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Litter Production and Nutrient Contents of Litterfall in Oak and Pine Forests at Mt. Worak National Park

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ABSTRACT: Litter production, nutrient contents of each component of litterfall and amount of nutrients returned to forest floor *via* litterfall were investigated from May 2005 through April 2006 in *Quercus mongolica, Quercus variabilis* and *Pinus densiflora* forests at Mt. Worak National Park. Total amount of litterfall during one year in *Q. mongolica, Q. variabilis* and *P. densiflora* forests was 542.7, 459.2 and 306.9 g m^{-2} yr^{-1}, respectively. Of the total litterfall, leaf litter, branch and bark, reproductive organ and the others occupied 50.3%, 22.7%, 10.1% and 16.9% in *Q. mongolica* forest, 81.9%, 7.2%, 3.1% and 7.9% in *Q. variabilis* forest, 57.4%, 12.8%, 5.6% and 24.1% in *P. densiflora* forest, respectively. Nutrients concentrations in oak litterfall were higher than those in needle litter. N, P, K, Ca and Mg concentration in leaf litterfall were 13.8, 1.1, 7.2, 4.2 and 1.3 mg/g for *Q. mongolica* forest, 10.5, 0.7, 3.2, 3.7 and 1.6 mg/g for *Q. variabilis* forest, 5.3, 0.4, 1.2, 2.8 and 0.6 mg/g for *P. densiflora* forest, respectively. The amount of annual input of N, P, K, Ca and Mg to the forest floor *via* litterfall was 43.36, 2.89, 21.38, 23.31 and 5.62 kg ha^{-1} yr^{-1} for *Q. mongolica* forest, 32.28, 2.01, 10.23, 20.29 and 7.78 kg ha^{-1} yr^{-1} for *Q. variabilis* forest, 15.80, 1.04, 3.99, 9.70 and 2.10 kg ha^{-1} yr^{-1} for *P. densiflora* forest, respectively.

Key words: Litterfall, Nutrient concentration, *Pinus densiflora, Quercus mongolica, Quercus variabilis*

INTRODUCTION

Forest ecosystems are self-maintained through primary production and nutrient cycling. Forest soil provides nutrients, water and medium for physical support for plant growth (Kimmins 1987). Soil nutrients are originated primarily from the weathering of soil minerals. However, nutrients release through decomposition of soil organic matter is fundamental for maintaining mature forest ecosystems (Daubenmire 1974, Barbour et al. 1987). Litterfall is one of the most important processes in forest ecosystems, because it is a major pathway for both nutrient and energy recycling to the forest floor (Bray and Gorham 1964, Wiegert and Monk 1972). Soil organic matter in forest ecosystems is originated from dead biomass of above- and below-ground. Litter is the food source for decomposer and detritivores, and the means by which nutrients are returned to the cycling pool (Barbour et al. 1987).

Decomposition processes in forest ecosystems have received considerable attention with regard to nutrient cycling (Baker et al. 2001). Through decomposition the nutrients within litter are converted into a form available for uptake by vegetation, thereby exercising a critical control on vegetation productivity.

As a part of National Long-Term Ecological Research Program in Korea, we have begun the study of carbon and nutrient cycling in major plant communities such as *Pinus densiflora, Quercus variabilis* and *Q. mongolica,* at Mt. Worak National Park in Chungbuk Province since April 2005. As a part of nutrient cycling, we are conducting the study of litter production and decomposition. The objective of the present study is to quantify the seasonal dynamics of biomass and nutrients in each component of litterfall of three forest types at Mt. Worak National Park. For this study, seasonal litterfall and nutrient contents of litterfall were analyzed, and total amount of nitrogen, phosphorus, potassium, calcium and magnesium returned to forest floor *via* litterfall were calculated.

