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Original article

What is important for ant assemblages in temperate forest soils?

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ABSTRACT

Ant assemblages in the soil have been studied at eight forest sites (4 oak forest sites, and 4 pine forest sites) in four study areas (1 seminatural area, and 3 industrialized areas) in South Korea for 6 years from 2002 to 2010. Soil cores and Tullgren funnel were used for the ant survey. Ant surveys were carried out once per year in autumn (from late September to mid-October). The soil pH was lower in the industrialized than in the seminatural area, showing the acidified soils in the industrialized areas. However, the soil acidification did not influence the ant assemblages. The results from the nonmetric multidimensional scaling ordination and from the community temperature index values indicate that temperature is a key determinant for structures of the soil ant assemblages. The ant assemblages were not different according to the forest types (oak forests *vs.* pine forests). Occurrence of ant species varied greatly among years, indicating that more replicates and advanced sampling method are needed for the monitoring of the soil ant assemblages.

Introduction

Soils are organic and inorganic particles supporting the living organisms in the terrestrial ecosphere. Soils provide nutrients, air, space, water, commensal microorganisms for growth of plants, and, therefore, soil characteristics are one of most important determinants for plant productivity in the terrestrial ecosystems (Sørensen 1997). Microorganisms such as fungi and bacteria in soils decompose organic matters, and provide nutrients to plants. Extremely abundant microanimals in soils feed on the microorganisms and on the decomposing organic matters. Ants are top predators in the soil ecosystems, and, therefore, may make cascading effects on the diverse soil organisms through food chains. Ants dig soils for nests, which provides air and nutrients to soils and contributes to soil turnover, and harbor many commensals. These activities increase productivity and biodiversity of soils (Wagner et al 1997). Therefore, ants are called ecosystem engineers (Folgarait 1998). Despite their significant contributions to soil ecosystems, ants in soils are usually overlooked for their importance and roles (Lobry de Bruyn 1999). Recently, ants have been acknowledged as standard bioindicators for diverse environmental changes (Agosti et al 2000). However, most attention is focused on ground-dwelling, litter-dwelling, and vegetation-dwelling ants (Agosti et al 2000). Only a few studies of the soil-dwelling ants (hereafter, soil ants) are found among the huge literatures of ant assemblages. In Korea, to my knowledge, there is no study specifically designed to find characteristics of the soil ant assemblages despite the long history of Korean ant study.

South Korea has experienced the rapid urbanization and industrialization since the early 1960s. These would acidify soils through acid rains in forested areas in this country. However, few studies on the ecological influences of soil acidification are reported on soil arthropods (Cho 1999; Kwak et al 1992). In this study, the primary aim was to find characteristics (species composition, abundance, richness) of ant assemblages in forest soils. The next aim was to test whether soil acidification would influence the ant assemblages. In South Korea, pine forests (*Pinus densiflora*) dominated forested areas (about 60%) in the 1970s, but oak forests (27%) and pine forests (23%) have been balanced since the 2000s as deforested forests were recovered by Korea's successful reforestation program (Bae and Lee 2006). Ant assemblages are known to be usually independent on forest types (deciduous forests and coniferous forests, or tree species; Kwon 2014, Kwon et al 2014b; Floren and Linsenmair 2001). This finding was also tested. Through the national survey on the ground-foraging ants, temperature was found to be the key factor for distribution of ants (Kwon and Lee 2015; Kwon et al 2014a). This finding indicates that the soil ant assemblages were also mainly determined by temperature. This

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prediction was also tested, and the influences of three factors (soil acidification, forest types, and temperature) on the soil ant assemblages were compared and discussed.

Materials and methods

Study area

Ants were sampled in the soils in both deciduous and coniferous forests at four study areas including one seminatural area (Hongcheon) and three industrialized areas (Gangwha, Seoul, and Ulsan) in South Korea (Table 1). Hongcheon (HC) is the least disturbed county of the four study areas, with the highest forest proportion in South Korea. Therefore, it is relatively uninfluenced by industries and urbanization. The altitude of the sampling sites in Hongcheon was relatively higher than in other areas. Seoul (SU) is the capital of South Korea and is inhabited by > 10 million people. The sampling sites were in the Namsan Mountain, an isolated urban forest with 84% of forested area and the biggest city park in Seoul. Gangwha (GH) is in the western part of Seoul, and its air environment has been influenced by the surrounding industrialized areas such as Seoul and Incheon in Korea and China's growing eastern industrial region. The sampling sites were at the foot of Manisan Mountain. Ulsan (US) is a metropolitan city with heavy industry including factories for ships, vehicles, chemicals, and oils. Mean annual mean temperatures (MATs) in the study areas were estimated by the temperature model of Kwon et al (2012). Mean annual precipitation is in the range of 1277.1–1450.5 mm (http://www.kma.go.kr; Table 1).

In each study area, two sampling sites (oak—deciduous, D—and pine forests—coniferous, C) which was 0.5–1 km apart from each other were chosen. The environmental conditions such as slope, altitude, and vegetation coverages were similar in oak and pine forests at the same study area (Table 1). Coverage of the canopy layer was > 85% in three study areas (Gangwha, Seoul, and Hongcheon), and 40–55% in Ulsan. Coverage of the shrub layer varied in different areas. *Pinus densiflora* was dominant in coniferous forests, whereas *Quercus acutissima* and *Quercus mongolica* were dominant in the deciduous forests.

