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Losses of Biomass and Mineral Nutrients during Decomposition of Herbaceous Plants in Riverine Wetlands

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ABSTRACT: The composition changes of litters were investigated to figure out the effects of the decomposition of *Humulus japonicus* on nutrient circulation and decomposition process in the riverine wetlands: Tan stream and Amsa-dong. Litterbags (mesh size 1 mm and 5 mm) were installed to monitor mass and nutrient changes of 5 types of litters: *H. japonicus* only, *Miscanthus sacchariflorus* only, *Phragmites communis* only, mixed litters including *H. japonicus*, and mixed litters without *H. japonicus* for 7 months. It was shown that k (decay rate) of the *H. japonicus* (2.68~3.12) was higher than that of *M. sacchariflorus* (1.83~2.16) and *P. communis* (0.02~1.18). The mass and organic remainings of the mixed litters including *H. japonicus* at Tan stream were 47.0~55.1% and 47.0~54.9% and those of the litterbags without *H. japonicus* were 49.2~65.4 % and 47.1~57.5%, respectively. This result indicated that the nutrient circulation was faster at *H. japonicus* community than others. Ca, Na, Mg, K, P, C, N and H contents reduced to around 40~80% of original. However, Na concentration increased up to 407~584% at 100 days and decreased to 248~498% at the end of the experiment. Decomposition rates were similar between 1mm and 5mm mesh size litterbags and this implies that plant litters in studied areas decomposed mainly by microbes rather than small animals. This study revealed that the fast growth of *H. japonicus* was resulted from fast decomposition in part: positive feedback of nutrient cycling.

Key words: Decay constant, Change of nutrient contents, C/N ratio, *Humulus japonicus*, Riverine wetlands

INTRODUCTION

Plant communities in a riverine wetland ecosystem, which connects the terrestrial ecosystem and aquatic ecosystem, protect waterside physically, form good scenery, offer habitats and shelter for the lives, create closeness of water space (or hydrophilic space), absorb contaminants, and purify water quality etc (Ahn and Song 2003). Riverine wetlands have high productivity and diversity of creatures. Due to plenty supply of water and high nutrient input from lands, unique plant communities are formed in riverine wetlands. However, some plants have destroyed the structure and function of these unique plant communities in Korean riverine wetlands (Seoul City 2003).

Humulus japonicus S. et Z. is an annual herbaceous plant in Korea and belongs to Cannabinaceae. This plant originated in south Asia and mainly distributes in tropical and subtropical zone (Bae 2000). Also, this plant settled in all over the Korea long time ago (Lee 1980). *Humulus japonicus* prevents the reproduction of other plants including *P. communis* and *M. sacchariflorus* and sometimes kills them by climbing and shading. It was reported that *H. japonicus* starts to grow under *M. sacchariflorus* and *P. communis* in May and reaches to the top of *P. communis* which dominates riverine wetlands. If there are typhoons or strong winds, *P. communis* falls down by the weight of *H. japonicus*, then it is covered wholly by *H. japonicus*, so that the plants under *H. japonicus* cannot grow due to lack of light. This has been happened in Bam island and Anseong stream in Korea (Seoul City 2001).

Though *H. japonicus* threatens the maintenance of ecological diversity and the structure of unique plant communities in riverine wetlands, there has not been enough research about *H. japonicus*. There were only few studies such as flora and plant community structure of *H. japonicus* (Seoul City 2002, 2003, 2005). It is necessary to have basic data and information to set a management program of *H. japonicus*. The purpose of this study is to investigate the effects of *H. japonicus* on the nutrient cycling, especially decomposition process in riverine ecosystems. This study is meaningful to reveal the mechanism of fast growing trait of *H. japonicus*.

