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Decomposition and Nutrient Dynamics of Aquatic Macrophytes in Lake Paldang

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ABSTRACT: This study examined the decomposition of blades and culms of aquatic emergent plant species, *Zizania latifolia*, *Phragmites communis* and *Typha angustata*, and changes in nutrient contents during decomposition. *Z. latifolia*, *P. communis* and *T. angustata* were the most frequently occurring species in Lake Paldang of Han River, Korea. Experiments were carried out from July 27 to December 14, 2005 in Lake Paldang using the litter bag method. The remaining masses of blade litter of each species at the end of experimental period were 21.2% of initial dry weight in *Z. latifolia*, 32.5% in *P. communis*, and 44.7% in *T. angustata*. In addition, the remaining mass of culm was 22.6% of initial dry mass in *Z. latifolia*, 56.4% in *P. communis*, and 38.1% in *T. angustata*. During the litter decomposition period, P, K, Na, and Mg concentration decreased rapidly within 10 days, but Ca and Mn concentration declined slowly. K contents remained below 10% of initial values in all litter samples retrieved during decomposition, whereas Ca and Mg concentration remained above 40% and 50% during decomposition in all three species. Na, P and Mn contents in litter varied among species and plant parts. P concentration in culms of *P. communis* remained at about 60% of initial concentration throughout the study, but the remaining P content in culms of *Z. latifolia* was only 10% of the original value at the end of the study period. The Mn concentration in blades of *P. communis* increased about 15-fold relative to the initial content by the end of experiment.

Key words: Decomposition, Emergent macrophyte, *Phragmites communis*, *Typha angustata*, *Zizania latifolia*

INTRODUCTION

Aquatic macrophytes are responsible for much of the organic matter production in wetlands (Gessner 2000, Wetzel and Howe 1999). Only a small fraction of this material is consumed by grazers. During the growth period, as emergent macrophytes absorb nutrients to their culms and leaves from sediments, they become a nutrient sink (Carpenter 1980, Carpenter and Lodge 1986). Many investigators have studied the production of matter and the absorption capacity of nutrients for fine-scale landscape management and cleanup of contaminated water (Denward and Tranvik 1998). Researchers have concentrated heavily on the removal of surplus nitrogen and phosphate from water using *P. communis*, *T. angustata* and *Z. latifolia* (Kim et al. 1988, Shin and Park 2001), but few studies have focused on nutrient cycling in aquatic ecosystem, the biological decomposition process of aquatic plant residues, and effects of decay of aquatic plants on water nutrient supplies.

Most emergent macrophytes eventually enter the detrital pool as litter, which then decomposes (Brock 1984, Gessner 2000, Polunin 1984). However, it can take years for litter to break down completely. A substantial component of above- and below-ground plant material can be buried in sediments, contributing to nutrient immobilization within wetlands and mediating energy flow at the ecosystem level (Richardson and Marshall 1986).

Plant decomposition includes all of the physical and chemical changes which occur after tissue senescence and death, starting with complex organic molecules and ending in simple inorganic elements (Brinson et al. 1981). The litter decomposition processes include mechanical fragmentation by animal grazers, weathering, leaching, autolytic production of dissolved organic matter, and digestion of labile and recalcitrant materials by bacteria and fungi (Swift et al. 1979, Chimney and Pietro 2006, Gessner 2000).

The present study measured the litter decomposition rate of *P. communis*, *T. angustata* and *Z. latifolia,* which are the dominant emergent macrophytes in the littorial zone of the Han River in Korea, using the litter-bag method. In addition, we examined release of nutrient elements from macophyte litter samples on an artificially suspended islet of aquatic macrophytes in Lake Paldang of the Han River, Korea.

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MATERIALS AND METHODS

Study Site

The study was carried out on an artificially suspended islet of aquatic macrophytes in Lake Paldang of the Han River, Teochon-myeon, Korea (N 37° 28' 25", E 127° 18' 01"). The experimental site has been managed by the National Institute of Environmental Water Resources of Korea to improve the natural aquatic environment including water purification, supplement of breeding space and habitats of various aquatic animals, and improvement of waterside scenery. The mean air temperature was 17.6℃ and the total precipitation was 1,228.5 mm during the experimental period from Jul. 27 to Dec. 14, 2005.

