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Article

Diversity of Soil Microbial Communities Formed by Different Light Penetrations in Forests

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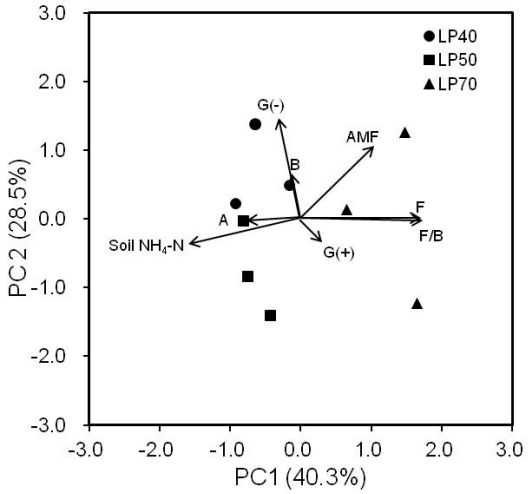
The present study investigated variations in soil microbial communities and the chemical properties of forest soils by differing amounts of penetrating sunlight. The soil temperature was significantly higher in higher light-penetrated soils. Higher light-penetrated soils (LP70) showed significantly more fungal communities than the lower light-penetrated soils (LP40 and LP50) ($p < 0.05$). The NH_4-N concentration in LP70 was significantly lower than those of LP40 and LP50, whereas the other chemical properties showed no significant difference among the soils. The cy19:0 to 18:1ω7c ratio was significantly lower in LP70 than in LP 40 and LP50 showing the negative correlation of light level with microbial stresses ($p < 0.05$). The soil microbial communities and the chemical properties that showed positive eigenvector coefficients for PC1 were the fungi to bacteria, fungi, arbuscular mycorrhizal fungi, and Gram-positive bacteria, whereas negative eigenvector coefficients were found for NH_4-N, actinomycetes, Gram-negative bacteria, and bacteria. Consequently, the amount of penetrating light was responsible for microbial compositions in the forest soils in correlation with the concentration of NH_4-N and soil temperature.

Key words: Microbial community, Light penetration, Forest soil, Fungi



Principal component (PC) analysis of the soil microbial communities subject to the different light penetrations. LP40, light penetration 40%; LP50, light penetration 50%; LP70, light penetration 70%; A, actinomycetes; AMF, arbuscular mycorrhizal fungi; B, bacteria; F, fungi; G(+), Gram-positive bacteria; G(-), Gram-negative bacteria.

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Introduction

Microbial communities in soil are a very important property for soil ecosystems in the forestry industry (Hynes and Germida 2013) since microbial diversity is an assessing indicator for soil quality and health (Mäder et al. 2002, Lee and Kim 2011, Yang et al. 2012). Soil microbial communities have been well evaluated in forest soils with long-term nitrogen fertilization (Blaško et al 2013) as well as in upland soils with different fertilization (Lee et al 2013). Light is one of the most effective environmental factors for community composition in soils (Rodriquez-Romero et al. 2010). Davies et al (2013) reported that light constructed phototrophic, bacterial, and fungal communities on soil surfaces. Although some reports showed that light had a significant effect on differentiation of soil microbial communities, the impact of penetrating light levels on forest soil microbial communities and chemical properties is less well studied.

In this study, we analyzed variations of soil microbial communities and chemical properties in forest soils sampled from regions receiving different levels of light penetrating light. These findings would provide basic information for forest soil management and forest development in Korea.

Materials and Methods

Soil sampling and chemical properties assay Soil was sampled from Mount Geumwon in Geochang County, South Gyeongsang province, Republic of Korea (35° 43' N and 127°46' E) on October 23, 2012. During the week before soil sampling, the average temperature was 8.6°C and the precipitation was 12.4 mm in this area. The experimental plot was generated from regions receiving 40%, 50% and 70% light and named LP40, LP50, and LP70 respectively. The plots (20 x 20 m) were laid out in a randomized complete block design with three replicates. The soil was classified in the Samgag series (sandy loam, Lithosols) based on the Korean taxonomy of soil classification (NIAST, 2000). These soils have thin brown sandy loam A horizons and moderately thick strong brown to yellowish brown sandy loam cambic B horizons. The 800g soil samples (0-15 cm depth) were collected from each plot using an auger. The samples were freeze-dried and maintained in a freezer at -20°C before analysis. The soil samples were crushed to pass through a 2mm sieve.

