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Ecological Role of Earthworms in Red Pine Forest in the Limestone Areas

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석회암지역 소나무림에서 지렁이의 생태학적 역할

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ABSTRACT

Ecological role of earthworms in red pine forest was investigated with emphasis on the population size, cast production and changes of physicochemical properties of soil by earthworm's activities. The density of earthworms was 62.8/m^2 in August, 1992. Average biomass of earthworms was 16.3 g/m^2. N and P concentrations in the tissue of earthworms were 28.5 mgN/g and 0.5 mgP/g, respectively. Cast production continued from April to November, with a peak in August. Annual production of earthworm casts was 5,379 g/m^2. Bulk density of surface soil decreased due to the earthworm's cast-forming activity. Clay fraction in surface soil increased by addition of casts. Soil chemical properties were significantly different between the surface soil and the earthworm casts. The amounts of organic matter, N, P, K, Ca and Mg added to the soil via earthworm casts during one year were 9.3 t/ha, 11.29 kg/ha, 0.78 kg/ha, 12.36 kg/ha, 140.29 kg/ha and 20.96 kg/ha, respectively. Earthworms can feed on waxy and resinous litter when it became palatable by decomposing processes.

Key words: Bulk density, Calcareous soil, Cast production, Earthworms, Limestone area, Soil texture

INTRODUCTION

Some species of animals are agents of soil disturbance in ecosystems as a result of digging burrows, soil ingestion and excretion (Donahue *et al.* 1983). Earthworms are the best-known group of large-animals inhabiting soil.They are important soil organisms which

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can influence on physicochemical properties of soil through ingesting decaying organic matter and mineral soil, and then excreting soil casts with the unassimilated organic particles as feces. The properties of earthworm casts quite differ from the normal top soil(Syers *et al.* 1979, Bhadauria and Ramakrishnan 1989). Several studies have shown that earthworm casts are enriched in nitrogen relative to the surface soil horizon(Gupta and Sakal 1967, Watanabe 1975, Syers *et al.* 1979). Lunt and Jacobson(1944) suggested that the increase of nitrogen content of casts has been attributed to the mixing of plant remains with mineral soil in the digestive tract of earthworm.

The distribution of earthworms is mainly governed by pH conditions of the soil. They occur in neutral, slightly alkaline, and slightly acidic conditions. It is known that earthworms are rare in soils with $pH<4.0\sim4.5$, but there are considerable differences between species in their preferred pH range. Earthworms burrow through soil and feed on dead organic materials. Their influence on the decomposition of organic matter and the formation of organo-mineral complexes has been studied since the time of Darwin (Wallwork 1970). And there are many literature relating to litter decomposition(Edwards and Heath 1963, Syers *et al.* 1979), maintenance of surface soil fertility(Barley and Jennings 1959, Wallwork 1970, Syers and Springett 1984, Bhadauria and Ramakrishnan 1989, Mun and Kim 1991). Earthworms feed on animal and plant residues and on most deciduous leaves(Donahue *et al.* 1983). Therefore, cast production by earthworms can alter nutrient status of soil.

In Korea, calcareous soils are developed in limestone areas in Kangwon and Ch'ungbuk Provinces. Many earthworm casts are observed in this limestone areas, such as in red pine, oak, and thuja forests. Earthworms, however, are rare in other coniferous forests in non-limestone areas with acidic soil reaction. It is supposed that cast-forming activity of earthworms in this limestone area could influence the nutrients cycling through modification of physicochemical properties of soil.

The purpose of the present study is to quantify the ecological role of earthworms in these limestone areas. For these, the density of earthworm populations, annual cast production and their nutrient content, and changes of physicochemical properties of soils were investigated.

METHODS

Study area

This study was carried out in a red pine forest which had developed at Maep'o near Tanyang(37° 03′N, 128° 18′E), Ch'ungbuk Province in Korea. Site characteristics, and floristic composition have been described in detail by Kim *et al.*(1990). Data of precipitation, air and soil temperature were obtained from Chech'on meteorological station which is located 4 km distance from the study site. During the experimental period, soil temperature was measured on monthly basis at 10 cm soil depth with soil thermometer(Weston, Model 2261).

