Spatial Variability of Soil Nutrients and Microbial Biomass of *Moso* Bamboo Forest under Different Management Types

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Abstract
The spatial variability of soils nutrients and microbial biomass of *Moso* bamboo forest under different management types was investigated in Jiangxi Province, China in this study and results showed soil nutrients decreased gradually from intensive management (IM) to general management (GM) and to extensive management (EM) types. Besides some fluctuations in the concentrations of available K(AK) and total N(TN), soil nutrients in Fengxin country (FXC) turned out to be relatively high in different soil levels, while they were relatively low in Tonggu country (TGC). There were extremely significant differences for available N (AN) in 0-10EM, 10-30EM in TGC and Yongfeng country (YFC), 30-50EM in TGC, 0-10EM and 30-50EM soil layer of available K(AK) in Jing'an country (JAC). There was no spatial effect on TN of 0-10EM in TGC. Interactions were significant among different management types and experimental sites for soil organic matter (SOM) in 0-10EM, AN and AK in 10-30EM soil layer. However, there were very significant interactions for SOM in 0-10EM and 10-30EM, AN and AK in 10-30EM. The available P (AP) and TN concentrations were not sensitive to interactions. Bacteria constituted the largest part of soil microbes, followed by actinomycetes and fungi. The amount of bacteria listed from highest to lowest is FXC, TGC, JAC, YFC in the IM and EM, while the sequence is FXC, JAC, YFC and TGC in the GM. The amount of fungi listed from highest to lowest is FXC, JAC, TGC and YFC. The amount of actinomycetes of JAC was largest, and was least in FXC. A very significant difference exists in the amount of actinomycetes with different management types. SOC and AN are related to amounts of bacteria and fungi, as well as AP to bacteria, AK to fungi. There was little relationship between the five soil nutrients and actinomyces.

Key Words
Management types, *Moso* bamboo (*Phyllostachys heterocyla* cv. Pubescens), Spatial variability

Introduction

Soil fertility is a comprehensive reflection of various aspects of soil and also an indicator of forest productivity. It will directly influence the growth of bamboo (Huang 2000). Microorganisms are important and active components of soil in forest ecosystems and almost all the biochemical reactions are involved in the soil (Zhou 2007). They play an important role in cycling of materials, energy transformations and maintenance of ecosystem functions (Jin 1991, Xu 1993, Jiao 1997, Nation Biodiversity research 1998). Many important biochemical processes and material cycling of soil can objectively reflect the soil fertility status (Guan 1986, Zhang 1987, Jin 1991, Chen 1993, Zheng 1995). Therefore, it is of great significance that carrying out the research on forest soil nutrients and microorganisms, which will help us use of soil appropriately, make best eco-efficiency of the stands, prevent soil fertility from declining and improve ecological quality of the environment. However, due to the complexity of forest soil conditions, breaking of terrains, spatial variability, spatial and temporal variability of forest soil nutrients is an even more concrete reflection of soil spatial variability. Research on nutrients and microorganisms of soil in *Moso* bamboo forestry will help us understand the geographic variability of it, explore and develop certain theory and techniques in studying accurate fertilization and protecting of *Moso* bamboo forest, and provide a scientific basis to establish *Moso* bamboo forest soil nutrient management systems.

Materials and Methods

Experimental forest overview

Experimental sites are located in northwest Jiangxi Province. It is typical subtropical humid monsoon climate in this region and as well as a main producing region of *Moso* bamboo in Jiangxi province. The investigation point are JAC, FXC, TGC and YFC (114º31'-115º55'E, 25º14'-28º88' N). Experimental plots were set in the central area of bamboo forest. Altitude at the sites is about 200-800 m above sea level. The soil is yellow red, more than 60 cm in depth, 8-16°C in slope, 4.12-5.5 of pH. The climate is mainly humid and mild, with abundant rainfall and sunshine. The average annual temperature is 16.2-19.7℃, with a long frost-free period of

240-307d. Daily average temperature is stable and activities above 0℃ accumulated temperature is 5926-6478℃; ≥10℃ accumulated temperature is 5050-5644℃. Extreme maximum temperature could be 41.6℃ while extreme minimum temperature could be -5.8℃. Average annual precipitation is 1624.9mm. Average sunshine hours were 1737.1 hours (1986). Water, heat, soil and habitat conditions are very suitable for bamboo growth. The experimental plots are mainly occupied by bamboo and most bamboo appear to be pure forest, while there are still a substantial proportion of some broad-leaved mixed forest with fir, natural defective forest.

