J.Mycopathol.Res. 64(1) : 147-156, 2026, ISSN : 0971-3719 (Print), 2583-6315 (Online) 10.57023/JMycR.64.1.2026.147
© Indian Mycological Society, Department of Botany,
University of Calcutta, Kolkata 700 019, India

Collection, isolation and morphological characterization of *Beauveria bassiana* and their field evaluation against whitefly (B*emisia tabaci*) and fruit borer (*Helicoverpa armigera*) of tomato (*Lycopercicum esculentum l.*)

KHEMCHAND NISHAD *, V.K. NIRMALKAR AND R.K.S. TIWARI
Section of Plant Pathology, BTC, CARS, Bilaspur- 495001, Chhattisgarh.

Received : 13.10.2025 Accepted : 18.02.2026 Published : 30.03.2026

An experiment was conducted at Bilaspur district of Chhattisgarh during the Kharif and Rabi season of 2024-25 with the aim to collect new indigenous isolates of entomopathogenic fungi and to characterized B*eauveria bassiana,* morphologically for identification and to know the variation among the isolates. Eight isolates of *Beauveria bassiana* (Bb –Bbˆ) were characterized on PDA medium to assess morphological variability. Colonies were white, powdery and radially growing with hyaline, septate hyphae. Distinct differences were observed in colony texture and spore size among isolates. Conidia were oval to hyaline, ranging from 1.97–2.61 µm in length and 1.27–2.09 µm in width. Efficacy of entomopathogenic fungi and their combinations against fruit borer (*Helicoverpa armigera*) and whitefly (*Bemisia tabaci*) of tomato was tested under field condition.Bbˆ showed the larger spores. In bio-efficacy trials Novaluron *5.25%* + Indoxacarb *4.5% SC* provided the highest control of *H. armigera* (83.35%), while *B. bassiana* + *Bacillus thuringiensis* (70.86%) and *B. thuringiensis* alone (66.09%) showed promising results. Thiamethoxam 75% SG (75.77%), *Verticillium lecanii* (71.52%) and *Verticillium lecanii* + *P. lilacinus* (67.27%) were most effective for reducing the infestation of *B. tabaci*,

Keywords : *Beauveria bassiana, Bemisia tabaci*,entomopathogenic fungi, *Helicoverpa armigera*, tomato

INTRODUCTION

Entomopathogenic fungi, bacteria and viruses, offer superior alternatives to the chemicals. Unlike chemical pesticides, they don't leave toxic residues in the environment or lead to resistance in insect hosts. These microbial biocontrol agents act as natural enemies to pests, devastating them without harmful side effects. They are more target-specific, effective in smaller quantities, and easily decompose without leaving problematic environmental residues. Among these, entomopathogenic fungi stand for their significant biodiversity, offering numerous possibilities for discovering ideal isolates to develop highly competitive biological control agents (Porte *et al*. 2025; Thomas and Read, 2007).

Entomopathogenic fungi have the unique ability to act as biological control agents, as they infect their hosts directly through the integument. These fungi are widely distributed throughout the world and are adapted to terrestrial agro-ecosystems wherever insects or other arthropods are present. Many important insect pests from the orders Coleoptera, Lepidoptera, Isoptera, and Hemiptera have been reported as susceptible to various isolates of entomopathogenic fungi and nematodes (Boopathi *et al.*2015)

Soil is the natural habitat for several important insect-pathogenic fungi such as *Beauveria spp.*, *Metarhizium spp.*, *Paecilomyces spp.* and *Lecanicillium spp.* and serves as a buffered medium against extreme biotic and abiotic influences (Shandilya*et al*. 2025). These soil-inhabiting entomopathogenic fungi play a significant role in regulating the populations of soil-dwelling insect pests (Jackson *et al*. 2000). Knowledge of the species composition and distribution of indigenous entomopathogenic fungi is essential, as it helps in isolating and identifying species within a particular habitat. Many entomopathogenic fungi belonging to the order *Hypocreales* (*Ascomycetes*) inhabit soil and

*Correspondence : khemchandn13@gmail.com

spend part of their life cycle outside their insect hosts. Isolation of these indigenous species and testing their potential as insect pathogens would aid in selecting the most virulent and well-adapted isolates for biological control of specific hosts in a given habitat.

Tomato cultivation faces significant challenges from a complex of insect pests, among them borers and sucking pests, leading to substantial economic losses in both quantity and quality of the produce. Among them pests, the tomato fruit borer was particularly destructive, causing yield losses of up to 55% (Talekar*et al.*2006) and as high as 40-50% (Pareek and Bhargava, 2003). Moreover, tomato was highly preferred host for *Bemisia tabaci*, a whitefly species that cause yield losses ranging from 50% to 100% (Verma *et al.*2023; Fauquet *et al.*2008).

In whitefly populations, natural mortality has been observed mainly due to entomopathogenic fungi such as *Aschersonia spp.*, *Beauveria bassiana*, *Lecanicillium spp.* and *Isariafumosorosea* (Ascomycota: Hypocreales) (Wraight *et al*. 2007). Different isolates of *Verticillium lecanii*, *B. bassiana*, *Paecilomyceslilacinus* and *Metarhizium anisopliae* have been reported for the control of many insect pests. Among these, *B. bassiana* is the most widely distributed and easily available species (Aung *et al.*2008).

