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Greenhouse evaluation of microbial consortia against sucking pest complex of chilli (*Capsicum annuum* L.)

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ABSTRACT: The present study evaluated the greenhouse efficacy of microbial consortia comprising actinobacteria, *Pseudomonas* spp. and arbuscular mycorrhizal fungi (AMF) against the major sucking pest complex of chilli (*Capsicum annuum* L.), including thrips (*Scirtothrips dorsalis*), aphids (*Aphis gossypii*), and whiteflies (*Bemisia tabaci*). The experiment was conducted in a completely randomized design with twelve treatments, including individual and combined microbial formulations and a chemical check (Diafenthiuron 50% WP). Insects were artificially introduced, and pest counts were recorded at 30, 60, and 90 days after transplanting. Among all treatments, the microbial consortium T5 (DBT 64 + AUDT 502 + AUDP 279) consistently showed the highest suppression of all three pest species—reducing thrips, whiteflies, and aphids by 56.96%, 64.55%, and 48.78%, respectively. This efficacy is attributed to synergistic effects enhancing induced systemic resistance (ISR) and secondary metabolite production. While the insecticide achieved maximum suppression, microbial treatments offered comparable results with long-term ecological benefits. *Lecanicillium lecanii* also showed promising biocontrol potential under controlled conditions. The findings demonstrate that microbial consortia are effective, eco-friendly alternatives for managing sucking pests in chilli and hold strong potential for integration into sustainable pest management frameworks.

Keywords: Chilli (*Capsicum annuum*), sucking pests, microbial consortia, actinobacteria, induced systemic resistance (ISR), integrated pest management (IPM).

INTRODUCTION

Chilli (*Capsicum annuum* L.) is a commercially important spice and vegetable crop in India, valued for its pungency, flavor, and nutritional attributes. India is the world's largest producer and exporter of chilli, contributing nearly 38% to the global production with a cultivated area exceeding 0.75 million hectares (Anonymous, 2021). However, chilli cultivation faces significant threats from a complex of sap-sucking insect pests, particularly thrips (*Scirtothrips dorsalis*), aphids (*Aphis gossypii*), and whiteflies (*Bemisiatabaci*), which cause direct injury through cell laceration and sap extraction, as well as indirect losses by transmitting viruses such as the chilli leaf curl virus and causing "murda" disease. Thrips, especially *Thrips parvispinus* and *Scirtothrips dorsalis*, have emerged as devastating pests in recent years. Their feeding causes silvering, curling, necrosis, and defoliation, significantly impacting flower retention and fruit formation. Yield losses of up to 85% have been reported under severe infestations (Prasannakumar et al., 2021). Losses ranging from 40 to 90% have been documented depending on pest density, cultivar susceptibility, and management practices (Kurbett et al., 2018). Since past, these pests have been managed through the frequent application of chemical insecticides, often leading to environmental concerns, pesticide residues, pest resurgence, and resistance development. Overuse of insecticides has also negatively impacted beneficial arthropods, including coccinellids and parasitoids, thereby weakening natural control mechanisms (Wade et al., 2020).In recent years, plant growth-promoting rhizobacteria (PGPRs) and endophytic actinobacteria have emerged as eco-friendly alternatives. These microbes enhance plant health not only by facilitating nutrient uptake and growth but also by triggering induced systemic resistance (ISR) and producing secondary metabolites with insecticidal and deterrent effects. Among these, *Streptomyces* spp., *Pseudomonas* spp. and arbuscular mycorrhizal fungi (AMF) such as *Glomus fasciculatum* have demonstrated potential across several crops, yet their role in managing chilli sucking pests under greenhouse conditions remains underexplored. Actinobacteria are known to activate jasmonic acid and ethylene-mediated ISR pathways, enhancing the expression of defenserelated enzymes such as peroxidase, polyphenol oxidase, and β-1,3-glucanase (Harun-Or-Rashid and Chung, 2017). In parallel, they produce secondary metabolites like phenazines, siderophores, and antibiotics that directly inhibit pest development and feeding (Aggarwal *et al.,* 2016). Notably, endophytic *Streptomyces* strains have demonstrated gut toxicity and feeding inhibition in *Spodoptera littoralis*, linked to metabolites such as diazinon and 4-nitrophenol (Diab et al., 2023), indicating their cross-spectrum potential against both chewing and sucking insect pests.Despite these advances, the potential of actinobacteria and PGPRs, particularly in microbial consortia, remains largely under-investigated in chilli pest management. This study was therefore undertaken to evaluate the efficacy of microbial consortia involving actinobacteria, AMF, and *Pseudomonas* spp. against the major sucking pest complex under greenhouse conditions, with the aim of developing an integrated, residue-free, and sustainable pest management strategy.

