Trichoderma longibrachiatum</i>	18.33	79.63
T ₄	<i>Trichoderma koningii</i>	40.66	54.82
T ₅	<i>Pseudomonas fluorescens</i>	37.16	58.71
T ₆	<i>Bacillus subtilis</i>	38.16	57.59
T ₇	Control	90.00	0.00
	SE (m)±	0.56	
	CD @ 1%	2.38	

(*) = Average of three replications

**Plate 2:** *In vitro* efficacy of bio-agents against *Fusarium solani***Fig 2:** *In vitro* efficacy of bio-agents against *Fusarium solani*

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