Collection, isolation and characterization of *B. bassiana* are quite important because the entomopathogenic fungi are quite effective to wide range of insect pest and orders. That's way the investigation was taken to investigate most virulent isolates of entomopathogenic fungi.

MATERIALS AND METHODS

The field survey was conducted from different district of Chhattisgarh region to collect the soil samples and infected insect cadavers.

Collection and isolation of entomopathogenic fungi from soil

Soil samples were collected from different locations in the Chhattisgarh region, including Agricultural College and KVK Farm Bhatapara, Balod, Mungeli, Bilaspur, KVK Kawardha, Agricultural College Farm, and KVK Bemetara (Table 1). Samples were taken from the rhizosphere zone at a depth of 5-15 cm using a screw auger, with about 200 g placed in labelled polythene bags. Moist samples were air-dried, ground, and passed through a 100-mesh sieve before use. One gram of sieved soil was suspended in 9 ml sterile distilled water, shaken for five minutes, and serially diluted. From 10{ ^{2} and 10{ ^{3} dilutions, 0.1 ml aliquots were spread on Sabouraud Dextrose Agar (SDA) supplemented with chloramphenicol and incubated at 25 ± 2 °C for 3-5 days. White, sporulating colonies were purified on Potato Dextrose Agar (PDA).

Collection and isolation of entomopathogenic fungi from insect cadavers

Insect cadavers showing characteristic whitish fungal growth were collected from soybean, groundnut, maize, rice, mungbean fields (Table 2). Samples were placed in 6 × 4 cm plastic containers and brought to the laboratory for fungal isolation. Cadavers were surface sterilized with 1% sodium hypochlorite, rinsed with sterile distilled water, and dried on filter paper. Infected tissues were aseptically cut into small pieces and transferred onto Sabouraud Dextrose Agar (SDA) plates, incubated at 25 ± 2 °C, and observed daily for fungal growth. Emerging colonies were purified and confirmed, then maintained on PDA slants at 4°C for further use (Nirmalkar *et al*. 2020a).

Morphological characterization of Beauveria bassiana

The culture of *Beauveria bassiana* used in the present study was obtained from the State Bio-control Laboratory (SBCL), Bilaspur, Chhattisgarh. The culture was maintained on Potato Dextrose Agar (PDA) slants at 4 ± 1 °C and was sub-cultured periodically to preserve its viability and purity for experiments.

Insect-harming fungus viz., *B. bassiana* was culturally examined based on its colony characters, i.e., colony texture, colony colour, spore shape, colony pigmentation, spore colour, spore size and growth pattern on PDA. The fungus was grown on PDA and allowed to evaluate colony characters at the 7thDAI. A tiny thread from a pure culture of *B. bassiana* of 15 days old was taken on glass slides with a sterile needle for morphological studies. Colony texture and colony colour of EPF were recorded on PDA at 8th DAI. While, for spore a small amount of 15th day old pure culture of *B. bassiana* was taken on glass slide with a sterile needle and observed under microscope. The mycelium was then examined under a microscope. Spores were measured under compound microscope at 40x magnification after the ocular micrometre was calibrated with a stage micrometre. The presence of conidiophores and phialides, two similar exterior morphological features, was recorded. Followed formula was employed for calculationof the concentration of conidia: -

No. of conidia (cm^2) = Average no. of spore × dilution factor × 4000 ×1000 (Nirmalkar *et al.*2020b)

Efficacy of different entomopathogenic fungi against fruit borer (Helicoverpa armigera) of tomato (Lycopercicum esculentum L.)

Field experiment was conducted at BTC, CARS Bilaspur (C.G.) during Rabi 2024-2025 to assess the bioefficacy of *Beauveria bassiana* against tomato fruit borer (*Helicoverpa armigera*) using the S-22 cultivar. The first foliar spray was applied at the Economic Threshold Level (ETL), defined as one larva or one damaged fruit per plant. Treatments were compared with an untreated control, and five plants per treatment were randomly tagged for observation. Data on pest incidence were recorded before spraying and at 3, 5 and 7 days after spraying, and percent mortality over control was calculated.

$$\text{Percent mortality} = \frac{\text{No. of dead larvae}}{\text{Total no. of larvae treated}} \times 100$$

Efficacy of different entomopathogenic fungi against whitefly (Bemisia tabaci) of Tomato (Lycopercicum esculentum L.)

A field trial was conducted at BTC, CARS Bilaspur (C.G.) during Rabi 2024–2025 to evaluate the efficacy of *Beauveria bassiana* against whitefly (*Bemisia tabaci*) in tomato (*Lycopersicum esculentum* L.) cv. S-22 under standard cultivation practices. Whitefly populations were recorded on five randomly selected plants, with three leaves (top, middle, and bottom) per plant, at one day before treatment and on the 3rd, 5thand 7th day after spraying. Foliar application was initiated at the Economic Threshold Level (ETL). Treatments were compared with an untreated control, and percent reduction in whitefly populations was calculated using the modified Abbott's formula (Urkude*et al.* 2024; Fleming and Ratnakaran, 2018).

$$P = [1- \{(Ta \times Cb) / (Tb \times Ca)\}] \times 100$$

Where, P = Percentage population reduction over control

Ta = Population in treatment after spray
Ca = Population in control after spray
Tb = Population in treatment before spray
Cb = Population in control before spray

RESULTS AND DISCUSSION

Isolation and identification of entomo pathogens

Insect cadavers were collected from various location of Chhattisgarh and collected 12 insect cadavers from different crops i.e. Moong (cadaver *Spodoptera litura*), Soybean (cadaver *Spodoptera litura*) and Moong (cadaver *Helicoverpa armigera*) (Fig.1). Amongst all cadavers two species of *Beauvaria bassiana* were isolated during the process and different others pathogen i.e. *Aspergillus* and *Fusarium* were isolated which was lesser pathogenic or non-pathogenic to insect and cannot consider for further study.

