phosphorus, available potassium, and organic matter levels, as well as enhanced activities of soil enzymes such as urease, protease, and cellobiohydrolase and increased chalcone isomerase activity. This indicates that improvements in soil fertility and microbial activity can jointly promote biomass accumulation and secondary metabolism in *T. hemsleyanum*. Application of organic fertilizer alone can also increase fresh root weight, but its promoting effect on total flavonoid content is relatively weaker, and its yield-increasing effect is mainly related to available potassium, available phosphorus, and protease activity (Jiang et al., 2023). Therefore, during understory cultivation, soil structure should be improved through the application of well-decomposed organic fertilizer, compost, biochar, and humus soil, and nutrients should be supplemented reasonably according to plant growth stages.

Field studies further emphasize the role of soil structure and microbial communities in tuberous root enlargement of *T. hemsleyanum*. After two consecutive years of cultivation in stony soils, *T. hemsleyanum* produced significantly larger tuberous roots than plants grown in similar soils from which stones had been removed. Stony soils had distinctive bacterial communities, higher microbial diversity, and enrichment of groups such as Actinobacteria and Rhizobiales. These differential bacteria were associated with host plant pathways related to phytohormone biosynthesis, photosynthesis, and stress resistance, indicating that microbial communities driven by stony soils can promote tuberous root initiation and enlargement in *T. hemsleyanum* (Hong et al., 2021). Comparative analysis of wild and cultivated rhizosphere environments also showed that higher available phosphorus and potassium contents and specific bacterial genera in wild soils were associated with increased total flavonoid content and phenylalanine ammonia-lyase activity in roots. Therefore, understory cultivation of *T. hemsleyanum* should establish a fertility management model based on organic fertilizer, balanced nitrogen, phosphorus, and potassium supply, and soil ecological health, so that soil conditions can truly support the simultaneous improvement of tuberous root yield and medicinal material quality.

6.3 Effects of cultivation years on the medicinal quality of *Tetrastigma hemsleyanum*

T. hemsleyanum is a perennial medicinal plant, and its tuberous root formation and accumulation of active substances follow an obvious temporal process. Generally, the shorter the cultivation period, the less sufficient the accumulation in the underground parts, resulting in smaller tuberous roots and underdeveloped dry matter content and medicinal quality. As the growth period extends, *T. hemsleyanum* continuously accumulates photosynthates and transports nutrients, leading to gradual enlargement of underground tuberous roots and improvements in the weight, fullness, and commercial value of the medicinal parts. Field observations have shown that larger tuberous roots of *T. hemsleyanum* usually begin to form in the later stage of the second growth year, and many cultivation systems also use tuberous roots of the same growth age for quality evaluation (Shi et al., 2022). Therefore, reasonably extending the cultivation cycle is one important way to improve the yield and quality of *T. hemsleyanum* medicinal materials.

However, a longer cultivation period is not always better. As cultivation time increases, problems such as nutrient depletion in understory soils, pathogen accumulation, root aging, and increased management costs may gradually emerge. If plants are continuously cultivated in the same plot for a long time without soil improvement or pest and disease control, plant vigor may decline, the rate of tuberous root decay may increase, and the stable supply of medicinal materials may be affected. Therefore, when determining the appropriate harvesting age for *T. hemsleyanum*, plant growth status, tuberous root size, medicinal material quality, market demand, and input-output ratio should be comprehensively considered, rather than using cultivation years as the sole criterion.

From the perspective of quality regulation, cultivation years and seasonal environments jointly affect the accumulation level and stability of medicinal components in *T. hemsleyanum*. A three-year trial with sampling every half month showed that the total flavonoid content and antioxidant activity in tuberous roots changed dynamically within a year and across different growth cycles, indicating that its secondary metabolism undergoes continuous adjustment. Seasonal analysis showed that under spring conditions with precipitation of 2.0~6.6 mm, temperature of 17.5°C~24.1°C, humidity of 67.3%~80.2%, and sunshine duration of 3.4~5.8 h, total flavonoid content in tuberous roots reached a relatively high level of 281.3~392.8 μg/g, suggesting that cool and moderately