MATERIALS and METHODS

Study Area

This study was carried out in the ecosystem preservation areas

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located in Amsa-dong and Tan stream. The Amsa-dong ecosystem preservation area is located near the Kwangnaroo citizen park along the Han river in Seoul (N 37°32', E 127°07'). This area was formed naturally by sediment accumulation. Although plant communities including *P. communis*, *M. sacchariflorus*, and *Salix koreensis* originally dominated this area, *H. japonicus* takes place of 40% of this area nowadays (Seoul City 2005). Water contents in soil ranged from 28% to 51% during the period of summer 2004 to 2005.

Tan stream originates from Yong-in city in Gyeonggi province, passes Songpa-gu and Kangnam-gu in Seoul, and then joins to Han river. The study site is located between Dogok-bridge and Suseo where is the boarder line between Kangnamgu and Songpagu. The species diversity in this area is high and *H. japonicus* occupies 9.3% of plant communities (Seoul City 2001). Water contents in soil ranged from 12% to 41% during the summer in 2004 and 2005.

Litterbag Preparation

Plants were harvested at four plant communities in Amsa-dong: *H. japonicus*, *M. sacchariflorus*, *P. communis*, *P. communis* and *H. japonicus* community in October 2004. Also, plants were harvested at *H. japonicus* community (Table 1) in Tan stream. They were put into 20 cm × 20 cm nylon litterbags of mesh size 1mm and 5mm. Litter types of litterbags consisted of *H. japonicus* only, *M. sacchariflorus* only, *P. communis* only, *P. communis* and *H. japonicus*, and mixed plants including and without *H. japonicus*. Mixed plants include all plants listed in Table 1. Leaf to stem ratio in litterbags was the same as leaf to stem ratio of each plants in the field. These litterbags were put under plant communities where plants were collected: *H. japonicus*, *M. sacchariflorus*, *P. communis*, *P. communis* and *H. japonicus* at Amsa-dong, and mixed plants including *H. japonicus* and mixed plants without *H. japonicus* at Tan stream. Incubation sites of litterbags were in the upper flat of riverine wetlands and were not flooded during incubation.

Litterbag Retrieval and Chemical Analyses

The litterbag retrieval was done at day 0, 1st, 3rd, 7th, 15th, 30th week after litterbag setting. Recovered 5 replicates were dried at 60℃ for more than 48 hours after adhering material on the outside of the litterbags was removed. Sample in each litterbag was weighted and ground with WILLY MINI-MILL (3380L10, THOMAS, USA) for the chemical analyses.

The weight loss and change of nutrient contents during decomposition were determined by measuring the remaining weight and organic nutrient concentration of litter in the litterbags. The remaining weight of litter was expressed as % of initial sample weight. The decay rate (k) was derived from the Olson's formula (1963). Decay rate (k) were determined by dry weight remaining at measurement after 204 days.

$$\frac{dC}{dt} = L - kC$$ (L = annual production of litter, C = amount of litter, k =decay rate)

Organic matter was decided with loss-on-ignition at 500°C for 4 hrs (Dean 1974, Boyle 2004). For the analyses of Na, Ca, K and Mg, ground samples were acid-digested with a microwave (MarsX press, CEM, USA). 0.2 g of sample was taken, 8 mL of Nitric acid and 2 mL of peroxide were added and digested. Major cations in digested solutions were analyzed with AA (240FS, Varian, USA). The digested acid was naturalized with sodium hydroxide and analyzed for P with acetic acid method (Kwon et al. 2006). C, N and H were analyzed with an element analyzer at the National Center for Inter-University Research Facilities (NCIRF) in Seoul National University.