Description of the sites, experimental design and soil sampling

Three different management types: IM, GM and EM. Each type was set to repeat three times, namely, three plots. The experimental plots were fertilized with bamboo appropriative fertilizer in the last ten days of February 2009 (375kg·hm^{-2}). Soil samples were collected in July 2009. Three points to S-sampling were selected in each plot, and each point was divided into three layers, namely, 0-10 cm, 10-30 cm and 30-50 cm. These soil samples of the same point with the same level were mixed and 1 kg from mixture was taken out and packed with sterile bags, and as soon as possible returned to the laboratory and processed within 2 days. 20 g fresh soil from samples of the 0-10cm soil layer were taken out and placed into sterile bags at 4℃ preservation for microbial analysis. The sub-samples of soil were air-dried for several days and processed through a 2-mm sieve for analysing physical and chemical properties.

Analysis of soil nutrients and microbial biomass

A sub-sample from each plot was analysed for chemical properties and microbial biomass. The chemical properties analysis was carried using the methods described by Lu (1998), and soil microbial biomass was carried with methods described by Cheng (2000).

Results

Variability characteristics of soil nutrients in different management type

Soil pH varied from 4.12 to 5.5 in those sites, appearing to be strong acid. Soil nutrients of the same experimental plots under different management types showed different features (Figure 1). Soil nutrients gradually decreased from IM to GM and EM in all depths.

The nutrients were relatively high in different soil layers except soil AK and TN in FXC, while low in TGC. We found that bamboo grew better in TGC than in FXC. The difference was in relation with sites conditions. SOM in 0-10 cm was three times than in 30-50 cm within same experimental plots. There was extremely significant difference among management types and SOC in 0-10 cm soil in TGC, and significant difference 10-30 cm and 30-50 cm in TGC, and SOM in 10-30 cm in YFC. AN in 0-10 cm was higher than 30-50 cm soil layer (Figure 1).The difference was very significant among management types of AN in 0-10 cm and 10-30 cm soil layer in TGC and YFC, and significant in 30-50 cm in TGC.

