interactions instead of treating years of continuous cultivation alone as the decisive risk factor. For *P. lactiflora*, that implies practical use of organic matter enhancement, pH and nutrient correction, avoidance of repeated hole replanting, and introduction of beneficial microbes such as *Bacillus*, which are biologically aligned with the mechanisms identified in replant soils (Xie et al., 2023).

4.3 Growth-stage precision management and quality improvement technologies

Growth-stage precision management should match perennial peony's temperature-dependent developmental stages, from dormancy release and sprouting to flowering, harvest, and post-harvest handling. Bud dormancy release is a major control point in warm-winter regions: high winter temperatures hinder flowering, while 'Hang Baishao' succeeds because of its lower chilling requirement, and chilling at 0~4℃ for four weeks plus 300 mg/L humic acid improved flowering advancement and quality under forcing conditions (Zhang et al., 2019b). Protected cultivation can then regulate harvest windows: high tunnels advanced first harvest by 21-34 days with yields of 15.7~19.4 stems/m², field plots yielded 16.1~20.8 stems/m², and combining both systems extended harvest duration to 38 days, although low tunnels with soil heating sometimes reduced quality because excessive temperature and humidity damaged buds and increased pest and disease pressure (Lewis et al., 2023).

Quality improvement also depends on stage-specific regulation of plant architecture, harvest age, and post-harvest processing. Paclobutrazol reduced plant height and crown width but increased stem diameter, leaf thickness, chlorophyll, water status, soluble sugar, and antioxidant enzyme activity, and improved flower diameter and fresh weight when applied at the flower-bud stage, although it also reduced anthocyanin content and total aroma compounds under some other application timings. For medicinal root production, the best combined yield-quality outcome was region-specific but clear in Tongliao: 4-year-old plants performed best, late September of the fourth year was the optimal harvest window, shade drying gave the highest quality, and paeoniflorin correlated positively with root dry weight (Guo et al., 2026). Wild-like cultivation adds a useful ecological option, because paeoniflorin content and product traits increased year by year under simulated natural conditions, while varietal metabolomics showed that root quality traits such as paeoniflorin, total phenols, flavonoids, and antioxidant capacity differ systematically among cultivars and are linked to rhizosphere microbial composition (Wu et al., 2025).

5 Optimization Strategies for Perennial Cultivation Models of *Paeonia lactiflora*

5.1 Establishment of a collaborative optimization model integrating cultivar selection, environmental adaptation, and cultivation management

A collaborative optimization model for perennial *P. lactiflora* should begin with cultivar stratification by adaptation traits, because low-latitude expansion is constrained by warming, humidity, and insufficient winter chilling. Multi-criteria screening identified 'Meiju', 'Hang Baishao', 'Hongpan Tuojin', and 'Bo Baishao' as Level I germplasm with strong adaptability and ornamental value under hot-humid conditions (Figure 2) (Wang et al., 2022). Chilling-requirement studies further showed that 'Hang Baishao' and 'Qihua Lushuang' are representative low-CR cultivars, and the Utah model was the most dependable framework for evaluating cultivar chilling demand across winters. This supports a coordinated introduction pathway in which germplasm is screened first for stress adaptation, then matched to target production zones and management schedules (Wang et al., 2020).

The second layer of collaboration is linking adaptive cultivars with standardized propagation systems and downstream quality goals. China's medicinal peony industry already contains rich cultivar resources across five main producing areas and 12 documented medicinal cultivars, which provides a broad germplasm base for differentiated deployment. Because conventional propagation is slow and breeding remains limited by fragmented germplasm knowledge and low efficiency, optimized embryo and tissue-culture systems are critical for rapidly multiplying selected materials (Xin et al., 2025). Mature-embryo culture reached 91.11% germination, 96.67% shoot induction, and 73.33% rooting, while low-chilling 'Hang Baishao' also now has a workable embryo-propagation and transplanting protocol. At the breeding end, large fertility differences among genotypes and the need for marker-assisted, trait-directed parent selection argue for using propagation, adaptation testing, and breeding as one continuous optimization chain rather than separate tasks (Qi et al., 2020).