Table 1. Plant coverage (%) measured at 2 m × 2 m quadrats at Tan stream site

Date	July 2004	October 2004
Humulus japonicus	65	80
Arundinella hirta		40
Chelidonium majus var. *asiaticum*	20	18
Phaseolus nipponensis	1	13
Stellaria aquatica	20.5	12
Artemisia selengensis		6
Aster pilosus	28	6
Setaria viridis		5.5
Digitaria sanguinalis		3
Artemisia princeps var. *orientalis*	12	3
Phragmites communis	1	
Glycine soja	30	
Equisetum arvense	15.5	
Erigeron annuus	15	
Ambrosia artemisiifolia var. *elatior*	2	
Commelina communis	1	
Dioscorea japonica	< 1	

RESULTS AND DISCUSSION

Decomposition Rate

The decomposition rate of *H. japonicus* was significantly higher than those of *M. sacchariflorus* and *P. communis* (Fig. 1). After 204 days, the remaining dry weight of *H. japonicus* and *M. sacchariflorus*

in 1 mm mesh size litterbag was 55.5 ± 5.7% and 72 ± 3.2% of original, respectively. Those in 5mm mesh size litterbag were 45.1 ± 5.1% and 74 ± 4.6%, respectively. The remaining dry weight in 1mm and 5mm mesh size litterbags of mixed plants including *H. japonicus* were 55.1 ± 3% and 47 ± 9.8%, respectively. Those in the litterbags of mixed plants without *H. japonicus* were 65.4 ± 8.6% and 49.2 ± 6.0%, respectively. This implies that *H. japonicus* is responsible for rapid decomposition of plants litter in mixed plants including *H. japonicus*. This might be partially responsible for the rapid growth rate (Ju et al. 2006).

The mass of all plant materials declined significantly over 50 days and decreased slowly up to about 66% (Fig. 1). Kim (2001) reported that the decomposition pattern of plant material generally can be divided into three phases: initial phase of rapid weight loss, middle phase of extended period of active microbial decomposition, and final phase of very slow decay of refractory compounds. The rapid weight loss at initial phase comes from the leaching of soluble compounds. In this study, the mass loss by 50 days was included in the first phase, with the second phase continuing to the end of incubation.

The organic decomposition of *H. japonicus* was significantly higher than those of *M. sacchariflorus* and *P. communis*. After 204 days, the organic remaining of *H. japonicus* and *M. sacchariflorus* in 1mm mesh size litterbag was 54.65% and 71.29% of original, respectively. Those in 5mm mesh size litterbag were 46.23% and 71.30%, respectively (Fig. 2).

Decay constant *k* for *H. japonicus*, *M. sacchariflorus*, *P. communis*, *P. communis* + *H. japonicus*, mixed plants including *H. japonicus*, and mixed plants without *H. japonicus* in 1mm mesh size litterbag were 2.68, 1.83, 1.18, 1.64, 4.03 and 5.61, respectively and those in 5mm mesh size litterbag were 3.12, 2.16, 0.02, 3.35, 4.49 and 4.29, respectively. Half-lives of *H. japonicus*, *M. sacchariflorus*,