Earthworm density and cast production

To estimate the numerical density of earthworm population, ten 50 cm×50 cm quadrats were established in July 1992. Existing earthworm casts in each quadrat were removed completely. After 1 month, the number of earthworm casts, considered as the number of earthworm, was counted in each quadrat. Some earthworms were sampled by hand-sorting method from the excavated soil for estimation of biomass. Biomass values were based on oven-dry weight at 50℃ for 24 h.

Cast production

To estimate earthworm cast production, five 1 m×1 m quadrats were set up in the study area in March, 1992. Existing earthworm casts in each quadrat were removed, and collected newly formed casts at every month from April to November in 1992. All the casts were brought to the laboratory and weighed after oven-dried at 50 ℃ for 48 h.

Surface soil(0~10 cm) and subsoil(10~20 cm) were sampled monthly during the experimental period. All the soil samples were air-dried and stored for analysis. Analysis of physicochemical properties of soil and earthworm casts were carried out as described by Allen *et al.*(1974) and Kim *et al.*(1990).

Changes of soil bulk density

In May, fifty live earthworms were sampled in the vicinity of the study site and brought to the laboratory. Five cylindrical pots, 16cm inner diameter and 20cm height, which contain calcareous soil, were prepared. Five live earthworms were put into each pot. Three additional pots, which contain the same amount of calcareous soil but without earthworms, were prepared as control. 200 ml of tap water was supplied in each pot at every other day. Changes of bulk density by earthworm activity were calculated by measuring the increase or decrease of height of pot soil every week.

RESULTS AND DISCUSSION

Population density and biomass

Many earthworms live in the extensive burrow systems and can respond to the disturbance of digging by moving away quickly from the center of disturbance. So, they present some difficult problems for quantitative sampling of their abundance and biomass (Lee 1985). There are many methods for field sampling of earthworm (Phillipson 1970, Lee 1985). However, the choice of method for population density of earthworm must be based on the soil conditions (Phillipson 1970). Expellent method with formaldehyde and hand sorting methods were not good in this study site due to the topographical features.

Density of earthworm population, based on the number of earthworm casts, was 62.8

/m^2 in August. Average body weight of sampled earthworms was 0.26 g/individual. Total biomass of earthworm population was 16.3 g/m^2. Population density and biomass of earthworms are quite different according to vegetation types, topography and physico-chemical conditions of soil(Satchell 1967, Wallwork 1970). Cuendet(1984) suggested that litter composition is the first factor determining earthworm abundance and biomass. Bhadauria and Ramakrishnan(1989) reported that the size of earthworm population had significant correlations with physical factors such as moisture and organic matter in the agricultural system. Density of earthworm in this study site was lower than those reported by Satchell(1967), Donahue *et al.*(1983) and Bhadauria and Ramakrishnan(1989). According to our observation, casts produced by juveniles were slender and easy to shatter. Therefore, the density of earthworm population, represented by the number of casts, in this study might be underestimated.

Cast production

Cast production continued from April to November(Fig. 1). In winter period, there was no cast production(Wallwork 1970). In April, cast production was about 150 g/m^2. It gradually increased till August when showed a peak with 1,200 g/m^2. In July, however, cast production decreased. The reason for this was that considerable amount of casts were shattered by heavy rain(Fig. 2). Many shattered casts were observed after rainfall in the field. In November, cast production decreased as the temperature become lower(Fig. 3). The soil témperature in March, when there was no earthworm activity, was lower than that in November.

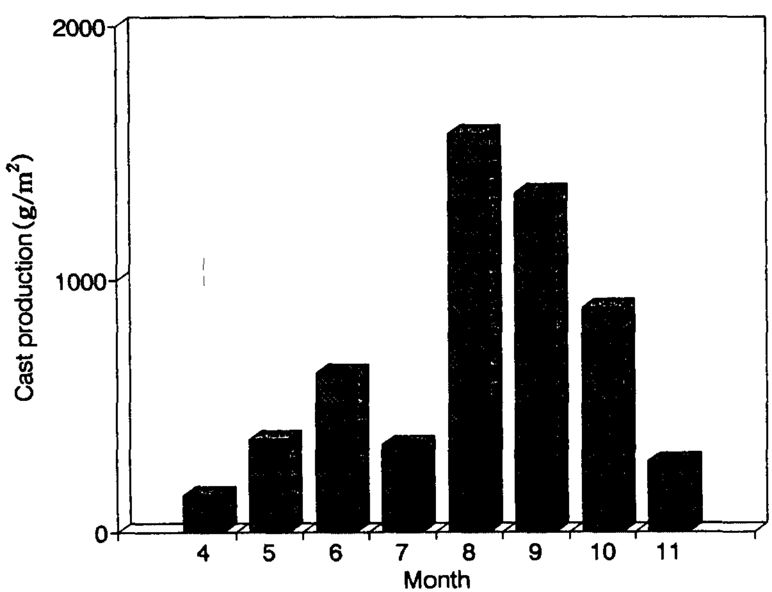

Fig. 1. Seasonal cast production in the study site.

