maximized stem diameter, branching, leaf area, and flower yield, indicating that topped plants benefit from stronger nutrient support once apical dominance is removed (Thakare et al., 2020). Comparable synergy appears with growth regulators: double pinching with triacontanol improved vegetative and floral parameters in cv. Pusa Kesari, while GA_3 at 300 ppm combined with pinching at 40 days improved leaves, flowers, and yield per hectare in Punjab conditions.

8.3 Simplified and precision pruning technologies for Hangbaiju

For Hangbaiju, the main production challenge is that branch promotion has traditionally depended on repeated manual decapitation, which is labor-intensive, costly, and associated with higher disease risk. This makes simplified pruning a practical necessity rather than only a refinement of crop management. Because Hangbaiju flowers are borne at branch termini, any simplified pruning method must still preserve high branch numbers if yield is to be maintained. A useful production direction is therefore to replace some manual topping operations with growth-regulating strategies that mimic the branching effect of repeated decapitation while reducing labor inputs.

Current evidence suggests that precision branch regulation in Hangbaiju can be achieved by combining fewer physical interventions with targeted chemical control. In pot-grown Hangbaiju, foliar application of 6-BA combined with Pro-Ca increased flower yield, and the highest yield was recorded in the 6-BA5 + Ca100 treatment in both experimental years. This approach is attractive for precision cultivation because the untreated control still relied on three manual decapitations, whereas the regulator-based system was explicitly tested as an alternative branch-management technology. Beyond yield, Hangbaiju stems are themselves a usable by-product rich in phenolic compounds, so pruning systems that standardize shoot removal could also improve residue collection and downstream valorization (Zhu et al., 2024). Overall, optimized Hangbaiju production depends on choosing the topping method that matches the production objective, then integrating it with spacing, nutrient scheduling, and labor-saving branch regulation. For most commercial loose-flower systems, moderate or repeated topping appears most effective for maximizing productive branching, but simplified precision approaches are likely to be the most sustainable long-term strategy for Hangbaiju.

9 Conclusions and Perspectives

Different topping methods consistently reshaped Hangbaiju architecture by weakening apical dominance and promoting axillary bud outgrowth. Single topping usually produced a moderate increase in branch number and canopy spread, while repeated topping generated more primary and secondary branches and a denser shoot system. The overall pattern shows that topping intensity controls how strongly vegetative growth is redirected from the main stem to lateral shoots. The branching response also depended on topping timing. Early topping tended to trigger earlier and stronger lateral bud release, whereas later or repeated topping often produced a more compact but more highly branched plant type. These differences indicate that branch formation is not determined by topping alone, but by the interaction between pruning intensity, developmental stage, and cultivar response.

Topping influenced flower yield mainly by changing the number of flowering branches and the balance between vegetative growth and reproductive development. Moderate topping often improved total flower number and yield because it increased the number of terminal flowering sites without excessively delaying flowering. In contrast, no topping favored earlier bud initiation and larger individual flowers, but generally produced fewer flowers per plant. Repeated topping usually increased total yield more strongly than single topping when the production goal was loose-flower output. However, too many topping events could prolong the vegetative phase and redistribute assimilates across too many shoots, which may reduce uniformity or delay harvest. The best treatment therefore depends on whether the target is early flowering, large flowers, or maximum total flower yield.

Current evidence still has several limitations. Most studies focus on a limited number of topping schedules, cultivars, and environments, so results cannot be generalized to all Hangbaiju production systems. Many reports also emphasize morphology and yield, while fewer examine hormone regulation, carbon allocation, canopy photosynthesis, and long-term field performance in an integrated way. Future research should combine topping with plant density, fertilization, irrigation, and growth-regulator management to define optimal production