Thirty-fivesoil samples were collected from different location of Chhattisgarh and used for serial dilution method. Among all collected soil samples six isolates of *B. bassiana* was identified. Earlier, different workers also reported entomopathogenic fungi from the larvae of *Spodoptera litura* and others. Nirmalkar*et al.* (2020 a) and Rajwade (2023) also found similar findings and isolated entomopathogenic fungi from insect cadavers of different crops i.e., Soybean, Groundnut and Pigeon pea. Various

Table 1: Details of soil sampling collected for isolation of entomopathogenic fungi *Beauveria spp.*

Month	Locations	Latitude and longitude	Standing Crop	Soil type	Sample code
August	Belgahana Bilaspur	22.437900°N 82.037800°E	Green gram	Sandy loam	S1-S10
August	Karwa Raipur	22.494577°N 82.000794°E	Soyabean	Sandy loam	S11-S14
August	AlesurBhatapara	21.729558°N 81.987413°E	Green gram	Loamy	S15-S18
August	KhuntaMungeli	22.115616°N 82.518716°E	Sugarcane	Loamy	S18-S20
August	Pendri Kalan Kawardha	22.120551°N 81.443864°E	Sugarcane	Loamy	S22-S25
August	Jeodan Khurd Kawardha	22.059028°N 81.296237°E	Redgram	Sandy loam	S26
August	DholiyaBemetara	21.773089°N 81.545342°E	Green gram	Loamy	S27
August	JhalBemetara	21.807380°N 81.558912°E	Soyabean	Sandy loam	S28
August	BTC CARS Farm Bilaspur	22.105576°N 82.138553°E	Green gram	Sandy loam	S29
August	Umarkhohi Bilaspur	22.601389°N 82.062455°E	Groundnut	Sandy	S30
August	Gaurela-Pendra-Marwahi	22.718084°N 81.897714°E	Black gram,Green gram	Loamy	S31-S35

Table 2 : Details of collection of insects cadavers for isolation of entomopathogenic fungi *Beauveria spp.*

Month	Locations	Latitude and longitude	Standing Crop	Insect	No. of cadavers collected	Sample code
October	BTC CARS Bilaspur	21.105576°N 82.138553°E	Moong	*Helicoverpa armigera*	3	Bv1-Bv3
October	IGKV Field	21.241389°N 81.719444°E	Soyabean	*Spodoptera litura*	3	Bv4-Bv6
October	IGKV Field	21.238611°N 81.716389°E	Moong	*Spodoptera litura*	6	B7-Bv12

Table 3 : Morphological characterization of *Beauveria bassiana* isolates

Isolates	Source of isolation	Colony observation			Conidial shape	Size of conidia	
		Growth pattern	Colour	Texture		Length (µm)	Width (µm)
Bb_1	Insect	Whitish cottony growth	White	Smooth	Oval	2.09	1.55
Bb_2	Soil	Whitish dense cottony growth	White	Smooth	Oval	2.35	1.58
Bb_3	Insect	Whitish dense cottony growth	White	Smooth	Oval	2.05	1.32
Bb_4	Insect	Raised cottony with dence	White	Smooth	Oval	2.45	1.39
Bb_5	Soil	Flat cottony	Creamy White	Powdery	Oval	2.23	1.27
Bb_6	Insect	Powdery whitish growth	Creamy White	Powdery	Oval	1.97	1.52
Bb_7	Soil	Flat cottony scatterd	White	Scatterd	Oval	2.24	1.31
Bb_8	Insect	Slightly whitish cottony growth	White	Powdery	Oval	2.61	2.09

researcher reported *Beauveria* spp. from various types of insects i.e., sugarcane borer (*Sesaniacretics*), corn and oriental corn borer and from different types of soils collected from various crops fields.

Morphological characterization of Beauvaria bassiana

Morphological characterization of *B.bassiana* isolates was carried out on PDA medium (Table3). Colonies appeared lightly raised, dense, with a white powdery surface and downy circular rings. Radial growth was observed with white powdery translucent mycelium. Hyphae were hyaline, cylindrical, septate, with a width of 3.2 ìm.

Eight isolates of *B. bassiana* (Bb –Bbˆ) were studied and observed their colony parameter and spore. All isolates formed white colonies, they showed differences in texture, height and spore sizes. Bb to Bb„ had dense, cottony, smooth colonies with raised centers (Fig.2). Their conidia (spore) were oval, clear (hyaline) and measured between 2.05–2.45/ ìm in length and 1.32–1.58/ ìm in width (Fig.3). Bb… and Bb† had flat, creamy white colonies with a powdery surface and their conidia were slightly smaller, ranging from 1.97–2.23/ ìm long and 1.27–1.52/ ìm wide. Bb‡ and Bbˆ formed flat to slightly raised colonies, powdery or scattered in appearance. Bbˆ had the biggest spores (2.61/ ×/ 2.09/ ìm) among all isolates.

