



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(4): 700-702
Received: 23-02-2026
Accepted: 28-03-2026

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Bio-insensitive management of soil borne diseases in French bean

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i4i.5463>

Abstract

Soil-borne diseases, particularly collar rot, caused by *Sclerotium rolfsii* constitute a major constraint to French bean (*Phaseolus vulgaris* L.) production by adversely affecting seed germination, plant stand, and yield. A field experiment was conducted over three consecutive Rabi seasons (2021–22, 2022–23, and 2023–24) at the Vegetable Research Station, Rajendranagar, Hyderabad, India, to assess the efficacy of bio-intensive disease management strategies employing talc-based biological control agents. The experiment followed a randomized block design with seven treatments and three replications. The treatments included seed treatment and root-zone soil drenching with *Trichoderma* spp., *Bacillus subtilis*, actinomycetes, their respective microbial consortia, a chemical fungicide (Captan 75% WP), along with an untreated control. Pooled analysis across three seasons demonstrated that the microbial consortia treatment consisting of *Trichoderma asperellum* + *Bacillus subtilis* (Ts) resulted in significantly higher seed germination (94.78%), minimum collar rot mortality at 75 days after sowing (DAS) (6.33%), and maximum marketable yield (2.96 t ha⁻¹), along with the highest benefit–cost ratio (2.52), compared to the untreated control. Treatments involving biological agents consistently performed superior to the control and were comparable to, or exceeded, the efficacy of the chemical fungicide treatment. The study concludes that integration of seed treatment and soil drenching with microbial consortia represents an effective, economically viable, and environmentally sustainable bio-intensive strategy for the management of collar rot in French bean, offering a promising alternative to sole reliance on chemical fungicides.

Keywords: *Phaseolus vulgaris*, collar rot, *Trichoderma asperellum*, *Bacillus subtilis*, seed treatment, soil drenching, biocontrol, bio-intensive management, soil-borne diseases

Introduction

French bean (*Phaseolus vulgaris* L.) is a widely grown leguminous vegetable crop cultivated for its edible pods and seeds, valued for its high nutritional quality and market demand. It provides a substantial source of plant-based protein and is enriched with essential vitamins, carotenoid pigments, and antioxidant constituents, contributing significantly to dietary nutrition in India and many other parts of the world. Soil-borne diseases, particularly collar rot, pose a major constraint to French bean production globally, leading to poor germination, weak stands, and severe yield losses. Conventional chemical fungicides provide effective disease suppression, but concerns regarding environmental impact, pathogen resistance and sustainability have led to increasing interest in bio-intensive management strategies. Biological control agents (BCAs) including *Trichoderma* spp., *Bacillus subtilis* and beneficial actinomycetes, are well-known for their ability to colonize the rhizosphere, outcompete pathogens, produce antimicrobial metabolites and stimulate systemic resistance in plants. Recent studies increasingly demonstrate that BCAs applied as microbial consortia exhibit synergistic interactions, leading to enhanced disease suppression, plant growth, and yield compared to single-agent applications (Kumari et al., 2025) [5].

Biopesticides and microbial antagonists present an eco-friendly option for disease suppression. Biological control is a vital component of Integrated Disease Management (IDM) due to its biodegradability, selectivity, minimal environmental impact and reduced risk of resistance development. Combined use of compatible biocontrol agents has been widely reported to result in greater disease suppression and improved plant performance compared to individual strains

due to synergistic and complementary interactions among microbial partners (Harman *et al.*, 2021) [4]. *Trichoderma* spp. has been widely reported to reduce root rot incidence and enhance plant growth and defence responses in French bean and related cropping systems (Poveda, 2021) [6]. Similarly, *Bacillus subtilis* and other plant growth-promoting rhizobacteria effectively suppress soil-borne pathogens such as *Rhizoctonia solani*, and their combined application with *Trichoderma* often results in enhanced disease control and crop productivity (Santoyo *et al.*, 2024) [7]. *Bacillus* spp. is highly preferred as biocontrol agents due to their ability to form endospores, which enable survival under adverse environmental conditions and facilitate ease of formulation and long-term storage. Consequently, *Bacillus*-based biopesticides dominate the global biocontrol market, accounting for a major share of commercially available products (Choudhary *et al.*, 2011) [2]. In addition to bacterial and fungal BCAs, Arbuscular mycorrhizal fungi (AMF) play a significant role in suppressing soil-borne pathogens, particularly *Fusarium* spp. and *Rhizoctonia solani*, through improved nutrient uptake, induced systemic resistance and modulation of rhizosphere microbial communities (Campo *et al.*, 2020) [1]. PGPR also contribute through growth promotion, disease reduction and production of antimicrobial metabolites such as phenazines and phloroglucinols. Since no single method ensures complete control, integrating multiple microbial agents is essential.