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 descriptions of study sites are as follows: *P. densiflora* forest is located at 380 m above sea level, south-west direction of Songgye valley (N 36°51'17", E 128°64'41"). Tree density was 1,300 trees/ha and average DBH was 14.6 ± 5.98 cm. In shrub layer, shurby *Q. variabilis, Fraxinus sieboldiana, Indigofera kirilowii*

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were distributed with low frequency. Herb layer was dominated by *Pteridium aquilinum* and *Miscanthus sinensis*. *Q. variabilis* forest is located at 330 m above sea level, a steep incline of 50 degrees, south-west direction of Yongha valley (N 36°53'19", E 128°68'55"). Tree density was 2,550 trees/ha and average DBH was 12.3 ± 4.71 cm. In shrub layer, *Lindera obtusiloba* and *Clerodendron trichotomum* were distributed with very low density. Herb layer was very sparse. *Q. mongolica* forest is located at 900 m above sea level, south-west direction (N 36°51'19", E 128°12'23"). Tree density was 950 trees/ha and average DBH was 26.8 ± 6.8㎝. In shrub layer, *Lindera obtusiloba* was dominated, and *Fraxinus rhynchophylla* and *Lespedeza maximowiczii.* were distributed with low density. In herb layer, *Codonopsis lanceolata* and *Aster scaber* were distributed with very low density. According to the Jechon meteorological station, about 30 km distance 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.

Litterfall Collection and Chemical Analysis

Five circular litter traps, opening area was 0.5 m^2, were established randomly in each study site on April 2005. Litter traps were leveled at approximately 50 cm above the ground to prevent input of resuspended windblown materials from the forest floor. Litterfall collections began on May 2005 and continued for 1 year on every month except for winter season. The litter collected from litter traps was brought into laboratory and separated into leaves, needles, branches & bark, reproductive parts and the others (mostly shrub leaves). Each component was weighed after drying at 80℃ drying-oven for 72 hours, and approximately 10 g of each sample were ground for chemical analysis.

Chemical analyses of each litter component were carried out 3 replicates. After litter samples were digested on block digestor, T-N and T-P were analyzed with Flow Injection Analyzer (Lachat: QuickChem 8000). Potassium, calcium and magnesium were determined with Atomic Absorption Spectrophotometer (Perkin-Elmer 3110) after wet digestion (Allen et al. 1974). All calculations of nutrient contents of sample materials were based upon the mean of three replicates analysis. Total amount of each nutrient returned to forest floor *via* litterfall for one year was calculated from nutrient concentration and dry weight of each component of litter.

RESULTS AND DISCUSSION

Litter Production

Litterfall in these study sites continued throughout the year with a marked seasonal variation (Fig. 1). In *Q. mongolica* forest, dry weight of litterfall showed a peak with a value of 301.6 g/m^2 in October. However, in *Q. variabilis* and *P. densiflora* forests showed peaks in November with values of 213.3 and 90.6 g/m^2, respectively. Second peaks were observed in oak forests, *Q. mongolica* forest through April to May and *Q. variabilis* forest on April due to the falling of reproductive organs (mainly male flower). However, second peak was not conspicuous in pine forest. In case of *Q. mongolica* forest, reproductive organs (mainly acorn) occupied 45.2% on September.

Total amount of litterfall during one year in *Q. mongolica, Q. variabilis* and *P. densiflora* forests was 542.7, 459.2 and 306.9 g m^{-2} yr^{-1}, respectively. Of the total litterfall, leaf litter, branch and bark, reproductive organ and the others occupied 50.3%, 22.7%, 10.1% and 16.9% in *Q. mongolica* forest, 81.9%, 7.2%, 3.1% and 7.9% in *Q. variabilis* forest, 57.4%, 12.8%, 5.6% and 24.1% in *P. densiflora* forest, respectively (Fig. 2). Percentage of leaf litterfall

