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BACILLUS-BASED BIOINOCULANTS AS DUAL BIOCONTROL AGENTS AGAINST FUNGAL PATHOGENS AND INSECT PESTS: INSIGHTS FOR FUSARIUM POAE AND AGRIOTES LINEATUS

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Abstract: Fungal pathogens and insect pests are among the most persistent threats to crop productivity worldwide. Acting simultaneously or sequentially, they compromise seedling establishment, reduce yield, and lower grain quality, while also threatening long-term soil fertility. Conventional management relies on separate fungicide and insecticide treatments, a strategy that is costly, environmentally unsustainable, and increasingly ineffective due to the emergence of resistant populations. These challenges highlight the urgent need for integrated solutions capable of addressing multiple stress factors within the same system. Among the most promising candidates are bioinoculants based on Bacillus spp., which possess remarkable metabolic and ecological versatility. Through the secretion of specific lipopeptides and hydrolytic enzymes, Bacillus strains suppress fungal growth, inhibit spore germination, and activate systemic plant defenses. At the same time, their entomopathogenic potential is reflected in the ability to colonize the rhizosphere, compete for resources, and release bioactive compounds that deter feeding or reduce insect survival. The capacity to combine antifungal and insect-suppressive activities within a single microbial agent represents a novel paradigm in biological control, offering the possibility of simplifying pest management while enhancing soil and plant health. Despite this potential, research has largely concentrated on well-characterized fungi such as Fusarium graminearum or insect models like lepidopteran larvae. In contrast, the cereal pathogen Fusarium poae and the soil-dwelling wireworm Agriotes lineatus remain severely underexplored, even though they cause significant economic damage through yield losses, seedling destruction, and contamination with harmful mycotoxins. Insights gained from studies on related Fusarium species and other insect pests, however, provide a valuable foundation for identifying selection criteria and functional traits in Bacillus strains with dual biocontrol potential against these overlooked threats. This review therefore situates dual biocontrol within a broader agricultural context while drawing attention to specific knowledge gaps that hinder the development of integrated microbial solutions. By synthesizing existing findings and projecting their implications for underrepresented targets such as F. poae and A. lineatus, the study highlights an innovative approach to crop protection. Ultimately,

Bacillus-based bioinoculants exemplify the next generation of sustainable tools that can reduce chemical dependence, support integrated pest management, and contribute to resilient cereal production systems.

Keywords: dual biocontrol, Bacillus spp., Fusarium poae, Agriotes lineatus, integrated pest management.

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Bacillus-Based Bioinoculants as Dual Biocontrol Agents Against Fungal Pathogens and Insect Pests: Insights for *Fusarium poae* and *Agriotes lineatus*

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BACKGROUND

Cereal crops such as barley, oats, and wheat are under constant threat from fungal pathogens and insect pests. *Fusarium poae* significantly reduces yield and contaminates grain with mycotoxins, representing a major risk to food and feed safety.

Agriotes lineatus damages roots and seedlings, leading to crop establishment failure and substantial economic losses.

Conventional chemical control is often inefficient, accelerates resistance development, and contributes to environmental contamination. Beneficial *Bacillus* species are increasingly recognized as sustainable biocontrol agents for cereal protection.

RESULTS

Bacillus strain	Target species	Effectiveness (%)	Mode of action	Assay Type	Mechanism of actiom	References
B. velezensis BHC 5.6	*F. poae*	67	mycelium growth	*in vitro*	the effect of secreted antibiotics and lytic enzymes	Knežević et al., 2025
	A. lineatus (larvae)	56.67	larval mortality	*in vitro* (with soil substrate)	the effect of secreted antibiotics and lytic enzymes	

Reports addressing both fungal pathogens and insect pests with the same *Bacillus* strain are exceptionally rare, especially for less frequently studied targets such as *F. poae* and *A. lineatus*. For this reason, the study of Knežević et al. (2025) was selected as a representative example of a single-strain application. More generally, both individual *Bacillus* strains and microbial consortia have been shown to be highly promising biocontrol agents with potential for sustainable crop protection.

CONCLUSION

In conclusion, the use of *Bacillus* strains represents a promising strategy for the management of fungal pathogens and wireworms in cereals. Nevertheless, many aspects remain insufficiently explored, including their interactions with crops under different environmental conditions and their long-term effectiveness in the field. Future studies should therefore focus on filling these gaps and on screening novel *Bacillus* strains with potential dual effects, which could further enhance their role in sustainable crop protection.

IPM STRATEGY

- •Competition for space and nutrients
- •Antibiotic production
- •Secretion of lipopeptides
- •Production of volatile organic compounds (VOCs)
- •Secretion of hydrolytic enzymes
- •Siderophore - mediated iron (Fe^{3+}) sequestration
- •Inhibition of mycotoxin synthesis
- •Biofilm formation
- •Induction of systemic resistance in host
- •Quorum sensing interference

- •Production of insecticidal toxins
- •Cuticle degradation enzymes
- •Production of lipopeptides with insecticidal activity
- •Siderophore - mediated iron deprivation
- •Gut colonization and microbiota disruption
- •Pore formation in gut epithelium
- •Production of volatile organic compounds (VOCs)
- •Induction of immune stress in host insect

- •Production of phytohormones
- •Siderophore - mediated iron supply to plants
- •Phosphate solubilization and nutrient mobilization
- •Induced systemic resistance activation
- •Production of ACC deaminase
- •Suppression of plant pathogens
- •Improved root colonization, growth promotion and nutrient uptake
- •Enhanced tolerance to abiotic stresses

NEXT STEPS

Despite the numerous benefits of Bacillus strains in controlling *F. poae* and *A. lineatus*, such as enhancing plant growth and yield, improving stress tolerance, inducing systemic resistance, protecting soil health, and reducing the need for chemical agents, several knowledge gaps and challenges remain that require further investigation. The main points are illustrated below.

- **Dual action** — fungi + insects
- **Carriers** — beads, biochar, polymers
- **Field validation** — real ecosystems
- **Rhizosphere** — microbial interactions
- **Mode of action** — metabolites
- **Stability** — pH, moisture, temperature
- **Antibiotic resistance** — safety check
- **Commercialization** — scalable products

Reference
Knežević, M., Dervišević, M., Jovković, M., Jevđenović, G., Maksimović, J., & Buntić, A. (2025). Versatile role of Bacillus velezensis: Biocontrol of Fusarium poae and wireworms and barley plant growth promotion. *Biological Control*, 105789.

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