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Editorial

Microbial interactions within Chinese traditional medicinal plants

Plants harbor diverse microbes (including bacteria, fungi, archaea, protists, and viruses) both inside and outside their tissues, so called the plant-associated microbiome. Decades of research have demonstrated the importance of plant microbiome in promoting the productivity and health of the plant in natural environment because of their essential functions in improving plant nutrition and plant resistance to biotic and abiotic stresses (Trivedi, Leach, Tringe, Sa, & Singh, 2020). Thus, a plant can be regarded as a holobiont comprising the host plant and the associated microbiota (Hassani, Durán, & Hacquard, 2018). Within the plant microbiota, mutualistic fungal and bacterial symbionts (e.g. mycorrhizal fungi and *Rhizobia*) are striking examples of microorganisms playing crucial roles in nutrient acquisition (Martin & van der Heijden, 2024) and non-symbitic plant growth-promoting rhizobacteria or fungi (PGPR or PGPF) also have drawn interest due to their ability to improve soil properties and confer stress tolerance in plants (Upadhyay et al., 2023).

Mycorrhiza is a mutualistic symbiosis formed between the plant roots and soil fungi, originating from 450 million years ago during the plant terrestrializtion (Puginier, Keller, & Delaux, 2022). It is estimated that about 90% of embryonic plants on Earth can form mycorrhizal symbiotic relationships with fungi. During the long evolutionary process, four representative mycorrhizal types with unique structures and functions have been formed: Arbuscular mycorrhiza (AM, 72%), Orchid mycorrhiza (ORM, 10%), Exomycorrhiza (ECM, 2%), and Ericoid mycorrhiza (ERM, 1.4 %) (Genre, Lanfranco, Perotto, & Bonfante, 2020). Mycorrhizal fungi absorb inorganic elements to plants such as water, nitrogen, and phosphorus from the soil in exchange for carbon (fatty acids and sugars) fixed by the host plant's photosynthesis for fungal growth (Shi, Wang, & Wang, 2023). Due to their crucial role in soil structure, nutrient cycling, plant diversity, and sustainable development of ecosystems, mycorrhizal symbiosis has been acknowledged as shaping the evolution of the biosphere since plant colonization, providing various ecosystem services in natural and agricultural environments, and has gradually become a cutting-edge topic in genomics, ecology, and agricultural applications in recent years (Lu & Hedin, 2019). The diverse roles of mycorrhizal fungi and PGPR as biofertilizers, biocontrollers, biomodulators, and more contribute to sustainable agriculture and environmental resilience (Zenteno-Alegría et al., 2024). These microbe also display huge potential in medicinal plant cultivation, disease control, and secondary metabolites accumulation promoting. Orchid medicinal plant *Gastrodia elata* and *Armilaria* spp. is a typical example of plant-fungi symbiosis in medicinal plant cultivation (Leng, Hou, Xing, & Chen, 2024). In this issue, Ouyang and coauthor summarizes the relationship between medicinal plants and their associated microorganisms, including their species, distribution, life activities, and metabolites and proposed the potential contribution of microorganisms in quality control and identifying the origin and storage time of Chinese herbal medicines (CHMs) and suggested that research should concentrate developing the optimal micro-ecological setting to improve the quality of CHMs instead of only focusing on pay active substance of CHMs (Ouyang et al., 2024).