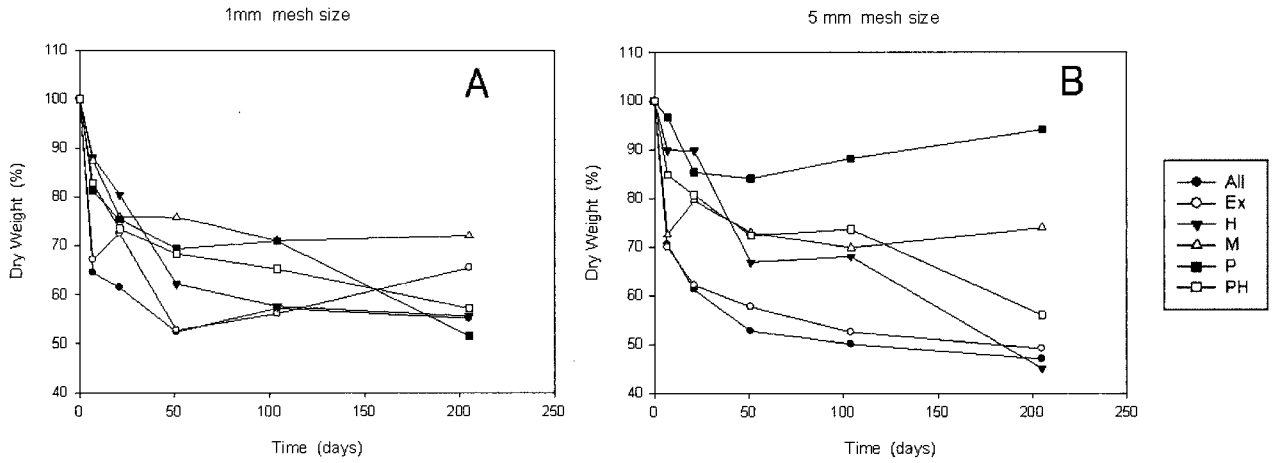

Fig. 1. The change of dry weight with time in 1 mm (A) and 5 mm (B) mesh size litterbags. All: mixed plants including *H. japonicus*, Ex: mixed plants without *H. japonicus*, H: *H. japonicus*, M: *M. sacchariflorus*, P: *P. communis*, PH: *P. communis* + *H. japonicus*.

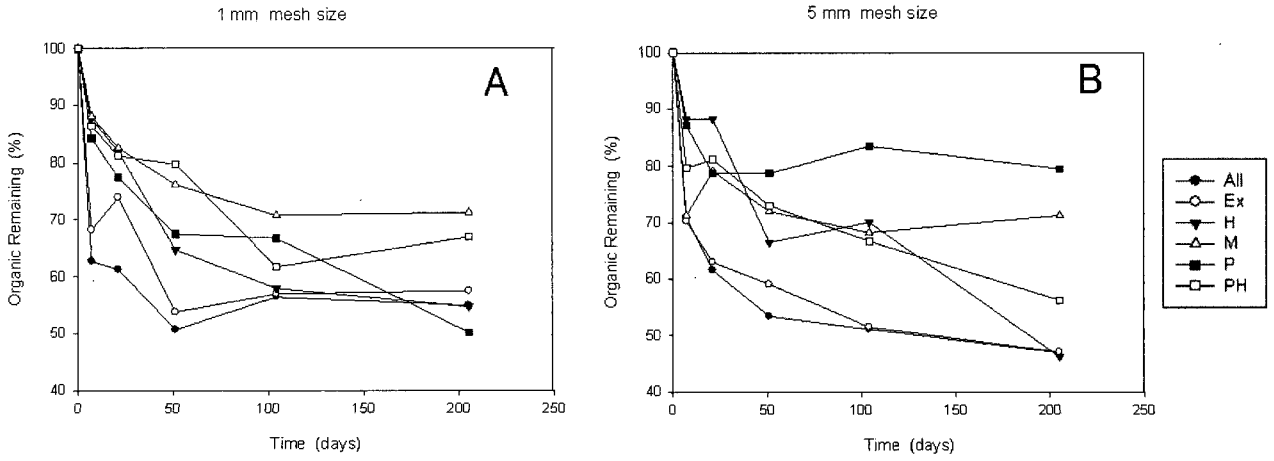

Fig. 2. The change of organic remaining with time in 1 mm (A) and 5 mm (B) mesh size litterbags. Abbreviation is the same as in Fig. 1.

P. communis, *P. communis* + *H. japonicus*, mixed plants including *H. japonicus*, and mixed plants without *H. japonicus* in 1mm mesh size litterbags (those in 5mm mesh size litterbags) were 0.25 (0.22), 0.37 (0.30) 0.58 (29.1), 0.42 (0.2), 0.17 (0.15) and 0.12 (0.16) year, respectively (Fig. 3). Even though we used two types of litterbag to reveal which plays more important role in decomposition of plants between microbes and small invertebrates, results from two types of mesh size were almost the same. This implies that only microbes are responsible for the decomposition of plants rather than small invertebrates in these riverine ecosystems.