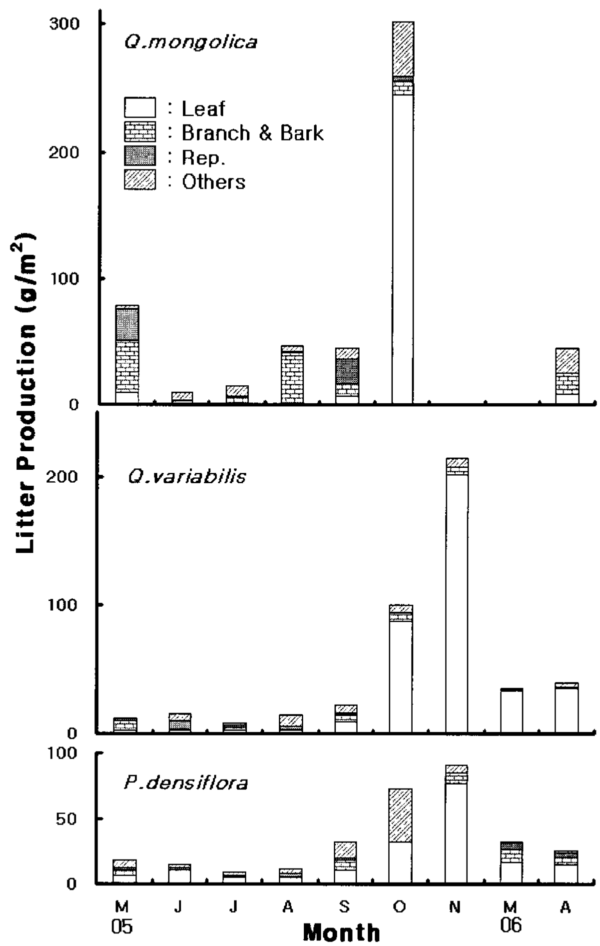


Fig. 1. Seasonal changes of each component of litterfall in *Q. mongolica, Q. variabilis* and *P. densiflora* forests at Mt. Worak National Park. Rep. represents reproductive organs. Others indicates mainly shrub leaves.

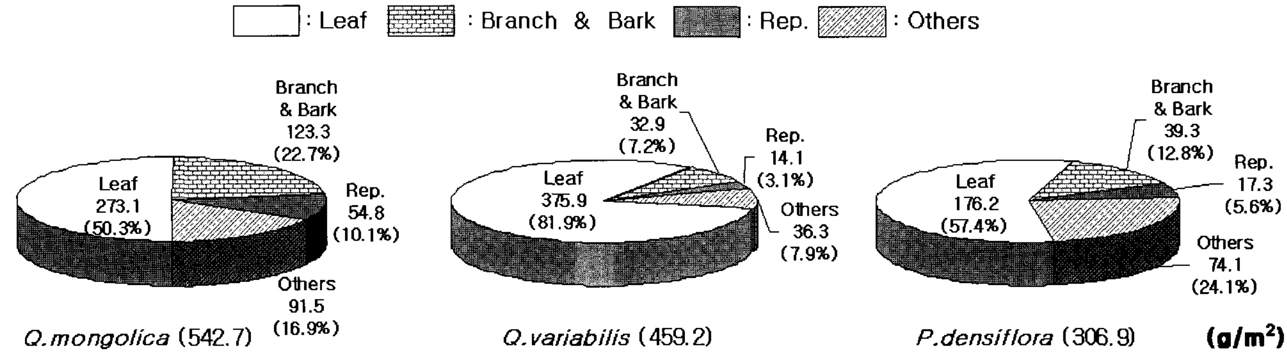


Fig. 2. Weight (g $m^2 yr^{-1}$) and percentage of each component of litterfall in *Q. mongolica, Q. variabilis* and *P. densiflora* forests at Mt. Worak National Park. Rep. represents reproductive organs. Others indicates mainly shrub leaves.

was the highest in *Q. variabilis* forest with 81.9% (375.9 g m^{-2} yr^{-1}), and those of branch & bark and reproductive organ were highest in *Q. mongolica* forest. Percentage of reproductive organ litterfall was also higher in *Q. mongolica* forest than the other forests. Acorn biomass collected in littertrap was higher in *Q. mongolica* forest than in *Q. variabilis* forest on September in 2005. Pine seeds were also collected in littertrap but their weight was low because they were much smaller than acorns. Bark was collected only in littertraps of *Q. mongolica* and *P. densiflora* forests. The bark of *Q. variabilis* was composed of thick cork and it did not peel out from the stems.