Similar findings were reported by Nirmalkar *et al*. (2020a); Patel *et al*. (2025); Kulu *et al*. (2015) who observed white mycelial growth with a powdery surface in *B.bassiana* on PDA medium. Affandi *et al*. (2013) also described white mycelium, cylindrical hyphae (3.5 ìm wide), and hyaline, septate conidiophores, with conidia ranging from globose (1–4 ìm) to oval (1.5–5 × 1.0–3.0 ìm). Asensio *et al*. (2003) recorded phialide sizes of 21.33–6.4 ìm and conidial sizes of 4.16–2.56 ìm.

In-vivo efficacy of entomopathogenic fungi against fruit borer (Helicoverpa armigera) of tomato (Lycopersicum esculentum L.).

T_{11}-Novaluron 5.25% + Indoxacarb 4.5% SC (83.35%) was the most effective treatment, showing a mean reduction over control with a larval count of 0.30 larvae^{-5} plants followed by T_2-*Beauveria bassiana* + *Bacillus thuringiensis* (70.86%) and a mean of 0.53 larvae, while T_3-*Bacillus thuringiensis* (66.09%). minimum effective was recorded in T_7-*Verticillium lecanii* (28.31%) and T_{10}-Thiamethoxam 75% SG

Table 4: *In-vivo* efficacy of entomopathogenic fungi against fruit borer (*Helicoverpa armigera*) of tomato

Treatments	CFUs ml^{-1}	Dose ml^{-lit}	Larval Mean/5Plants				Mean	% Reduction over control			Mean
			DBS	3DAS	5DAS	7DAS		3DAS	5DAS	7DAS	
T_1 - *Beauveria bassiana*	1×10^8	10	0.75	0.80 (5.12)	0.63 (4.53)	0.61 (4.45)	0.68	53.04 (46.72)	66.45 (54.62)	69.31 (56.34)	62.93
T_2 - *Beauveria bassiana* + *Bacillus thuringiensis*	1×10^8	10	0.73	0.66 (4.65)	0.49 (3.99)	0.45 (3.81)	0.53	61.41 (51.58)	73.93 (59.29)	77.24 (61.64)	70.86
T_3 . *Bacillus thuringiensis*	1×10^8	10	0.87	0.74 (4.91)	0.59 (4.38)	0.54 (4.21)	0.62	57.35 (49.22)	68.58 (55.89)	72.34 (58.25)	66.09
T_4- *Metarhizium anisopliae*	1×10^8	10	0.75	0.84 (5.26)	0.67 (4.68)	0.63 (4.56)	0.71	50.72 (45.39)	64.30 (53.31)	67.80 (55.49)	60.94
T_5– *Paecilomyceslilacinus*	1×10^8	10	0.95	0.96 (5.61)	0.91 (5.44)	0.88 (5.39)	0.92	43.97 (41.52)	51.31 (45.73)	55.17 (47.95)	50.15
T_6- *Metarhizium anisopliae* + *Paecilomyceslilacinus*	1×10^8	10	1.41	1.00 (5.70)	0.95 (5.60)	0.94 (5.57)	0.97	41.64 (40.16)	48.79 (44.29)	52.14 (46.21)	47.53
T_7 - *Verticillium lecanii*	1×10^8	10	0.88	1.18 (6.24)	1.31 (6.55)	1.44 (6.89)	1.31	30.95 (33.79)	29.08 (33.24)	24.89 (31.20)	28.31
T_8 - *Verticillium lecanii* + *Paecilomyceslilacinus*	1×10^8	10	1.05	1.08 (5.93)	1.11 (6.01)	1.13 (6.09)	1.10	37.00 (37.43)	40.77 (39.67)	42.75 (40.81)	40.17
T_9- *Bacillus thuringiensis* + *Paecilomyceslilacinus*	1×10^8	10	0.97	0.83 (5.19)	0.75 (4.95)	0.74 (4.92)	0.77	51.88 (46.06)	59.87 (50.86)	62.59 (52.28)	58.11
T_{10} - Thiamethoxam 75% SG	-	0.40	1.46	1.19 (6.26)	1.18 (6.23)	1.16 (6.17)	1.18	30.37 (33.43)	36.34 (37.04)	41.03 (39.81)	35.91
T_{11} - Novaluron 5.25% + Indoxacarb 4.5% SC	-	0.75	0.74	0.31 (3.19)	0.30 (3.15)	0.30 (3.11)	0.30	81.53 (64.85)	83.55 (66.38)	84.97 (67.28)	83.35
T_{12} - Untreated control	-	-	1.35	1.72 (7.53)	1.87 (7.84)	1.97 (8.05)	1.85	-	-	-	0.00
Mean			0.99	0.94	0.90	0.90		44.99	51.91	54.19	
CD 5%			NS	0.30	0.25	0.25		1.35	1.40	1.37	
SEm (±)				0.30	0.25	0.25		1.35	1.40	1.37	
CV			NS	9.50	8.09	8.28		6.73	6.39	6.10	

Data given in parenthesis arcsine percentage transformation. BS- Before Spray, DAS- Day After Spray,

(35.91%). Among different observation days, the highest larval reduction was observed at 7th DAS (54.19%), followed by 5th DAS (51.91%) and lowest at 3rd DAS (44.99%), when a conidial load of 1×10x CFU-mlwas applied at 10 ml -lt water was applied (Table4).