Sampling

Ants in soils were sampled for 6 years (2002, 2003, 2004, 2006, 2007, 2010) from 2003 to 2010 with a soil core (diameter 4.8 cm, depth 5 cm) at each sampling site from late September to early October. In Korea, soil arthropods are more abundant in surface soil (0–5 cm) than in deep soil (5–10 cm, 10–15 cm; Cho 1999; Oh and Kim 2000; Kwak et al 1992). They are also more abundant in autumn months such as October (Choi 1996; Oh et al 2001; Kwak et al 1992) because the climate condition in this period is relatively stable, with rare occurrence of heavy rains. At each sampling site, 10 soil samples (2 soil cores per sample) were linearly collected with a 5-m interval between each replicate. A Tullgren funnel (also known as a Berlese funnel) was used to extract ants from soil samples with electric light (20W/220V) for 72 hours. The extracted specimens were identified to species level using the key for Korean ant species (Kwon et al 2012).

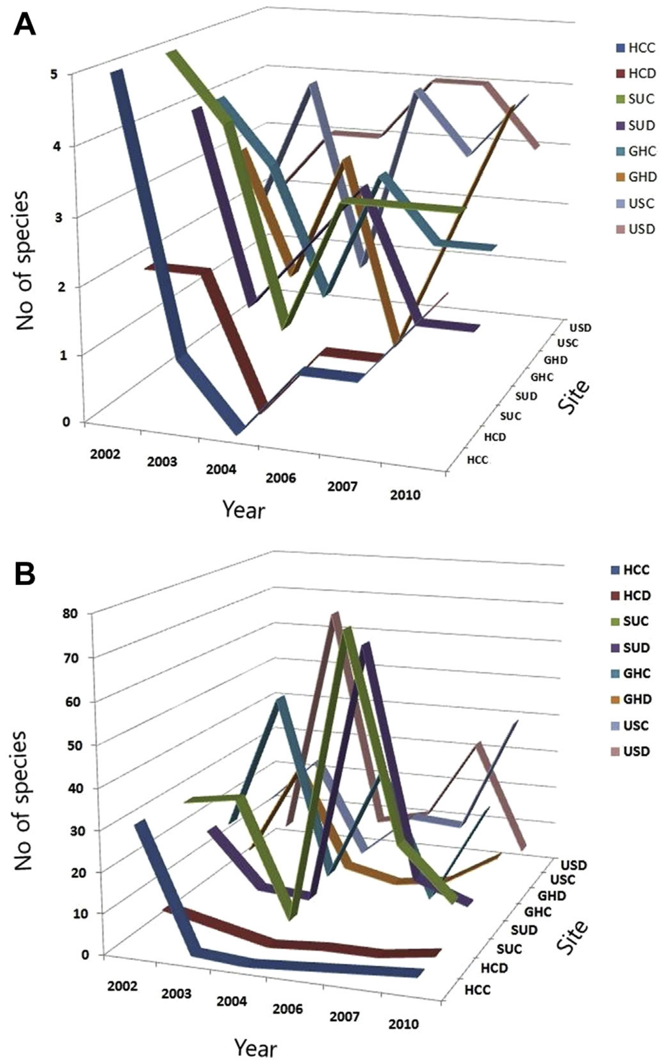

Figure 1. Yearly change of richness (A, number of species) and abundance (B, number of individuals) of the ant assemblages in eight sampling sites. Environments for the sites are shown in Table 1. GH = Gangwha; HC = Hongcheon; SU = Seoul; US = Ulsan.

Table 1. Environmental factors of the study site. Annual mean temperatures in the study areas that were estimated using the temperature model of Kwon et al (2012). Annual mean precipitations were obtained from http://www.kma.go.kr.

Study area	Forest type	Site	Altitude (m)	MAT (°C)	MAP (mm)	Coverage (%)		Dominant species	
						Canopy layer	Shrub layer	Canopy layer	Shrub layer
Hongcheon (N37.74686	Deciduous	HCD	805	7.3	1346.7	90	80	*Quercus mongolica*	*Sasa borealis*
E128.4368)	Coniferous	HCC				85	30	*Pinus densiflora*	*Spiraea miyabei*
Seoul (N37.54383	Deciduous	SUD	85	10.4	1450.5	98	65	*Quercus mongolica*	*Disporum smilacinum*
E127.0008)	Coniferous	SUC				98	60	*Pinus densiflora*	*Eupatorium rugosum*
Gangwha (N37.61058	Deciduous	GHD	64	10.3	1405.4	85	10	*Quercus mongolica*	*Rhododendron mucronulatum*
E126.4519)	Coniferous	GHC				95	5	*Pinus densiflora*	*Kalopanax pictus*
Ulsan (N35.51197	Deciduous	USD	59	12.9	1277.1	40	90	*Quercus acutissima*	*Andropogon brevifolius*
E129.3069)	Coniferous	UDC				55	100	*Pinus densiflora*	*Persicaria perfoliata*

MAP = mean annual precipitation; MAT = mean annual temperature.