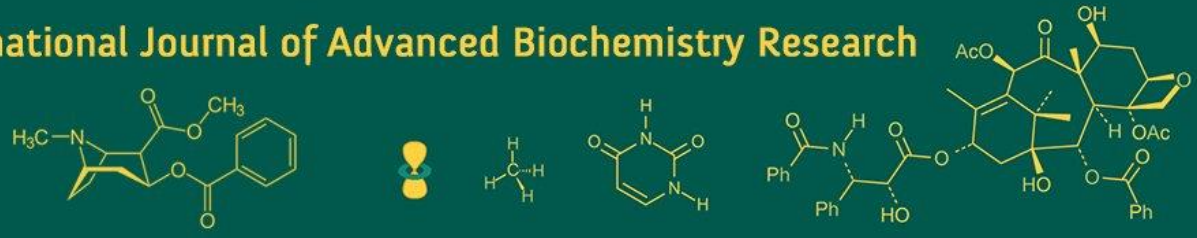
International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(7): 1044-1048
www.biochemjournal.com
Received: 12-05-2025
Accepted: 15-06-2025

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Compatibility of *Trichoderma asperellum* with some selected fungicides, insecticides and weedicides

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i7m.4882

Abstract
An experiment An *in vitro* study conducted in 2024-2025 at the College of Agriculture, Nagpur evaluated the compatibility of five fungicides, five insecticides, and five weedicides with *Trichoderma asperellum*. Among fungicides, propineb and copper oxychloride showed high compatibility, with inhibition rates of 3.25% and 6.64%, while systemic and combination types completely suppressed growth. Insecticides were generally more favorable; indoxacarb, thiamethoxam + lambda-cyhalothrin, and imidacloprid had no adverse effects, whereas fipronil and emamectin benzoate were moderately inhibitory. Of the weedicides, pendimethalin was compatible (7.70% inhibition), while imazethapyr, oxyfluorfen, and glyphosate caused partial inhibition. Propaquizafop + imazethapyr proved highly incompatible. These findings support the potential integration of *T. asperellum* with select agrochemicals in pest and weed management, pending field-level validation.

Keywords: *Trichoderma asperellum*. fungicides, insecticides, weedicides

1. Introduction
Plant diseases play a major role in decreasing agricultural output, with estimated crop losses ranging from 10% to 40% (Tyskiewicz *et al.*, 2022) [15]. Although chemical pesticides remain the most widely used method to combat these diseases, their overuse poses significant environmental hazards. Additionally, indiscriminate application of these chemicals can lead to the emergence of resistant strains of pathogens (Bora *et al.*, 2024) [3] To address these challenges, Integrated Disease Management (IDM) offers a more dependable and eco-friendly solution. IDM involves the strategic combination of multiple control methods including chemical treatments, cultural practices, and biological interventions to effectively manage plant diseases while promoting long-term sustainability. Biological control agents (BCAs) represent a crucial component within the framework of Integrated Disease Management (IDM). *Trichoderma* species are extensively applied as fungal antagonists targeting a range of phytopathogenic fungi and nematodes. Their inhibitory mechanisms primarily involve the secretion of hydrolytic enzymes and antimicrobial compounds. In addition to pathogen suppression, *Trichoderma* also contributes to enhanced plant development through its bioactive interactions with plant physiology (Lopez-Bucio *et al.*, 2022) [6]. Assessing the interaction of potential biocontrol agents with commonly applied agrochemicals including fungicides, insecticides, and weedicide is a critical step in formulating a disease management framework that prioritizes ecological safety and long-term efficacy. Analyzing the influence of fungicides insecticides and weedicides on both target pathogens and antagonistic organisms enables informed selection of compatible chemical agents and resilient biocontrol candidates via *in vitro* assays. Furthermore, specific experimental outcomes have demonstrated a synergistic effect between *Trichoderma* species and fungicides when concurrently utilized for the suppression of soil-borne phytopathogens. The objective of the study was to assess the compatibility of *Trichoderma asperellum* with selected fungicidal, insecticidal, and weedicidal agents under controlled *in vitro* conditions. This evaluation aimed to determine whether the biocontrol potential of *T. asperellum* could be preserved or enhanced when applied alongside conventional agrochemicals. The results are expected to support the development of synergistic disease management strategies that minimize chemical inputs while maintaining high levels of plant protection.

