



Review

Bacillus-based biocontrol of *Agriotes lineatus* and *Fusarium poae* as underrecognized threats in cereal production

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ABSTRACT

Recently, the use of microbial bio-inoculants has become a commonly used agricultural practice for suppression of various insect pests and bacterial or fungal phytopathogens. To develop sustainable crop protection strategies, innovative approaches are needed that can solve more than one threat simultaneously. This review examines the potential of *Bacillus* strains for managing insect pests (wireworms) and phyto-pathogenic fungi belonging to the *Fusarium* genus, with a special focus on *Agriotes lineatus* and *Fusarium poae*. Although these insects and fungi can affect a range of crops, this study highlights their impact on cereals (wheat, barley, and oats), where their effects can cause significant economic losses. The innovative aspect of this review lies in identifying knowledge gaps in existing research, highlighting areas that require comprehensive investigation to fully realize the potential of *Bacillus*-based biocontrol agents against these threats. Additionally, we outlined the *Bacillus* spp. mechanisms of action against both wireworms and *Fusarium* spp., which indicates that properly selected strains could be used as bio-inoculants for dual protection of cereals. While the use of *Bacillus* biocontrol agents in cereal protection remains in its early stages, their dual-biocontrol potential positions them as promising tools for next-generation crop protection.

1. Introduction

Cereal crops such as wheat, barley, and oats are among the most important staple foods worldwide, serving as primary sources of calories, protein, and essential nutrients for both human and livestock consumption. Cereals are cultivated on nearly half of the world's total cultivated land which emphasizes their significance in global agriculture (FAO, 2025). Despite the diversity of the Poaceae family, only a few species are widely used for human consumption and animal feed (Wrigley, 2017). Among cereals, wheat (*Triticum* spp. L.) is the most important staple crop worldwide, covering approximately 30% of the global cereal crop area (Rana et al., 2024; Biel et al., 2020; Diekmann, 2009). Following wheat in terms of its significance are barley (*Hordeum vulgare* L.) and oats (*Avena sativa* L.), which are both notable members of the subfamily Pooideae (Belitz et al., 2009). Barley and oats globally rank as fourth and seventh, respectively, in production volume and land area coverage (FAO, 2025; Zhou, 2009). However, these crops are continuously exposed to a wide range of insect pests and fungal phyto-pathogens that affect rhizosphere, plant root system and

above-ground parts of the plants.

The production of cereals is frequently threatened by soil-dwelling insect pests, particularly wireworms, which are the larvae of click beetles (family Elateridae). These insects exhibit significant variation among species in their life history strategies, including differences in habitat preferences, the length of their life cycle, and their feeding behaviors (Costa et al., 2011). While adult click beetles are primarily plant feeders, they rarely cause direct damage to crops. In contrast, the larval form, commonly known as wireworms, are found in soil, decaying plant matter, or wood, where they exhibit a wide range of feeding habits. Although many species feed on plants, only a small subset of them are problematic in agricultural settings. In particular, *Agriotes* species are frequently associated with crop damage, such as feeding on seeds and young roots, causing poor germination, stunted growth, plant death, uneven stands, while also creating entry points for secondary pathogens which can reduce yield and grain quality (Traugott et al., 2015).

Fungal phyto-pathogens pose a severe threat to agricultural sustainability, by simultaneously lowering the crop yield and posing a threat to human health. One of the most common fungal genera affecting

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