中型土壌動物の動態と葉リターの分解

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Leaf litter decomposition in relation to dynamics of soil mesofauna

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Summary

Chapter 1　Introduction

In forest ecosystems, decomposition of plant litter is controlled by the interactions between climate conditions, litter quality and decomposer organisms (Swift et al., 1979; Lavelle and Spain, 2001). In general, climate appears to be a dominant factor in litter decomposition at a regional scale, whereas litter quality largely prevails at the local scale, which in turn, ultimately influences the activities of decomposer organisms. Because soil microorganisms are mainly responsible for primary decomposition and soil respiration, the contributions of decomposer animals to the forest ecosystem functioning might have been evaluated to be low or even insignificant. However, soil mesofauna, including microarthropods have been considered to increase the rates of litter decomposition and nutrient cycling either indirectly, by affecting the activity of composition of microbial communities, or directly by fragmenting litter and excreting nutrients into the soil systems (e.g., Seastedt, 1984; Verhoef and Brussaard, 1990; Lussenhop, 1992).

In this thesis, decomposition processes of the leaf litters of two tree species (i.e. *Quercus serrata* Thunb. and *Cryptomeria japonica* D. Don) were studied using a modified litterbag method (referred to as a litter box) in a deciduous, broad-leaved forest and an adjacent Japanese cedar plantation in Yoshiwa, Hiroshima Prefecture, western Japan, and were evaluated by the changes in litter mass loss, carbon and nitrogen dynamics and mesofaunal abundances in the litters. In order to improve in understanding of the ecological role of decomposer animals in the forest ecosystems, the impacts of soil mesofauna on the litter decomposition processes in the field was mainly investigated.

広島大学総合科学部紀要Ⅳ理系編、第30巻（2004）
＊広島大学審査学位論文
口頭発表日：2004年２月16日、学位取得日：2004年３月３日

Chapter 2 Leaf litter decomposition in relation to dynamics of soil mesofauna in litter boxes with different mesh sizes in a *Quercus serrata* forest

In order to clarify the contribution of soil mesofauna to litter decomposition, the decomposition of oak leaf litter in a *Quercus serrata* forest stand was studied for 12 months using litter boxes. The box was made from PVC (Polyvinyl chloride) cylinder (diameter: 10.1 cm, height: 9.0 cm) and both top and bottom sides were covered with different mesh sizes (1 mm and 25 μm). The litter boxes with 25 μm mesh size were used to exclude mesofauna and the boxes with 1 mm mesh size were used to allow immigration of microbiota and mesofauna. The microclimatic conditions (temperature, humidity and litter moisture content) in the boxes did not differ between the two treatments. The 25 μm mesh treatment was very effective in excluding all mesofauna in the field. The weight loss of leaf litter was significantly higher in the 25 μm boxes than that in the 1 mm boxes at 3 months, but the differences in the two treatments were not significant after 6, 9 and 12 months. The annual decomposition constants (k) were 0.572 and 0.529 yr^{-1} in the 1 mm and 25 μm boxes, respectively. The amounts of nitrogen remaining were not significantly different between the two treatments throughout the study period. The C/N ratio was significantly lower in the 1 mm boxes than in the 25 μm boxes at 12 months. The litter respiration was more sensitive to soil temperature in the absence of mesofauna. The results indicate that the mesofauna had a negative effect on the litter weight loss in the nitrogen immobilization phase (0−3 months), but their contribution to the rates of weight loss and nitrogen mineralization of *Q. serrata* leaf litter was negligible over a one-year period. The results suggest that feeding activities by mesofauna have either stimulatory or inhibitory effects on the litter microbial activities.