MATERIALS AND METHODS

The study was conducted during Rabi 2023 under greenhouse conditions at the Department of Entomology, University of Agricultural Sciences, Dharwad. Chilli seeds were primed by soaking them in the grown cultures of individual microbial isolates. The suspensions were incubated for 10 minutes to facilitate attachment of bacterial cells to the seed coat. Subsequently, the seeds were air-dried as described by Ramanathan et al. (2000).Primed seeds were raised in nursery trays and transplanted into pots 35 days after sowing (DAS). The experiment was laid out in a Completely Randomized Design (CRD) and included twelve treatments: T1 – *Streptomyces* spp. DBT-64 (1×10□ cfu/g) at 20 mL/L; T2 – *Streptomyces* spp. AUDT-626 (1×10□ cfu/g) at 20 mL/L; T3 – *Streptomyces* spp. AUDT-502 (1×10□ cfu/g) at 20 mL/L; T4 – *Pseudomonas* spp.AUDP-279 (1×10□ cfu/g) at 20 mL/L; T5 –DBT-64 + AUDT-502 + AUDP-279; T6 –AUDT-626 + AUDT-502 + AUDP-279; T7 –DBT-64 + AUDT-502 + AUDP-279 + arbuscular mycorrhizal fungi (AMF); T8 –AUDT-626 + AUDT-502 + AUDP-279 + AMF; T9 – AMF (*Glomus fasciculatum*); T10 – *Lecanicilliumlecanii* (2×10□ cfu/g) at 2 g/L; T11 – Diafenthiuron 50% WP at 1.0 g/L; and T12 – untreated controlwith three replications each. The crop was maintained following recommended agronomic practices. Treatments were imposed twice: first at 10 days after transplanting (DAT) and again at 45 DAT.Actinobacterial and mycorrhizal formulations were applied as soil drenches, while *L.lecanii* and Diafenthiuron 50% WP were sprayed using a knapsack sprayer. Populations of thrips (*S. dorsalis*), aphids (*A. gossypii*), and whiteflies (*B.tabaci*) were artificially established by releasing insects reared on untreated chilli potted plants maintained under insecticide-free conditions. Insect release was carried out 10 DAT.

Data Recording and Analysis

Observations on insect populations were recorded from top, middle, and lower leaves of randomly selected plants in each replication. Data were recorded at 30, 60, and 90 days after transplanting. Insect count data were subjected to square root transformation prior to statistical analysis. The data were analyzed using analysis of variance (ANOVA) following the procedure described by Gomez and Gomez (1984). Percent reduction over the untreated control was calculated using the formula proposed by Henderson and Tilton (1955).

RESULTS AND DISCUSSION

Efficacy of microbial inoculants and consortia against chilli sucking pests under greenhouse conditions

The present study evaluated the efficacy of actinobacterial isolates, *Pseudomonas* spp., arbuscular mycorrhizal fungi (AMF), and their consortia against major sucking pests of chilli under greenhouse conditions. Observations recorded at 30, 60 and 90 days after transplanting (DAT),revealed significant variations in pest populations across treatments.

Efficacy of microbial inoculants and consortia against thrips, *S. dorsalis*

Significant differences in thrips populations were observed across treatments (Table 1). Among microbial consortia, T5 (DBT 64 + AUDT 502+ AUDP 279) recorded the lowest mean thrips population at harvest (1.77) with a 56.96% reduction over the untreated control. This was followed by T6 (AUDT 626+AUDT 502+ AUDP 279) (53.13%), T7 (DBT 64 + AUDT 502+ AUDP 279+AMF) (51.28%), and T8 (AUDT 626+ AUDT 502+ AUDP 279+ AMF) (49.41%). Individual microbial treatments showed moderate efficacy: T3 (39.04%), T1 (37.95%), T2 (35.98%), and T4 (37.07%). The chemical standard T11 (Diafenthiuron 50% WP) exhibited the highest suppression with a 70.22% reduction over control.

Efficacy of microbial inoculants and consortia against whiteflies, *B.tabaci*

A similar trend was observed in whitefly infestation (Table 2). T5 (DBT 64 + AUDT 502+ AUDP 279) achieved the highest reduction (64.55%), followed by

Table 1. Impact of microbial inoculants and consortia against thrips, *S. dorsalis*

