with a complex aphid sexual attractant had a control effect "significantly superior" to spraying imidacloprid, while also offering a non-spray alternative during the sensitive bloom period. This is one of the most concrete Hangbaiju-linked comparisons accessible in the present evidence set (Cao et al., 2024).

4.4 Economic benefits and application value

Without inventing cost or profit data, the most responsible way to discuss economic benefits is to focus on mechanisms by which biological control can create value and on the accounting framework growers or cooperatives can use to evaluate interventions.

In Hangbaiju, value creation can occur through (i) preventing stand loss from soil-borne diseases, (ii) stabilizing harvestable flower quantity within the narrow harvest window, and (iii) protecting marketability via reduced contamination or defect rates (such as aphid bodies in tea infusion). The available Hangbaiju aphid study is explicitly framed around consumer experience and product contamination, implying that pest suppression can translate into better product acceptance even if biomass yield changes are not reported (Cao et al., 2024). A practical field evaluation can compute the net benefit of a biological control package as:

$$\Delta \Pi=(Y_b \cdot P_b - C_b)-(Y_c \cdot P_c - C_c)$$

where Y is saleable yield (not just biomass), P is price (often quality-graded), and C is total control cost (inputs + labor + application time). For Hangbaiju, "saleable yield" should be adjusted for contamination defects and harvest timing losses, reflecting the narrow harvest window reported for Tongxiang (Zang et al., 2023).

From a technology-adoption standpoint, biological control has application value when it reduces operational risk. The Bacillus meta-analysis suggests that preventive applications can deliver stronger control, and the Trichoderma–bacteria synergy review emphasizes that compatibility and formulation are key for performance—both points underscore that economic benefit depends on reliable, scalable delivery rather than theoretical efficacy alone (Table 1) (Serrão et al., 2024).

5 Case Study

5.1 Background of the case

This case study is organized around Tongxiang-linked Hangbaiju production constraints and two documented control problems that directly link pest pressure to product acceptance: bloom-stage aphid contamination and soil-borne wilt risk. Tongxiang, Zhejiang is repeatedly referenced in accessible Hangbaiju literature as a major production region, and a surveyed expansion to nearly 4000 hm^2 with a narrow ≈25-day harvest window underscores why these problems are operationally disruptive (Zang et al., 2023).

The planting and management context highlighted in the accessible studies reflects typical field constraints: dense plantings that complicate scouting and treatment precision, strong dependence on short-term labor availability during harvest, and high sensitivity of marketability to defects that are visible in the brewed tea. In this setting, "management practice" is not only a set of agronomic steps but also an implicit risk strategy: preventing late-season emergencies that cannot be safely or economically solved during the harvest rush (Figure 3) (Zang et al., 2023).

Pest and disease occurrence in this case is characterized by (i) a bloom-stage aphid (*Macrosiphoniella sanborni*) that hides within flowers and can be harvested with the product, and (ii) Fusarium-associated wilt, with evidence indicating *Fusarium incarnatum* as a causal agent in chrysanthemum wilt cases, driving interest in microbial antagonists or metabolite-based control (Cao et al., 2024).

5.2 Implementation of biological control measures

The core implementation evidence here comes from two peer-reviewed studies that address different control windows but are complementary in an integrated Hangbaiju program.