2. Materials and Methods

The present investigation on "Compatibility of *Trichoderma asperellum* with Some Selected fungicides, insecticides and weedicides." was studied during 2024-2025 at Department of Plant Pathology, College of Agriculture, Nagpur. selected isolate has previously demonstrated efficacy against several major phytopathogens, substantiating its potential as a reliable biocontrol agent. For the purpose of experimental consistency, the culture was subcultured and preserved on Potato Dextrose Agar (PDA) medium, prepared with the following constituents: potato (250 g), dextrose (20 g), agar (20 g), and distilled water (1 L). The PDA medium provided optimal conditions for fungal growth, ensuring the viability and stability of the *T. asperellum* culture throughout the study period.

2.2 *In-vitro* Compatibility of fungicides,insecticides and weedicides

An *in vitro* experiment was conducted to evaluate the compatibility of *Trichoderma asperellum* with five fungicides, five insecticides, and five weedicides using the poisoned food technique. Recommended concentrations of each chemical were mixed into sterilized molten Potato Dextrose Agar (PDA), which was then dispensed into separate sterile Petri dishes. Control sets contained PDA without chemical additives. mycelial discs (0.5 cm diameter) were excised from a seven-day-old *T. asperellum* culture and placed centrally on each treated plate. The dishes were incubated at 28 ± 2 °C, and radial growth (cm) was recorded on the third, fifth, and seventh days. Complete colony development was observed on the control plates by day seven.radial mycelial growth was quantified by measuring colony diameter. Growth on untreated (control) plates was compared to that on plates amended with different concentrations of test compounds, and inhibition was calculated as a percentage. The inhibition percentage was determined using the formula

$$\text{Percent inhibition (I)} = \frac{C-T}{T} \times 100$$

Where,
I = percent inhibition of mycelial growth
C = Growth of mycelium in control (mm)
T = Growth of mycelium in treatment (mm).

3. Results and Discussions

This study investigates the *in vitro* compatibility of *Trichoderma asperellum* with fungicides, insecticides, and weedicides using the poisoned food technique. The results of the experiments were presented here under

3.1 Compatibility of *Trichoderma asperellum* with Some Selected Fungicides

Efficacy of five fungicides at respective concentration was tested *in-vitro* by following poison food technique for mycelial growth of *T. asperellum*

Table 1: *In-vitro* compatibility of fungicides against *Trichoderma asperellum*

Treatment		Conc gm/100 ml of media	*T. asperellum*					
			Mean Colony diameter (mm)			Percent growth inhibition over control		
			3 DAI	5 DAI	7 DAI	3 DAI	5 DAI	7 DAI
T_1	Copper oxychloride 50% WP	0.30	36.25	62.75	82.62	34.09	23.93	6.64
T_2	Propineb 70% WP	0.30	27.12	65.75	85.62	50.69	20.30	3.25
T_3	Tebuconazole 50% Trifoxystrobin 25%	0.30	0.00	0.00	0.00	100.00	100.00	100.00
T_4	Captan 70% Hexaconazole 5% WP	0.15	0.00	0.00	0.00	100.00	100.00	100.00
T_5	Carbendazim 12% + Mancozeb 63% WP	0.25	0.00	0.00	0.00	100.00	100.00	100.00
T_7	Control	-	55.00	82.50	88.50	-	-	-
F test			Sig	Sig	Sig			
S.E(±m)			0.49	0.69	0.78			
C.D (P=O.O1)			2.04	2.90	3.78			

The data presented in Table. 1 and plate 1(a), All fungicides tested showed varied inhibition levels against *T. asperellum*. Among them, T_1 Copper Oxychloride 50% WP exhibited the least inhibition at 34.09%, followed by T_2 Propineb 70% WP at 50.69% after 3 days of inoculation (3 DAI). T_3, T_4, and T_5—consisting of Tebuconazole 50% + Trifloxystrobin 25%, Captan 70% + Hexaconazole 5% WP, and Carbendazim 12% + Mancozeb 63% WP showed complete inhibition (100%) on the same day.

