Korean J Biol Sci 4: 51-55, 2000

Mass Loss and Changes of Mineral Nutrients during the Decomposition of Mushrooms, *Russula alboareolata* and *Lactarius violascens*

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Key Words:
Basidiomycetes
Decomposition
Immobilization
Mushrooms
Nutrients

Mass loss and changes of mineral nutrients during the decomposition of mushrooms, *Russula alboareolata* and *Lactarius violascens*, were investigated for 7 d from June 29 to July 5 in 1999 in an oak stand in Kongju, Korea. At 7 d after installation of litterbags, the remaining mass of *R. alboareolata* and *L. violascens* was 9.4% and 25.9%, respectively. The mass loss rate of *R. alboareolata* was significantly higher than that of *L. violascens*. Concentration of N, P, K, Ca and Mg of *R. alboareolata* and *L. violascens* were 37.7 mg/g, 0.97 mg/g, 38.25 mg/g, 0.04 mg/g, and 0.75 mg/g for *R. alboareolata* and 45.7 mg/g, 1.31 mg/g, 24.0 mg/g, 0.06 mg/g, and 0.80 mg/g for *L. violascens*, respectively. Concentrations of nutrients in *R. alboareolata* and *L. violascens* were much higher than those in the surrounding leaf litter. N, P, Ca and Mg concentrations in the decomposing mushroom tissue were higher during the experimental period in both species than initial concentrations. Potassium increased during the first 3 d and then decreased in both species. Potassium contents in the mushroom were much greater than those of Ca and Mg. Except for Ca, there was no immobilization period in all the nutrients during decomposition. At 7 d after installation of litterbags, the remaining N, P, K, Ca and Mg of *R. alboareolata* and *L. violascens* were 9.8%, 8.9%, 2.7%, 47.7%, and 14.8% of the initial contents for *R. alboareolata* and 28.2%, 30.5%, 19.6%, 199.9%, and 42.1% for *L. violascens*, respectively. Nutrients could be relocated spatially during the formation and decomposition of the Basidiomycetes fruiting body.

Decomposition, the process by which the complex organic structure of biological materials is reduced to mineral form, plays an important role in the supply of plant nutrients in forest ecosystems (Kelly and Beauchamp, 1987). The decomposition process is controlled by many factors such as climate, chemical composition of substrate, and interactions among litter decaying organisms (Swift et al., 1979). In terrestrial environments, higher fungi are the major agents of litter decomposition (Harley, 1972; Kaarik, 1974; Dighton and Boddy, 1989; Boddy and Watkinson, 1998), though bacteria and microarthropods also play a significant role in litter decomposition. Litter decaying organisms have a short life span and decompose rapidly after death.

In many temperate deciduous forests, mushrooms represent a significant part of biomass production and subsequently contribute to litter formation (Kim et al., 1996). In another experiment which was conducted at the same site, biomass production of mushrooms in July 1999 amounted to 30.6 kg/ha. Fungi accumulate substantial concentrations of macronutrients and micronutrients in a wide variety of forest ecosystems. Mushrooms generally contain high nutrient concentrations which are several-fold higher than their ambient substrates (Cromack et al., 1977). Mun et al. (2000) reported that N and P contents in mushrooms were much higher than the surrounding litter. Therefore nutrients are often relocated spatially during the formation and decomposition of mushrooms. However, the importance of mushrooms in nutrient cycling in forest ecosystems has been overlooked because of the dominance of plant litter on the forest floor (Stark, 1972; Rochefort et al., 1990). Thus, little is known about the decay rate and changes of nutrients during the decomposition of mushrooms.

The purpose of the present study is to investigate the role of mushrooms in nutrient cycling in a temperate deciduous forest. The decay rate of mushrooms and the changes of nutrients during decomposition were thus studied.

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Materials and Methods

Litterbag preparation

R. alboareolata and *L. violascens* are litter decaying fungi. They appear from early summer till late autumn on the deciduous forest floor in Korea (Park, 1991). The mature *R. alboareolata* pileus diameter is 5-8 cm, and that of *L. violascens* is 4-10 cm. These mushrooms were collected, from an oak forest floor in Kongju, Chungnam Province in Korea in June 28, 1999.

Litterbag method is very commonly used for decomposition studies, though it has several drawbacks (Swift et al., 1979). In this experiment, the litterbag method was used. Litterbags, 15×15 cm, were made of nylon mesh with 2-mm^2 holes. The litterbag mesh size (2×1 mm) was large enough to allow the free passage of a few animals which influence the process in this system. Each litterbag enclosed a cluster of fresh mushrooms and an aluminum tag giving the weight of the mushrooms. The moisture content of fresh mushrooms were determined, and then the dry weight of mushrooms was calculated in each litterbag. Mushroom litterbags were scattered on the forest floor in June 29, 1999.

