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Soil Properties of *Quercus variabilis* Forest on Youngha Valley in Mt. Worak National Park

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ABSTRACT: Soil properties of *Quercus variabilis* forest on Youngha valley at Mt. Worak National Park were studied as a part of Korea National Long-Term Ecological Research. Soil sampling was carried out along the 50 cm soil depth with 10cm intervals at every quarter from May 2005 through July 2006. Fresh soil was used for NH_4^+-N, NO_3^--N, and soil water content determination. Remaining soils were air dried in the shade, and then used for determination of soil pH, T-N, T-P and exchangeable cation. Average soil organic matter in top soil was 8.5 ± 1.2% and decreased with soil depth. Bulk density of top soil was 0.82 ± 0.07 g/cm^3 and increased with soil depth. Soil organic matter and bulk density showed a negative linear correlation (R^2=0.8464). Soil pH in top soil and subsoil was similar. T-N, NH_4^+-N, NO_3^--N and T-P in top soil were 1.9 ± 0.5 mg/g, 7.3 ± 1.0 mg/kg, 2.0 ± 0.4 mg/kg and 0.2 ± 0.05 mg/g, respectively. K^+, Ca^{2+} and Mg^{2+} in top soil were 84.6 ± 24.4, 408.8 ± 137.8 and 93.4 ± 23.0 mg/kg, respectively. They decreased with soil depth. Amounts of organic matter, T-N, NH_4^+-N, NO_3^--N, T-P, K^+, Ca^{2+} and Mg^{2+} in 50 cm soil depth were 250.9, 3.45, 0.025, 0.003, 0.639, 0.181, 0.845 and 0.302 ton ha^{-1} 50 cm-depth^{-1}, respectively.

Key words: Exchangeable cation, Nutrients, Organic matter, *Quercus variabilis*, Soil properties

INTRODUCTION

Soil is the one of the three major components of the biosphere. It provides the physical and chemical conditions necessary for plant life, and consequently for most forms of animal and microbial life (Kimmins 1987). On a dry-weight basis, root systems usually comprise no more than one-quarter of a seed plant, but the roots are so finely divided that they frequently occupy a mass of soil greater than the volume of the atmosphere occupied by the above-ground parts (Daubenmire 1974).

Forest soil provides nutrients, water and medium for physical support for plant growth. They are critical to the cycling of nutrient, a process that has influences on the growth of individual trees and the functioning of entire forest ecosystems. Therefore, soil forms the foundation of forest ecosystems in many ways. Jenny (1980) suggested that physico-chemical properties of forest soil are influenced by parent material, climate, vegetation, time, etc. Plants absorb nutrients and water through root from the soil, and, in turn, they influence physico-chemical properties of soil through litter production, root exudation, root growth and death. Consequently, dominant species, tree ages and density of dominant species, composition of understory vegetation, and topography may influence the soil properties through biomass production, litter production and decomposition rate.

As a part of National Long-Term Ecological Research Program, we began to study the primary production and nutrient cycling in major plant communities, *Q. variabilis, Q. mongolica and Pinus densiflora* at Mt. Worak National Park in Chungbuk Province in April 2005. The objective of this study was to obtain primary data for nutrient cycling in *Q. variabilis* forest. For this study, we analyzed soil organic matter, bulk density, T-N, inorganic nitrogen (NH_4^+-N and NO_3^--N), T-P and exchangeable cation, and we calculated amount of each nutrient in unit area within 50 cm soil depth.

MATERIALS AND METHODS

Study Area

The Mt. Worak National Park is located between Mt. Soback and Mt. Sogri (N 36°47'～36°55', E 128°4'～128°12'), and stretches over both Gyeongsangbuk-do and Chungcheongbuk-do. The highest peak of the Mt. Worak National Park, Munsubong, is 1,162 m above sea level. The geology of most area of the Mt. Worak National Park is composed of sedimentary rock, metamorphic sedimentary rock and grinite (Son et al. 1979).

