disease establishment. These findings map directly onto Hangbaiju field realities: if application is delayed until symptoms surge near harvest, biological control often appears "unstable," but when microbial tools are integrated earlier as preventive management, performance is more reliable (Serrão et al., 2024).

A Hangbaiju-specific microbial-control example is the use of Streptomyces diastatochromogenes 1628 metabolites against Fusarium-associated wilt. In the Chinese Journal of Biological Control report, metabolites of *S. diastatochromogenes* 1628 were tested against *Fusarium incarnatum* (identified as the pathogen), with pot-trial results reporting both protective and therapeutic effects after 14 and 28 days, with protective efficacy higher than therapeutic efficacy. This pattern aligns with the broader meta-analysis conclusion that preventive use tends to be stronger than "curative" use once disease is established.Technologically, the field is also moving toward multi-microbe or consortium approaches. Poveda and Eugui argue that Trichoderma–bacteria co-inoculations can produce synergistic benefits, sometimes approaching chemical-pesticide outcomes, but they emphasize formulation and compatibility as key steps for real-world adoption. For Hangbaiju, this highlights a practical boundary: the most promising microbial agents are not always the most deployable unless they are formulated for local transport, storage, and farmer-friendly application schedules (Poveda and Eugui, 2022).

3.2 Botanical pesticides

Botanical pesticides occupy a strategic middle ground for Hangbaiju: they can reduce reliance on broad-spectrum synthetics while maintaining the operational simplicity of spray-based programs. Yet botanical pesticides are not inherently "weak"; the best ones have distinct modes of action and can be embedded into IPM programs as selective tools.

Azadirachtin (from neem) is one of the most globally recognized botanical insecticides. In a 2021 review, it is characterized as a potent antifeedant and insect growth disruptor with low residual power and relatively low toxicity to many biocontrol agents, predators, and parasitoids, a profile that fits integrated programs where natural enemies are valued rather than collateral damage. The same review also notes practical limitations, including stability and the need for strategies (including formulation innovations such as nano-enabled delivery) to control release rate and improve field persistence (Kilani-Morakchi et al., 2021).

Evidence from chrysanthemum-focused trials shows that plant extracts can achieve meaningful suppression of aphids under protected cultivation. In a 2024 study evaluating several botanical insecticides against *Aphis gossypii* on chrysanthemum (plastic house conditions), the extract of *Chrysanthemum cinerariaefolium* at 3.0 and 3.5 g/L achieved reported average efficacy values of 76% and 72%, respectively, and was described as the most consistent treatment among those tested. This is important for Hangbaiju because it illustrates a realistic control magnitude for botanicals—strong enough to be operationally relevant, especially when combined with monitoring, sanitation, and conservation biological control (Hutapea et al., 2024).

Botanical tools also connect to the chrysanthemum plant's own defense chemistry. Research on pyrethrum flowers shows that producing aphid alarm pheromone can repel herbivores and recruit carnivores, illustrating how plant-derived signals and compounds can function simultaneously as direct defense and as ecological regulation. While pyrethrum is not Hangbaiju, the principle is transferable: integrated programs can combine plant-derived chemistry, physical trapping, and natural enemies without relying on a single "silver bullet" insecticide (Hutapea et al., 2024).

3.3 Utilization of natural enemies

Natural-enemy utilization in chrysanthemum production spans augmentative release (adding commercially produced natural enemies) and conservation biological control (managing habitats, nectar resources, refuges, and pesticide selectivity to sustain resident enemies). Hangbaiju is largely field-grown, which can make repeated augmentative releases less predictable than in controlled greenhouses; nonetheless, greenhouse studies still provide valuable mechanistic guidance for timing and target life stages.