By day 5 DAI, inhibition dropped for T_2 to 20.30% and T_1 to 23.93%. T_3, T_4, and T_5 maintained full inhibition at 100%.

On day 7, the inhibition by T_2 further declined to 3.25%, with T_1 at 6.64%. Treatments T_3, T_4, and T_5 again exhibited complete (100%) inhibition of mycelial growth

In a similar way Maheshwary N.P. *et al.*, (2020) [8] reported that Trichoderma was compatible with copper hydroxide, copper oxychloride, mancozeb and metalaxyl and least compatible with captan whereas it was incompatible with tebuconazole, propiconazole and carbendazim. Among combination fungicides, metalaxyl + mancozeb was found to be highly compatible whereas tebuconazole + trifloxystrobin, azoxystrobin + difenoconazole and carbendazim + mancozeb were incompatible.

3.2 *In-vitro* compatibility of *Trichoderma asperellum* with Some Selected insecticide

The data presented in Table. 2 and plate 1(b) shows compatibility of insecticides with *T. asperellum* is crucial for effective IPM. Using the poisoned food technique, varied inhibition levels were observed across all treatments, gradually decreasing over time. At 3 DAI, Imidacloprid 70 WS (T_4) showed the least inhibition (29.58%), followed by Propineb 70% WP (T_5) at 33.08% and Fipronil 5 EC (T_2) at 33.10%. Emamectin Benzoate 5% SG (T_1) showed the highest inhibition (60.61%), with Thiamethoxam + Lambda-cyhalothrin (T_3) at 44.11%. By 5 DAI, inhibition dropped: T_5 (10.29%), T_4 (14.49%), T_3 (17.97%), T_2 (20.86%), and T_1 (32.31%). At 7 DAI, T_5 was most compatible (2.02%), followed by T_3 (6.25%), T_4 (7.92%), T_2 (10.00%), and T_1 (13.68%). These results indicate Propineb and Imidacloprid are moderately compatible, while Emamectin Benzoate and

Thiamethoxam + Lambda-cyhalothrin significantly inhibit fungal growth and may reduce biocontrol efficacy.

The study by Nasreen *et al.* (2024) [9] highlights the compatibility of various insecticides with *Trichoderma asperellum* for effective IPM use. Acephate, Thiamethoxam, Flubendiamide, and Spiromesifen were highly compatible, showing negligible inhibition. Imidacloprid and Cartap Hydrochloride caused moderate inhibition (23.11%-32.00%), suggesting conditional use. Quinalphos and Dimethoate were strongly inhibitory (74.66% and 57.33%), indicating incompatibility with *T. asperellum* and potential disruption of its biocontrol efficacy.

