Natural-enemy–based control can also appear unstable when environmental conditions exceed the organism's tolerance or when pesticide programs unintentionally remove the enemies. Even in the successful thrips control study, the authors note very high summer temperatures and still report effective suppression, but this is a reminder that natural enemies have climatic and ecological requirements that must be built into the management plan (Jung et al., 2019).

6.2 Influence of environmental conditions

Hangbaiju is field-grown in complex outdoor scenes where light, shade, wind, and plant overlap are significant enough that even computer vision studies treat these as major confounding factors. From a biological control perspective, the same field complexity translates into microclimate variation: humidity pockets, shading effects on leaf wetness duration, and uneven coverage for sprays or microbial applications (Zang et al., 2023). Botanical pesticides' low residual power—identified as a strength for safety and selectivity—can also be a limitation under heavy rainfall or intense sunlight, where persistence may be too short to control rapidly reproducing pests. The azadirachtin review emphasizes low residual power and also discusses practical problems of application and the need for improved stability or controlled release approaches (Kilani-Morakchi et al., 2021).

Microbial agents likewise depend on environmental fit. Survival, colonization, and antagonistic activity vary with temperature, soil moisture, organic matter, and interactions with resident microbiota. This is one reason why consortium approaches and formulations are central in current research: not because single strains are uninteresting, but because field stability often requires buffering against environmental variability (Poveda and Eugui, 2022).

6.3 Technical promotion challenges

Promoting biological control in Hangbaiju is partly a technology-transfer challenge. Many tools require (i) quality-controlled products, (ii) correct timing, and (iii) operational discipline (monitoring, threshold decisions, record keeping). These requirements can conflict with smallholder constraints or with rapid expansion of planting area where extension services cannot keep up.

The Tongxiang survey cited in the dataset paper explicitly notes labor constraints during the short harvest window, which implies that a biological control program that demands intensive late-season operations is less likely to be adopted. In other words, technical promotion requires designing programs that reduce complexity during the most labor-constrained period, not adding new chores (Zang et al., 2023).

Compatibility across measures is another promotion challenge. For example, botanicals may be "low toxicity" to natural enemies in general, but actual compatibility depends on formulation, dose, and life stage of beneficial organisms. The azadirachtin review notes that neem-based insecticides can have slight to moderate toxicity and that pre-imaginal stages may be more susceptible in laboratory conditions, implying that real-world programs must be designed with selectivity awareness rather than assuming universal safety (Kilani-Morakchi et al., 2021).

6.4 Cost and farmer awareness issues

Biological control is often perceived as costly because benefits are distributed across time: preventive microbial inoculation may prevent future losses but does not always produce immediately visible "knockdown," and conservation biological control produces diffuse benefits that are harder to attribute to a single purchase.

However, cost perception also depends on what the farmer is optimizing. In Hangbaiju, where consumer rejection from contaminants can erase value quickly, investments in bloom-stage non-spray control (like trapping) may be economically rational even if they do not increase biomass yield. The bloom-stage aphid study provides an unusually direct link between pest presence and consumer experience, which can be used in extension messaging to reframe cost-benefit discussions around product acceptance, not only yield (Cao et al., 2024).Farmer awareness is also tied to clarity of protocols. The most adoptable approaches tend to have simple rules: when to apply, how often, and what success looks like. The more biological control relies on complex, multi-step mixtures or frequent monitoring without accessible decision support, the more it risks underuse or misuse—both of which produce "instability" that is actually a training and support failure (Poveda and Eugui, 2022).