96.67%, shoot proliferation coefficients of 3.48, and rooting rates of 73.33%, showing that standardized in vitro protocols can sharply compress the early propagation phase (Xin et al., 2025). Complementary regeneration studies show that tissue culture is not only useful for multiplication but also for germplasm conservation, cultivar improvement, and later genetic engineering (Duan et al., 2022). Standardization also now extends to rooting and acclimation: embryo-derived shoots rooted best after 7 days of darkness followed by 28 days of light, and modified half-strength medium with double calcium, putrescine, indole-3-butyric acid, and coumarin produced 75% rooting with 8.3 roots per shoot.

The technical advantage of this model is that it converts a long, variable perennial crop into a more controllable production chain spanning propagation, nursery management, protected cultivation, and harvest standardization. In a bio-nursery system, a 15/5℃ day-night regime increased shoot proliferation relative to constant 15℃, 6 mmol/L calcium during root induction improved post-transplant vigor, and acclimation was suitable in a closed greenhouse at 20℃ after cold treatment, all of which support stable commercial seedling supply. Standardized protected production can also regulate market timing: high tunnels advanced initial harvest by 21~34 days while maintaining 15.7~19.4 stems/m², although extra soil heating under low tunnels reduced quality under excessive temperature and humidity. Standardization is also supported by harvest-year optimization, because both chemical profiling and bioactivity testing indicate that a 4-year growth period is sufficient for desired root quality, avoiding unnecessary extension of the production cycle (Jin et al., 2026).

3.3 Ecological and green cultivation model and development potential

Ecological and green cultivation models focus less on maximal input intensity and more on matching perennial biology with soil health, rhizosphere function, and environmentally safer disease control. This direction is well supported because *P. lactiflora* root secondary metabolism is closely linked to rhizosphere microorganisms, and current evidence shows that root metabolites respond jointly to abiotic conditions such as soil water, precipitation, and pH and to biotic factors such as *Alternaria* (Wu et al., 2025). Rhizosphere studies further show that the rhizosphere contains enriched carbohydrates and organic acids, more complex and stable microbial co-occurrence networks, and more cooperative microbial relationships than bulk soil, making it a practical target for ecological regulation. In ornamental cultivars, pH and alkaline phosphatase significantly affected rhizosphere bacterial communities, while some cultivars enriched more stress-tolerant growth-promoting bacteria, indicating that green cultivation can combine soil management with cultivar choice (Zu et al., 2022). More broadly, rhizosphere engineering research supports two complementary routes for sustainable agriculture: precise agronomic management of environment-dominated microbiomes and breeding for plant genetic-dominated microbiome assembly (Mahmud et al., 2021; Xun et al., 2024).

Its development potential is especially strong because ecological practices can improve both sustainability and product quality while reducing chemical dependence. In medicinal peony fields, grass management increased paeoniflorin content relative to inter-tillage, suggesting that moderated competition and less intensive soil disturbance can sometimes favor medicinal quality even when weed pressure rises (Seki et al., 2021). Disease management can also shift toward biological control: *Bacillus subtilis* SY8 suppressed four major fungal pathogens, reduced black spot incidence, increased defense-related enzyme activities, and restructured microbial communities toward greater bacterial diversity and fewer pathogenic fungi. Varietal evidence likewise suggests that long-domesticated local lines can maintain stable phenotypes for decades and differ in paeoniflorin, phenolics, flavonoids, and antioxidant capacity, which creates room for ecological model selection around both adaptation and quality (Wu et al., 2025). The ecological green model appears best suited for the next stage of perennial *P. lactiflora* development because it integrates quality formation, soil-microbiome management, and biological disease suppression into a lower-input cultivation framework while retaining clear commercial potential.

4 Key Management Technologies for Continuous Perennial Production of *Paeonia lactiflora*

4.1 Elite germplasm selection and standardized seedling propagation technology

Elite germplasm selection for continuous perennial production should prioritize regional adaptability, especially chilling requirement, heat-humidity tolerance, flowering stability, and division-propagation potential. In