Litterbag retrieval and chemical analysis

The first retrieval of mushroom litterbags was done on July 1, 2 d after installation, and then they were retrieved everyday until July 5. Three litterbags of each species were retrieved on each sampling date. Adhering soil particles and litter debris on the outside of litterbags were removed. The contents of litterbags were weighed individually after drying at 50℃, and then each sample was ground with a mixer for chemical analysis.

Mass loss and change of nutrients during decomposition were determined by measuring the remaining mass and nutrient concentration of mushrooms contained in the litterbags. Mass loss of the remaining mushrooms was expressed as a percent (%) of the initial sample weight.

Total-N was determined by a modified micro-Kjeldahl method (Allen et al., 1974). Wet digestion method was used for P, K, Ca and Mg determination. P content was determined by a molybdenum blue color method (Allen et al., 1974). K, Ca and Mg were determined with an atomic absorption spectrophotometer (Perkin-Elmer 3110).

The quantity of each nutrient remaining at each sampling date was calculated using the concentration of nutrient in the tissue and the mass of the remaining tissue in the litterbag. The remaining quantity of each nutrient was then expressed as a percentage of the amount contained in the original tissue.

Comparisons of the mean mass loss between the two species were carried out using Student's *t* test with the SPSS 8.0 program for Windows.

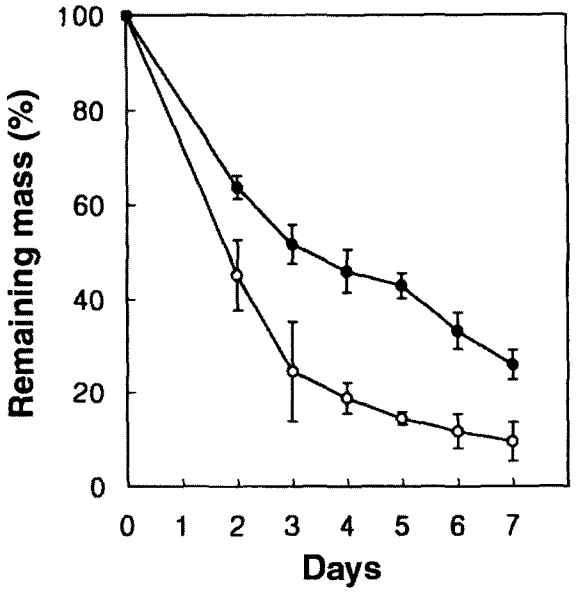

Fig. 1. Mean percent mass remaining in *R. alboareolata* (○) and *L. violascens* (●) decomposing at the oak stand. Bars indicate standard deviation.

Results and Discussion

Mass loss

R. alboareolata and *L. violascens* lost 55.8% and 36.4% of their initial mass over the first 2 d, respectively. At 7 d after installation of the litterbag, the remaining mass of *R. alboareolata* and *L. violascens* was 9.4% and 25.9% of the initial mass, respectively (Fig. 1). During the whole experimental period, mass loss of *R. alboareolata* was significantly greater than that of *L. violascens* ($p < 0.01$).

Mun et al. (2000) reported that the mushroom, *Lepista nuda*, lost 65% of its initial mass in 7 wk, from November 7 to December 28, 1998, when the average temperature of the surface-soil was 8.1℃ in November and 2.8℃ in December. In this experiment, the average temperature of the surface-soil from June 29 to July 6 was 19.4℃, which was much higher than that of Mun et al. (2000).

Consumption of mushrooms by animals appears to be significant in this experiment (Mitchell and Parkinson, 1976; Cromack et al., 1977, Courtney et al., 1990). Rich fauna, including springtails, mites, and many insect larvae which feed on mushrooms were observed throughout the decomposition process. Fungal tissue is highly nutritious and often associated with decomposing organisms. In contrast to green plants which contain cellulose, lignins and pectins, which are difficult to digest, mushrooms offer a relatively accessible carbon source, such as polysaccharides, chitin, α-D-glucan, and β-D-glucan for insects (Courtney et al., 1990).

The moisture content of litter is crucial for the decomposition process. Freshly fallen leaves may have

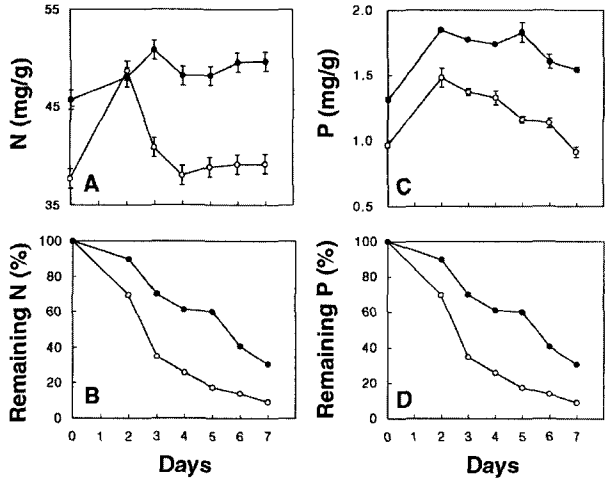

Fig. 2. Changes in N concentration (A), remaining N (B), P concentration (C) and remaining P (D) in the decomposing *R. alboareolata* and *L. violascens* at the oak stand. Bars indicate standard deviation.

