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LOCAL MICROBIOMES, GLOBAL SOLUTIONS: THE FUTURE OF CROP BIOPROTECTION LIES IN NATIVE BACTERIAL BIOINOCULANTS

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ABSTRACT

Cereal crops, including wheat, barley, and oats, are fundamental to global food security but are increasingly exposed to the adverse impacts of climate change, which is altering the dynamics of soil-borne phytopathogens. Rising temperatures, erratic precipitation, and extreme weather events have been linked to the enhanced survival, virulence, and spread of pathogens such as *Fusarium*, *Pythium*, and *Rhizoctonia* spp., leading to significant yield losses, quality reduction, and increased contamination with mycotoxins. Traditional reliance on chemical pesticides to manage these pathogens is proving unsustainable due to declining efficacy under variable climatic conditions, the emergence of resistant pathogen strains, and growing concerns over environmental pollution and human health risks. Microbial biocontrol represents a promising, eco-friendly alternative, particularly through the use of plant growth-promoting rhizobacteria (PGPR) such as *Bacillus* and *Pseudomonas* species. These beneficial microbes exhibit multiple antagonistic mechanisms—ranging from the production of antifungal compounds (e.g., iturins, fengycins, phenazines), secretion of siderophores and hydrolytic enzymes, to the induction of systemic resistance and effective rhizosphere colonization—making them valuable agents in plant protection. Their spore-forming ability and stress tolerance further enhance their potential for application in diverse agroclimatic zones. However, a key limitation of currently available bioinoculants is their inconsistent field performance, often due to poor adaptation of commercial strains to local environmental and soil conditions. This has led to a novel and increasingly supported paradigm: the exploration and utilization of native, locally adapted microbial strains for the development of next-generation bioinoculants with superior efficacy and ecological compatibility. These native strains, derived from region-specific soil microbiomes, are more likely to exhibit robust performance under local abiotic stresses and may establish more stable interactions with plants. It also highlights the strategic importance of integrating microbiome research, local soil biodiversity, and targeted strain selection into the development of next-generation bioinoculants. By harnessing the functional potential of indigenous microbial communities—adapted to specific climatic and edaphic conditions—it is possible to discover strains with superior efficacy, environmental resilience, and compatibility with native agroecosystems. This integrative approach not only enhances the reliability and performance of biocontrol agents in the field, but also aligns with key objectives of EU strategies such as the Farm to Fork and European Green Deal, which aim to reduce chemical pesticide use by 50% by 2030, restore soil health, and support biodiversity-based sustainable agriculture. Developing bioinoculants from native beneficial bacteria offers a climate-smart solution for the sustainable protection of cereal crops against emerging soil pathogens. This review underscores the need to shift from generalized, commercial approaches toward

regionally optimized microbial biocontrol, tailored to local agroecosystems. Such innovation is not only critical for maintaining crop productivity and food security under climate stress, but also for meeting the long-term goals of ecological intensification and sustainable agriculture.

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