At 3rd DAS, T_{11}-Novaluron 5.25% + Indoxacarb 4.5% SC recorded the highest fruit borer reduction 81.53%, followed by T_2-*Beauveria bassiana* + *Bacillus thuringiensis* (61.41%) and T_3-*B. thuringiensis* (57.35%), Treatments T_1-*B. bassiana* (53.04%), T_9-*B. thuringiensis* + *Paecilomyceslilacinus*(51.88%) and T_4-*Metarhizium anisopliae* (50.72%) showed comparable efficacy. T_5-*P. lilacinus* and T_6-*M. anisopliae* + *P. lilacinus*were statistically at par with each other. The lowest reduction was observed in T_{10}-Thiamethoxam 75% SG (30.37%) and T_7-*Verticillium lecanii* (30.95%), followed by T_8-*V. lecanii* + *P. lilacinus*(37.00%). showing least effective under field conditions.

Highest mortality was recorded in T_{11}-Novaluron 5.25% + Indoxacarb 4.5% SC (83.55%) at 5th DAS followed by T_2-*Beauveria bassiana* + *Bacillus thuringiensis* (73.93%) and T_3-*Bacillus thuringiensis* (68.58%). All showed significant difference with each other, T_3-*Bacillus thuringiensis* (68.58%), T_1-*Beauveria bassiana* (66.45%) and T_4-*Metarhizium anisopliae* (64.30%), showed similar effect, means parallel effect in reducing fruit borer populations followed by T_9-*Bacillus thuringiensis* + *Paecilomy ceslilacinus* (59.87) and T_5-*Paecilomyces lilacinus* (51.31), T_6-*Metarhizium anisopliae* + *Paecilomyceslilacinus* (48.79) significant difference with each other, while least percent reduction of fruit borer population was recorded in T_7-*Verticillium lecanii* (29.08%) followed by T_{10}-Thiamethoxam 75% SG (36.34%) and T_8-*Verticillium lecanii* + *Paecilomyceslilacinus* (40.77%).

Mortality at 7th DAST_{11}-Novaluron 5.25% + Indoxacarb 4.5% SC (84.97%) showed the

Table 5 : *In-vivo* efficacy of entomopathogenic fungi against white fly (*Bemisia tabaci*) of tomato

Treaments	CFUs ml^{-1}	Dose ml^{-lit}	No. of whiteflies $^{-3}$ leaves/ Plant				Mean	Reduction over control			Mean
			DBS	3DAS	5DAS	7DAS		3DAS	5DAS	7DAS	
T_1 - *Beauveria bassiana*	1×10^8	10	3.54	2.10 (8.28)	1.99 (8.09)	1.95 (8.01)	2.01	56.28 (48.60)	61.78 (51.82)	64.47 (53.39)	60.84
T_2 - *Beauveria bassiana + Bacillus thuringiensis*	1×10^8	10	4.23	2.48 (9.00)	2.45 (9.01)	2.54 (9.17)	2.49	48.24 (43.97)	52.97 (46.69)	53.78 (47.16)	51.66
T_3- *Bacillus thuringiensis*	1×10^8	10	4.01	3.20 (10.26)	3.11 (10.14)	3.10 (10.12)	3.14	33.47 (35.29)	40.42 (39.42)	43.84 (41.41)	39.24
T_4- *Metarhizium anisopliae*	1×10^8	10	3.26	2.38 (8.86)	1.96 (8.04)	1.88 (7.87)	2.07	50.40 (45.21)	62.36 (52.14)	65.73 (54.17)	59.50
T_5 - *Paecilomyceslilacinus*	1×10^8	10	4.09	2.27 (8.66)	2.18 (8.47)	2.13 (8.39)	2.19	52.60 (46.48)	58.20 (49.71)	61.20 (51.46)	57.33
T_6- *Metarhizium anisopliae + Paecilomyceslilacinus*	1×10^8	10	3.44	2.09 (8.25)	1.85 (7.80)	1.76 (7.60)	1.90	56.43 (48.68)	64.39 (53.37)	67.96 (55.55)	62.93
T_7 - *Verticillium lecanii*	1×10^8	10	4.27	1.63 (7.32)	1.36 (6.67)	1.38 (6.73)	1.46	66.05 (54.38)	73.85 (59.38)	74.66 (59.76)	71.52
T_8 - *Verticillium lecanii + Paecilomyceslilacinus*	1×10^8	10	4.00	1.80 (7.70)	1.64 (7.35)	1.61 (7.26)	1.68	62.46 (52.25)	68.68 (55.96)	70.68 (57.21)	67.27
T_9- *Bacillus thuringiensis + Paecilomyceslilacinus*	1×10^8	10	3.61	2.23 (5.58)	2.28 (6.63)	2.31 (8.73)	2.27	53.43 (46.95)	56.28 (48.60)	57.94 (49.56)	55.89
T_{10} - Thiamethoxam 75% SG	-	0.40	4.53	1.40 (7.03)	1.25 (6.64)	1.14 (6.26)	1.26	70.89 (55.70)	76.05 (59.56)	80.35 (62.24)	75.77
T_{11} - Novaluron 5.25%+Indoxacarb 4.5% SC	-	0.75	4.87	2.73 (9.50)	2.87 (9.74)	2.92 (9.81)	2.84	43.12 (41.03)	45.04 (42.14)	46.84 (43.17)	45.00
T_{12} - Untreated control	-	-	4.17	4.81 (12.65)	5.22 (13.21)	5.51 (13.54)	5.18	-	-	-	-
Mean			4.00	2.43	2.35	2.36		49.45	55.00	57.29	
CD 5%			NS	1.31	1.14	1.18		3.80	4.15	4.08	
SEm (±)				0.44	0.39	0.40		1.29	1.41	1.38	
CV			NS	8.74	7.79	8.09		6.10	6.18	5.96	

