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Editorial

Back to beginning: Searching for Rosetta Stone of enhancing herbal medicine quality

Chinese herbal medicines (CHMs) are an integral part of ecosystem service for humankind and represent one of most important bioresources in our planet, in which nature's ability is fully unlocked to prevent/treat human diseases. From the world-wide research and practice in recent years, we can feel that the process of globalization of traditional Chinese medicine (TCM) is accelerating; especially since the outbreak and spread of COVID-19 since December 2019, the world has gained more recognition of its important/unique values. Nowadays, considerable studies have focused on the quality evaluation of CHMs (Liu, 2021), which, however, cannot meet the growing demand for drug safety, if the problem of pesticide residues and heavy metals in CHMs cannot be effectively tackled. Hence, the eligible medicinal plant cultivation pattern should be actively explored, so as to solve the quality problems of CHMs from the source and provide quality CHMs sustainably. In the review "How to improve CHMs quality: Enlighten from CHMs ecological cultivation" (Cao et al., 2021), the situation and characteristics of medicinal plant resources, including wild-harvested and cultivated ones, in different historical periods are scrutinized. In *Dream Creek Talk* of Song Dynasty, the scholar Shen Kuo thought that "In ancient times, herbs are mostly collected in February or August, which is very inappropriate. It's just that the February grass has sprouted and the August seedling hasn't dried up, so it's easy for the picker to recognize it, but it's not a good time for medicine picking". Shen sagaciously realized the influence of ecological/environmental factors on the quality of phytomedicine; he said that "the peach and plum trees in ZhuYue of southern China bear fruit in winter, while those in the northern desert only bloom in summer. This is the difference of telluric effluvium (i.e., soil/climate conditions). The crops in the same Mu germinate first with good water and fertilizer conditions. . . . How can the collection of herbs be limited to a fixed month". The growth stage, season and phenological factors should be paid attention to when harvesting TCM plants. Based on ancient experiences, the ecological cultivation is recommended in developing medicinal plant cultivation to obtain quality CHMs.

The rhizosphere, a slender region of soil, is unswervingly influenced by roots and associated soil microbes. Studies on rhizosphere microbes of TCM plants are critical for applied microbiology, microbial ecology, and industrial biotechnology with regard to ecological cultivation and CHM quality (Hao & Xiao, 2017). In contrast to the inability of culturing most rhizosphere microbes (around 99%) in the laboratory, currently there are enormous advances in applying culture-independent techniques based

on molecular biology and omics to the study of rhizosphere microbial community structure/composition and plant–microbe interactions. The various omics tools, such as FISH, stable isotope probing (SIP), next/third generation sequencing, etc., evolve quickly to provide more comprehensive understanding of the rhizosphere microbiota and microbiome. The flexible applications of high-throughput sequencing technologies, e.g., amplicon sequencing, shotgun metagenomic sequencing, whole genome sequencing, and transcriptome sequencing, continuously address the biology and biotechnology potentials of the rhizosphere microbiome of medicinal plants. The review "How to improve CHMs quality: Enlighten from CHMs ecological cultivation" (Cao et al., 2021) discusses recent findings and future challenges in the study of rhizosphere microbes, highlighting multi-faceted roles of microbial inoculants. Moreover, the evolution of research methods and innovative combinations of different techniques should also be encouraged. The top-down approaches such as metagenomics and bottom-up approaches targeting individual species or strains should be integrated and combined with modeling approaches to afford a wide-ranging understanding of the microbial community as a whole.

Searching for Rosetta Stone of enhancing herbal medicine quality is never an easy task. Green technologies, e.g., bioaugmentation and biostimulation, are cost effective and eco-friendly, and are becoming Rosetta Stone for the remediation of soil heavy metal and pesticides. The bacteria, fungi and their consortia can be combined with physical and chemical techniques for the targeted remediation of soil organic pollution, heavy metal contamination or both. The review of Cao et al. (2021) exemplifies the representative studies, summarizes the potentials of microbial strains in transforming/degrading pollutants, and highlights the roles of biochar and mineral elements in laboratory, greenhouse and field conditions. The complexity of microbial remediation is ascribed to not only the variations of physiological and metabolic traits, but also numerous environmental factors, including abiotic factors, e.g., pH, temperature, type of soil, pollutant concentration, content of water and organic matter, additional carbon and nitrogen sources, and biotic factors, e.g., inoculum size, interactions between the introduced strains and autochthonous microbes, and survival of inoculants, etc. The ingeniously combined remediation and rational applications of molecular methods will maximize the soil remediation without much cost.

Microbes in arable soil participate in the biogeochemical cycling of nitrogen, which profoundly impact on the fertility and green-

house gas emission. As the effects of environmental factors on the structure and functions of microbial communities have not been thoroughly elucidated, it is necessary to perform the microcosm/mesocosm study to collect the soil samples under different moisture (e.g., constant and wetting)/pH/gas (air, 10% acetylene, oxygen and argon) regimes and investigate the alterations of microbial community structure, gene abundance and nitrogen metabolic functions under different conditions by high-throughput sequencing, quantitative PCR and RT-PCR, SIP, physicochemical analyses and bioinformatics. The impact of moisture/gas regimes, processing time and interaction item on $\text{NH}_4^+\text{-N}$ and $\text{NO}_3^-\text{-N}$ would be conspicuous. The water/gas regime could significantly affect the microbial community diversity. The key responsive microbial classes under different moisture/pH/gas conditions would be disclosed in such a study. Novel microbial species that are positively correlated with moisture and N_2O emission will be found; the dominant processes of nitrogen cycle, e.g., denitrification, nitrate reduction to ammonium, nitrification, nitrogen mineralization/fixation, in different types of soil will be determined, which, along with the co-occurring network and gene-species correlation heatmap, are invaluable information in improving medicinal plant growth and production of medicinal compounds. Medicinal plant

scholars should communicate and cooperate with soil researchers more. The findings therefrom shed light on the prevention and control of soil fertility decline and global warming, as well as heavy metals and pesticide residues exceeding the standard in CHM products.

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