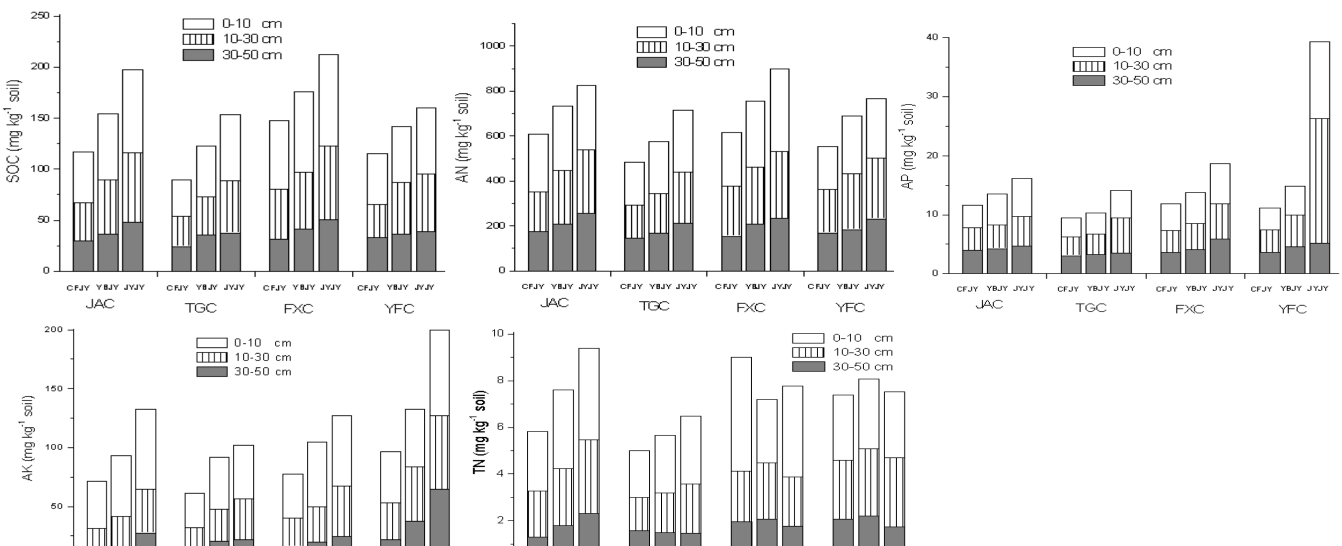

Figure 1. Management type of soil nutrients of bamboo forestry cylindrical scale figure.

Soil AP was low in experimental region, which suggested P fertilizer should be added and soil P content of bamboo supply should be increased. There was extremely significant difference among management types and nutrients in 0-10 cm and 10-30 cm in JAC, AP in 0-10 cm in TGC. Soil AK in TGC was lower than 50mg kg^{-1} (Figure 1). Part of the forest soil should be replenished with K fertilizer in order to meet the needs of growth of bamboo. Soil AK was more than 70.0mg kg^{-1} only in YFC. There was significant difference by ANOVA among management types and AK of 0-10 cm and 30-50 cm in JAC. Soil TN in 0-10 cm was 2-3.92g kg^{-1} in JAC. The difference was not significant among management types to TN except 0-10 cm soil layer in TGC. The difference was extremely significant among alternation management types and experimental zones of SOM in 0-10 cm, AN and AK in 10-30 cm (Table 1). There was significant difference of SOM and AP in 30-50 cm soil layer, while no effect in experimental zone. There was no effect of interactions to AP in 0-10 cm and 10-30 cm and TN in 30-50 cm soil layer.

Table 1. Two-factor (management and zone) analysis of variance P value of interaction.

	0-10EM		10-30EM		30-50EM	
O.M	PM=0.000**	PZ=0.000**	PM=0.000**	PZ=0.002**	PM=0.003**	PZ=0.092
Available N	PM=0.006**	PZ=0.031*	PM=0.000**	PZ=0.000**	PM=0.000**	PZ=0.015*
Available P	PM=0.079	PZ=0.346	PM=0.179	PZ=0.331	PM=0.024*	PZ=0.053
Available K	PM=0.002**	PZ=0.039*	PM=0.001**	PZ=0.002**	PM=0.053	PZ=0.040*
Total N	PM=0.556	PZ=0.408	PM=0.079	PZ=0.019*	PM=0.768	PZ=0.334

*Note: P_M: accompanied probability of management, PZ: accompanied probability of zone, * correlation is significant (P<0. 05); ** Correlation is very significant(P<0. 01). The same as below.*

Difference to the number of soil microbes in different management types of bamboo forestry

There was obvious difference of the quantity of soil microbes in bamboo forestry (Tab.2). Bacteria biomass had the largest amount, followed by actinomycetes and fungi. The proportion of bacteria, fungi and actinomycetes varied with bamboo forestry soil.

Table 2. the same experimental area of different treatments on soil microbial quantity and LSD comparison.

Sample	Manage	Bacteria×107cfu·g -1		Fungi×105cfu·g-1		Actinomyces×106cfu·g-1		Total Micro.×107cfu·g-1
	JYJY	4.80±0.035Aa		1.67±0.38Aa		6.0±0.59Aa		5.42
JA	YBJY	3.83±0.035Bb	**	2.00±0.38Aa	*	1.5±0.59Bb	**	4.00
	CFJY	0.70±0.035Cc		0.50±0.38Bb		1.25±0.59Bb		0.83
	JYJY	5.43±0.42Aa		1.75±0.30Aa		1.80±0.39Aa		5.63
TG	YBJY	1.75±0.42Bb	**	0.3±0.30Bb	**	1.50±0.39Aa	**	1.90
	CFJY	1.20±0.42Aa		0.05±0.30Bb		0.10±0.095Bb		1.21
	JYJY	10.80±0.54Aa		2.50±0.34Aa		1.10±0.095Aa		10.94
FX	YBJY	9.65±0.54Aa	**	1.31±0.34Bb	*	0.90±0.095Aa	**	9.87
	CFJY	6.05±0.54Bb		1.01±0.34Bb		0.50±0.095Bb		6.11
	JYJY	3.39±0.43Aa		1.88±0.25Aa		1.33±0.13Aa		3.54
YF	YBJY	2.07±0.43Bb	**	1.02±0.25Bb	**	1.29±0.13Aa	**	2.21
	CFJY	0.41±0.43Cc		0.46±0.25Bb		0.51±0.13Bb		0.47