Yi et al. (2005) reported that litter production of *Q. mongolica* natural forests ranged from 314.3 to 554.9 g m^{-2} yr^{-1} (average 428.5 g m^{-2} yr^{-1}). Litter production of oak forests in Korea ranged from 248.0 to 876.1 g m^{-2} yr^{-1}(Mun and Joo 1994, Son et al. 2004). In temperate deciduous forests, litter production ranged from 230 to 710 g m^{-2} yr^{-1} (Reich and Nadelhoffer 1989). Litter production of oak forests in this study fell within those ranges.

Mun and Kim (1992) and Mun and Joo (1994) reported that litter production in *P. densiflora* and *P. rigida* forests was 453.5 and 653.2 g m^{-2} yr^{-1}, respectively, Kim (2006) also reported that litter production in *P. densiflora* forest was 470 g m^{-2} yr^{-1}. Litter production of pine forest in this study was much lower than that of above results. This difference might be related to tree density, age and canopy cover among them (Gholz et al. 1985).

Nutrient Content of Litterfall

Nitrogen concentrations in leaf litterfall generally decreased as the season progressed from spring through October in oak and pine forests (Fig. 3A). In oak forests, however, N concentration in leaf litterfall on April was lower than that of May. N concentration in the others, mainly consisted of shrub leaves, were similar with those in leaf litterfall in oak forests. However, N concentration in the others in pine forest were higher than that in needle litterfall. N concentrations in each component of litterfall in oak forests were higher than those in pine forest. Average N concentration of leaf litterfall, branch and bark, reproductive organ and the others was 13.8, 5.8, 5.0 and 13.4 mg/g for *Q. mongolica*, 10.5, 4.8, 9.2 and 10.2 mg/g for *Q. variabilis*, 5.3, 3.1, 2.4 and 8.4 mg/g for *P. densiflora*, respectively.

Phosphorus concentrations in leaf litterfall also generally decreased as the season progressed from spring through October in oak and pine forests (Fig. 3B). Like N concentration, P concentrations in leaf litterfall on April in oak forests were lower than those of May. P concentrations in each litterfall component of oak forests were higher than those in pine forest. Average P concentration of leaf litterfall, branch and bark, reproductive organ and the others was 1.1, 0.4, 0.6 and 1.1 mg/g for *Q. mongolica*, 0.7, 0.3, 0.7 and 0.7 mg/g for *Q. variabilis*, 0.4, 0.3, 0.3 and 0.4 mg/g for *P. densiflora*, respectively.

Potassium concentrations in leaf litterfall of *Q. mongolica* were much higher than those of *Q. variabilis* and *P. densiflora*. K concentration in leaf litterfall also decreased as the season progressed from spring through October in oak and pine forests (Fig. 4A). Like N and P concentration, K concentrations in leaf litterfall on April in oak forests were lower than those of May. K concentrations in each litterfall component of pine forest were much lower than those in oak forests. Average K concentration of leaf litterfall, branch and bark, reproductive organ and the others was 7.2, 2.3, 3.5 and 3.6 mg/g for *Q. mongolica*, 3.2, 2.7, 4.8 and 4.6 mg/g for *Q. variabilis*, 1.2, 0.3, 0.4 and 1.7 mg/g for *P. densiflora*, respectively.