The study site of *Q. variabilis* forest is located at altitude of 330 m, a steep incline of 50 degrees, south-west direction of Yongha valley (N 36°53'19", E 128°68'55"). In April 2005, 10 m × 20 m permanent quadrat was established in the study area. Tree density

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was 2,550/ha, average DBH was 12.3 ± 4.7 cm and average tree height was 9.6 ± 3.6 m. In shrub layer, *Lindera obtusiloba* and *Clerodendron trichotomum* were distributed with very low density. Herb layer was very sparse. According to the Jecheon meterological station, about 30 km apart from the study area, annual average temperature and precipitation for thirty years from 1976 through 2005 was 10.1℃ and 1,349.8 mm, respectively.

Soil Sampling and Analysis

Soil sampling was carried out randomly chosen four site outside of the permanent quadrat in March, June, September, December from June 2005 through March 2006. Soil sampler, stainless cylinder 5cm in diameter and 10 cm in heigh, was used to collect samples for bulk density determination. The cylinder was pressed into the soil in a straight line as possible at every 10 cm interval till 50 cm depth. Soil samples were dried to constant weight in 105℃ oven and weighed, and then divided by their volume to determine soil bulk density. Soil samples for nutrients analysis were collected at every 10 cm intervals within 50 cm soil depth. They were sealed in vinyl bag and carried to the laboratory. Soil water content, NH_4^+-N and NO_3^--N in fresh soil were determined in the laboratory. Soil water content was determined by gravimetric method weighing before and after drying at 105℃ dry oven. Certain amounts of fresh soil were extracted with 2M KCl for NH_4^+-N and NO_3^--N. NH_4^+-N and NO_3^--N in soil extractant were analyzed with Flow Injection Analyzer (Lachat: QuickChem 8000). All soil NH_4^+-N and NO_3^--N data was presented on an oven dry weight basis. Remaining soils were used for determination of organic matter, soil reaction, total nitrogen, phosphorus and exchangeable cation after air-dried in the shade place. Soil organic matter was determined by loss on ignition with 600 ℃ electric furnace. Soil reaction was determined with pH meter. After soil samples were digested on block digestor, T-N and T-P were analyzed with Flow Injection Analyzer (Lachat: Quick-Chem 8000). After extracting with 1 M ammonium acetate, exchangeable cation (K, Ca and Mg) was determined with Atomic Absorption Spectrophotometer (Perkin-Elmer 3110) (Allen et al. 1974). Total amount of each soil nutrient (ton ha^{-1} 50 cm-$depth^{-1}$) was calculated by multiplying the fraction of nutrient by respective measurements of soil bulk density (g cm^{-3}) of soil.

RESULTS AND DISCUSSION

Soil Organic Matter and Bulk Density

Organic matter is an essential component of soil that stores and supplies plant nutrients, and aids water infiltration into the soil. Organic matter content of top soil in this study site was 8.5 ± 1.19% but decreased with soil depth with a value of 4.5 ± 0.40% at 50 cm depth (Fig. 1a). It was quite lower than that of *Q. mongolica* forest (Kim et al. 2006). Kim et al. (2006) reported that organic matter contents of top soil and 50 cm-depth soil of *Q. mongolica* stand were 13.0 ± 1.80 and 7.2 ± 0.99%, respectively. However, organic matter contents of this *Q. variabilis* stand were higher than those of *P. densiflora* stand (Jeon et al. 2006), which were 4.3 ± 0.80 and 2.5 ± 0.45%, respectively. The differences of soil organic matter among the three stands seemed to be related to difference of litter production among them (Shin et al. 2006). Soil organic matter has intimate association with physico-chemical properties of soil. The most of soil organic matter come from the aboveground litterfall and subsequent decomposition. However, recent studies have suggested that in many forests the largely unmeasured

