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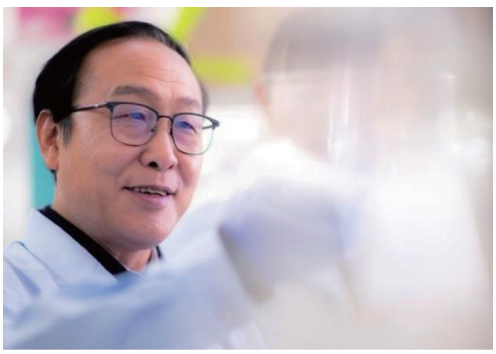
Profile of Prof. Ke-Qin Zhang



Dr. Ke-Qin Zhang is a microbiologist who has spent more than 40 years on harnessing the natural existing nematophagous microorganisms to combat against plant-parasitic nematodes. Dr. Zhang received his Ph.D. degree from China Agricultural University in 1998 and then joined as the director of the Key Laboratory of Industrial Microbiology and Fermentation Technology of Yunnan in Yunnan University. In 2015, with the support of the Ministry of Science and Technology and the Yunnan Provincial Government, the laboratory became the State Key Laboratory for Conservation and Utilization of Bio-Resources in Yunnan. Dr. Zhang has been the director of this state key laboratory since its inception.

Plant-parasitic nematodes are the second most important plant pathogens in agriculture. They have caused agricultural losses estimated at ~170 billion US dollars annually (Abad et al., 2008). Chemical pesticides can kill the plant-parasitic nematodes but years of chemical treatments have led to the increasing resistance of nematodes and the severe damage to the environment. Nematophagous fungi are carnivorous fungi that specialize in trapping and killing nematodes in natural environments and have been proposed as alternative agents to control the harmful plant-parasitic nematodes (Zhang and Hyde, 2014). Dr. Zhang began his journey of uncovering nematode characteristics, revealing the molecular mechanisms of the interactions between nematophagous microorganisms and nematodes, and developing effective biological agents to control plant-parasitic nematodes. He explored a diverse collection of nematophagous fungi that exhibited potent killing ability against nematodes and isolated the lead compounds with high activities. His work has led to the development of widely used, high-efficiency biocontrol products against plant-parasitic nematodes in the agricultural field.

Systematically characterized a large collection of important nematophagous microbial resources

For decades, Dr. Zhang and his team have established the biggest repository of nematophagous microorganism resources in the world. After exploring more than 10,355 strains of microorganisms collected from 31 provinces in China, they identified four new genera and 69 new species with potent anti-nematode ability. As of now, six types of trapping devices produced by nematode-trapping fungi are characterized, and two of which (Acanthocytes from *Stropharia rugosoannulata* and spiny balls from *Coprinus comatus*) were discovered by Dr. Zhang's group (Luo et al., 2006; Luo et al., 2007). They further found that these two new trap structures can immobilize and kill nematodes through mechanical force (Luo et al., 2006; Luo et al., 2007). Also, he clarified the evolution of trapping devices and resolved the phylogenetic relationships among nematode-trapping fungi (Ji et al., 2020a; Li et al., 2005).

Dr. Zhang's group has identified a total of 328 chemical compounds from different microbial species, including 140 new compounds, 26 of which contain novel skeletons. Among these compounds, eight showed strong abilities to attract nematodes. Significantly, two PKS-NRPS hybrid thermolides identified from the thermophilic fungus *Talaromyces thermophilus* showed potent inhibitory activities against three notorious nematodes with LC_{50} values of 0.5–1 μg mL^{-1}, comparable to the commercial nematicide avermectins, providing a new class of promising lead compounds for nematicide discovery (Guo et al., 2012).