Calcium concentrations in leaf litterfall of oak forests were slightly higher than those of *P. densiflora*. Unlike N, P and K, Ca concentrations in leaf litterfall showed no distinct seasonal pattern (Fig. 4B). Ca concentrations in each litterfall component did not differ significantly among three species. Average Ca concentration of leaf litterfall, branch and bark, reproductive organ and the others was 4.2, 5.6, 4.5 and 3.3 mg/g for *Q. mongolica*, 3.7, 4.9, 3.2 and 2.9

mg/g for *Q. variabilis*, 2.8, 3.9, 1.4 and 3.5 mg/g for *P. densiflora*, respectively.

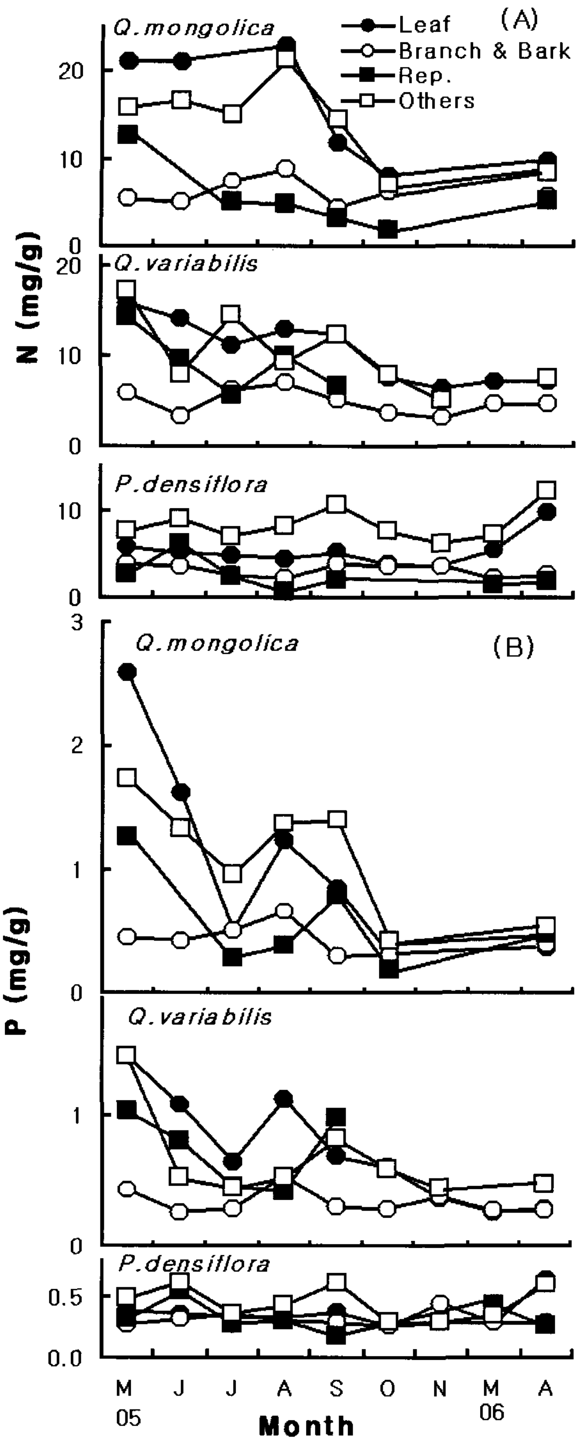


Fig. 3. Seasonal changes of N (A) and P (B) concentration of each component of litterfall in *Q. mongolica, Q. variabilis* and *P. densiflora* forests at Mt. Worak National Park. Rep. represents reproductive organs. Others indicates mainly shrub leaves.