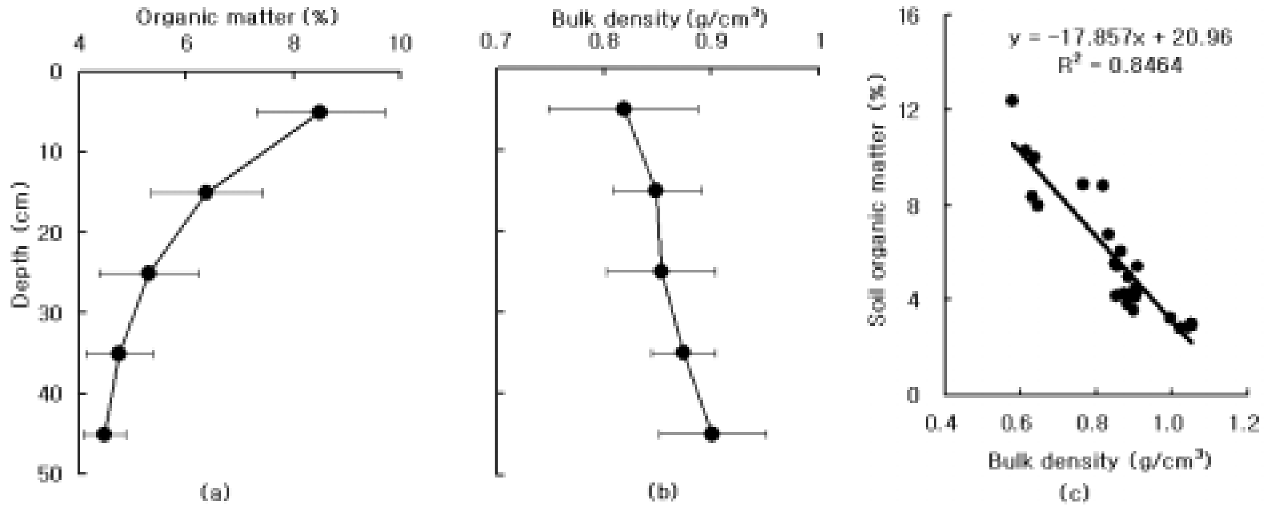

Fig. 1. Soil organic matter (a) and bulk density (b) along the soil depth of the study area. A negative correlation between soil organic matter and bulk density (c). Horizontal bars indicate standard deviation.

belowground litterfall (dead roots) may equal or exceed aboveground litterfall (Grier et al. 1981, Fogel 1985, Joslin and Hendrick 1987, Hendrick and Pregitzer 1992, McClaugherty et al. 1982, 1984). Total amount of organic matter in unit area of this *Q. variabilis* stand was 250.877 ton ha^{-1} 50 cm-$depth^{-1}$(Table 1).

Bulk density is closely related to porosity, and, in turn, with the degree of aeration and the infiltration capacity of soil. For the quantitative determination of nutrient content of soil, the knowledge of bulk density is of particular importance. Soil bulk densities of top soil and 50 cm-depth soil in this *Q. variabilis* stand were 0.82 ± 0.07 and 0.90 ± 0.05 g/cm^3, respectively (Fig. 1b). It increased along the soil depth. Soil bulk density mainly seemed to be related to organic matter content of soil. Soil organic matter and bulk density showed a negative linear correlation (R^2 = 0.8464) (Fig. 1c).

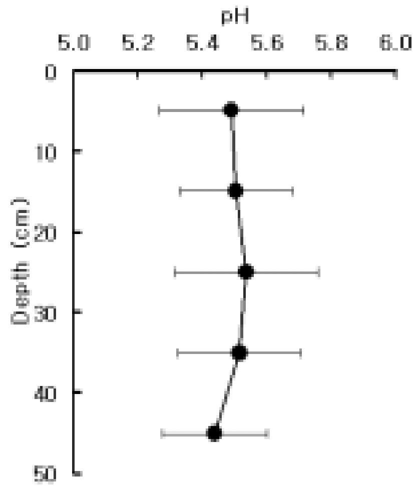

Fig. 2. Soil pH along the soil depth of the study area. Horizontal bars indicate standard deviation.