Soil microbial community assay The assay of soil microbial communities was conducted based on the previously reported method (Lee and Kim, 2011; Lee et al 2013; Yang et al, 2012). The FAME was profiled using an Agilent 6890 GC with a flame ionization detector and the microbial types were identified based on the Sherlock Microbial Identification System (Microbial ID, Ins., Newark, DE).

Statistical analysis All data was statistically analyzed using the SAS software version 9.2 (SAS Institute, Cary, NC). The measured individual soil microbial and chemical variables were compared using a one-way analysis of variance (ANOVA). Fisher's exact test was used at a 5.0% level of significance ($p < 0.05$). To determine the overall effects of the amount of penetrating light in forest soils, soil microbial communities and chemical data were analyzed by principal component analysis (PCA).

Results and Discussion

The forest soils sampled from different light-penetration regions were analyzed for their chemical properties. The soil temperature was significantly higher in higher light-penetration regions. The soil pH of LP40 was significantly lower than that of LP70 (Table 1). In general, all soils showed acidity resulted from low exchangeable Ca concentration in these forest soils. The NH_4-N concentration in LP70 was significantly lower than that of LP40 and LP50, whereas the other chemical properties of the soils showed no significant difference.

The fungal communities were significantly more prevalent in LP70 than in LP40 and LP50 ($p < 0.05$). The fungal communities were known to be more sensitive to environmental conditions than bacterial communities due to their high

Table 1. Chemical properties of forest soils as affected by light penetration.

Light	pH	EC	OM	Avail. P_2O_5	Exch. Cation				NH_4-N	Temperature
					K	Ca	Mg	Na		
	1:5	dS m^{-1}	g kg^{-1}	mg kg^{-1}	----------	$cmol_c$ kg^{-1}	----------		mg kg^{-1}	°C
LP40†	4.6	0.16	109	24	0.16	1.13	0.42	0.30	7.4	10.8
LP50	5.0	0.16	127	11	0.13	1.98	0.41	0.28	8.2	11.3
LP70	5.2	0.13	110	16	0.17	1.89	0.42	0.27	4.9	12.2
LSD‡ ($p < 0.05$)	0.55	NS	NS	NS	NS	NS	NS	NS	2.64	0.75

†LP40, light penetration 40%; LP50, light penetration 50%; LP70, light penetration 70%.

‡The Fisher's least significant difference (LSD) was used to detect and separate the mean treatment differences at 5.0% levels of significance, NS not significant.

Table 2. Soil microbial communities in the forest soils expressed as % total fatty acid methyl esters subject to the different light penetrations.

Light	B[†]	G(-)	G(+)	A	F	AMF	G(-)/G(+)	F/B
LP40[‡]	32.7	18.7	11.9	3.5	11.3	3.0	1.58	0.35
LP50	33.0	18.2	12.7	3.2	11.6	1.9	1.43	0.35
LP70	32.8	18.3	12.5	3.1	16.7	3.1	1.47	0.51
LSD[§] ($p < 0.05$)	NS	NS	0.81	NS	1.06	0.93	0.094	0.031

[†]A, actinomycetes; AMF, arbuscular mycorrhizal fungi; B, bacteria; F, fungi; G(+), gram-positive bacteria; G(-), gram-negative bacteria.

[‡]LP40, light penetration 40%; LP50, light penetration 50%; LP70, light penetration 70%.

[§]The Fisher's least significant difference (LSD) was used to detect and separate the mean treatment differences at 5.0% levels of significance, NS not significant.

