



## Seasonal changes impact soil bacterial communities in a rubber plantation on Hainan Island, China

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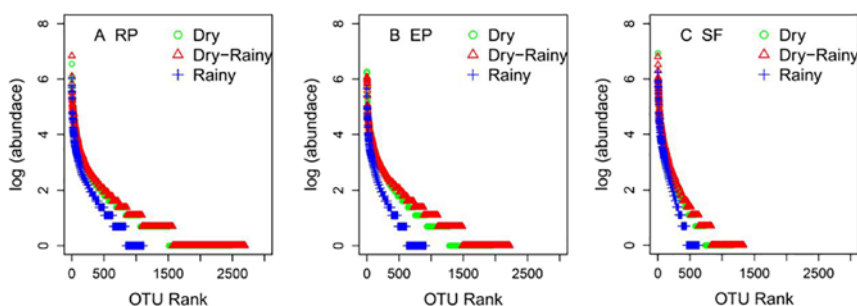
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### HIGHLIGHTS

- Bacterial diversity of soils in dry season was higher than in rainy season.
- Seasonality effect was most pronounced for bacterial compositions and diversity.
- Seasonal changes explained the largest part of the total variance of bacterial community compositions.

### GRAPHICAL ABSTRACT



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### ABSTRACT

Rubber plantations have expanded rapidly over the past 20 years in tropical Asia and their impacts on regional ecosystems have garnered much concern. While much attention has been given to the negative impacts on aboveground diversity and function, the belowground bacterial soil community has received much less attention. Here, we investigated the community composition and diversity of soil bacteria of rubber plantations on Hainan Island in south China. The goals of the study were to describe changes in bacterial compositions and diversity across seasons. We found that seasonality defined by differences in rainfall amount strongly influenced bacterial communities. At both the Phylum and Family levels, we found significant differences in the total number of taxa, as well as the composition of the community as a function of season. Diversity of soil samples in the dry-rainy season was highest of three seasons, suggesting that bacterial structure was more sensitive in alternate periods of season. Diversity in the rainy season was substantial lower than in dry season. Results from a redundancy analysis showed that seasonal changes explained the largest part (31.9%) of the total variance of bacterial community composition. In conclusion, seasonal change had the greatest influence on bacterial communities, which overshadowed the effects of soil nutrient as well as other factors, and controls the bacterial communities in soils of RP in tropical region of Hainan.

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## 1. Introduction

Rubber (*Hevea brasiliensis*) trees are one of the most economically important plant species in tropical ecosystems. Over the last 20 years, rubber plantations have expanded rapidly in much of Asia (Li et al., 2015). In southern China, rubber plantations (RP) now occupy approximately one quarter of the total flora of Hainan Island (Wang et al., 2012). Despite this rapid increase in the prevalence of rubber plantations, their effects on the local soil microbial community have not been examined. Because of the important link between soil microbial communities and ecosystem function, it is important that we develop a better understanding of how environmental factors can mediate the dynamics and structure of belowground communities.

Soil microbial organisms interact with each other and affect the functioning of the soil ecosystem (Wagg et al., 2014). Agricultural practices have been shown to cause a loss to microbial biodiversity (Rodrigues et al., 2013), and can lead to dramatic changes in bacterial compositions over a relatively short time period (Neill et al., 1997, 1999; Lan et al., 2017). Given recent efforts to quantify soil health and its influence on ecosystem functioning (Pierce and Larson, 1993), it is imperative that we develop a better understanding of the underlying mechanism driving soil bacterial composition and diversity (Van Horn et al., 2013). However, factors controlling the distribution and abundance of soil microorganisms are still poorly understood (Rousk et al., 2010).

One of the clearest environmental influences on soil bacterial communities is the chemical and physical properties of the soil substrate itself. Edaphic factors have been shown to exert strong influences on microbial community composition at both regional and continental scales (Fierer and Jackson, 2006; Lauber et al., 2008). Grayston et al. (2001) found plant productivity, temperature, and moisture to have the strongest effects on soil microbial community structure. Thus, spatial variability in soil properties in large part controls the structure, diversity, and composition of belowground bacterial communities.

Much less attention, however, has been given to temporal variability and its impacts on soil bacterial communities. Habekost et al. (2008) observed that distribution patterns of microbial communities in grassland soils changed with time, mainly in response to plant performance. Regan et al. (2014) concluded that spatial distribution patterns of soil microorganisms change over a season and that chemical soil properties are more important controlling factors than plant density and diversity. Although a few previous studies have examined the response of microbial composition to environmental change over multiple years (Sheik et al., 2011; Gutknecht et al., 2012), only a handful have considered the effect of seasonal variation on these responses (Lage et al., 2010; Bell et al., 2014). Temporal variability in the soil microbial community composition was shown in response to seasonal variation in temperature, moisture and plant activity (Buckley and Schmidt, 2002; Horz et al., 2004; Waldrop and Firestone, 2006; Koch et al., 2007). Although these examples show that soil microbial communities are influenced

by seasonal change, but, to what extent seasonal changes affect the compositions and diversity of soil bacterial community are still poorly understood.

