SCIENCE CHINA
Life Sciences

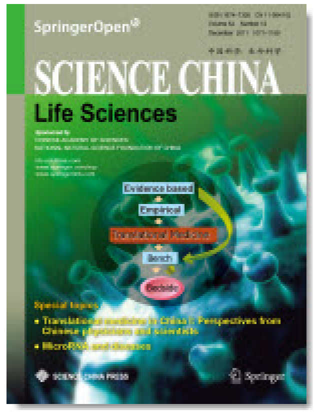
Decoding the secret of species coexistence: A perspective from soil fungi

Zhang Jian and Liu Lan

Citation: SCIENCE CHINA Life Sciences; doi: 10.1007/s11427-019-1591-8

View online: http://engine.scichina.com/doi/10.1007/s11427-019-1591-8

Published by the Science China Press



Decoding the secret of species coexistence: A perspective from soil fungi

Journal:	*SCIENCE CHINA Life Sciences*
Manuscript ID	SCLS-2019-0554.R1
Manuscript Type:	Research Highlight
Date Submitted by the Author:	06-Nov-2019
Complete List of Authors:	Zhang, Jian Liu, Lan
Keywords:	species coexistence, soil fungi, species diversity, biodiversity, long-term monitoring
Speciality:	Ecology and Environmental Biology

Decoding the secret of species coexistence: A perspective from soil fungi

Lan Liu[1,2], Jian Zhang[1,2]*

[1]Zhejiang Tiantong Forest Ecosystem National Observation and Research Station, School of Ecological and Environmental Sciences, East China Normal University, Shanghai 200241, China

[2]Shanghai Institute of Pollution Control and Ecological Security, Shanghai 200092, China

*Correspondence: jzhang@des.ecnu.edu.cn

"What determines species diversity" was listed as one of the 25 highlighted and extremely challenging questions in the journal *Science* on its 125th anniversary (Pennisi, 2005). Why are there so many species in the world? How do these species coexist in one community? Ecologists and evolutionary biologists have struggled with these questions for centuries. A leading explanation, particularly in tropical forests, is Janzen-Connell hypothesis (Janzen 1970 and Connell 1971), which suggests that local abundance of seeds and seedlings is negatively affected by conspecific neighbors through accumulation of host-specific natural enemies (conspecific negative density dependence: CNDD). Plant community diversity can be maintained when common species suffer stronger CNDD than rare species ('rare species advantage').

Mounting literature in recent years has provided compelling evidence that soil fungal pathogens play a crucial role in limiting conspecific neighbors. However, few studies have paid attention to other functional groups of soil fungi beneath plant and interact with plant roots, such as symbiotic mutualists and decomposers, and the mechanical roles of different fungal functional groups to CNDD remain largely elusive across species and ecosystems.

Inspired by previous studies on the CNDD, Chen and the collaborators (2019) conducted a study in a 24 ha stem-mapping subtropical forest dynamics plot in China to uncover the underlying mechanisms. They used the long-term (2006-2014) tree seedling census data to investigate the conspecific neighborhood effects on seedling survival and collected soil samples in plant rhizosphere from 322 individual trees belonging to 34 species to identify the soil fungal taxa using DNA sequencing. They found that seedlings experienced strong CNDD from both conspecific seedlings and adult neighbors, and tree mycorrhizal types influenced the strength of CNDD. Arbuscular mycorrhizal (AM) plants were more negatively affected by conspecific neighbors compared to ectomycorrhizal fungi (EcM) and ericoid mycorrhizal (ErM) plants, while EcM and heterospecific neighbors generally facilitated seedling survival. By combining the fungal accumulation rates in both diversity and density with the seedling survival data, they showed that pathogen accumulation was positively related to the interspecific variation in CNDD, whereas EcM fungi accumulation favored seedling survival. These results provide direct evidence that both mycorrhizal fungi and fungal pathogens mediate the strength of the CNDD. The findings are indicative of a conceptual shift towards the mechanical understanding of the complex interactions between plants and their enemies and allies.

What we can learn from this work is at least threefold. First, long-term biodiversity monitoring is key to uncover the secret of species coexistence. Short-term monitoring in plant demography often ignores the impacts of environmental fluctuations over time, and cannot capture the temporal variations of local neighbor effects. Chen et al.'s work provides us a great example of how long-term biodiversity data contribute to our deep understanding of species coexistence. The 24 ha permanent plot they utilized is one of nearly 70 forest dynamics plots belonging to the global network of the Forest Global Earth Observatory (ForestGEO, https://www.forestgeo.si.edu; Figure 1). Since the first ForestGEO plot was established in Barro Colorado Island of Panama in 1981 by Dr. Stephen Hubbell and Dr. Robin Foster, these long-term monitoring plots with detailed spatial and temporal information have become important platforms to test the existing hypotheses and theories in ecology and evolution, and develop new hypotheses or theories (e.g., neutral theory in community ecology) (Hubbell 2001; Anderson-Teixeira et al., 2015). Second, further collaboration across different disciplines is critical toward a comprehensive understanding of species coexistence. Chen et al. (2019) is one of the collaborative studies between plant ecologists and microbiologists. Recent advances in molecular phylogeny, bioinformatics, remote sensing, and other techniques provide a lot of opportunities for cross-discipline collaboration to understand the origin of species and maintenance of biodiversity. Third, towards a unified theory of species coexistence, there is still a long way to go. Although Chen et al. (2019) shed new insight into species coexistence mechanisms in a subtropical forest, the large variations of their results across plant species, fungal guilds, and plant life stages suggest that the strength of CNDD may vary across different ecosystems along latitudinal and elevational gradients. The global network of the ForestGEO across diverse forest ecosystems (Figure 1) could serve as the research platform for further studies and eventually decode the secret of species coexistence.

