branching under later pinching rather than the unpinched control (Chandio et al., 2023). For Hangbaiju, the most reasonable conclusion is that the optimal topping method is the one that maximizes productive branching without imposing excessive delay or over-fragmenting assimilates among too many shoots. A case study built on these comparisons would therefore be well positioned to identify whether single early topping or two-time topping gives the best balance for branch formation and flower yield in *Chrysanthemum morifolium*.

7 Integrated Mechanisms Underlying the Effects of Different Topping Methods on Flower Yield

7.1 Release of apical dominance and branching compensation

Different topping methods first act by removing the active shoot apex, thereby weakening apical dominance and releasing suppressed axillary buds. In chrysanthemum, bud outgrowth is strongly governed by apical control, and removal of the shoot apex or floral transition releases lateral buds from inhibition. The same mechanism is supported by decapitation studies showing that intact plants maintain repressed lateral buds because the apex sustains height growth and suppresses bud activity through weak sugar absorption and limited auxin export from buds. After decapitation, those buds break dormancy by exporting more auxin and importing more sugar, which explains why topping rapidly initiates compensatory branching rather than merely stopping stem elongation (Sun et al., 2021).

This compensatory response is regulated by a coordinated hormone–sugar network rather than by auxin alone. In chrysanthemum, release from apical dominance coincides with decreased auxin and increased cytokinin in subapical buds, together with reduced expression of branching repressors such as CmBRC1 and CmMAX1. More broadly, rapid cytokinin accumulation after tip removal appears to be associated with enhanced sugars during the early bud-release phase, while gibberellin contributes more strongly to sustained post-release growth (Cao et al., 2023). This staged view helps explain why stronger or repeated topping usually increases branch number: each removal event reopens dormant buds and renews competitive branch establishment across the canopy.

7.2 Canopy restructuring and photosynthetic productivity

Once buds are released, topping reshapes the canopy by reducing vertical dominance and expanding lateral spread, which changes light interception and the distribution of assimilatory surface. Field studies in chrysanthemum show that no pinching generally maintains the greatest plant height, whereas pinching at 30-40 days after transplanting increases branch number, stem girth, or plant spread depending on treatment timing. Repeated pinching intensifies this structural shift, producing shorter but wider and more highly branched canopies than the control (Ehsanullah et al., 2021). Because canopy architecture governs internal light distribution and resource-use efficiency, these morphological changes are not only geometric but functional for biomass production and flower formation.

The physiological benefit of canopy restructuring depends on whether added branches improve productive light capture more than they increase self-shading. Moderate canopy closure in edible chrysanthemum improved photosynthesis-related traits and increased flower yield, showing that a partially moderated light environment can enhance rather than reduce productivity. In Hangbaiju, branch-promoting regulation by 6-BA plus Pro-Ca increased leaf chlorophyll content and raised flower yield, indicating that architectural control and leaf physiological status can improve together during the floral growth phase. Topping therefore raises yield most effectively when it creates a canopy with enough lateral leaf area and branch spread to intercept light efficiently without imposing excessive mutual shading or an overly long vegetative delay.

7.3 Coupling mechanisms of branch formation, flower bud differentiation, and yield formation

The yield effect of topping ultimately depends on how newly formed branches are converted into reproductive shoots. In Hangbaiju, flower yield depends strongly on shoot branch number because flowers are borne terminally, so each additional successful branch can become an added inflorescence-bearing unit. Across chrysanthemum genotypes, branching and flowering traits vary together, and highly branching material can also show high flower number per plant, confirming that reproductive output is closely tied to shoot architecture rather than to stem elongation alone (Bala and Kaur, 2026). At the developmental level, axillary meristem formation is itself a