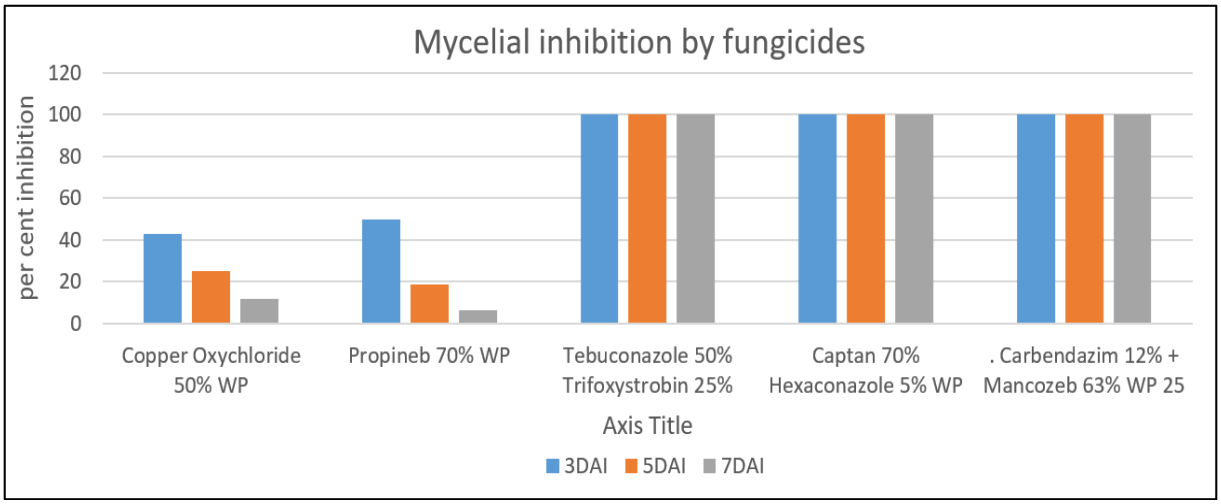

Fig 1: Effect of fungicides on percent growth inhibition of *T. asperellum*

Table 2: *In-vitro* compatibility of *Trichoderma asperellum* with Some Selected insecticide

Treatment		Conc ml/100 ml of media	*T. asperellum*					
			Mean Colony diameter (mm)			Percent growth inhibition over control		
			3 DAI	5 DAI	7 DAI	3 DAI	5 DAI	7 DAI
T_1	Emamectin Benzoate 5% SG	0.40	26.78	58.38	77.68	60.61	32.31	13.68
T_2	Fipronil 5 EC	0.50	45.56	68.25	81.00	33.10	20.86	10.00
T_3	Thiamethoxam 12.6% + Lambda Cyhalothrin 9.5% ZC	0.40	38.00	70.75	84.37	44.11	17.97	6.25
T_4	Imidacloprid 70 WS	0.50	47.88	73.75	82.87	29.58	14.49	7.92
T_5	Indoxicarb 15.8 EC	0.07	45.50	77.37	88.18	33.08	10.29	2.02
T_7	Control	-	68.00	86.25	90.00	-	-	-
F test			Sig	Sig	Sig			
S.E(± m)			0.74	0.48	0.38			
C.D (P=O.O1)			3.10	2.02	1.59			