Data given in parenthesis arcsine percentage transformation. BS- Before Spray, DAS- Day After Spray,

highest reduction in fruit borer population followed by T_2-*Beauveria bassiana* + *Bacillus thuringiensis* (77.24%) and T_3-*B. thuringiensis* (72.34%), showing significant differences. T_3-*B. thuringiensis* (72.34%) and T_1-*B. bassiana* (69.31%) showed similar efficacy in reducing larval populations. T_9-*B. thuringiensis* + *Paecilomyceslilacinus* (62.59%), T_5-*P. lilacinus* (55.17%) and T_6-*Metarhizium anisopliae* + *P. lilacinus* (52.14%) recorded lowest reductions with significant differences. Lowest reduction was observed in T_7-*Verticillium lecanii* (24.89%), followed by T_{10}-Thiamethoxam 75% SG (41.03%) and T_8-*V. lecanii* + *P. lilacinus* (42.75%).

Similar finding was also reported by Tripathi*et al.* (2005) evaluated the comparative efficacy of selected bio-pesticides against the tomato fruit borer (*Helicoverpa armigera*) under field condition. Among the treatments, *Beauveria bassiana* recorded the highest fruit borer reduction (57.58%) followed by *Verticillium lecanii*(47.10%) and *Metarhizium anisopliae* (44.46%). The results indicated that *Beauveria bassiana* was the most effective and economically viable option for managing *H. armigera* in tomato.

In-vivo efficacy of different entomopathogenic fungi against Whitefly (Bemisia tabaci) of Tomato (Lycopercicum esculentum L.)

Highest mean reduction of whitefly population was recorded in T_{10}-Thiamethoxam 75% SG (75.77%; 1.26 whiteflies^{-3} leaves), followed by T_7-*Verticillium lecanii* (71.52%; 1.46 whiteflies) and T_8-*V. lecanii* + *Paecilomyceslilacinus* (67.27%), all treatments significant suppression the population. The lowest reduction was observed in T_3-*Bacillus thuringiensis* (39.24%), T_{11}-Novaluron + Indoxacarb (45.00%) and T_2-*Beauveria bassiana* + *B. thuringiensis* (51.66%),

Fig 1 : Insect cadavers collected from blackgram, greengram and soyabean field

which were comparatively less effective. Overall, maximum reduction occurred at 7 DAS (57.29%), followed by 5 DAS (55.00%) and minimum at 3rd DAS (49.45%) (Table5). Mortality at 3rd DAS T_{10}-Thiamethoxam 75% SG (70.89%) recorded the highest reduction in whitefly population followed by T_7-*Verticillium lecanii* (66.05%) and T_8-*V. lecanii* + *Paecilomyceslilacinus* (62.46%), all the treatments showing significant differences. T_6-*Metarhizium anisopliae* + *P. lilacinus* (56.43%), T_1-*Beauveria bassiana* (56.28%), T_9-*B. thuringiensis* + *P. lilacinus* (53.43%), T_5-*P. lilacinus* (52.60%), T_4-*M. anisopliae* (50.40%) and T_2-*B. bassiana* + *B. thuringiensis* (48.24%) was at par, indicating similar efficacy. The lowest reduction was observed in T_3-*B. thuringiensis* (33.47%) and T_{11}-Novaluron + Indoxacarb (43.12%), which differed significantly.

T_{10}-Thiamethoxam 75% SG (76.05%) showed the maximum reduction in whitefly population, followed by T_7-*Verticillium lecanii* (73.85%) and T_8-*V. lecanii* + *Paecilomyceslilacinus* (68.68%) at 5th DAS, indicating significant superiority. T_6-*Metarhizium anisopliae* + *P. lilacinus* (64.39%), T_4-*M. anisopliae* (62.36%), T_1-*Beauveria bassiana* (61.78%) and T_5-*P. lilacinus* (58.20%) were statistically at par, showing comparable efficacy. The lowest reduction was recorded in T_3-*B. thuringiensis* (40.42%) and T_{11}-Novaluron + Indoxacarb (45.04%), which differed significantly.

Mortality at 7th DAS T_{10}-Thiamethoxam 75% SG (80.35%) showed the highest reduction in whitefly population, followed by T_7-*Verticillium lecanii* (74.66%), T_8-*V. lecanii* + *P. lilacinus* (70.68%), T_6-*Metarhizium anisopliae* + *P. lilacinus* (67.96%),