The present field experiment was carried out at Vegetable

Research Station, Rajendranagar (Hyderabad) as part of All India co-ordinated research project (AICRP) to test talc-based seed treatments and root-zone soil drenching of BCAs, alone and in combination, against soil-borne collar-rot disease in French bean and their effects on germination, disease severity (mortality at 25 and 75 DAS) and marketable yield ($t\ ha^{-1}$).

Materials and Methods

The experiment was conducted during three consecutive Rabi seasons (2021–22, 2022–23 and 2023–24) at the Vegetable Research Station, Rajendranagar, Hyderabad situated at an altitude of 545 m above mean sea level and at 78°39'93" E longitude and 17°32'27" N latitude. The soil type of experimental field was loamy in texture, neutral in reaction, low in available nitrogen and phosphorus, high in potassium and belongs to the order Alfisol. French bean variety 'Phalguna' was grown at a spacing of 40 cm × 20 cm on ridges and furrows. The recommended dose of fertilizer (120:60:60 kg N:P:K ha^{-1}) was applied through urea, single superphosphate (SSP), and muriate of potash (MOP). The full dose of phosphorus and half doses of nitrogen and potassium were applied as basal dressing before sowing the seeds in the rows. Twenty-five days after sowing (25 DAS), half of nitrogen and half of potash were applied as top dressing during hoeing. The experiment was conducted in randomized block design (RBD) comprising seven treatments and replicated three times, with each plot measuring 5 m × 3 m (15 m^2). The treatment details are presented in Table 1.

Table 1: Treatment details

Treatment No.	Formulation
T ₁	Seed treatment by talc-based <i>Trichoderma asperellum</i> (IIVR) @ 10 g/kg seed and soil drenching @ 1% in root zone at time of earthing.
T ₂	Seed treatment by talc-based <i>Trichoderma</i> (TTV-2 IIVR strain) @ 10 g/kg seed and soil drenching @ 1% in root zone at time of earthing
T ₃	Seed treatment by talc-based <i>Bacillus subtilis</i> (CRB-7-IIVR) @ 5 g/kg seed and soil drenching @ 0.5% in root zone at time of earthing
T ₄	Seed treatment by talc-based <i>Actinomyces</i> sp. N-1.2 (IIVR) @ 10 g/kg seed and soil drenching @ 1% in root zone at time of earthing.
T ₅	Seed treatment by consortia of <i>Trichoderma asperellum</i> + <i>Bacillus subtilis</i> (CRB-7) @ 10 g/kg seed and soil drenching @ 1% in root zone at time of earthing
T ₆	Seed treatment by Captan 75% WP @ 2.5 g/kg seed and soil drenching @ 0.25% in root zone at earthing.
T ₇	Untreated control

Results

Pooled analysis of data from three consecutive Rabi seasons (2021–22, 2022–23, and 2023–24) indicated that the imposed treatments had a non-significant effect on germination percentage at 15 DAS. However, the treatments exerted a significant effect on collar rot mortality at both 25 and 75 DAS across all seasons. Collar rot mortality was markedly reduced in all bio-agent treatments compared to the untreated control. At 25 DAS, the lowest mortality was recorded in T₂ (3.51%), followed by T₆ (3.65%) and T₁ (3.95%). At 75 DAS, the lowest mortality was observed in T₅ (6.33%), followed by T₆ (7.19%) and T₂ (7.34%). The untreated control recorded the highest collar rot mortality (7.71% at 25 DAS and 12.96% at 75 DAS) across the three seasons. The influence of treatments on marketable yield and benefit–cost (B:C) ratio was also significant. Treatment T₅ recorded the highest marketable yield (2.96 $t\ ha^{-1}$) and B:C ratio (2.52), followed by T₁ (2.75 $t\ ha^{-1}$ and 2.27) and T₆ (2.73 $t\ ha^{-1}$ and 2.23). The untreated control consistently produced the lowest yield (1.23 $t\ ha^{-1}$) and B:C ratio (0.46). These findings are in agreement with Singh and Prasad (2019) [8], who reported that the combined application of *Trichoderma* and *Bacillus*

species improved yield and profitability in legume crops.