In recent years, remarkable progress has been made developing better methods to characterize and describe soil biodiversity. Specifically, the development of robust molecular approaches that rely on direct DNA extraction from the soil matrix has revolutionized the field of microbial ecology (Orgiazzi et al., 2015). These methods, while still in their infancy, allow for the quick and accurate assessment of the species composition and diversity of bacterial communities.

In this study, we investigated the community structure and diversity of bacteria in soils of rubber plantations across three seasons. The aim was to understand seasonal variability of soil bacteria and to determine which environmental factors might have the greatest influence on the varying diversity. The fast generation times of microbes mean that compositions can turnover quickly, even across seasons (Bardgett et al., 1999; Kennedy et al., 2006; Cregger et al., 2012; Gutknecht et al., 2012). Therefore, besides dry season and rainy season, we also detect the bacterial compositions and diversity in the alternate periods of drought and rain (here we call it dry-rainy season). We focused on the following questions: how does bacterial composition and diversity change across seasons, and to what extent do seasonal changes affect soil bacterial structure in rubber plantations in south China? Plants may affect the soil microbial community directly via nutrient and water uptake, litter input, and root exudates, or indirectly, by changing composition or abundance of the decomposer community (Regan et al., 2014). Thus, we selected eucalyptus plantations (EP) and secondary tropical forest (SF) to further confirm the results that seasonal variation was a main driver of dynamic change of soil bacterial communities. We try to find positive evidence of following hypothesis: Seasonal changes is the most important factor controlling the soil bacterial structure and diversity in tropical regions of Hainan.

## 2. Materials and methods

### 2.1. Study site

Hainan Island (18°10'–20°10'N and 108°37'–111°03'E) is the largest island in Southern China. With an area of approximately 34,000 km<sup>2</sup> (Lopez et al., 2009), it is the largest island in the Indo-Burma biodiversity hotspot (Francisco-Ortega et al., 2010). The study area is located in the west central part of Hainan Island. This area has a tropical monsoon climate with a rainy season from May to October and a dry season from November to April (Luo, 1985). The annual average temperature is 23.5 °C. The hottest month, July, has an average temperature of 27.8 °C. The coldest month, January, has an average temperature of 17.5 °C. The full temperature range annually is approximately 3–33 °C. The mean annual precipitation is 1815 mm and approximately 84% is accumulated between the months of May and October.

**Table 1**  
Soil properties of the three forests measured at the three sampling seasons.

Forest type	No. of samples	Season	WC (%)	MBC (mg/kg)	pH	SOM (%)	TN(g/kg)	TP(g/kg)	TK(g/kg)
Rubber plantation	12	Dry	12.18 ± 1.74a	110.17 ± 89.46a	3.54 ± 0.15a	1.86 ± 0.44a	0.88 ± 0.25a	1.08 ± 0.46a	26.91 ± 16.25a
	12	Dry-rainy	18.09 ± 2.92b	104.85 ± 84.74a	4.55 ± 0.43b	1.58 ± 0.43a	0.84 ± 0.28a	0.69 ± 0.17b	27.82 ± 16.40a
	12	Rainy	17.95 ± 2.07b	184.43 ± 77.58b	3.58 ± 0.19a	2.18 ± 0.51a	0.95 ± 0.44a	0.59 ± 0.12b	19.55 ± 11.43b
Eucalyptus plantation	3	Dry	13.91 ± 1.11a	59.98 ± 23.98a	3.79 ± 0.34a	2.03 ± 0.01a	0.82 ± 0.11a	0.66 ± 0.04a	34.05 ± 1.97a
	3	Dry-rainy	19.07 ± 2.09b	59.80 ± 25.27a	5.15 ± 0.34b	1.81 ± 0.29a	0.85 ± 0.10a	0.51 ± 0.12b	36.03 ± 0.88a
	3	Rainy	20.49 ± 1.20b	148.40 ± 35.46b	3.98 ± 0.33a	2.05 ± 0.23a	1.01 ± 0.07b	0.41 ± 0.05c	20.93 ± 0.89b
Secondary forest	3	Dry	10.96 ± 1.62a	97.01 ± 46.86a	3.26 ± 0.06a	2.71 ± 0.36a	0.67 ± 0.11a	0.46 ± 0.05a	5.52 ± 0.41a
	3	Dry-rainy	18.72 ± 2.08b	89.28 ± 41.21a	4.44 ± 0.05b	2.35 ± 0.12b	0.85 ± 0.05b	0.32 ± 0.03b	4.92 ± 0.83a
	3	Rainy	19.13 ± 1.80b	185.13 ± 40.70b	3.60 ± 0.02a	2.40 ± 0.07b	0.95 ± 0.08c	0.23 ± 0.02c	3.90 ± 0.29b

Values shown in Table 1 are means ± standard error; ns: not significant; Different letters indicate significant differences at P-values < 0.05.

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