Treatments	PTC	30 DAT	60 DAT	90 DAT	Mean	Reduction (%)
T1	4.45 (2.11)	3.04 (1.74)	2.84 (1.69)	2.64 (1.62)	2.84 (1.69)	37.95
T2	4.55 (2.13)	3.13 (1.77)	2.93 (1.71)	2.73 (1.65)	2.93 (1.71)	35.98
T3	4.64 (2.15)	2.99 (1.73)	2.79 (1.67)	2.59 (1.61)	2.79 (1.67)	39.04
T4	4.73 (2.17)	3.08 (1.75)	2.88 (1.70)	2.68 (1.64)	2.88 (1.70)	37.07
T5	4.09 (2.02)	2.17 (1.47)	1.97 (1.40)	1.77 (1.33)	1.97 (1.40)	56.96
T6	4.18 (2.04)	2.21 (1.49)	2.01 (1.42)	1.81 (1.35)	2.01 (1.42)	56.08
T7	4.27 (2.07)	2.08 (1.44)	1.88 (1.37)	1.68 (1.30)	1.88 (1.37)	58.92
T8	4.36 (2.09)	2.12 (1.46)	1.92 (1.39)	1.72 (1.31)	1.92 (1.39)	58.05
T9	4.91 (2.22)	3.40 (1.84)	3.20 (1.79)	3.00 (1.73)	3.20 (1.79)	30.08
T10	4.82 (2.20)	3.17 (1.78)	2.97 (1.72)	2.77 (1.66)	2.97 (1.72)	35.11
T11	4.00 (2.00)	1.02 (1.01)	0.82 (0.91)	0.62 (0.79)	0.82 (0.91)	82.08
T12	4.76 (2.19)	4.43 (2.10)	4.51 (2.12)	4.79 (2.19)	4.58 (2.14)	-
SEm±	0.03	0.04	0.05	0.06	0.05	-
CD	NS	0.12	0.14	0.16	0.15	-

***NS- Non-significant, PTC- Pre - treatment count**

Table 2. Impact of microbial inoculants and consortia against whiteflies, *B. tabaci*

Treatments	PTC	30 DAT	60 DAT	90 DAT	Mean	Reduction (%)
T1	3.51 (1.87)	3.11 (1.76)	3.48 (1.87)	3.74 (1.93)	3.44 (1.86)	39.87
T2	3.62 (1.90)	3.20 (1.79)	3.53 (1.88)	3.81 (1.95)	3.51 (1.87)	38.65
T3	3.48 (1.87)	3.35 (1.83)	3.63 (1.91)	3.92 (1.98)	3.63 (1.91)	36.55
T4	3.79 (1.95)	3.42 (1.85)	3.70 (1.92)	3.99 (2.00)	3.70 (1.92)	35.33
T5	3.40 (1.84)	2.21 (1.49)	2.03 (1.42)	1.85 (1.36)	2.03 (1.42)	64.55
T6	3.72 (1.93)	2.34 (1.53)	2.17 (1.47)	1.97 (1.40)	2.16 (1.47)	62.28
T7	3.36 (1.83)	2.08 (1.44)	1.91 (1.38)	1.72 (1.31)	1.90 (1.38)	66.76
T8	3.89 (1.97)	2.44 (1.56)	2.25 (1.50)	2.06 (1.44)	2.25 (1.50)	60.71
T9	3.55 (1.88)	3.71 (1.93)	3.83 (1.96)	3.98 (1.99)	3.84 (1.96)	32.95
T10	3.67 (1.92)	3.66 (1.91)	3.58 (1.89)	3.77 (1.94)	3.67 (1.92)	35.91
T11	3.45 (1.86)	1.92 (1.39)	1.76 (1.33)	1.59 (1.26)	1.76 (1.33)	69.32
T12	3.69 (1.92)	4.83 (2.20)	5.83 (2.41)	6.52 (2.55)	5.73 (2.39)	-
SEm±	0.03	0.04	0.05	0.06	0.05	-
CD	NS	0.12	0.14	0.16	0.15	-

***NS- Non-significant, PTC- Pre - treatment count**

T6 (61.36%), T7 (60.00%), and T8 (58.18%). Individual microbial treatments, T1 to T4, recorded moderate efficacy ranging from 35.33% to 39.87%. The chemical control T11 showed the greatest reduction in whitefly population (72.73%), outperforming all microbial treatments.

Efficacy of microbial inoculants and consortia against aphids, *A. gossypii*

The aphid population was significantly reduced in microbial consortia treatments (Table 3). T5 (DBT 64 + AUDT 502+ AUDP 279) led to the highest suppression (48.78%), followed by T6 (46.34%), T7 (43.90%), and T8 (41.46%). Individual actinobacterial and pseudomonas treatments—T1 (19.51%), T2 (17.07%), T3 (14.63%), and T4 (12.20%)—showed lower efficacy. The insecticide treatment T11 once again recorded the maximum reduction (65.85%) among all treatments.