Soil pH

Soil pH of top soil and 50 cm-depth soil were not different significantly (Fig. 2). The pH range of top soil and 50 cm-depth soil were 5.10～5.87 and 5.24～5.78, respectively. They showed somewhat acidic. Soil pH varies with the type of soil, depth of the soil, type of vegetation, season and weather. Weathering of igneous rocks which are rich in silica can result in the production of acidic minerals. Acids may also be produced during the decomposition of soil organic matter and litter of most conifers. By contrast, Kim et al. (1990) reported that pH range of *P. densiflora* forest in limestone area was pH 7.9～8.3. Soil pH is important in determining the availability of many nutrients (Donahue et al. 1986, Mun 1988).

Nitrogen and Phosphorus

Nitrogen occurs in both organic and inorganic forms in the soil. However, most of the soil nitrogen exist in organic form in soil organic matter. In this study, inorganic nitrogen (NH_4^+-N + NO_3^--N) occupies only about 1% of total nitrogen. Total nitrogen contents of top soil and 50 cm-depth soil were 1.9 ± 0.54 and 0.3 ± 0.07 mg/g, respectively (Fig. 3a). Total nitrogen in upper soil layer (0～20 cm soil depth) was significantly higher than that of lower soil layer (30～50 cm soil depth). Most of the total nitrogen in forest soil originated from soil organic matter. The pattern of total nitrogen along soil depth was quite similar with that of soil organic matter (Fig. 1a). Total nitrogen in this *Q. variabilis* stand was similar with that of *Q. mongolica* stand (Kim et al. 2006). However, total nitrogen in this *Q. variabilis* stand was significantly higher than that of *P. densiflora* stand (Jeon et al. 2006).

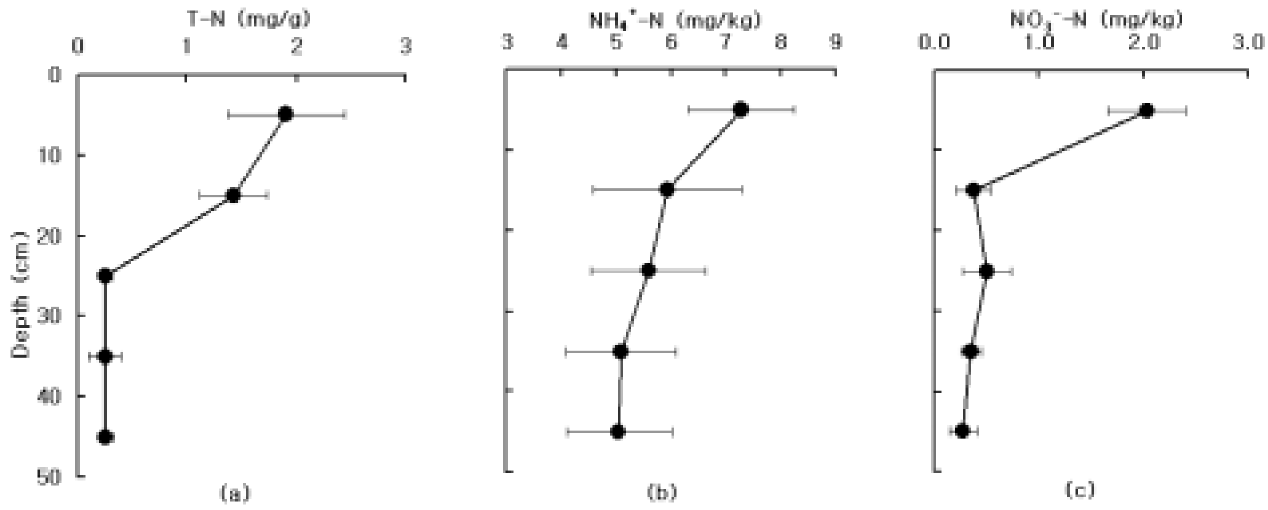

Fig. 3. Total nitrogen (a), NH_4^+-N (b) and NO_3^--N (c) contents along the soil depth of the study area. Horizontal bars indicate standard deviation.