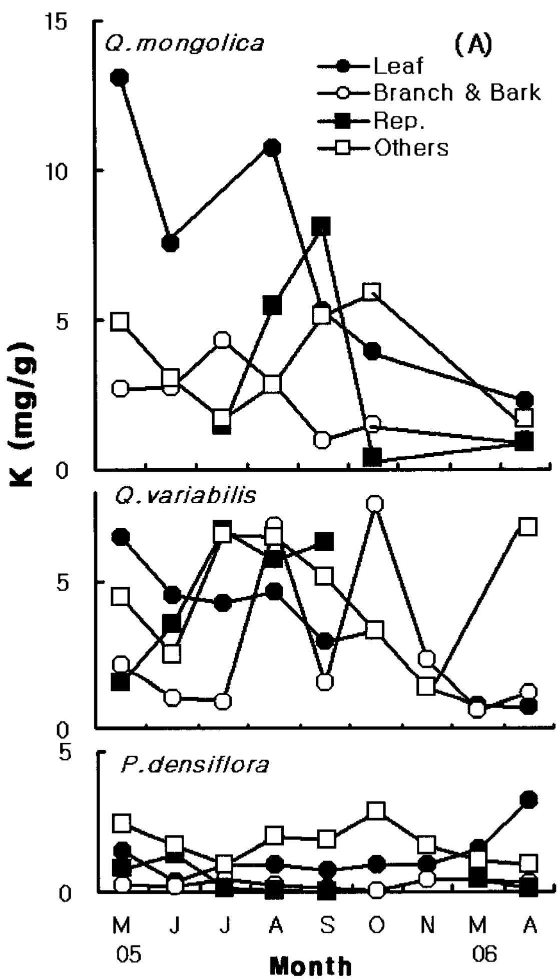
Magnesium concentrations in each component of litterfall were significantly lower than those of K and Ca And Mg concentrations of litterfall in oak forests were higher than those in pine forest (Fig. 4C). There was no distinct seasonal pattern in Mg concentrations of litterfall. Average Mg concentration of leaf litterfall, branch and bark, reproductive organ and the others was 1.3, 0.7, 0.8 and 1.1 mg/g for *Q. mongolica*, 1.6, 1.3, 0.9 and 0.9 mg/g for *Q. variabilis*, 0.6, 0.2, 0.2 and 0.6 mg/g for *P. densiflora*, respectively.

Nutrients Returned to Forest Floor

The amount of each nutrient returned to forest floor *via* litterfall was summarized in Table 1. As shown in Table 1, the amount of annual input of N, P, K, Ca and Mg to the forest floor was 43.36, 2.89, 21.38, 23.31 and 5.62 kg ha^{-1} yr^{-1} for *Q. mongolica* forest, 32.28, 2.01, 10.23, 20.29 and 7.78 kg ha^{-1} yr^{-1} for *Q. variabilis* forest, 15.80, 1.04, 3.99, 9.70 and 2.10 kg ha^{-1} yr^{-1} for *P. densiflora* forest, respectively. In general, the amount of nutrients returned to forest floor *via* litterfall in oak forests was much higher than that in pine forest. This is because annual input of litterfall and nutrient concentration of unit weight of litterfall in oak forests were greater than those in pine forest (Figs. 2~4).

According to Choi et al. (2006) and Kim (2007), the amount of soil organic matter and nutrients in oak forests were much greater than those in pine forest. In case of soil nitrogen, total amount in *Q. mongolica*, *Q. variabilis* and *P. densiflora* forest was 5.23, 3.45, 2.06 ton ha^{-1} 50-cm^{-1}, respectively. These results suggest that forest soil nutrients status are greatly influenced by litterfall and subsequent litter decomposition. In our preliminary data of long-term litter decomposition study in *Q. mongolica*, *Q. variabilis* and *P. densiflora* forests, weight loss of oak litter was greater than that of needle litter during the early period of litter decomposition (our unpublished data). Mun and Joo (1994) also reported that weight loss of oak litter was greater than that of needle litter (*P. rigida*).

