enhance branching often improve flower production per plant. Quantitative studies support that pattern: pinching at 30 days after transplanting increased branches and flower yield in annual chrysanthemum, while double or repeated pinching often produced even more branches and flowers than no pinching. At the same time, the response is not one-dimensional. No pinching can advance bud initiation and flowering and often gives larger individual flowers, whereas more intensive pinching tends to delay flowering and reduce single-flower size even as total flower number rises (Mohanty et al., 2025). Some studies likewise show that double pinching maximizes flower count but not necessarily flower yield by weight or economic return, because single pinching at the right stage can outperform double pinching for total harvested mass and benefit-cost ratio). This means the agronomic value of topping depends not only on whether pinching is applied, but on how many times it is done and when it is imposed.

That variability is exactly why research on different topping methods remains necessary for Hangbaiju. Existing chrysanthemum evidence shows that the optimal pinching regime differs with genotype, production target, and associated cultivation conditions. In *Chrysanthemum morifolium* cv. Ratlam Selection, pinching at 30 days after transplanting promoted branch number and plant spread, indicating that early topping can strongly improve branch formation in the same species targeted here. In other chrysanthemum types, however, double pinching produced the highest numbers of flowers or branches, while single pinching sometimes gave the best balance among yield, flower quality, and plant form. Studies that combined pinching with growth regulators or nitrogen further indicate that topping effects interact with crop management background, affecting not only branching but also leaf area, stem thickness, flowering span, and total yield. This broader evidence suggests that a topping treatment cannot be assumed optimal across all production systems, and recommendations developed for annual chrysanthemum, spray chrysanthemum, or pot types may not transfer directly to Hangbaiju grown for capitulum harvest. A focused study on different topping methods in Hangbaiju is therefore significant for both theory and practice: theoretically, it helps clarify how manipulation of apical control shapes branch formation and yield allocation in *C. morifolium*; practically, it can identify a topping regime that improves flower-head production while balancing flowering time and plant architecture for commercial cultivation. On that basis, the present study examines the effects of different pinching treatments on branch formation and flower yield of *Chrysanthemum morifolium* to provide a more targeted foundation for efficient Hangbaiju production.

2 Biological Basis of Growth and Branch Formation in Hangbaiju

2.1 Characteristics of vegetative and reproductive growth in Hangbaiju

Hangbaiju is a perennial short-day chrysanthemum in which vegetative growth and reproductive transition are tightly connected to production performance. In chrysanthemum, substantial variation exists in plant height, spread, branching, and flowering behavior among genotypes, indicating that branch architecture is a biologically variable trait rather than a fixed cultivar feature (Bala and Kaur, 2026). In Hangbaiju specifically, flowers are borne at the tops of branches, so shoot architecture directly determines the capacity for reproductive output and final harvestable flower number.

The transition from vegetative to reproductive growth also changes the pattern of meristem activity along the shoot. In one chrysanthemum genotype that underwent floral transition, the apex shifted from vegetative growth at the early stage to floral transition and then stopped initiating new axillary buds, showing that reproductive development restructures further branch initiation potential. Photoperiod studies support the same trade-off, because conditions favoring stronger vegetative growth increased branch and leaf formation, whereas greater flower induction tended to coincide with reduced branch or leaf production as resources and developmental priority shifted toward reproduction (Yang et al., 2024).

2.2 Apical dominance and axillary bud development

The biological basis of branch formation in chrysanthemum begins with apical dominance, whereby the active shoot tip suppresses outgrowth of axillary buds below it. During vegetative growth, chrysanthemum plants show short inhibited buds near the apex, and this pattern is a direct expression of apical control over lateral development. More generally, axillary branch development proceeds through bud formation, bud release or dormancy, and bud