Litter Samples and Litter Bag Preparation

According to Cho (1992) and Lee et al. (2002) data, *T. angustata*, *Z. latifolia*, and *P. communis* are the dominant emergent macrophytes in the littoral zone of Lake Paldang. At Lake Paldang, these species showed production levels of 1,760, 1,639, and 1,466 g DM m^{-2} yr^{-1}, respectively, and frequencies of occurrence of 54.2, 45.8, and 50.0%, respectively. Therefore, these three macro-hydrophytes species were chosen for our experiments. We collected plant samples in May 2005, and separated the samples into blades and culms. The plant samples were cut into 5 cm sections and dried at 60℃.

To investigate patterns of biomass reduction and nutrient leaching from plant litter samples, we made 12 cm × 12 cm litter bags composed of polyethylene-resin-coated glass fiber meshes. The mesh size was 1.2 mm × 1.2 mm and the litter bags were closed with polyethylene thread after 2～3 g litter samples were placed in each bag. Four replicates were prepared for each species. Batting bags were prepared in same way as ordinary litter bags, using sheets of glass filter paper which were approximately the same size as the litter samples.

We hung the litter bags at a depth of 1 m from the water surface on 27 July, 2005. The litter bags were recovered after 12 days (8 August, 2005), 35 days (31 August), 55 days (22 September), 76 days (12 October), 97 days (2 November), and 140 days (14 December).

Water and Plant Analysis

We measured the water temperature and collected water samples each time we conducted litter bag retrievals. The water samples were stored at 4℃ in clean 1 L polyethylene bottles until analysis. Water pH was determined using a Corning 345 pH meter, and water samples filtered using 0.45 μm pore sized filters were used to analyze NO_3^- and NO_2^- concentrations using an Ion Chromatograph (Sykam GmbH, Model S-135). Total dissolved phosphate was determined by ascorbic acid reduction methods.

The four litter bag replicates for each species were periodically retrieved from the experiment site. The litter samples were gently cleaned to remove adhering debris and macro-invertebrates, and then dried to constant mass at 60℃. Litter samples were prepared by wet digestion following the methods of Helrich (1990) using HNO_3 and $HClO_4$ to determine the concentrations of K, Ca, Mg, Mn and P by ICP (JY-Ultima-2).

RESULTS

Changes in Water Condition

Water temperature for the experimental period ranged from 13.0 to 26.3℃, and dissolved oxygen (DO) ranged from 0.69 to 6.67 mg/L. DO showed negative correlation with water temperature (Pearson correlation = −0.956, $p<0.05$). The pH fluctuated between 6.36 and 7.59. Nitrate nitrogen concentrations of water ranged from 1.66 to 11.90 mg/L and total phosphate (TP) ranged from 0.017 to 0.063 mg/L. Nitrate concentrations of water were relatively high during the summer and low in winter, and nitrate and total P were negatively correlated (Pearson' correlation = −0.974, $p<0.01$) (Table 1).

Changes in Dry Mass of Litter

Decomposition of blades and culms of each species in litter bags proceeded rapidly throughout the experimental period (Fig. 1). The greatest litter weight loss was observed during the initial decomposition period. After 97 days, culms and blades of *Z. latifolia* showed the fastest decomposition, with the remaining mass of culms and blades at only 22.6% and 21.2% of the original mass, respectively.

Table 1. Changes in water conditions at the study site during the experimental period in 2005 (mean ± SD, n=4)

Date	27 Jul.	8 Aug.	31 Aug.	22 Sep.	12 Oct.	2 Nov.
Water temp. (℃)	26.3 ±0.3	25.1 ±0.2	23.1 ±0.2	20.5 ±0.2	18.1 ±0.2	13.0 ±0.4
NO_3^--N (mg/L)	1.66 ±0.75	3.54 ±0.80	5.84 ±0.75	5.95 ±0.63	8.08 ±0.13	11.90 ±5.25
Total P (mg/L)	0.063±0.026	0.056±0.005	0.050±0.005	0.044±0.003	0.029±0.002	0.017±0.012
DO (mg/L)	0.69 ±0.34	1.09 ±0.45	1.95 ±0.18	1.71 ±0.24	4.31 ±0.17	6.67 ±2.05
pH	6.36 ±0.07	7.16 ±0.08	6.95 ±0.07	6.86 ±0.13	7.59 ±0.08	7.06 ±0.03