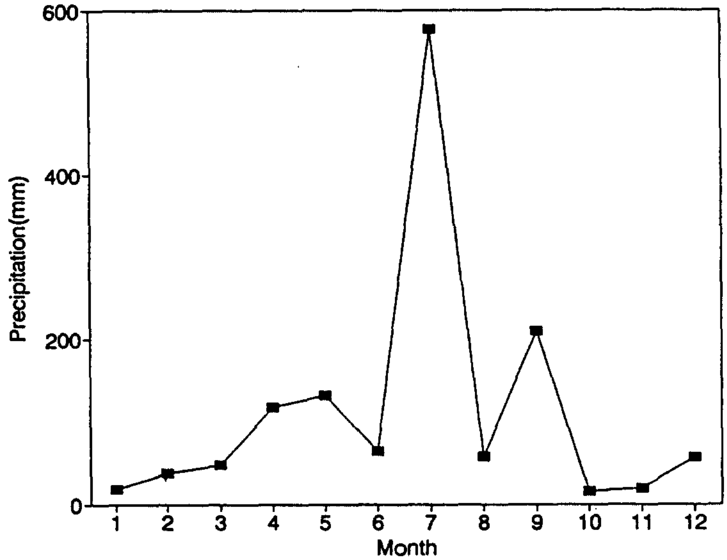

Fig. 2. Seasonal precipitation of Chech'on, about 4 km apart northwestward from the study area, in 1992.

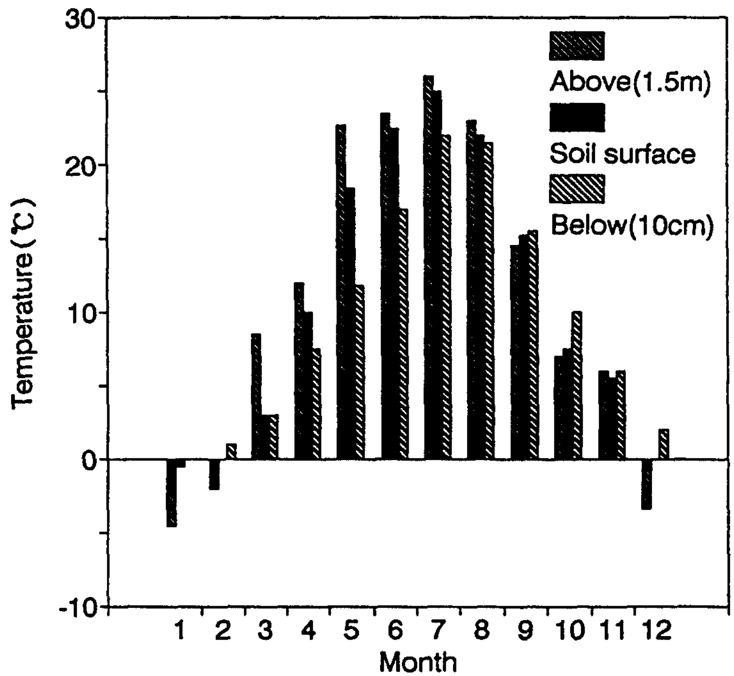

Fig. 3. Seasonal aboveground, soil surface and belowground temperature of the study area in 1992.

Total amount of casts produced in 1992 was 5,375 g/m^2. This might be underestimated because considerable amounts of casts were shattered after heavy rain. Bhadauria and Ramakrishnan(1989) reported that 4,000 g/m^2 of casts was produced in 15-yr agricultural system. Syers *et al.*(1979) reported that annual cast production was 3,300 g/m^2 in a pasture ecosystem.

Earthworm casts consist of excreted masses of soil mixed with residues of comminuted and digested plant residues(Lee 1985). Therefore, the addition of casts on the forest floor can alter the physicochemical properties of surface soil. However, not all earthworms cast at the soil surface. Some species deposit casts in other soil space and it is not easy to estimate the quantity of subsurface casting or its significance in aggregate formation and soil structure(Lee 1985).