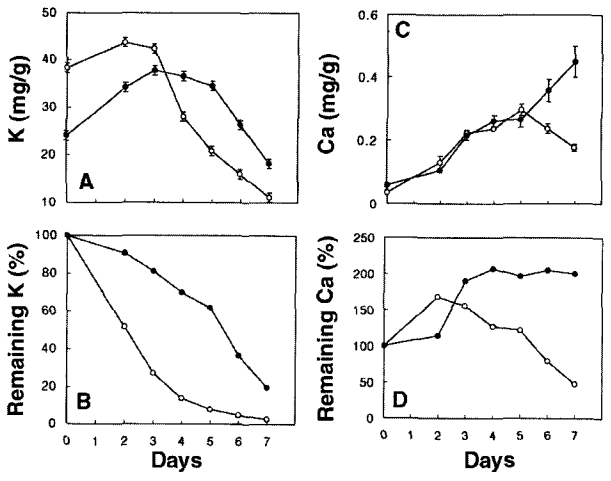

Fig. 3. Changes in K concentration (A), remaining K (B), Ca concentration (C) and remaining Ca (D) in the decomposing *R. alboareolata* and *L. violascens* at the oak stand. Bars indicate standard deviation.

moisture contents of up to 200% of the dry weight. But if left to dry under normal conditions in temperate climates, a moisture content of about 30-35% will be obtained (Swift et al., 1979). In this experiment, however, freshly collected mushrooms had moisture contents of up to 900-1100% of the dry weight, and maintained this high moisture content throughout the duration of the experiment.

Changes of nutrients

N concentration of *R. alboareolata* increased from 37.7 mg/g at time zero to 48.7 mg/g at 2 d, and then decreased to 39.2 mg/g at 7 d after installation of the litterbag (Fig. 2A). The initial N concentration of mushrooms is about 20 times greater than that in the surrounding litter (Lee, 1994). The remaining N decreased sharply during the first 3 d to about 26.6% of the original N capital. By the end of the experiment, *R. alboareolata* contained 9.8% of the original N capital (Fig. 2B). N concentration of *L. violascens* increased from 45.7 mg/g at time zero to 50.8 mg/g at 3 d, and then decreased to 49.7 mg/g at 7 d after installation of the litterbag (Fig. 2A). The remaining N decreased steadily during the first 5 d to about 45.2% of the original N capital. By the end of the experiment, *L. violascens* contained 28.2% of the original N capital (Fig. 2B).

P concentration of *R. alboareolata* also increased from 0.97 mg/g at time zero to 1.48 mg/g at 2 d after installation of a litterbag, and then decreased to 0.91 mg/g at 7 d after installation of a litterbag (Fig. 2C). The remaining P decreased sharply (Fig. 2D). By the end of the experiment, *R. alboareolata* contained 8.9% of the original P capital. P concentration of *L. violascens* also increased from a value of 1.31 mg/g at time zero to 1.85 mg/g at 2 d, and then decreased to 1.54 mg/g at 7 d after installation of the litterbag (Fig. 2C). The remaining P decreased to 59.8% during the first 5 d. By the end of the experiment, *L. violascens* contained 30.5% of the original P capital (Fig. 2D).

K concentration of *R. alboareolata* also increased from 38.3 mg/g at time zero to 43.7 mg/g at 2 d, and then decreased to 11.17 mg/g at 7 d after installation of the litterbag (Fig. 3A). The remaining K showed a similar pattern with N and P. By the end of the experiment, *R. alboareolata* contained 2.7% of the original K capital (Fig. 3B). K concentration of *L. violascens* also increased from 24.0 mg/g at time zero to 37.7 mg/g at 3 d, and then decreased to 18.2 mg/g at 7 d after installation of the litterbag (Fig. 3A). The remaining K decreased to 61.6% during the first 5 d. By the end of the experiment, *L. violascens* contained 19.7% of the original K capital (Fig. 3B).

Ingold and Hudson (1993) reported that K, P, Mg and S were all needed in significant amounts in the mushroom culture medium. However, Ca, an essential element in the nutrition of green plants, is not apparently needed by all fungi. In this experiment, Ca concentration was the lowest among nutrients in both species. Mun et al. (2000) reported that the mushroom, *Lepista nuda*, also had a low Ca concentration compared to other nutrients.