Mun and Kim (1992) reported that the amount of N and P returned to forest floor *via* litterfall in pine forest at limestone area was 29.02 and 2.81 kg ha^{-1} yr^{-1}, respectively, which was greater than that of this pine forest. This is because litter production in this pine forest was much less than that of Mun and Kim (1992). Mun and Joo (1994) reported that amount of N, P, K, Ca and Mg returned to forest floor *via* litterfall in *Q. acutissima* forest in Kongju area was 61, 0.64, 15, 32 and 13 kg ha^{-1} yr^{-1}, respectively. Amount of N, Ca and Mg in our oak forests was less that that of Mun and Joo (1994). However, amount of P in our oak forests was much greater than that of Mun and Joo (1994). This suggests that nutrient concentrations of unit weight of litterfall are also important for the quantities of nutrients returned to forest floor.



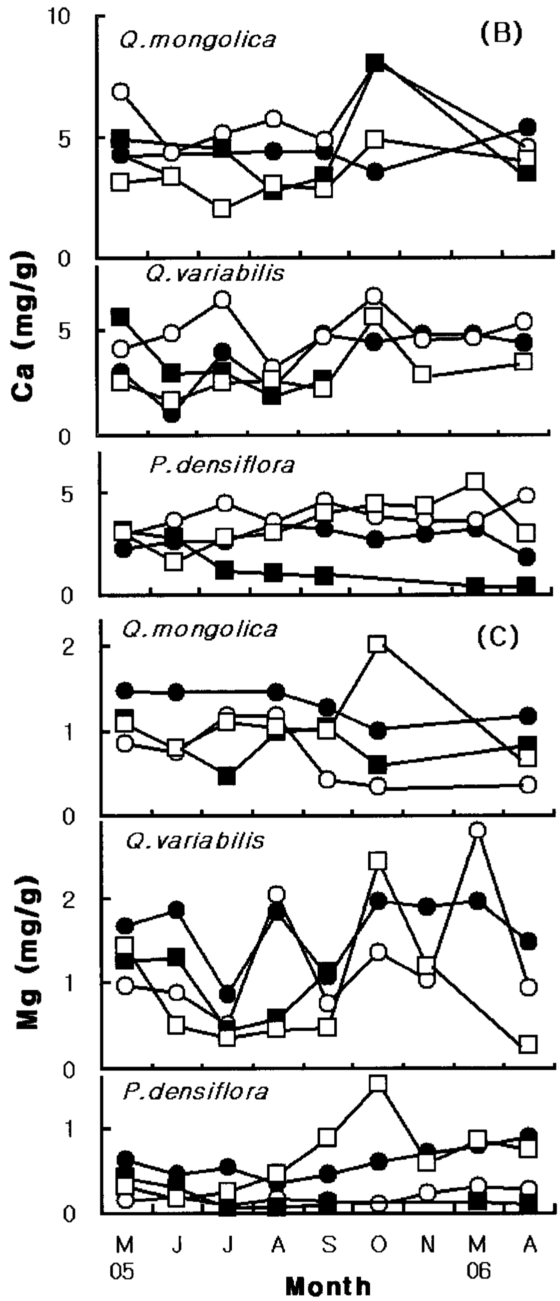


Fig. 4. Seasonal changes of K (A), Ca (B) and Mg (C) concentration of each component of litterfall in *Q. mongolica*, *Q. variabilis* and *P. densiflora* forests at Mt. Worak National Park. Rep. represents reproductive organs. Others indicates mainly shrub leaves.

Table 1. Amount of each nutrient (kg $ha^{-1}yr^{-1}$) returned to forest floor via litterfall in *Q. mongolica*, *Q. variabilis* and *P. densiflora* forests at Mt. Worak National Park

Forest type	Nutrients				
	N	P	K	Ca	Mg
Q. mongolica	43.36	2.89	21.38	23.31	5.62
Q. variabilis	32.28	2.01	10.23	20.20	7.78
P. densiflora	15.80	1.04	3.99	9.70	2.10

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