Across chrysanthemum research in the last decade, biological control is no longer treated as a niche alternative but increasingly as a main pillar of sustainability-oriented production systems. The large 2015–2025 review explicitly lists biocontrol agents-Trichoderma spp., Bacillus spp., predatory mites, and entomopathogenic fungi—as demonstrated tools and argues for future integration with microbiome management, molecular breeding, and RNA-based tools to achieve more durable control (Chen et al., 2025).

At the microbial-technology frontier, two developments are especially relevant for Hangbaiju growers and extension teams. One is the move from single strains to compatible consortia and co-inoculations. An open-access review in *Biological Control* argues that co-inoculations of Trichoderma with beneficial bacteria (often Bacillus or Pseudomonas) can produce synergistic benefits, and highlights that formulation and compatibility are central steps if such synergy is to translate outside the lab (Poveda and Eugui, 2022). The second development is the more explicit coupling of "biocontrol" with "plant growth and quality." A greenhouse study on co-inoculation of Bacillus velezensis and Pseudomonas aeruginosa in chrysanthemum reports improvements in growth and quality relative to single-strain inoculation, while also pointing to induced defense and immune activation (e.g., upregulation of defense-related transcription factors) as part of the mechanism. This matters for Hangbaiju because quality parameters—flower integrity, harvest timing, and market acceptance—are tightly linked to both stress and disease pressure (Wang et al., 2024).

This study has two practical objectives. The first is to summarize the biological control technologies most relevant to Hangbaiju cultivation, with attention to what is actually deployable under field constraints—timing, labor, weather, bloom-stage restrictions, and the economics of repeated applications. The second is to evaluate field application effects using traceable published evidence, focusing on comparative suppression of pests/diseases, yield and quality implications where reported, and practical performance compared to conventional chemical programs.

2 Major Pests and Diseases and Control Requirements in Hangbaiju

2.1 Major diseases and their characteristics

Hangbaiju disease management is best understood as a set of "risk windows" rather than a static list. Soil-borne diseases (wilt, root rots, blights under continuous cropping or soil fatigue) tend to build over time and intensify when production becomes more intensive, while foliar diseases fluctuate with weather, canopy density, and late-season management. The broad chrysanthemum review for 2015–2025 emphasizes that fungal pathogens cause leaf spot, wilt, rust, blight, and rot, affecting both yield and quality, and that improved molecular identification is changing how these diseases are classified and managed (Chen et al., 2025).

A key disease point that is directly relevant to Hangbaiju biological control is the wilt complex linked to Fusarium. The Hangbaiju-focused study in the Chinese Journal of Biological Control identifies the wilt pathogen for chrysanthemum as Fusarium incarnatum based on morphological and ITS sequence analysis, highlighting that "Fusarium wilt caused huge yield loss" and framing accurate identification as the foundation for effective control. This is important for practice: if the pathogen is misidentified, chemical or biological choices can be mismatched, leading to costly failures.

For Hangbaiju leaf and flower quality, foliar disease pressure is also significant, but accessible open literature in this query is more detailed on insect contamination than on leaf-spot epidemiology within Tongxiang fields. In such cases, a practical review approach is to focus on biological-control principles that are robust across multiple foliar pathogens—preventive microbiome support, canopy microclimate management, and the use of antagonists with broad-spectrum suppression—rather than overfitting recommendations to one pathogen that may not be uniformly dominant across production bases (Chen et al., 2025).

2.2 Major insect pests and their damage patterns

The insect damage profile of Hangbaiju has one unusual, market-critical feature: pests can directly contaminate the harvested flower product. The bloom-stage aphid case is the clearest example. Cao and colleagues describe M. sanborni as feeding on flowers and hiding within them, then being harvested and remaining in processed