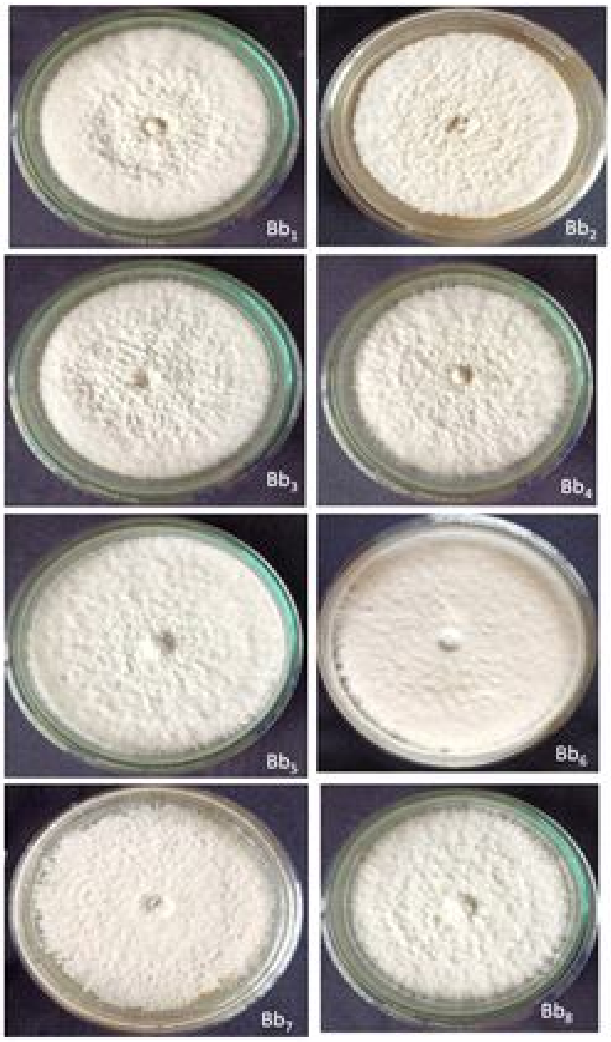

Fig 2: Colony characterization of different isolates of *B.bassiana (Bb1-Bb8)*

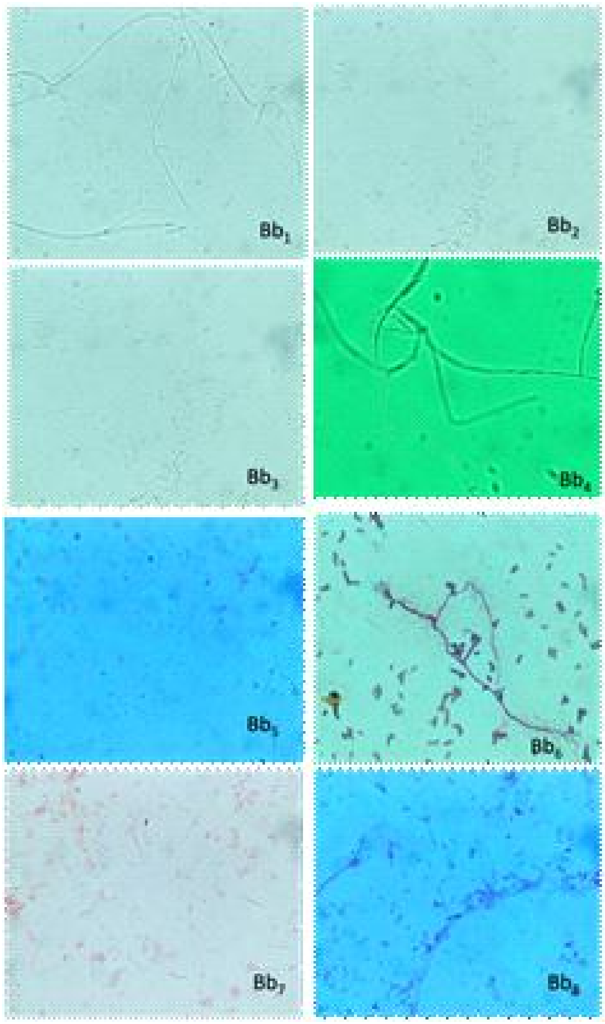

Fig 3: Mycelium and conidia of eight different isolates of *Beauveria bassiana* at 40x (Bb1-Bb8)

T_4-*M. anisopliae* (65.73%) and T_1-*Beauveria bassiana* (64.47%), indicating intermediate and consistent performance. The lowest reduction was recorded in T_3-*B. thuringiensis* (43.84%) and T_{11}-Novaluron + Indoxacarb (46.84%), which showed non-significant difference.

Similar findings were also reported by Urkude*et al*. (2024) and Khadija, *et al*. (2019,)who reported similar type of finding.Urkude, *et al*(2024) reported that *Beauveria bassiana* 50%+ *L. lecanii* 50% recorded highest mortality (76.18%) of whitefly followed by chemicals, while Khadija *et al*., find 41.47% mortality of whitefly by entomopathogenic fungi.

STATISTICAL ANALYSIS

To compare different numerical observation, data was statistically analysed using appropriate design *i.e.,* factorial CRD with desired transformation as applicable**.**

CONCLUSION

Beauveria bassiana showed white powdery colonies with cottony to flat texture. Mycelium was hyaline, septate, and cylindrical. Conidia were oval, hyaline, and measured 1.9-2.61/ ìm in length and 1.27–2.09/ ìm in width.

Bio-efficacy, particularly *Beauveria bassiana* + *Bacillus thuringiensis* and *Verticillium lecanii* + *Paecilomyceslilacinus*, demonstrated effective suppression of *H. armigera* and *B. tabaci*. Their consistent performance highlights the potential of entomopathogenic fungi as eco-friendly components in integrated pest management strategies.

ACKNOWLEDGEMENTS

Authors are thankful to Section of Plant Pathology, BTC, College of Agriculture and Research Station, Bilaspur (IGKV), Chhattisgarh for support to conducting investigation.