The difference of decay rate between *H. japonicus* and other plants might be resulted from the differences in C:N ratio. In general, N content is responsible for the activity of microbes and the amount of nitrogen was resulted in the difference of decomposing microbes (Swift et al. 1979). Mun et al. (2000a) reported that the decomposition of a plant was more rapid in high levels of nitrogen in an organ. While the C:N ratio was slightly changed from 24.78~28.68 to 17.12~17.44 in the early period of decomposition of *H. japonicus* in this study, it was significantly changed from 55.63~62.01 to 31.90~40.50 in those of *M. sacchariflorus* in 1mm and 5mm mesh size litterbags (Fig. 4).

Smith and Smith (2001) suggested that the immobilization of nitrogen continues until C:N ratio of 15~30 and then mineralization starts. C:N ratio of *H. japonicus* was constantly in the range of mineralization and this appropriate C:N ratio could make microbes to decompose organic material actively. The initial C:N ratio of *M. sacchariflorus was* more than 55 and then showed an stable trend above 30. The C:N ratio in others remained at around 30. This might result in late decomposition of *M. sacchariflorus*, compared with others.

Changes of Nutrient Contents

Nitrogen concentrations in 1 mm and 5 mm mesh size litterbags were not significantly different (Fig. 5). Initial N concentrations of *H. japonicus* and *M. sacchariflorus* were 13.2~15.4 and 6.9~7.5 mg/g, respectively. Nitrogen concentrations of *H. japonicus* and *M.*

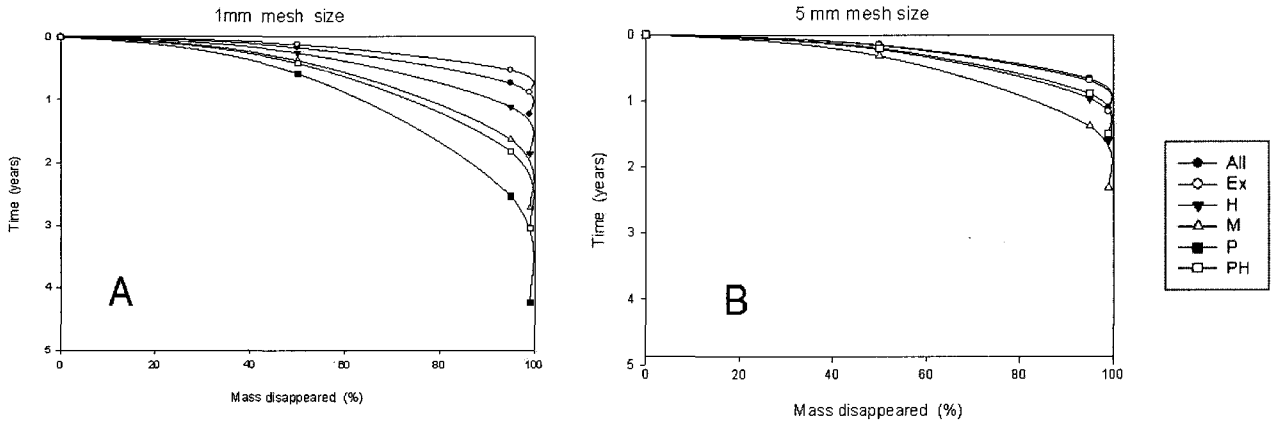

Fig. 3. The change of mass with time in 1 mm (A) and 5 mm (B) mesh size litterbag. Abbreviation is the same as in Fig. 1.