Chapter 3 Comparison of faunal exclusion methods for assessing mesofaunal effects on the decomposition of leaf litter: chemical (naphthalene) and physical (mesh size) exclusion methods in the field

This study was to compare two faunal exclusion treatments, i.e. chemical (naphthalene application) and physical (mesh-size bag) treatments, in order to examine the potential biases of the two methods for quantifying the contribution of soil mesofauna to the decomposition rate of leaf litter in the field. The decomposition of oak (*Quercus serrata*) leaf litter was studied from March 1999 until March 2000 at a mid-temperate forest. Measured amounts of litter were placed on the forest floor by using litter boxes with three different experimental treatments (1 mm mesh, 25 μm mesh and naphthalene). One year later, the weight loss of leaf litter in the control (1 mm mesh), naphthalene and 25 μm mesh treatments were 43, 27 and 41%, respectively, and there were significant differences in litter weight loss between the naphthalene and 25 μm mesh treatments. Nitrogen concentrations of leaf litter were significantly correlated with the weight loss rates in other two treatments except for the naphthalene treatment. Application of naphthalene altered nitrogen dynamics in the decomposing leaf litter. The 25 μm mesh treatment boxes were more effective in excluding all mesofauna than those of the naphthalene

treatment boxes in the field. The contributions of mesofauna to the litter decomposition rate were estimated as 46% in the naphthalene treatment, but as 7% in the 25 μm mesh treatment. These results indicate that quantitative assessment of the effect of litter mesofauna on the decomposition rate using a naphthalene method may overestimate the actual effects in the field.

Chapter 4 Contribution of microarthropods to the decomposition of needle litter in a Japanese cedar (*Cryptomeria japonica* D. Don) plantation: a comparison between the defaunated and control mesh boxes

To evaluate the effect of microarthropods on the decomposition of low-quality litter with relatively high C/N ratio and lignin content, the decomposition of needle litter in a Japanese cedar (*Cryptomeria japonica* D. Don) plantation was examined using litter boxes with different mesh sizes (1 mm and 25 μm) over a two-year period. The litter moisture contents did not differ between the two types of mesh boxes. No microarthropods were found in the defaunated (25 μm mesh) treatment boxes throughout the study period. During the first 5-month period of field incubation, the weight loss of needle litter was significantly higher in the defaunated treatment than in the control (1 mm mesh) treatment. However, the litter weight losses in the control treatments were significantly higher than those in the defaunated treatments after 10 months. The density of total microarthropods per gram dry litter increased with the advance of decomposition process, and was significantly correlated with the weight loss rate of needle litter. Collembolans and oribatid mites were the predominant groups, and accounted for almost 77% of all the collected animals. The presence of microarthropods in the boxes had no significant effect on the amounts of nitrogen immobilized in the litter. The C/N ratios of needle litter in the control treatments were consistently and significantly lower than those in the defaunated treatments after 10 months. During the whole study period, the annual decomposition rates (k) of *C. japonica* needle litter were 0.377 yr^{-1} in the control treatment and 0.298 yr^{-1} in the in the defaunated treatment, respectively. Based on Seastedt's equation (1984), the soil microarthropods increased the decomposition rate of needle litter (k_{fauna}/k_{total}) by 21% during the study period. These results showed that the activities of microarthropods accelerate the overall decomposition rate of *C. japonica* needles both by litter fragmentation and facilitating microbial growth, even though they temporarily inhibit decomposition.

Chapter 5 Discussion and conclusions

Assessing the role of soil mesofauna and microbes in the decomposition of plant litter is important in understanding nutrient cycling in forest ecosystems. However, the complexity of soil organism communities, associated with the large spatiotemporal variability in both microbial and faunal populations makes it difficult to study these interactions in the field. The approach of litter mesh box is a useful tool in efforts to answer questions about mesofaunal and microbial interactions in structurally complex systems under field conditions.

In this study, the two investigated forests differed in the abundance of total mesofauna, litter

decomposition rate, vegetation type, and litter supply. The annual decomposition rate of *Q. serrata* leaf litter was faster than that of *C. japonica* needle litter in the area of the same temperature and moisture conditions. Soil mesofauna did not affect to increase the rates of mass loss and nitrogen mineralization of oak leaf litter (*Quercus serrata*) either directly by the litter fragmentation, or indirectly through stimulation of microbial activity. The effects of soil mesofauna on the decomposition rates of *C. japonica* needle litter were largely increased with the advance of decomposition over a two-year period. Although the cedar plantation tends to cause harmful influences on the various soil-litter processes, soil mesofauna (predominantly microarthropods) play a relatively more important role in the litter decomposition in a Japanese cedar plantation than in a deciduous broad-leaved forest.