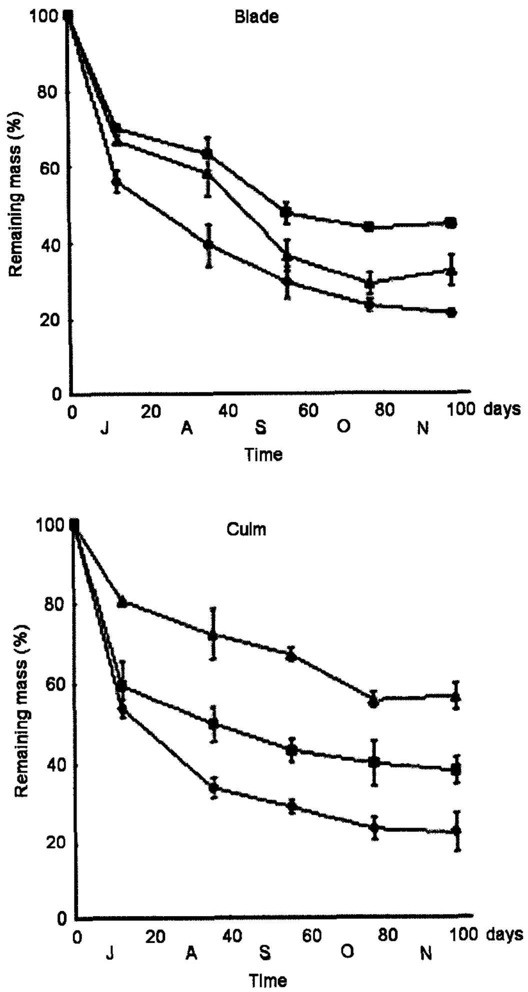

Fig. 1. Mass loss (mean ± SD, n=4) from submerged blades (top) and culms (down) of the emergent macrophytes, *Z. latifolia* (circles), *P. communis* (triangles) and *T. angustata* (squares), in an experimental station in Lake Paldang, Han River, Korea.

Decomposition of blades and culms of *P. communius* and *T. angustata* occurred at different rates. Culms of *P. communius* showed faster decay than blades, but *T. angustata* showed faster decay in culms than in blades. The remaining mass of culms and blades of *P. communius* at the end of the experiment was 56.4% and 32.5% of initial mass, respectively, whereas *T. angustata* showed a remaining mass of 38.1% and 44.7% of initial dry weight of culms and blades, respectively. Kim et al. (2002) and Mun et al. (2000a, b, 2001) reported the same pattern of dry mass loss in these three species in the lower Nakdong River.

Changes of Nutrient Contents in Litter

The nutrient contents of different plant species and tissue parts showed conspicuous differences. Nutrient contents of *P. communis* were lower than *Z. latifolia* or *T. angustata*. In particular, culms of *P. communis* had remarkably low nutrient contents. Conversely, culms and blades of *T. angustata* exhibited higher nutrient contents than the other saprophyte species. *T. angustata* had relatively high concentrations of K, Na, Ca, and Mg in its culms, and K, Na, Ca, and Mn in its blades. On the other hand, *P. communis* showed lower concentrations of P, Ca, and Mn, and intermediate concentrations of K and Na in blade tissue. The blades and culms of *P. communis* contained very low Mn contents (Shin et al. 2006).

The greatest leaching of nutrient elements occurred during the initial stages of decay, i.e. within 10 days, after which the relative nutrient concentrations increased. K always decreased more rapidly than litter mass. Na also decreased faster than litter mass in leaves and culms of *T. angustata,* and culms of *Z. latifolia* and *P. communis*. However, P, Ca, Mg, and Mn decreased more slowly than mass in each aquatic plant (Fig. 2).