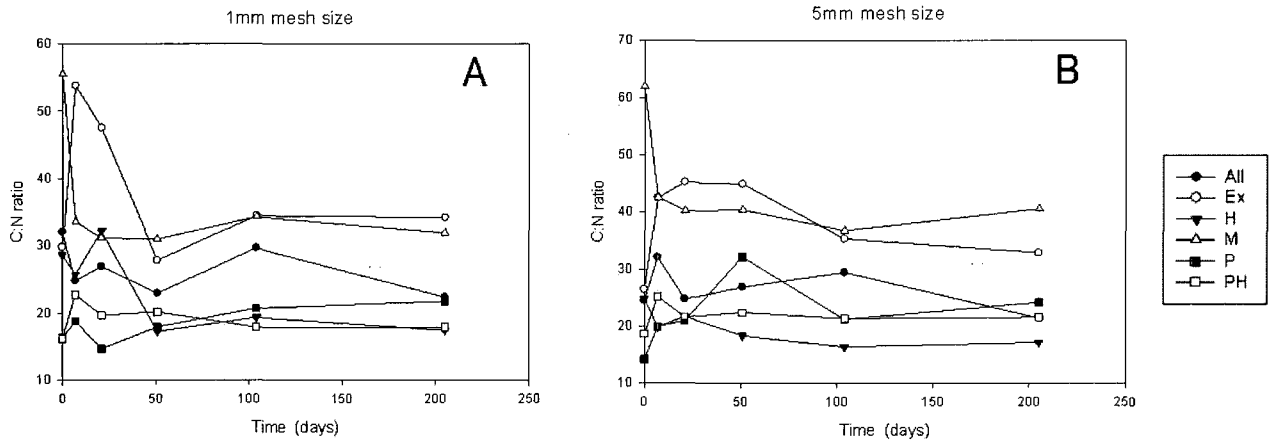

Fig. 4. The change of C:N ratio with time in 1 mm (A) and 5 mm (B) mesh size litterbags. Abbreviation is the same as in Fig. 1.

sacchariflorus increased to 22.3~23.3 and 10.2~12.9 mg/g at 204 days, respectively.

If N is not enough for microbes, N is a critical factor which causes slow decomposition (Smith and Smith 2001). However, N concentration of *H. japonicus* was high enough for microbes and mineralization could start from the initial phase. The higher N concentration of *H. japonicus* in the early period than *M. sacchariflorus* might result in more rapid decomposition of *H. japonicus* than *M. sacchariflorus*. Even though the N concentration of other plants increased continuously, N concentration of *H. japonicus* was higher than others at 204 days.

Percent remaining N of *H. japonicus* decreased during the first month and then increased to 160% after 1 month (Fig. 6). Similar pattern was observed in *M. sacchariflorus*. Even though N concentration were high in *H. japonicus*, the immobilization was appeared in the early period after leaching. Mun et al. (2000b) reported that the immobilization was appeared in *P. communis* after three months. Also, increase of nitrogen levels was observed in the long-term study (Anderson 1973, Gholz et al. 1985, Kelly and Breaucamp 1987). But immobilization of N in *P. communis* was not apparent in this study. This result coincide with that a rapid loss of nitrogen in the early stage has been noted in *P. australis* (Polunin 1982) and in *Carex* spp. (Chamie and Richardson 1978). However, Anderson (1978) reported that nitrogen level in *P. australis* litter increases with incubation time in a eutrophic lake.

The initial P concentrations of *H. japonicus* and *P. communis* were 0.21~0.24 and 0.11~0.13 mg/g and became 0.15~0.18 and 0.16~0.09 mg/g at 204 day, respectively (Fig. 7). Those in the litterbag of mixed plant including and without *H. japonicus* were 0.12~0.19 and 0.11~0.13 mg/g in 1mm mesh size, respectively and fluctuated around initial values. Also, P concentrations in others fluctuated around initial value.