Note: The data in the table for the various parties mean ± SD; the same experimental area with the columns of different letters that significant differences.

The quantity of bacteria in a decreasing order was as FXC, TGC, JAC and YFC in IM and EM, and FXC, JAC, YFC and TGC in GM (Table 2). The largest amount of bacteria in IM in FXC was 26.3 times than in EM in YFX, indicating that rich microbial resources in FXC. The quantity of bacteria biomass was greater than other plots in FXC. There was extremely significant difference among management types and the quantity of bacteria, which meant that management types had great impact on soil bacteria in bamboo forest soil. The quantity of fungi in a decreasing order was as FXC, JAC, TGC and YFC, the quantity of fungi in FXC was 1.5 times JAC in IM, 500 times than TGC in EM (Table 2). There was extremely significant management type and the quantity of fungi in TGC and YFC, and significant difference in JAC and FXC. The quantity of Actinomycetes was greater in JAC than others, while it was the lowest in FXC and 18.3% times in JAC. There was extremely significant difference among management types and the quantity of soil actinomycetes.

Table 3. Correlation among soil quantity of microorganism and nutrient.

microorganism	SOM		Available N		Available P		Available K		Total N	
	R	P	R	P	R	P	R	P	R	P
Bacteria	0.879**	0.000	0.803**	0.002	0.717**	0.009	0.422	0.172	0.509	0.091
Fungi	0.847**	0.001	0.866**	0.000	0.664*	0.018	0.746**	0.005	0.508	0.091
Actinomces	0.444	0.148	0.327	0.299	0.504	0.094	0.573	0.051	0.288	0.364

Correlation analysis of soil nutrients and microorganisms

The results of correlation among the quantity of soil microorganisms and nutrients showed that there was extremely significant among SOM, AN, AP and bacteria, and no correlation to soil AK and TN, but it had a certain degree of positive correlation (Table 3). The difference was very significant (P<0. 01) among SOM, AN and AK and fungal. There was significantly correlation between Fungi and AP, while no difference to TN. No significant difference was among five soil nutrients and actinomyces, while a positive correlation to some extent. It showed the quantity of actinomycetes was not sensitive to soil nutrients.

Conclusions

(1) Bamboo forestry soil was strongly acidic. The soil nutrients in a decreasing order was as IM, GM and EM. The soil nutrient was high except AK and TN of different soil layer in FXC, while low in TGC. There was extremely significant difference SOM in 0-10 cm and AN and AK in 10-30 cm of interaction of management types and the experimental sites, and significant difference of SOM and AP in 30-50EM soil layer on management types, while no significant difference to experimental sites. There was no effect on interaction on AP in 0-10 cm and TN in 30-50 cm.

(2) The quantity of bacteria was of the largest amount, followed by actinomycetes and fungi at least. The quantity of bacteria in a decreasing order was as FXC, TGC, JAC and YFC in IM and EM conditions, and FXC, JAC, YFC and TGC in GM. The order of the quantity of fungi was FXC, JAC, TGC and YFC, and a great influence of fungi to management types. The quantity of actinomycetes was higher in JAC than others, while was lowest in FXC.

(3) There was extremely significant difference among bacteria with SOM, AN, AP, and no correlation to AK and TN, but positive correlation to a certain degree. There was correlation between fungal and SOM, AN, AK, and a very significant difference and significantly correlated with AP, while little to TN. The difference among five kinds soil nutrients and actinomyces was not significant, but a positive correlation to some extent. It showed the quantity of actinomycetes was not sensitive to soil nutrients.

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