DISCUSSION

Litter decomposition is an integrated function of the ecosystem involving microbes, animals and physico-chemical interactions, so the decay rates of litter differ dramatically between places and seasons (Benfield and Webster 1985, Iversen 1975, Suberkropp 1995, Melillo et al. 1982, 1984). Litter decomposition processes such as leaching, comminution and catabolism were highly influenced by physico-chemical factors, the surrounded environment and biotic factors (Swift et al. 1979).

We selected three dominant emergent macrophytes. *Z. laitfolia*, *P. communis*, and *T. angustata*, in Han River littoral zone, and carried out litter decomposition experiment using the litter bag method. In *Z. latifolia*, there was no difference between the decomposition rate of blade and culm litter. Culms of *P. communis* were decomposed more slowly than blade tissue, but the culms of *T. angustata* decomposed more rapidly than the blades. These results are in accordance with reports of Mun (2000a, b) and Gessner (2000).

Mun (2000a, b and 2001) found that after 13 months, the remaining masses of blades and culms of *T. angustata, Z. latifolia,* and *P. communis* were 34.7% and 59.2%, 16.9% and 14.7% and 29% and 57.4% of initial mass, respectively. However, our results indicated a similar level of decomposition after only 100 days. The experimental seasons of the experiments were different, but overall decomposition patterns were similar.

Differences in decomposition rates between plant species or plant parts have been discussed by many authors. Litter quality as defined by chemical composition markedly influences the decomposition rates of different types of plant litter (Melillo et al. 1982, 1984, Chimney and Pietro 2006, Welsh and Yabitt 2003, Shin et al. 2006). Shin