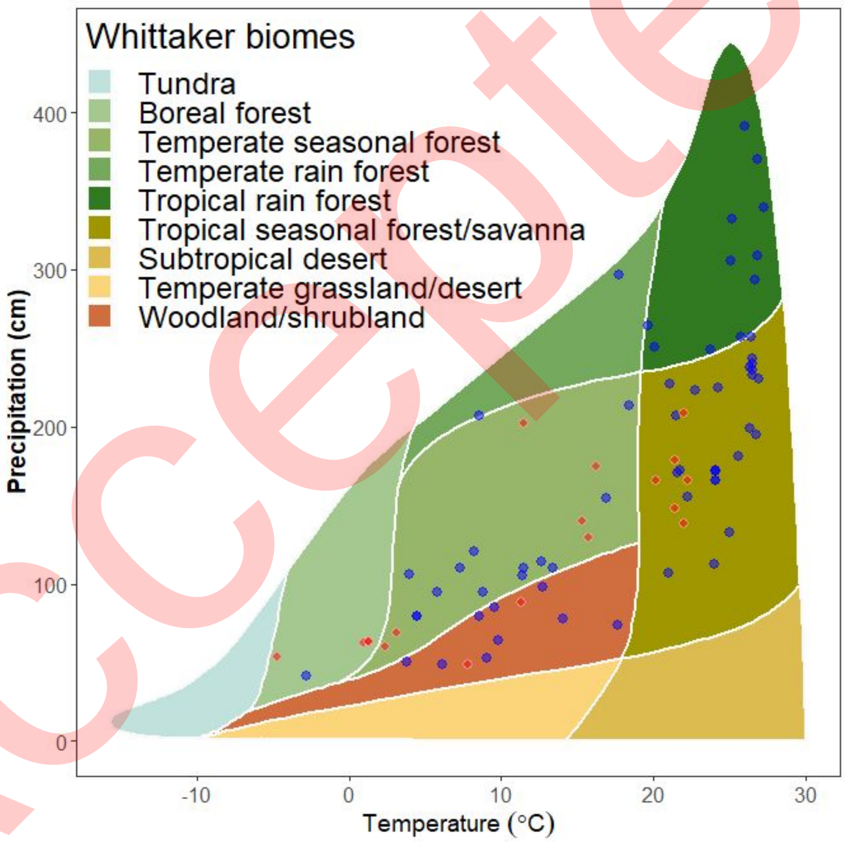


Figure 1 Globally distributed forest dynamics plots of ForestGEO (Forest Global Earth Observatory) superimposed upon Whitttaker's classic climate-biome diagram (Whittaker, 1975). Red points stand for 17 plots from CForBio (Chinese Forest Biodiversity Monitoring Network, http://www.cfbiodiv.org), and blue points for other ForestGEO plots.

References

Anderson-Teixeira K.J., Davies S.J., Bennett A.C., Gonzalez-Akre, E.B., Muller-Landau, H.C., Wright, S.J. Salim, K.A., Zambrano, A.M.A., Alonso, A., Baltzer, J.L., et al. (2015). CTFS-ForestGEO: a worldwide network monitoring forests in an era of global change. Glob Chang Biol 21, 528-549.

Chen, L., Swenson, N.G., Ji, N.N., Mi, X.C., Ren, H.B., Guo, L.D., and Ma, K.P. (2019). Differential soil fungus accumulation and density dependence of trees in a subtropical forest. Science 366, 124-128.

Connell, J. (1971). On the role of natural enemies in preventing competitive exclusion in some marine animals and in rain forest trees. In Dynamics of Populations, P.J. den Boer, and G.R. Gradwell, ed. (Wageningen: Centre for Agricultural Publishing and Documentation), pp. 298-313.

Hubbell, S.P. (2001). The Unified Neutral Theory of Biodiversity and Biogeography (Princeton: Princeton University Press).

Janzen, D.H. (1970). Herbivores and the number of tree species in tropical forests. Am Nat 104, 501-528.

Pennisi, E. (2005). What determines species diversity? Science 309, 90.

Whittaker, R.H. (1975). Communities and Ecosystems (New York: Macmillan Publishing Co. Inc.).