Uncovered the molecular interactions between microorganisms and nematodes and enlightened a new way to control nematodes

Effective biological management strategies against plant-parasitic nematodes have not yet been established, partly due to the lack of knowledge of the basic biology underlying nematophagous microorganism-nematode interactions. To understand the interactions between this microscopic predator-prey system, Prof. Zhang and his team performed a series of systematic studies. In 2010, they reported a "Trojan horse" mechanism of bacterial pathogenesis against nematodes (Niu et al., 2010). The ComP-ComA system, a conserved quorum sensing system in the genus *Bacillus*, is essential for the Trojan horse-like pathogenesis in *Bacillus nematocida* (Deng et al., 2013). This pattern of bacterium-nematode interaction enriches our understanding of microbial pathogenesis. In 2011, Dr. Zhang's group reported the first genome of the nematode-trapping fungus *Arthrobotrys oligospora* Fres. (ATCC24927) and proposed a model for the formation of a nematode-trapping device in this fungus (Yang et al., 2011). Further, Dr. Zhang's group identified that the lifestyle transition in fungi from scavengers to predators is mediated by microRNA-like RNAs (milRNAs) through RNA interference (RNAi) machinery, providing new insights into understanding fungal adaptation and the mechanisms underlying fungal infections of nematodes in particular (Ji et al., 2020b).

Dr. Zhang and his team has also been engaged in elucidating the ecological mechanisms that cause the instability of biocontrol agents in the environment. Soil fungistasis can adversely affect the germination and growth of nematicidal fungal species in the wild field. To address this, Zhang's group identified a variety of key factors that influence fungi germination and growth in the soil, thereby providing guidelines for the application of biological agents in soil environments (Xu et al., 2004; Zou et al., 2007). They also found that bacteria can release urea to trigger a lifestyle switch of the fungus *A. oligospora* from saprophytic to nematode-predatory form, promoting nematode elimination by *A. oligospora*. Their findings highlight the importance of multiple predator-prey interactions in prey defense mechanisms (Wang et al., 2014).

Nematodes can also sense and defend against nematophagous microbes. Zhang and his team revealed a previously unidentified role for autophagy protecting against tissue damage triggered by pathogenic bacteria in *Caenorhabditis elegans* and suggested that autophagy-mediated anti-bacteria function might be a conserved innate immune response in diverse organisms (Zou et al., 2014). Also, they identified that the transcription factor FOXO/DAF-16 could act in a cell-autonomous way to regulate epidermal immune responses to fungal infections (Zou et al., 2013). In addition, Dr. Zhang and colleagues characterized two endocrine mechanisms in nematode adaptation to nutrient deprivation and low temperature (Chen et al., 2019; Tao et al., 2016).

Established an efficient biocontrol system against plant-parasitic nematodes, ensuring the safety of economic crops in China

To ensure the safety of economic crops in China, Dr. Zhang established an efficient biocontrol system to minimize crop infections caused by plant-parasitic nematodes. He led the development of a system to (i) facilitate fungi germination and growth in the soil, (ii) initiate the switch of nematophagous fungi from saprophytic to pathogenic, and (iii) mobilize these fungi to trap and kill the parasitic nematodes. So far, Dr. Zhang and his team have developed four new biocontrol products to control nematodes, three of which have obtained national certifications. These new products are currently applied to control plant-parasitic nematodes on vegetables, citrus, tobacco, and traditional Chinese medicine crops in Yunnan, Guizhou, Shandong, Guangxi, and other provinces.

Overall, Dr. Zhang has made significant contributions to ensuring the safety of agricultural production in China. He has published 62 national invention patents and 219 articles in renowned journals such as *Proceedings of the National Academy of Sciences of the United States of America*, *Nature Communications*, *Science Advances*, *Journal of the American Chemical Society*, *Annual Review of Phytopathology*. He has been frequently invited to write topical reviews in high-impact journals, including one review on the biological control of crop pathogenic nematodes for the *Annual Review of Phytopathology* (Li et al., 2015). He has served as an editor of the journal *Science China Life Sciences*, as well as other journals. He was elected as Vice President of the Chinese Society for Microbiology and Vice Chairman of the Mycological Society of China. He has won many awards, including the Ho Leung Ho Lee Prize for Science and Technology Progress and the Outstanding Achievement Award of Yunnan Province. Due to his outstanding contributions to biocontrol of plant-parasitic nematodes, Dr. Zhang was elected as a fellow of the Chinese Academy of Sciences in 2021.

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