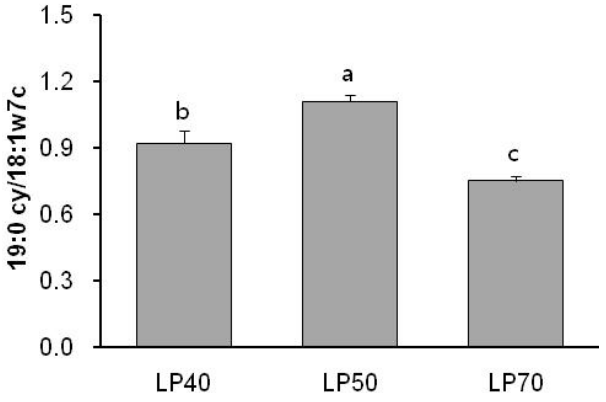

Fig. 1. Ratio of fatty acid cy19:0 to 18:1w7c of different forest soils as affected by light penetration. Means by the same letter within a column are not significantly different at 0.05 probability level according to DMRT. Bars represent one standard deviation of the mean.

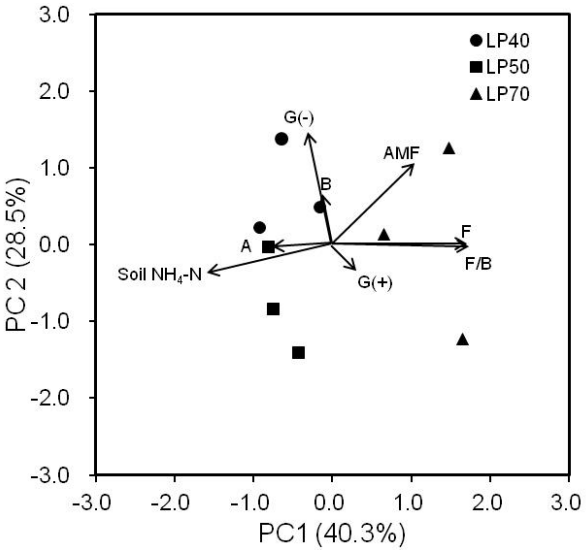

Fig. 2. Principal component (PC) analysis of the soil microbial communities subject to the different light penetrations. The variance explained by each PC axis is shown in parentheses. The arrows indicate eigenvectors of the individual soil microbial communities of PC. LP40, light penetration 40%; LP50, light penetration 50%; LP70, light penetration 70%; A, actinomycetes; AMF, arbuscular mycorrhizal fungi; B, bacteria; F, fungi; G(+), Gram-positive bacteria; G(-), Gram-negative bacteria.

dependency on high organic matter (Hamman et al. 2007, Lee et al. 2013). Furczak and Joniec (2007) reported that ammonification was negatively correlated with filamentous and cellulolytic fungi. The activity of ammonium oxidation bacteria, *Nitrosomonas* species, was significantly decreased by lower temperatures caused by lack of light penetration (Groeneweg et al. 1994). The size of a fungal community was negatively affected by NH_4-N concentration in forest soils (Wallandeer et al. 1999). In this study, fungi were the most affected forest soil microbial community most affected by the amount of light penetration which was negatively correlated with NH_4-N concentration.

The ratio of Gram-negative bacteria to Gram-positive bacteria was significantly decreased in the LP50 and LP70 samples compared to the LP40 sample by enlarged Gram-positive bacteria community ($p < 0.05$). It was interpreted that the Gram-negative bacteria were more dependent on the amount of available organic matter (Mechri et al. 2010) and Gram-positive bacteria were more responsive to light level. The cy19:0 to 18:1ω7c ratio, an indicator of environmental stress in bacterial communities (Guckert et al. 1986), was significantly lower in LP70 than in LP 40 and LP50 showing the negative correlation of light level with microbial stresses (Fig. 1). To verify the effects of light penetration on forest soil microbial communities, PCA was applied to all of the individual FAME biomarkers. PC1 explained 40.3% of the variance, whereas PC2 explained 28.5%, to give a cumulative total of 68.8% (Fig. 2). The PC1 of the PCA separated the samples from different light-penetration plots ($p < 0.05$). The soil microbial communities and the chemical properties that showed positive eigenvector coefficients for PC1 were the fungi to bacteria, fungi, arbuscular mycorrhizal fungi, and Gram-positive bacteria, whereas negative eigenvector coefficients were found for NH_4-N, actinomycetes, Gram-negative bacteria, and bacteria. Consequently, the amount of light penetration was responsible

for microbial compositions in the forest soils in correlation with the concentration of NH_4-N and soil temperature. This result provides a foundation for forest development and conservation.

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