Ca concentration of *R. alboareolata* increased from 0.04 mg/g at time zero to 0.30 mg/g at 5 d after installation of the litterbag (Fig. 3C). Unlike other nutrients, the remaining Ca increased sharply during the first 2 d about 168% of the initial Ca, and then decreased to 122% at 5 d after installation of the litterbag. By the end of the experiment, however, the remaining Ca was 47.7% of the initial Ca capital (Fig. 3D). Ca concentration of *L. violascens* increased from 0.06 mg/g at time zero to 0.45 mg/g at 7 d after installation of the litterbag (Fig. 3C). The remaining Ca increased sharply during the first 4 d to 206.8% of initial Ca, and then decreased to 199.9% of the initial Ca capital at the end of the experiment (Fig. 3D).

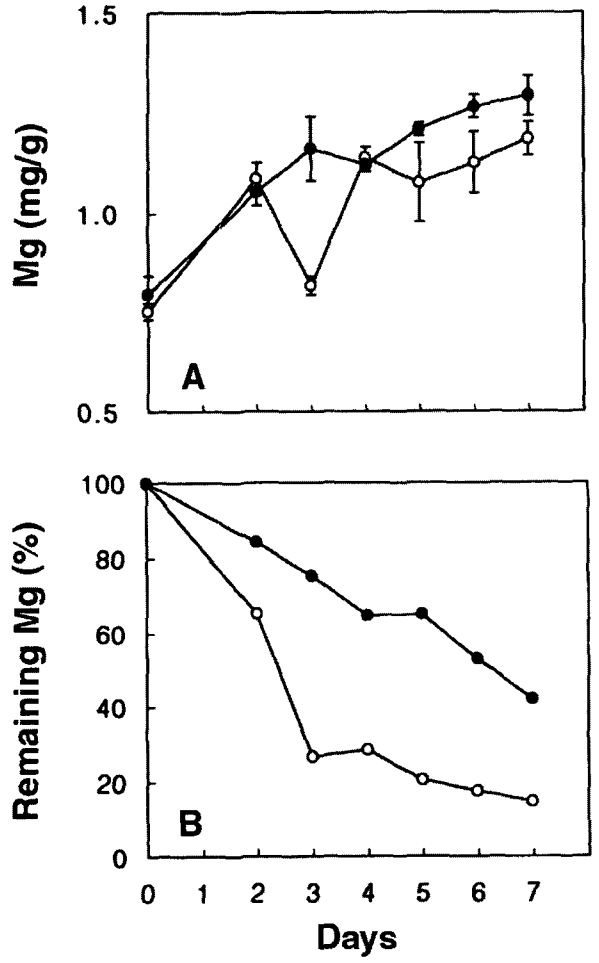

Fig. 4. Changes in Mg concentration (A) and remaining Mg (B) in the decomposing *R. alboareolata* and *L. violascens* at the oak stand. Bars indicate standard deviation.

Mg concentration during the experimental period was higher than that of initial concentration (Fig. 4A). Unlike Ca, the remaining Mg of *R. alboareolata* decreased sharply to 27% at 3 d after installation of the litterbag. By the end of the experiment, the remaining Mg of *R. alboareolata* was 14.8% of the initial Mg capital (Fig. 4B). The Mg concentration of *L. violascens* increased from 0.80 mg/g at time zero to 1.29 mg/g at 7 d after installation of the litterbag (Fig. 4A). The remaining Mg content of *L. violascens* decreased to 65.2% of the initial Mg content at 5 d after installation of the litterbag (Fig. 4B).

Woodlands are often nutrient-poor habitats and large trees are major sinks for all nutrients (Farley and Fitter, 1999). Gross et al. (1995) found that soil N concentration was six times lower in a woodland site than a newly abandoned field. Plants can exhibit root growth plasticity in response to nutrient heterogeneity. Fine root growth, which is usually associated with nutrient uptake, occurs predominantly in the upper 20 cm of the forest soil (Hendrick and Pregitzer, 1996). Therefore, in a low-nutrient environment, nutrient-rich patches may be an important source of nutrients for plant growth. More knowledge about the temporal and spatial scales of nutrient heterogeneity in natural habitats is needed in order to interpret the ecological significance of such responses. According to this study, nutrients could be relocated spatially during the formation and decomposition of the fruiting body of Basidiomycetes. Production and decomposition of mushrooms in forest ecosystems, therefore, may lead to nutrient heterogeneity of the forest soil. More information about biomass production and decomposition processes of mushrooms will be needed in the future in order to investigate nutrient cycling in forest ecosystems.

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[Received November 15, 1999; accepted December 18, 1999]