The most frequent inorganic forms of nitrogen are ammonium (NH_4^+) and nitrate (NO_3^-) ions. NH_4^+-N concentrations of soil were higher than those of NO_3^--N in this *Q. variabilis* stand. They also decreased with soil depth (Figs. 3b and c). NH_4^+-N of top soil and 50 cm-depth soil were 7.3 ± 0.96 and 5.1 ± 0.96 mg/kg, respectively (Fig. 3b). NO_3^--N of top soil and 50 cm-depth soil were 2.0 ± 0.37 and 0.3 ± 0.13 mg/kg, respectively (Fig. 3c). Mun and Choung (1996) reported that NH_4^+-N and NO_3^--N in burned and unburned top soil in Kusungri were 78.9, 14.6 mg/kg and 1.55, 2.48 mg/kg, respectively. Inorganic nitrogen in this *Q. variabilis* stand were lower than those of the *Q, mongolica* stand (Kim et al. 2006), and higher than thoset of the *P. densiflora* stand (Jeon et al. 2006). Amounts of T-N, NH_4^+-N and NO_3^--N in unit area of this *Q. variabilis* stand were 3.448, 0.025 and 0.003 ton ha^{-1} 50 cm- $depth^{-1}$, respectively (Table 1).

Organic nitrogen may be stored in soils for a long time, but much of it is transformed to NH_3 or NH_4^+ by the process of ammonification (Binkley et al. 1986). And then, they are converted to nitrate by the process of nitrification. Nitrate occurs almost entirely in solution and is readily available to plants. Most ammonium ionsare held in a readily exchangeable form on cation exchange sites. Plants use both forms of inorganic nitrogen.

Total phosphorus contents of top soil and 50 cm-depth soil were 0.2 ± 0.05 and 0.1 ± 0.03 mg/g, respectively (Fig. 4). They also decreased along the soil depth. They were similar to that of the *Q, mongolica* stand (Kim et al. 2006), and were higher than that of the *P. densiflora* stand (Jeon et al. 2006). Phosphorus can exist in a number of organic forms, including chelates of iron and aluminum phosphate (Kimmins 1987). Amount of total phosphorus in unit area of this *Q. variabilis* stand was 0.64 ton ha^{-1} 50 cm-$depth^{-1}$ (Table 1).

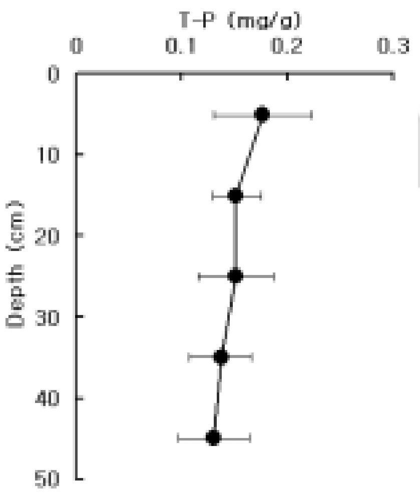

Fig. 4. Phosphorus contents along the soil depth of the study area. Horizontal bars indicate standard deviation.

Table 1. Amount of organic matter (O.M.) and nutrients in unit area of the *Q. variabilis* stand (ton ha^{-1}50 cm-$depth^{-1}$)

O.M.	T-N	NH_4^+-N	NO_3^--N	T-P	K^+	Ca^{2+}	Mg^{2+}
250.877	3.448	0.025	0.003	0.639	0.181	0.845	0.302

Exchangeable Cation

Potassium occurs in a wide range of soil minerals (Donahue et al. 1986). It exists almost entirely inorganic forms in the soil. Potassium released rapidly from organic matter following death. Potassium concentrations of top soil and 50 cm-depth soil were 84.6 ± 24.4 and 30.0 ± 9.8 mg/kg, respectively (Fig. 5a). They decreased rapidly from top soil through 20 cm-depth soil, and then showed more or less similar values. Levels of available potassium are generally higher in organic than in mineral horizons (Kimmins 1987). Potassium concentrations in this stand were similar to those of *Q. mongolica* stand (Kim et al. 2006), and were much higher than those of *P. densiflora* stand (Jeon et al. 2006). However, they were much lower than those of Mun and Jeong (1996).

