atypical “Jitou-type”, “Jiang-type”, “Cylinder-type,” and “Baiji-type”, exhibit different mucilage cell densities and comprehensive nutritional and medicinal values, with Baiji-type and Jitou-type showing superior quality (Hu et al., 2022). For *P. kingianum*, the improved variety ‘Linyun 1’ accumulates higher levels of amino acids, alkaloids, and phenolic acids than traditional germplasm, demonstrating the additional influence of intraspecific genetic variation on metabolite profiles (Xiao et al., 2024).

Beyond species and variety, geographical origin and local environmental conditions exert significant but sometimes inconsistent effects on quality. Provenance trials of 11 *P. cyrtonema* accessions across three heterogeneous garden sites revealed highly significant differences in growth and medicinal components, with saponin content increasing with altitude and temperature while flavonoid accumulation was promoted in drier conditions (Cheng et al., 2026). A multi-origin comparison of 40 germplasm resources from ten provinces found that *P. cyrtonema* from Huaihua, Lu’an, Hezhou, and Lishui, along with *P. kingianum* from Baoshan, exhibited the highest overall nutritional quality, with polysaccharide content exceeding 20% (Li et al., 2025). However, HPLC fingerprinting of 25 *P. cyrtonema* batches from six provinces showed that chemical composition specificity lacked obvious regularity with longitude, latitude, or altitude, suggesting that local environmental variation may override broad geographic patterns (Zhou et al., 2021). For *P. kingianum*, rhizosphere microbial communities and soil variables such as hydrolysable nitrogen and available potassium further influence active ingredient content, indicating that soil ecology is an additional quality driver. Cultivation mode also matters: intercropping *P. cyrtonema* with *Paris polyphylla* increased polysaccharide content by 12.1% compared with monoculture.

2.2 Effects of cultivation years and harvest time on rhizome quality

Cultivation years significantly influence the accumulation of bioactive components in *Polygonatum* rhizomes, though the optimal harvest age varies by species and target constituent. In *P. cyrtonema*, functional components increased significantly during the one- to four-year growth period, with the most active accumulation occurring between years three and four, followed by a significant decline from years four to five (Pu et al., 2024). A separate temporal study of *P. cyrtonema* found that polysaccharide and alcohol-soluble extractive contents peaked at the two-year age section and then decreased with age, while provenance and harvesting season also affected quality significantly (Su et al., 2019). Transcriptomic and metabolomic profiling of biennial and triennial *P. cyrtonema* identified 1 721 differentially expressed genes and 150 differential metabolites, with the phenylpropanoid biosynthetic pathway being the most crucial enrichment pathway, confirming that growth years are a critical factor affecting active substance accumulation. For *P. kingianum*, metabolomic analysis showed that differential compounds were mainly enriched in traditional germplasm at year one, while the improved ‘Linyun 1’ variety showed greater variety and higher content of differential compounds at year three. Studies on *P. kingianum* polysaccharide content across different growth years identified the fourth year after planting as the best harvest time for polysaccharide accumulation (Xiao et al., 2024).

Seasonal and harvest timing effects are equally consequential, as rhizome quality fluctuates dramatically from spring to autumn. In *P. cyrtonema*, spring-harvested rhizomes contained more flavonoids, alkaloids, and phenolic acids, while autumn-harvested rhizomes comprised more steroids, yielding unequal quality depending on the target application. For *P. odoratum*, polysaccharide content peaked in spring at 13.3% before declining through summer and fall, driven by a “source-sink” conversion mechanism in which overwintering starch reserves are mobilized into polysaccharides via upregulated α-amylase and invertase (Zhu et al., 2026). However, another *P. odoratum* study found that autumn-harvested rhizomes were highest in polysaccharides and saponins and thus more suitable for medicinal use, while summer-harvested rhizomes were richer in soluble sugars and free amino acids with better taste for food applications (Yuan et al., 2023). A separate study recommended late August to early September as the optimum harvest window for *P. odoratum* in northeast China based on drying rate and polysaccharide content. For *P. cyrtonema*, phenological data indicated that rhizomes should be harvested when aboveground parts have just withered, as neither the traditional February/August collection nor strict spring/autumn harvesting yielded the highest polysaccharide and extractive contents (Su et al., 2019).