Discussion

The superior performance of the *Trichoderma* spp. and *Bacillus* spp. consortia (T₅) can be attributed to their complementary biological mechanisms. *Trichoderma* spp. contributes through mycoparasitism, production of cell wall-degrading enzymes, and efficient rhizosphere colonization, whereas *Bacillus* spp. produces a wide range of antimicrobial metabolites, including lipopeptides, siderophores, and volatile compounds. This synergistic interaction enhances suppression of soil-borne pathogens and promotes plant growth more effectively than individual applications (Gouda *et al.*, 2018) [3]. Both microbial groups are known to induce systemic resistance and improve nutrient uptake, thereby enhancing plant vigor and resilience. The combined application ensures both rapid and sustained disease suppression through multiple modes of action, unlike chemical fungicides, which primarily act through contact and often show reduced persistence over time. The reduced collar rot incidence and increased yield observed in treatment T₅ in the present study clearly demonstrate the advantage of microbial

consortia over single bio-agents and chemical control. The improved germination and early seedling vigor further support the plant growth-promoting effects of these biological control agents. These findings are in agreement with earlier reports

indicating that microbial consortia are more effective in managing soil-borne pathogens and enhancing crop productivity in legumes and other horticultural crops.

Table 2: Effect of bio-intensive management practices on germination, collar rot incidence, and yield of French bean (*Phaseolus vulgaris* L.) (pooled over Rabi seasons, 2021–24)

Treat-ments	Germination (%) 15 DAS				Mortality (%) due to collar rot 25 DAS				Mortality (%) due to collar rot 75 DAS				Marketable yield (t/ha)				B: C ratio
	2021-22	2022-23	2023-24	Pooled Mean	2021-22	2022-23	2023-24	Pooled Mean	2021-22	2022-23	2023-24	Pooled Mean	2021-22	2022-23	2023-24	Pooled Mean	
T ₁	90.67	90.33	92.00	91.00	3.80	3.83	4.22	3.95	7.11	7.45	8.27	7.61	2.62	2.79	2.83	2.75	2.27
T ₂	92.67	92.67	91.33	92.22	3.50	3.38	3.64	3.51	7.52	7.37	7.12	7.34	2.32	2.36	2.62	2.43	1.89
T ₃	94.00	94.33	93.00	93.77	4.10	4.20	4.75	4.35	8.31	9.06	8.28	8.55	2.14	2.17	2.31	2.21	1.62
T ₄	92.33	93.33	93.33	92.99	6.41	6.34	7.14	6.63	7.66	7.89	8.35	7.97	1.77	1.83	2.01	1.87	1.21
T ₅	94.00	95.67	94.67	94.78	4.50	4.85	5.31	4.89	6.41	6.09	6.50	6.33	2.87	2.95	3.06	2.96	2.52
T ₆	92.43	94.43	91.60	92.82	3.60	3.60	3.76	3.65	7.01	7.17	7.38	7.19	2.61	2.66	2.91	2.73	2.23
T ₇	90.00	91.33	90.67	90.66	7.50	7.64	8.02	7.72	13.09	12.74	13.06	12.96	1.14	1.30	1.24	1.23	0.46
SEm±	1.37	1.39	1.16	1.30	0.80	0.797	0.72	0.77	0.56	1.116	1.03	0.90	0.28	0.254	0.18	0.24	-
C.D. at 5%	NS	NS	NS	NS	2.48	2.483	2.24	2.40	1.75	3.477	3.19	2.81	0.88	0.792	0.55	0.74	-
C.V.%	3.24	3.25	2.18	2.89	11.09	11.092	9.50	10.56	11.59	11.708	10.62	11.31	22.18	19.191	12.69	18.02	-



Fig 1: Field view of the experimental plots illustrating the effect of bio-intensive management practices on soil-borne diseases in French bean

Conclusion

The present study demonstrates that seed treatment coupled with root-zone soil drenching using a talc-based consortium of *Trichoderma asperellum* and *Bacillus subtilis* (T₅) is highly effective in improving germination, minimizing collar rot incidence, and enhancing yield and economic returns in French bean. The integration of compatible microbial consortia offers a sustainable, eco-friendly, and economically viable strategy for the management of soil-borne diseases, reducing reliance on chemical fungicides. This approach can be recommended for wider adoption in French bean cultivation under similar agro-climatic conditions.

Acknowledgement

The authors gratefully acknowledge the Indian Institute of Vegetable Research (IIVR), Varanasi, for providing the microbial consortia under the All India Coordinated Research Project (AICRP), which supported the successful conduct of this experiment.

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