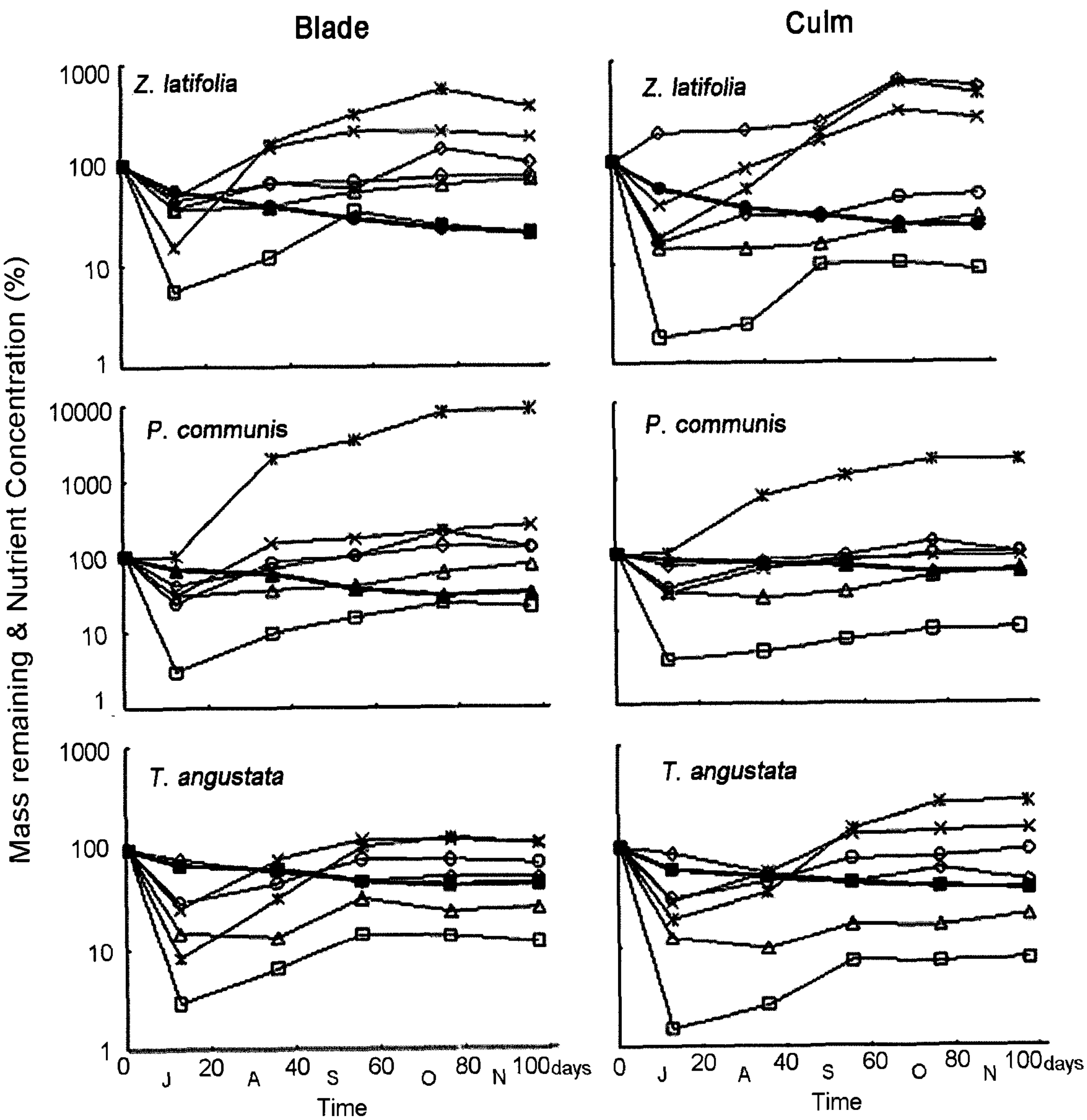

Fig. 2. Changes in dry mass of each emergent macrophyte and the concentration of nutrient elements during experimental period, from Jul. 27 to Dec. 14, 2005. The values show mass and concentration of each nutrient relative to the initial values for litter samples. Symbols indicate the each nutrient element (-●-, -■-, -▲-, mass remaining of blade and culm of each species; -○-, P; -△-, Na; -□-, K; -◇-, Ca; -X-, Mg; -*-, Mn).

et al. (2006) and Yang and Shim (2003) concluded that the decomposition rates of emergent macrophytes and terrestrial tree leaf litter were positively related with N concentration in plant tissues while showing a negative correlation with lignin, C/N, and lignin/N. Lignin is known as more resistant to decomposition than other structural polymers (Chimney and Pietro 2006, Melillo et al. 1982, 1984, Welsh and Yavitt 2003, Gessner 2000). Moreover, water conditions such as N and P contents influence the fungal and algal communities which control the decomposition rate of aquatic plant litter (Gessner 2000, Gessner and Chauvet 1994, Kuehn and Suberkropp 1998, Royer and Minshall 2001).

Further studies will be required to better understand the relationships among aquatic plant decomposition, water nutritional condition, microbes and detritus-grazing aquatic micro-arthropods, and phenological properties of emergent macrophytes such as the time of submergence of each plant part. Nutrient concentrations of emergent macrophytes vary among plant species and tissues (Gessner 2000). Many authors have suggested that most nutrient elements in emergent macrophytes are rapidly leached in the initial period of litter decomposition. However, although some decomposing litters exhibited initial losses of N and P, several emergent shoot litters showed increases in net N and P by microbial immobilization during the decomposition of litter (Wrubleski et al. 1997, Gessner 2000, Kuehn and Suberkropp 1998, Cho 1992). The increase of P content is generally attributed to uptake by decomposer microbes associated with the plant tissue (Chimney and Pietro 2006) and net immobilization of P by the decomposing plant tissue (Gessner 2000).

Other studies have reported changes in the chemical contents of macrophyte litter during decomposition similar to our findings, e.g., rapid loss of K compared to other constituents such as Ca and Mg, Na, P content (Chimney and Pietro 2006). In our experiments, Mn concentrations in *P. communis* dramatically increased during decomposition. The concentration of Mn at end of experiment exhibited a 15-fold increase relative to the initial concentration in blades, and a 4-fold increase relative to the initial composition in culms of *P. communis*, which showed the highest concentration of Mn in the litter samples retrieved last, and the lowest concentrations in the initial litter samples. The rapid loss of some constituents and not others can be explained by differential mobility of individual ions in plant tissues and other complex mechanisms (Chimney and Pietro 2006) but further study is needed to clarify this issue.

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