In nature, biotic and abiotic stresses such as drought, heat, salinity, cold and pathogen infection etc. are major constrains to plant growth and survival. Stressful condition can cause plant nutritional and hormonal imbalance, physiological disorders, ion toxicity, susceptibility to diseases (Nadeem, Ahmad, Zahir, Javaid, & Ashraf, 2014). Vast studies showed mycorrhizal fungi or PGPR can alleviate plant stresses by activating the host response system in response to the stress or generating beneficial substances or antistress metabolites (Kumar & Nautiyal, 2022). Thus, application of rhizosphere engineering by microbial inoculation is promising in enhancing the plant ability against stressful climatic conditions or phytopathogens (Rodriguez et al., 2019). Qian et al. described the effect on the accumulation of saponins of medicinal plant *Paris polyphylla* Smith var. *yunnanensis* (Franch.) Hand. −Mazz. (Chonglou in Chinese) combination inoculated with arbuscular mycorrhizal fungi (AMF) and plant growth-promoting endophytes (PGPE) in drought stress. The authors highlight the interesting result that double inoculation with AMF + PGPE greatly increased the photosynthetic capacity and improved the proportion of N, P, and K in the rhizome of *P. polyphylla* var. *yunnanensis* and significantly enhanced the saponins contents of *P. polyphylla* var. *yunnanensis* and induced the up-regulated expression of UGTs genes involved in saponin synthesis pathways under moderate drought stress (Qian et al., 2024). Zhang and coauthor reviewed the roles of endophytic fungi in medicinal plant abiotic stress response to major factors such as salt, heavy metal, water, temperature stress by enhancing photosynthesis and phytohormone accumulation, enhancing resistance to osmotic stress, improving oxidative stress resistance and assisting in ion transport (Zhang et al., 2024). This review also points out the deficiencies and burning issues of available studies and present promising research topics for the future. Undoubtedly, this paper provides guidance for endophytic fungi

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research to improve the ability of medicinal plants to resist abiotic stress.

Beside remediation soil health, enhancement of plant growth and production during interaction with host plants, plant microbiome, especially endophytes that inhabit the internal tissues of health plants without causing apparent harm to the plant are able to biosynthesize medicinally important ''phytochemicals'', originally believed to be produced only by their host plants (Ancheeva, Daletos, & Proksch, 2020). Some promising lead compounds structures which hold great promises as potential drug candidates from endophytic fungi have been described in the literature (Martinez-Klimova, Rodríguez-Peña, & Sánchez, 2017), thus endophyte are also recognized as new and precious resources for nature products in drug discovery. Wang et al. isolated several compounds with inhibitory activity against human cancer cells and cytotoxic activity against HepG-2 cells and found a new tetracyclic triterpenoid from the endophytic fungus *Fusarium sporotrichioides* isolated from *Rauwolfia yunnanensis* (Wang, Liu, Yang, Li, & Pei, 2023). Tang and coauthor isolated and identified five metabolites from *Penicillium* HDS-Z-1E, an endophytic fungal strain isolated from *Taxus cuspidata* and found a new compound with potential activators of catalase (an important liver protective enzyme class of terminal oxidative enzymes) (Tang et al., 2024). In addition, several new indole derivatives are isolated and identified in endophytic fungus *Colletotruchum* sp. HK from leaves of *Nerium indicum* (Chen et al., 2024). Collectively, these studies enriched the nature products resources from plant microbes for drug discovery in future.

Plant microbiome, as essential components of the plant holobiont, usually regards as plant's second genome, play a critical role in maintaining plant health and fitness (Trivedi et al., 2020). Researches on function and mechanism of plant micrbiome in crops made breakout progress and provided an opportunity to develop strategies for sustainable agricultural practices (Gupta, Anand, Gaur, & Yadav, 2021). In recent year, the application of next generation sequencing techniques and modern cost-effective high-throughput molecular approaches greatly improve our knowledge and better understand the role of plant microbiome from gene to ecosysterm (Shi, Wang, & Wang, 2023). Most recent years, association between plant microbiome, especially rhizosphere microorganisms including mycorrhizal fungi and PGPB and quality of medicinal plants have received extensive attention. However, whether or to what extent rhizosphere microorganisms can contribute to the construction of the quality evaluation system of Chinese medicinal materials is unclear. Yang et al. comprehensively reviewed role of rhizosphere microbes in the survival and quality formation of medicinal plants such as enhancing stress resistance, preventing continuous cropping obstacle, promoting quality formation of medicinal plants, improving edaphic environment, solving cultivation problem of endangered medicinal plants and proposed a new concept of rhizosphere microbial markers (micro-markers), expounded the relevant research methods and ideas of applying the new concept, highlighted the importance of micro-markers in the quality evaluation and control system of traditional Chinese medicines (TCMs) and introduced the potential value in soil environmental assessment, plant pest control and quality assessment of TCMs (Yang et al., 2024). Based on the unique attribute of medicinal plants, this review greatly broad our understanding for plant microbiome function and application and also is important reference for future research in this field.

In sum, these studies deepen our comprehension of plant microbiome and plant health and unveil the diverse role especially in medicinal plant ecological cultivation and quality evaluation

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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