Among all microbial treatments, T5 consistently exhibited superior efficacy across thrips, whiteflies, and aphids, indicating broad-spectrum pest suppression. This effectiveness likely stems from synergistic interactions among microbes that amplify induced systemic resistance (ISR) mechanisms in the host plant. Actinobacteria are known to activate jasmonic acid and ethylene signaling pathways, resulting in increased accumulation of defense enzymes like peroxidases, polyphenol oxidases, and pathogenesis-related proteins (Conn et al., 2008). Similarly, arbuscular mycorrhizal fungi (AMF) enhance nutrient uptake, promote plant vigor, and modulate hormonal pathways, all of which contribute to improved host resistance.These findings align with those of Goudjal et al. (2014), who demonstrated the ability of *Streptomyces* spp. to suppress *Rhizoctonia solani* through hydrolytic enzyme production and systemic resistance induction. Plant growth-promoting rhizobacteria (PGPR) such as *Pseudomonas* spp. used in consortial treatments (T7 and T8), produce phenazine, hydrogen cyanide, siderophores, and β-1,3-glucanase—all of which are associated with ISR activation and insect suppression in chilli (Naik et al., 2011).The utility of these microbial consortia is further validated by field-based IPM studies, where *Pseudomonas*spp. application significantly reduced the incidence of sucking pests and lowered insecticide usage by over 30%, while increasing yield by 28% compared to non-IPM plots (Naik et al., 2011). Similarly, bio-intensive IPM modules combining *L.lecanii*, Azadirachtin, neem cake, and trap/barrier crops provided consistent control of thrips and mites (1.88/leaf and 1.16/leaf, respectively), while conserving natural enemies such as spiders and coccinellids (Kurbett et al., 2018). Although chemical-intensive modules offered the highest pest reduction and yield (12.36 q/ha), the bio-intensive systems delivered greater ecological balance. While the synthetic insecticide Diafenthiuron remained the most effective standalone treatment across all pests,

Table 3. Impact of microbial inoculants and consortia against aphids, *A. gossyphii*

Treatments	PTC	30 DAT	60 DAT	90 DAT	Mean	Reduction (%)
T1	3.40 (1.84)	3.00 (1.73)	3.31 (1.82)	3.60 (1.90)	3.29 (1.81)	19.51
T2	3.50 (1.87)	3.09 (1.76)	3.39 (1.84)	3.69 (1.92)	3.39 (1.84)	17.07
T3	3.61 (1.90)	3.18 (1.78)	3.51 (1.87)	3.80 (1.95)	3.50 (1.87)	14.63
T4	3.70 (1.92)	3.29 (1.81)	3.61 (1.90)	3.90 (1.97)	3.62 (1.90)	12.20
T5	3.30 (1.82)	2.30 (1.52)	2.10 (1.45)	1.90 (1.38)	2.10 (1.45)	48.78
T6	3.80 (1.95)	2.41 (1.55)	2.20 (1.48)	2.00 (1.41)	2.20 (1.48)	46.34
T7	3.20 (1.79)	2.11 (1.45)	1.90 (1.38)	1.71 (1.31)	1.89 (1.37)	53.66
T8	3.91 (1.98)	2.51 (1.58)	2.30 (1.52)	2.08 (1.44)	2.31 (1.52)	43.90
T9	3.40 (1.84)	3.40 (1.84)	3.60 (1.90)	3.81 (1.95)	3.60 (1.90)	12.20
T10	3.61 (1.90)	3.51 (1.87)	3.30 (1.82)	3.58 (1.89)	3.46 (1.86)	15.37
T11	3.29 (1.81)	1.90 (1.38)	1.70 (1.30)	1.51 (1.23)	1.69 (1.30)	58.54
T12	3.50 (1.87)	3.80 (1.95)	4.10 (2.02)	4.39 (2.10)	4.10 (2.02)	-
SEm±	0.03	0.04	0.05	0.06	0.05	-
CD	NS	0.12	0.14	0.16	0.15	-

***NS- Non-significant, PTC- Pre - treatment count**

microbial consortia provide long-term advantages. They reduce reliance on chemicals, maintain beneficial arthropods, and improve soil health—features critical for sustainable pest management in crops like chilli where residue concerns are high.Among the biocontrol agents, *L. lecanii* has shown high efficacy under controlled environments. Abdulle et al. (2020) reported up to 93% mortality of *B.tabaci* in vitro within 7 days using *L. lecanii* strain V-3. Likewise, Wade et al. (2020) demonstrated aphid suppression in tomato using *L. lecanii* at 5 mL/L, achieving efficacy comparable to chemical insecticides. Although its performance in the field is influenced by environmental factors like humidity and temperature, these studies highlight its biopesticidal potential. In contrast, ISR-inducing microbes offer consistent performance across varied environmental conditions, providing a more stable approach to pest suppression.Overall, the consortia involving actinobacteria, *Pseudomonas* spp.and AMF not only proved effective against chilli sucking pests but also offer a promising alternative to chemical pesticides. Their integration into eco-friendly IPM frameworks can support sustainable pest management strategies.

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