DECLARATION

Conflict of interest. Authors declare no conflict of interest

REFERENCES

Affandi, A., Chailani, S.R., Mimbar, S.M., Wiroatmodjo, B. 2013. Isolation and phenotypic characterisation of morphology in fungus *Beauveria bassiana* (balsamo) vuille min colony naturally from leaf surface, soil, and insect as host in tomato plantation. *Agrivita J. Agricult. Sci.***34**: 303-310.

Asensio, L., Carbonell, T., López-Jiménez, J.A. and Lopez-Llorca, L.V., 2003. Entomopathogenic fungi in soils from Alicante province [Spain]. *Spanish J. Agricult. Res.* **1**: 37-45.

Aung, O.M., Soytong, K., Hyde, K.D.. 2008. Diversity of entomopathogenic fungi in rainforests of Chiang Mai Province, Thailand. *Fungal Divers*.**30**:15-22.

Boopathi, T., Karuppuchamy, P., Kalyanasundaram, M. 2015. Microbial control of the exotic spiralling whitefly, *Aleurodicusdispersus* (Hemiptera: Aleyrodidae) on eggplant using entomopathogenic fungi. *Afr. J. Microbiol. Res.***9**: 39-46.

Fauquet, C.M., Briddon, R.W., Brown, J.K., Moriones, E., Stanley, J., Zerbini, M., Zhou, X. 2008. Geminivirus strain demarcation and nomenclature. *Arch.Virol.***153**: 783-821.

Fleming, R., Ratnakaran. 1985 Evaluating single treatment data using Abbot's formula with modification. *J. Econ. Entomol.***78**:1179.

Kulu, I.P., Abadi, A. L., Afandhi, A., Aidawati, N. 2015. Morphological and Molecular Identification of *Beauveria bassiana* as Entomopathogen Agent from Central Kalimantan Peatland, Indonesia. *Inter.J. Chemtech Res.***8**: 2079-2084

Nirmalkar, V.K., Lakplae, N., Tiwari, R.K.S. 2020a. Natural occurrence and distribution of entomopathogenic fungi from Chhattisgarh. *Int. J. Curr. Microbiol. App. Sci.* 9: 1990-1998.

Nirmalkar, V.K., Tiwari, R.K. and Nirala, Y.S. 2020b. Efficacy of different carbon and nitrogen sources against mycelial growth and sporulation of *Beauveria bassiana* and *Metarhizium anisopliae*. *J.Soil and Crops***30**: 206-212.

Pareek P. L., Bhargava, M.C. 2003. Estimation of avoidable losses in vegetables caused by borers under semi-arid condition of Rajasthan. *Insect Environ.***9**: 59-60.

Patel, B., Nirmalkar, V.K., Tiwari, R.K.S. 2025. Collection, isolation and morphological characterization of *Beaveria* isolates. *J. soil and crops* 35: 81-86.

Porte, R.K., Nirmalkar, V.K., Tiwari, R.K.S. 2025. Interaction and toxicity evaluation of novel insecticides and fungicides with entomopathogenic fungi *Paecilomyces*lilacinus for sustainable pest management. *Plant Arch.* **25**: 569-579.

Rajwade, H., Verma, P., Nirmalkar, V.K., Tiwari, R.K.S. 2023. Efficacy of entomopathogenic-fungi *Paecilomyces* spp. against rice stem borer (*Scirpophagaincertulas* L.) and leaf folder (*Cnaphalocrocismedinalis* L.) under natural field condition. *Biologic.Forum***15**: 1168-1174.

Shandilya, A., Nirmalkar, V.K., Tiwari, R.K.S., Nirala, Y.S. 2025. To evaluate the potential isolates of *L. lecanii*against whitefly (*Bemisia tabaci*) and aphid (*Lipaphiserysimi)* under natural field condition. *Biologic. Forum* **17**: 134-139.

Talekar, N.S., Opena, R.T., Hanson, P. 2006. *Helicoverpa armigera* management: a review of AVRDC's research on host plant resistance in tomato. *Crop Protect.***25**: 461-467.

Thomas, M.B., Read, A.F. 2007. Fungal bioinsecticide with a sting. *Nature Biotechnol.* **25**: 1367-1368.

Tripathi, R., Singh, N. P. 2005. Field efficacy of bio pesticide and insecticide against *Helicoverpa armigera* on tomato crop. *Shashpa***12**: 65-66.

Urkude, S., Nirmalkar, V.K., Kumar, D., Tiwari, R.K.S. 2024. Bioefficacy of *Licannicillumlecanii* against aphid (*Aphid craccivora*) of French bean and white fly of green gram. *J. Soils and Crops***33**: 283-288.

Verma, P., Nirmalkar, V.K., Rajwade, H. and Tiwari, R.K.S. 2023. Field efficacy of *Lecanicilliumlecanii* and combination of entomopathogenic fungi against rice stem borer (*Scirpophagaincertulas* l.) and leaf folder (*Cnaphalocrocismedinalis* L.) under natural field condition. *J. Soils and Crops*33: 99-105.

Wraight, S.P., Inglis, G.D., Goettel, M.S. 2007. Fungi. In: *Field Manual of Techniques in Invertebrate Pathology: Application and Evaluation of Pathogens for Control of Insects and Other Invertebrate Pests*. (Eds. L.A.Lacey, H.K.Kaya), Springer, Dordrecht, the Netherlands 223-248.