

Tea-applied chrysanthemum showed a related pattern at the production scale: two-time pinching produced the highest crown width, flower number, fresh mass, yield per plant, and yield per unit area, while postponing pinching reduced plant height, and a separate factorial study found that the statistical interaction between planting time and pinching was non-significant for measured flowering and yield traits, suggesting that pinching timing matters greatly but does not always interact strongly with calendar planting date (Thumar et al., 2020). Overall, different topping methods regulate Hangbaiju through a common developmental mechanism: removal of terminal dominance promotes lateral shoot growth, but the agronomic outcome depends on how many times, how early, and at which hierarchical positions the plant is pinched. For practical flower production, single topping tends to provide a balanced canopy response, whereas repeated or hierarchically optimized topping is more suitable when maximizing branch number and total flower yield is the primary goal.

4 Effects of Topping Treatments on Branch Formation and Canopy Structure of Hangbaiju

4.1 Changes in plant height, stem diameter, and internode characteristics

Topping consistently suppresses vertical elongation in chrysanthemum by removing the active apex and weakening apical dominance, so unpinched plants generally remain the tallest while topped plants become shorter and more compact. In annual chrysanthemum, no pinching produced the greatest plant height, whereas pinching at 30 or 40 days after transplanting significantly reduced height, showing that even a single topping event can redirect growth away from the main axis (Nagdeve et al., 2021). More intensive topping strengthens that effect, as thrice-pinched plants were much shorter than unpinched controls in field-grown chrysanthemum. A similar pattern appears in treatment combinations with growth regulators, where double pinching at 25 and 40 days gave the shortest plants, again indicating that repeated apex removal limits internode extension.

Stem thickening and shortening of the canopy framework often accompany reduced plant height after topping. Pinching at 40 days increased stem girth compared with no pinching in annual chrysanthemum, suggesting that reduced longitudinal growth is associated with stronger radial development. A newer study likewise found that pinching increased stem diameter while no pinching maintained the greatest height, reinforcing the trade-off between elongation and structural robustness (Mangulal et al., 2025). Internode behavior follows the same trend, because the longest internodal distance was recorded in unpinched plants, while stronger pinching shifted plants toward shorter, denser shoot architecture. Nitrogen-interaction results support this interpretation: maximum stem diameter, branch number, plant spread, and leaf area occurred under pinching with adequate nitrogen rather than under the tallest no-pinching treatment.

4.2 Formation of primary, secondary, and higher-order branches

The most direct architectural consequence of topping is the release of axillary buds, which increases the number of primary branches and creates the structural basis for secondary and tertiary branching. In *Chrysanthemum morifolium* cv. Ratlam Selection, pinching at 30 days after transplanting produced the highest branch number throughout growth, consistent with the view that early apex removal stimulates lateral bud outgrowth. In another chrysanthemum study, pinching increased primary and secondary branch numbers together with stem diameter and plant spread, showing that lateral activation is not confined to one branch order. Hormone evidence supports the same mechanism: cytokinin treatment increased chrysanthemum branch number and lateral bud diameter, whereas auxin and strigolactone treatments inhibited branching (Wang et al., 2024).

As topping intensity rises, branch hierarchy becomes progressively more complex, but the strongest increase in branch order does not always coincide with the best overall flower yield. Double pinching maximized primary branches and flower number in annual chrysanthemum, indicating that two sequential releases from apical control can amplify reproductive shoot formation. In spray-type chrysanthemum, pinching three times at 30, 40, and 50 days produced the highest primary, secondary, and tertiary branch numbers, demonstrating a clear cumulative effect of repeated pruning on branch hierarchy. Genetic and architectural analyses further show that upper primary branch number and total lateral bud production are highly variable chrysanthemum traits and are sensitive to environment, which helps explain why topping responses differ among cultivars and production systems (Sun et al., 2022). Even so, branch proliferation has practical limits, because larger individual flowers are often retained in