Calcium and magnesium in soils originate largely from the weathering of primary minerals (Kimmins 1987). They also released from organic matter by decomposition. Calcium concentrations of top soil and 50 cm-depth soil were 408.8 ± 137.8 and 95.9 ± 52.7 mg/kg, respectively. They also decreased along the soil depth (Fig. 5b). The higher concentration of calcium in top soil in this study site seems to be related to organic matter addition from the aboveground. Jeon et al. (2006) reported that calcium concentrations of top soil and 50 cm-depth soil in pine forest were 119.13 and 52.80 mg/kg, respectively, which were quite lower than those in this study. However, calcium concentrations in this *Q. variabilis* stand were quite lower than those of *Q. mongolica* stand (Kim et al. 2006). Magnesium concentrations of top soil and 50 cm-depth soil were 93.4 ± 23.0, 60.4 ± 17.9 mg/kg, respectively (Fig. 5c). They were similar to those of *Q. mongolica* stand (Kim *et al.* 2006). However, they were much higher than those of *P. densiflora* stand (Jeon et al. 2006). Amounts of potassium, calcium and magnesium in unit area of this *Q. variabilis* stand were 0.181, 0.845 and 0.302 ton ha^{-1} 50 cm-$depth^{-1}$, respectively (Table 1).

The chemical composition of soil, especially inorganic nitrogen and exchangeable cation, is strongly affected by its water relationships. In humid areas, where there is an excess of precipitation over evapotranspiration, at least seasonally, chemicals released by weathering or decomposition of organic matter may be leached out of the upper layers of soil (Donahue et al. 1986). Leaching also depends on the ion exchange capacities of the soil, the uptake of minerals by plants, and the balance of ions in soil solution (Donahue et

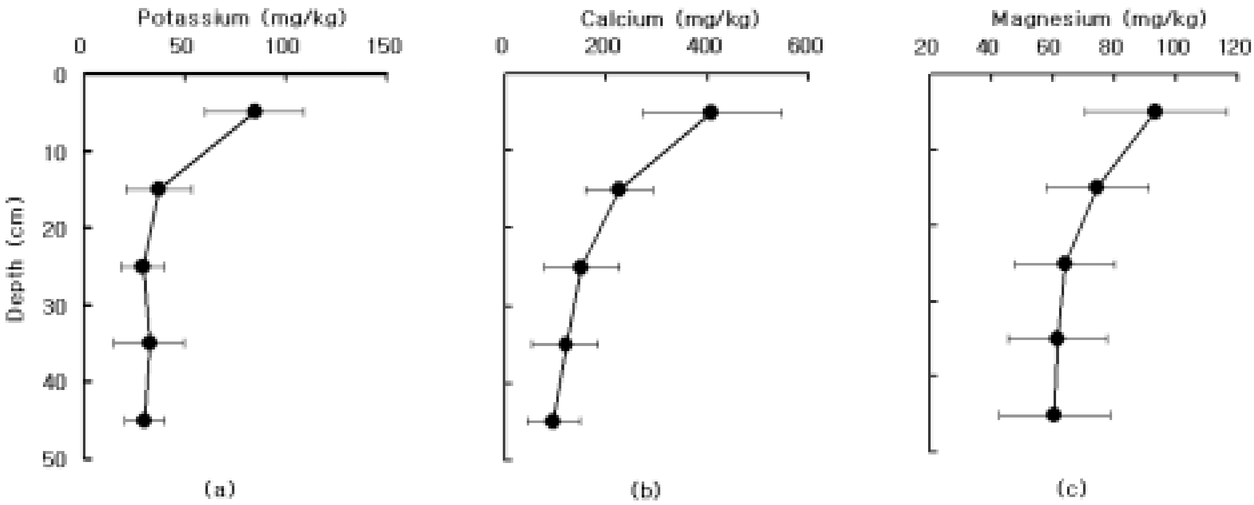

Fig. 5. Potassium (a), calcium (b) and magnesium (c) contents along the soil depth of the study area. Horizontal bars indicate standard deviation.

al. 1986, Kimmins 1987). In this *Q. variablis* stand, concentrations of soil nutrient seemed to be related primarily to soil organic matter content. Therefore, litter production and subsequent decomposition rates are very important to understand soil chemical properties in forest ecosystems.

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