Comparison with conventional chemical control can be framed as follows. Aphid control: the trap-based approach outperformed imidacloprid spray in field effectiveness (as reported). Wilt management: microbial metabolites provide protective/therapeutic effects but are better framed as preventive tools than emergency cures, unlike some chemical fungicide programs. This difference is not a disadvantage; it is a design constraint that integrated programs exploit by shifting part of control earlier in the season, when intervention is easier and less risky for product quality (Cao et al., 2024).

5.4 Yield and economic benefit analysis

The accessible bloom-stage aphid study does not report yield gains in kg or yield loss avoided; it is primarily framed around control efficacy and "clean product" outcomes. For Hangbaiju, however, product acceptance is a form of economic yield. If infestation leads to aphid bodies in tea infusion and consumer rejection, then reducing adult aphids during bloom protects not only flowers but the market pathway that turns those flowers into revenue. In this sense, the economic benefit is plausibly concentrated in reduced defect rate and improved consumer acceptance, even if biomass yield is not explicitly measured (Cao et al., 2024).

For the wilt study, the phrase "huge yield loss" is used to motivate the work, but the accessible search-level summaries emphasize pathogen identification and biocontrol effect estimation rather than a complete farm-economics dataset. Without inventing numbers, the economic logic should be expressed as risk reduction: effective preventive microbial control reduces stand loss probability and stabilizes plant health, which can preserve harvestable flowers within the narrow harvest window described for Tongxiang.

A practical on-farm evaluation can combine (i) avoided spray costs during bloom due to trap deployment, (ii) reduced labor and compliance risk from late chemical applications, and (iii) avoided revenue loss from downgraded or rejected product. This can be calculated using simple farm accounting (Section 4.4), but the present review does not assign numerical values without traceable reports (Cao et al., 2024).

5.5 Case summary and practical insights

First, timing is not a minor detail; it is the structure of effectiveness. Trap-based control is matched to the bloom-stage contamination risk and can outperform a conventional spray in that stage, while microbial disease suppression is most credible as a preventive input rather than a last-minute cure.

Second, combination strategies succeed when they combine different mechanisms rather than duplicating the same mechanism. The aphid strategy combines visual and olfactory cues; microbial strategies combine antagonism and induced resistance; botanical tools combine feeding deterrence and growth disruption with relatively low impact on beneficials. Integrated programs that mix these mechanisms are less likely to fail from a single weak link (such as poor spray coverage or short persistence) (Cao et al., 2024).

Third, scalability depends on formulation and farmer-facing simplicity. The Trichoderma–bacteria synergy review explicitly notes compatibility and formulation as key steps. In Hangbaiju, where harvest labor and timing are already tight, a biological strategy that adds complex, frequent operations is unlikely to be adopted widely, even if biologically "promising" (Poveda and Eugui, 2022).

6 Existing Problems and Limitations

6.1 Instability of control effects

A recurrent critique of biological control is "instability," but much of this instability is predictable when the control tool is deployed in a way that contradicts its mode of action. The Bacillus meta-analysis shows that protective inoculation tends to outperform therapeutic application, implying that using microbial tools only after disease has surged will systematically produce disappointing results (Serrão et al., 2024).

Similarly, botanical insecticides can show variable results when pest population stage structure and plant developmental stage shift. The botanical insecticide chrysanthemum trial describes that aphid populations and their spatial distribution changed across plant developmental stages, and different botanical treatments produced different responses. This suggests that timing and concentration are not optional details but the determinants of whether botanicals behave as reliable tools (Hutapea et al., 2024).