

Other production-efficiency case studies combine thinning with pruning or irrigation management. Under the traditional Fujian pruning system, about half of the panicles are thinned, but double-heading pruning was developed to conserve nutrients in the remaining shoots and produced larger fruit together with higher yield. In water-limited orchards, preharvest deficit irrigation interacted with crop-load management in a different way: heavier thinning was not required under the mild stress conditions tested, and four fruits per panicle still provided the highest revenue while saving irrigation water. A related irrigation case study further showed that a short preharvest deficit-irrigation program could produce sweeter, earlier fruit with better handling performance, although excessive water restriction reduced fruit size (Hueso et al., 2021). Overall, the case-study evidence shows that loquat thinning works best as targeted crop-load regulation rather than simple fruit removal. Across different cultivars and management systems, moderate-to-strong thinning improves fruit size and market quality, but the best commercial outcome usually comes from combining appropriately timed thinning with bagging, pruning, or irrigation strategies suited to local production goals.

8 Challenges and Future Research Directions in Loquat Fruit Thinning Technology

8.1 Current limitations in the application of fruit thinning techniques

Manual thinning remains the most precise option in loquat, but its main weakness is that it is slow, labor-intensive, and expensive. In loquat, hand thinning is still valued because it can control the number of retained fruits more effectively than chemical or mechanical alternatives, yet this precision depends on trained labor and raises production costs. Earlier loquat studies reached the same practical conclusion, describing hand thinning as a slow and expensive operation that restricts wider commercial expansion. Manual thinning is also limited by its timing and biological variability. Late hand thinning in loquat has been described as of limited usefulness because it is commonly performed after a substantial part of the competitive phase among fruits has already occurred. Even when thinning is effective, results vary with cultivar, season, and orchard conditions, and recent loquat field work explicitly notes that climate, thinning timing, intensity, and other cultural practices all interfere with final fruit properties (Nordi et al., 2025).

Chemical thinning can reduce labor demand, but its commercial use in loquat is constrained by narrow margins between effective and excessive thinning. NAA responses in ‘Golden Nugget’ were closely dose-dependent, with the highest doses producing the largest fruits but also the lowest yield per tree. NAA_m offers a partial alternative, since end-of-bloom applications increased fruit diameter and only slightly reduced total yield, but thinning rates remained variable within trees, which weakens predictability at orchard scale. Beyond efficacy, current thinning methods also create broader operational and biological constraints. Mechanized orchard thinning in other fruit crops still often relies on subjective operator judgment for speed, spindle rotation, and working distance, which results in low precision and uncertain damage to non-target tissues (Lei et al., 2023). In loquat specifically, stronger thinning can improve size and sweetness, but it has also been associated with higher purple spot incidence, showing that quality gains can be accompanied by physiological risk.

8.2 Development trends of precision fruit thinning technologies

A clear development trend is the shift from uniform thinning toward precision crop-load management based on sensing, detection, and tree-specific decisions. In apple systems, rapid and accurate fruitlet detection before thinning is already considered essential for early yield estimation and automatic thinning. The same logic is now extending to decision systems that support thinning timing and fruit-removal choices under natural orchard conditions, with recent models showing real-time detection performance suitable for automated management (Wang et al., 2025). The technical foundation of this trend is machine vision. Deep-learning systems can now segment fruitlets and canopy structures with high precision and low inference time, which is a prerequisite for selective thinning under complex orchard conditions (Sapkota et al., 2023). However, current vision systems still face persistent challenges from occlusion, clustered fruits, variable illumination, and incomplete spatial information, and 2D-only pipelines lose useful depth cues that could improve thinning decisions.

A second trend is the integration of perception with robotic or variable-rate actuation. Field-tested robotic blossom-thinning platforms have already shown targeted thinning of selected clusters, but commercial deployment