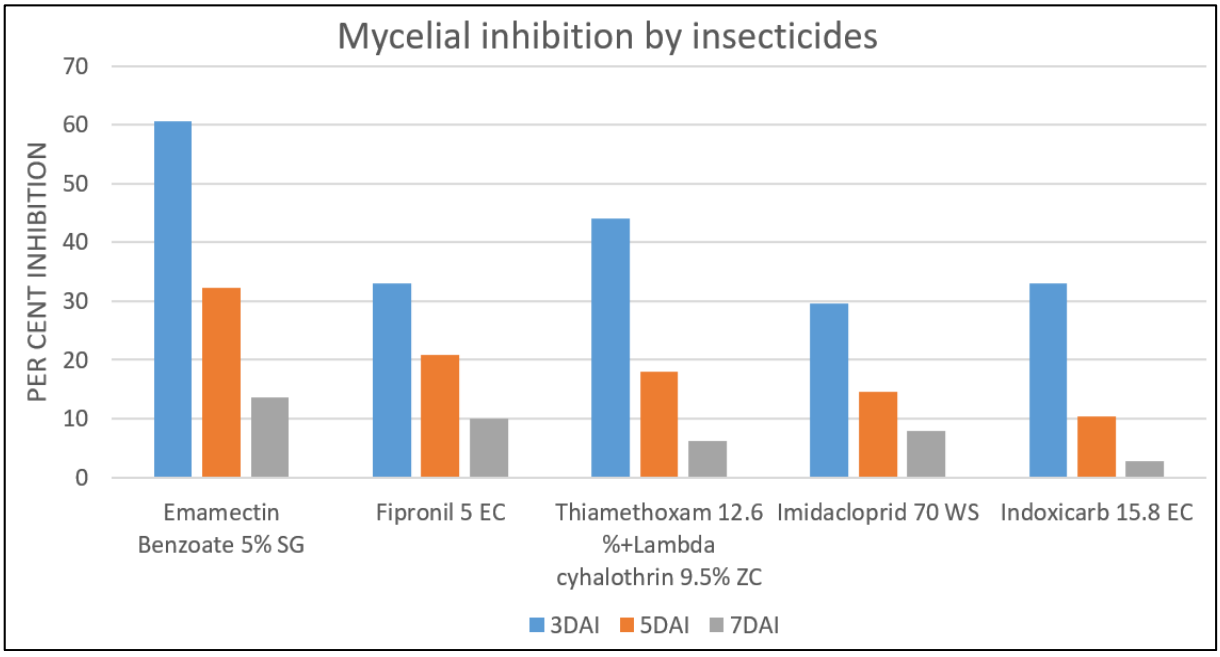

Fig 2: Effect of insecticides on percent growth inhibition of *T. asperellum*

3.3 *In-vitro* compatibility of *Trichoderma asperellum* with Some Selected weedicides.

The data presented in Table.3 and plate 1(c), Weedicides shows varying compatibility with *Trichoderma asperellum*, which is crucial for integrated weed and disease management. All tested weedicides exhibited varying inhibition levels on the growth of *Trichoderma asperellum* (Nagpur isolate-TMR), gradually declining over time. At 3 DAI, Pendimethalin 38.7 CS (T_5) showed the lowest inhibition (15.85%), followed by Imazethapyr 10% SL (T_4) at 21.78% and Oxyfluorfen 23.5 EC (T_3) at 39.09%. The highest inhibition was observed with Propaquizafop 2.5% + Imazethapyr 3.75% (T_1) at 90.77%, followed by Glyphosate 41 SL (T_2) at 48.93%. By 5 DAI, inhibition reduced further: T_5 (14.87%), T_4 (19.09%), T_3 (19.41%), T_2 (22.51%), and T_1 (84.97%). At 7 DAI, T_5 remained most compatible (8.70%), followed by T_4 (12.75%), T_3 (16.52%), T_2 (18.07%), and T_1 (81.16%). These results suggest that Pendimethalin and Imazethapyr are more compatible with *T. asperellum*, while Propaquizafop + Imazethapyr and Glyphosate substantially inhibit fungal growth, especially during early exposure.

Findings by Theertha, V. K *et al.* (2017) [14] revealed the compatibility of *Trichoderma asperellum* with selected weedicides using the poisoned food technique. Pendimethalin and Imazethapyr showed low inhibition, indicating high compatibility and suitability for biocontrol-based weed management. In contrast, Glyphosate and Propaquizafop + Imazethapyr exhibited strong inhibition, suggesting poor compatibility and potential interference with *T. asperellum* activity.

Table 3: *In-vitro* compatibility of *Trichoderma asperellum* with Some Selected weedicides

Treatment		Conc ml/100 ml of media	*T. asperellum*					
			Mean Colony diameter (mm)			Percent growth inhibition over control		
			3 DAI	5 DAI	7 DAI	3 DAI	5 DAI	7 DAI
T_1	Propaquizafop 2.5% + Imazethyper 3.75% ME	0.40	5.93	12.06	16.81	90.77	84.97	81.16
T_2	Glyphosate 41 SL	0.50	32.81	62.18	73.132	48.93	22.51	18.07
T_3	Oxyflurofen 23.5 EC	0.10	39.13	64.67	74.50	39.09	19.41	16.52
T_4	Imazethyper 10% SL	0.06	50.25	64.93	77.87	21.78	19.09	12.75
T_5	Pendamethalin 38.7 CS	0.30	54.06	68.31	81.46	15.25	14.87	8.70
T_7	Control	-	64.25	80.25	89.25	-	-	-
F test			Sig	Sig	Sig			
S.E(±m)			0.75	0.70	0.55			
C.D (P=O.O1)			3.12	2.94	2.33			

