unpinched controls while more heavily pinched plants distribute assimilates across a greater number of flowering shoots.

4.3 Canopy structure and light energy utilization

Once topping increases lateral branching, its importance extends beyond branch number to the three-dimensional structure of the canopy. In flower crops, canopy architecture regulates microclimate, light interception, and resource-use efficiency, and traits such as plant height, branching pattern, and foliage distribution determine how light is distributed within the canopy (Nateshkumar et al., 2025). This is directly relevant to Hangbaiju because topping changes exactly those structural traits, especially canopy width and branch arrangement. Studies in chrysanthemum repeatedly show that pinching increases plant spread, with early pinching often producing the broadest canopy and repeated pinching producing the most expanded crown.

Broader canopy-physics studies clarify why these structural changes matter for light-energy utilization. Light interception and biomass production depend not only on total leaf area but on how radiation penetrates the canopy, with smaller or more open canopies often showing better penetration per unit leaf area, while excessive mutual shading reduces efficiency. Branch angle, internode spacing, and pruning pattern also alter light capture, and simulated canopies show that pruning and reshaping can improve PAR distribution and photosynthetic performance by reducing self-shading (Ran, 2025). Crop-level evidence reaches the same conclusion: optimizing canopy structure improves photosynthesis and yield by improving light-interception distribution within the stand rather than merely increasing vegetative mass. Overall, Hangbaiju topping treatments influence yield formation through a linked sequence of effects: reduced main-stem elongation, enhanced multi-order branching, and reorganized canopy light capture. The most favorable treatment is therefore unlikely to be the one that produces either the tallest plants or the greatest branch number alone, but the one that builds a canopy with efficient branch distribution and effective internal light use.

5 Effects of Topping Methods on Physiological Characteristics and Flower Bud Formation in Hangbaiju

5.1 Leaf photosynthetic characteristics and assimilate accumulation

Different topping methods influence leaf physiological status mainly by changing source–sink balance and canopy development. Pinching generally increases leaf number, and repeated pinching often produces the largest leaf display, indicating stronger assimilatory surface development than in unpinched plants (Ehsanullah et al., 2021). In combination treatments, double pinching also increased leaf area, leaf area index, and leaf area duration, showing that topping can extend the functional photosynthetic surface available for assimilate production.

These structural changes are accompanied by physiological adjustments associated with assimilate accumulation. Single pinching produced the highest leaf area in one annual chrysanthemum study, whereas double pinching maximized branch proliferation, suggesting that moderate topping can favor leaf-level assimilatory capacity while stronger topping favors redistribution into new sinks. Leaf chlorophyll intensity also increased under repeated pinching, which supports the view that topping can enhance the photosynthetic competence of remaining foliage even while delaying reproductive advance.

5.2 Carbon and nitrogen metabolism and dry matter allocation

The effects of topping on carbon and nitrogen metabolism are best understood through changes in assimilate redistribution after the shoot apex is removed. Pinching redirects carbohydrates toward axillary buds and developing lateral shoots, which explains the common increase in branching and canopy expansion after treatment. A related flowering-yield study similarly noted that in pinched plants, energy was shared among developing side branches rather than being concentrated mainly in the main stem, indicating a basic shift in assimilate allocation pattern.

Chrysanthemum dry-matter studies show why this redistribution matters for flower production. During normal growth, dry-matter accumulation continues through inflorescence development, and the developing inflorescence becomes a strong assimilate sink, while nitrogen accumulation peaks earlier and later demand is increasingly met