Changes of soil bulk density

Earthworm affect pore space in soils by burrowing and depositing casts as loosely packed aggregates on soil surface. Edwards and Lofty(1977) reported that earthworm burrows constitute about 5% of total soil volume. There was a significant difference in soil bulk density between the treatment and the control pots(Fig. 4). In treatment pots, soil bulk density decreased rapidly. After 5 weeks, it decreased to 80% of the original bulk density. However, that of control pots increased to 110% of the original bulk density. Lowered bulk density was mainly due to the burrowing and cast-forming activity of earthworms. Burrows enable earthworms to select the conditions that suit them best from the range of microenvironments available in one or more soil horizons, while retaining ac-

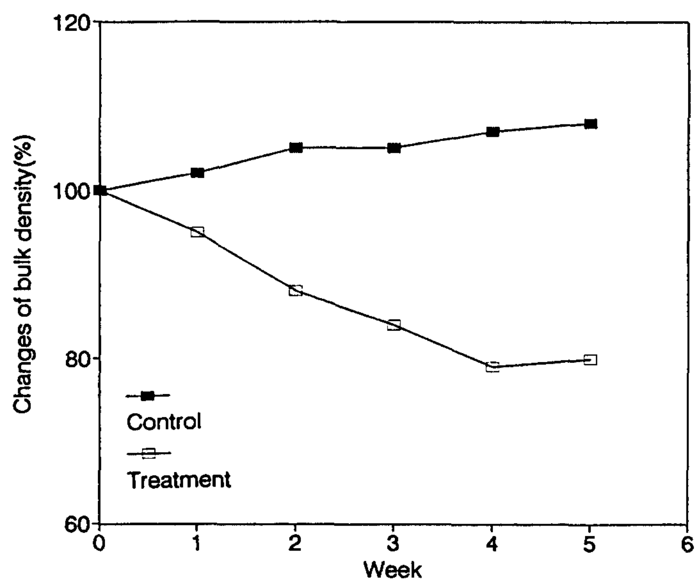

Fig. 4. Changes of relative soil bulk density with and without earthworms.

cess to forage for food at the surface when conditions are favorable(Lee 1985). Burrowing activity of earthworm can enhance aeration and water filtration of soil, and root development of herb and shrub species.

Physicochemical properties of soil

Soil texture was quite different among surface soil, subsoil and casts(Fig. 5). Sand content of subsoil ranged 70~80% while that of top soil ranged 40~50%. Clay content of top soil and subsoil was 25% and 10%, respectively. Sand and clay content of casts was 15% and 60%, respectively. The greater amount of clay in the top soil than in the subsoil may be due to the addition of casts. Moisture and nutrient holding capacity was positively related to the clay content of the soil(Foth 1984). Therefore, cast production by earthworms can affect soil chemical properties(Mun and Kim 1991).

Earthworms have influence on the supply of plant nutrients in several ways. Syers and Springett(1984) reported that 18 to 92 kg/ha of nitrogen was released annually by earthworms into the depending on their population size, mainly as dead tissue as well as excretion of mucus, urea, uric acid and ammonia.

Another route of nutrient supply is through the cast production. The nitrogen and phosphorus concentration in the tissue of earthworm were 28.5 mg/g and 0.55 mg/g, respectively. Bhadauria and Ramakrishnan(1989) reported that the addition of nutrients through dead earthworm tissue was substantial only for nitrogen and potassium. In our result, concentration of nitrogen in tissue was much higher than that of phosphorus. Mun and Kim