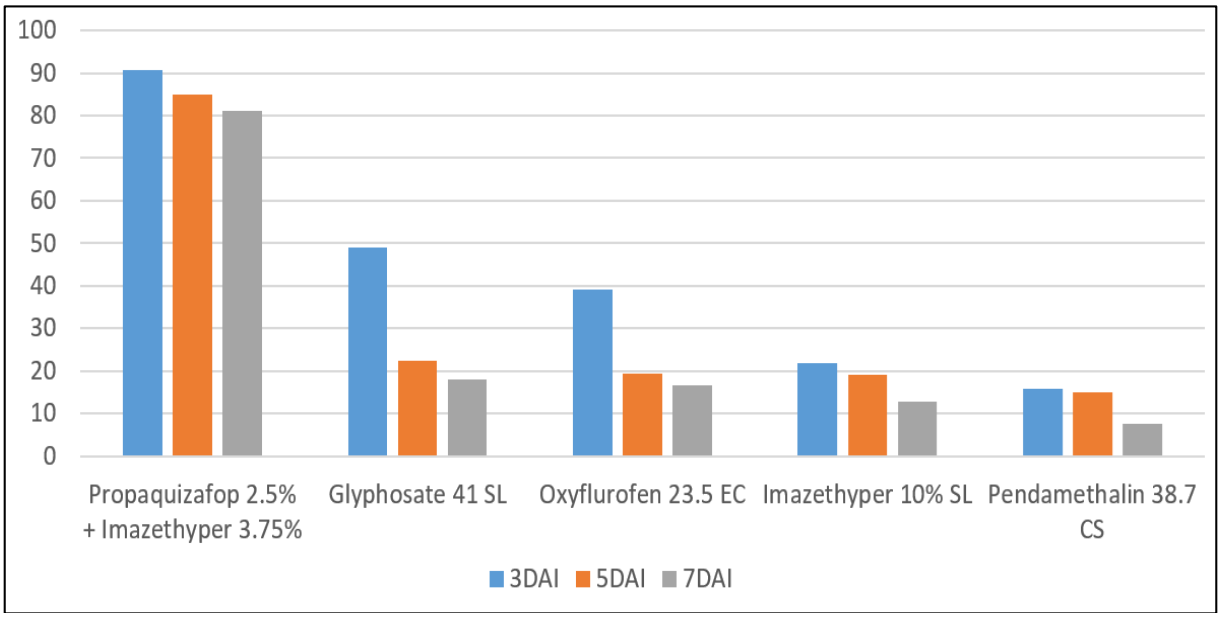

Fig 3: Effect of insecticides on percent growth inhibition of *T. asperellum*

(a) (b) (c)

Plate 1: Compatibility of fungicides (a), insecticides (b) and weedicides (c) against *T. asperellum* by Poisoned Food Technique 7 DAI

Conclusion

The salient features of the present investigation are as under

- Copper Oxychloride and Propineb showed moderate compatibility with *T. asperellum*.
  Tebuconazole blends, Captan + Hexaconazole, and Carbendazim + Mancozeb caused full inhibition unsuitable for biocontrol.
- Among insecticides, Propineb and Imidacloprid were gentlest on fungal growth.
  Emamectin Benzoate and Propaquizafop + Imazethapyr significantly inhibited *T. asperellum*, reducing its potential in IPM programs.
- Pendimethalin and Imazethapyr were the most weedicide-compatible options.

5. Acknowledgement

I am thankful to the Head of the Plant Pathology section, College of Agriculture, Nagpur for providing all the necessary facilities for conducting the research work.

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