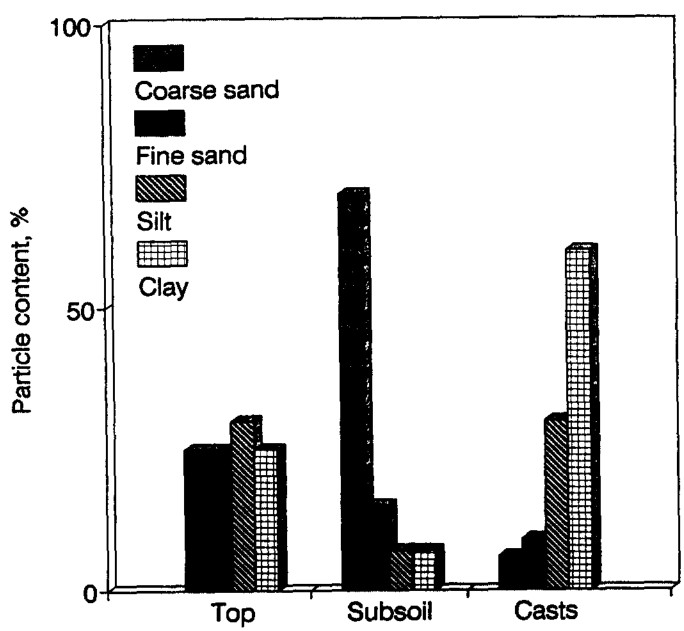

Fig. 5. Comparisons of soil texture among top soil, subsoil and earthworm casts.

(1991) reported that the casts had about 1.5 times of total nitrogen, 1.8 times of available phosphorus, 2, 1.3 and 1.6 times of exchangeable potassium, calcium and magnesium, respectively, than the top soil did. The amount of organic matter and nutrients added to the surface soil *via* cast production were shown in Table 1.

Table 1. Amount of organic matter and nutrients(kg /ha) added to the top soil *via* cast production during one year

	Organic matter	N	P	K	Ca	Mg
Concentration	0.17g / g	0.21mg / g	0.02mg / g	0.23mg / g	2.61mg / g	0.39mg / g
Total amount	9,300	11.29	0.78	12.36	140.29	20.96

Most of the casts were produced over the surface litter, which made surface litter mix well with moistened soil. This can accelerate the microbial litter decomposition due to the increased moisture content of litter. Earthworms play a key role in the removal of the surface litter(Lee 1985). Raw(1962) reported that earthworms removed litter at a rate of 20 $g \cdot m^2 \cdot day^{-1}$ in an apple orchard, where the biomass of *L. terrestris* was 168 g/m^2. However, removal of litter from the soil surface by earthworms does not imply that all the removed litter is digested. Only little amount of ingested organic material is digested. Most of the ingested organic material is macerated, mixed with soil particle, passed through the gut and excreted as casts which were finely ground physically but with little chemical change(Lee 1985). Nielsen and Hole(1964) noted that some species, especially *L. terrestris*, pull leaves or parts of leaves into their burrows and eat them when they are partially decomposed.

Donahue *et al.*(1983) pointed out that earthworms do not feed on the needle litter of waxy and resinous conifers. In this red pine stand, herb and shrub layer developed well (Kim *et al.* 1990, Mun and Kim 1991), and it was thought that litter originated from these herbs and shrubs might serve as food sources for earthworms. However, we could observe many earthworms in a *Thuja orientalis* stand, which is located in the same limestone area, where the herb layer was almost absent. And most of the earthworms in this stand did not produce casts and were distributed under the thick waxy litter layer. This suggest that earthworms can feed on waxy and resinous litter when it became palatable by decaying processes.

적 요

석회암지역 소나무림에서 지렁이 개체군의 크기, 캐스트 생산량과 그로 인한 토양의 이화학적 성질의 변화를 조사하여 지렁이의 생태학적 역할을 파악하였다. 단위 면적당 캐스트의 수를 측정하여 산출한 지렁이 개체군의 밀도는 62.8 /m^2, 생물량은 16.3 g /m^2 이었다. 지렁이의 캐스트 생산은 4월부터 시작되어 11월까지 계속되었으나 8월에 최대치를 보였고, 연간 캐스트 생산

량은 5,379 g /m² 이었다. 지렁이의 캐스트 생산 활동으로 토양의 가비중이 감소되었으며, 캐스트를 통해 연간 표층토에 첨가되는 유기물, 질소, 인, 칼륨, 칼슘 및 마그네슘의 양은 각각 9.3 t /ha, 11.29 kg /ha, 0.78 kg /ha, 12.36 kg /ha, 140.29 kg /ha 및 20.96 kg /ha 이었다. 지렁이 조직의 질소와 인 함량은 각각 28.5 mg /g과 0.5 mg /g으로 인에 비해 질소의 함량이 높은 것으로 나타났다. 지렁이는 납질이며 레진을 함유한 침엽수의 낙엽을 먹지 않는 것으로 알려져 있으나 본 석회암지역의 소나무군락이나 측백나무군락에서는 지렁이가 분해과정에 있는 이들 낙엽을 먹이원으로 이용하는 것으로 판단된다.

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