The remaining P in 1mm mesh size litterbags decreased in 7 days, increased to the peaks in 49 days, and then decreased (Fig. 8A). At

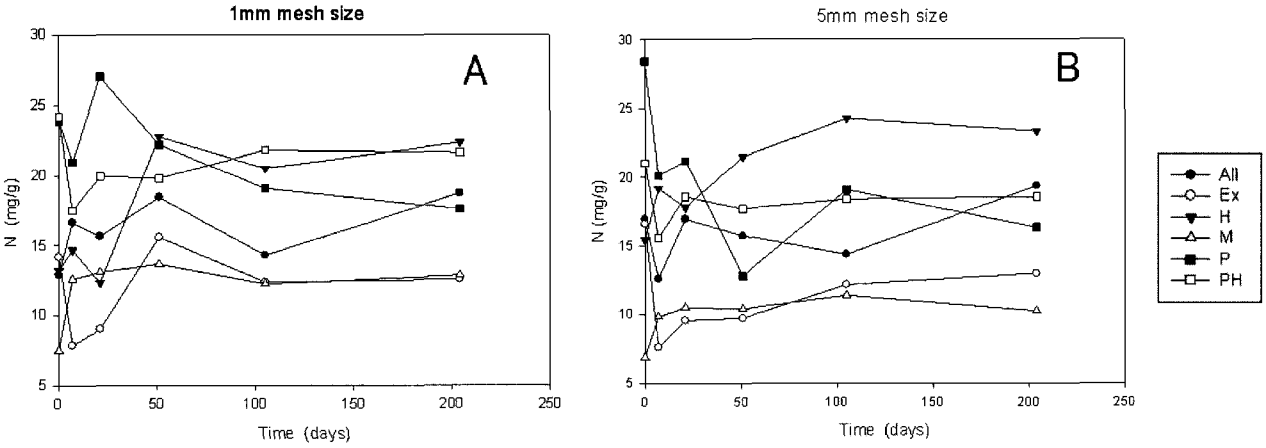

Fig. 5. The change of N concentration with time in 1 mm (A) and 5 mm (B) mesh size litterbags. Abbreviation is the same as in Fig. 1.

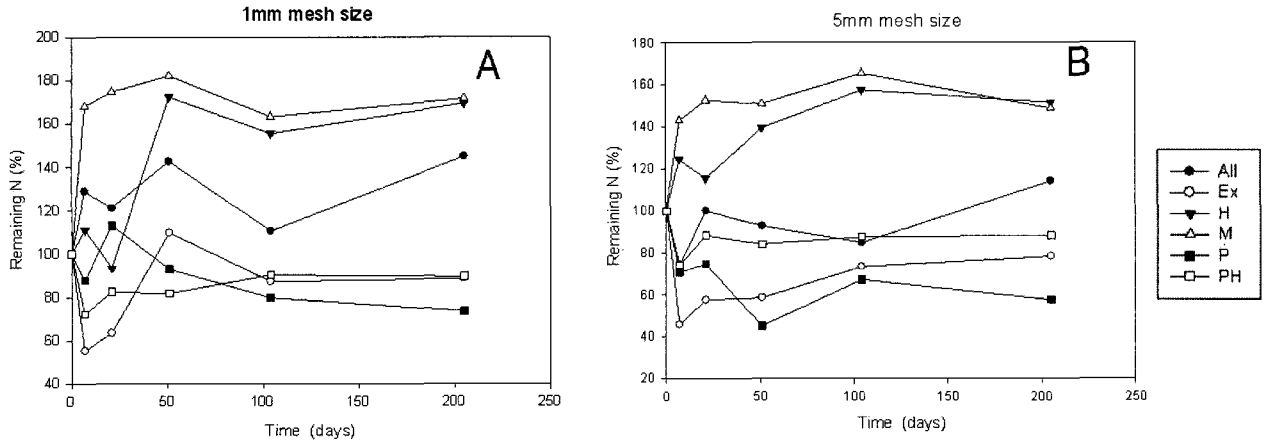

Fig. 6. The change of remaining N with time in 1 mm (A) and 5 mm (B) mesh size litterbags. Abbreviation is the same as in Fig. 1.

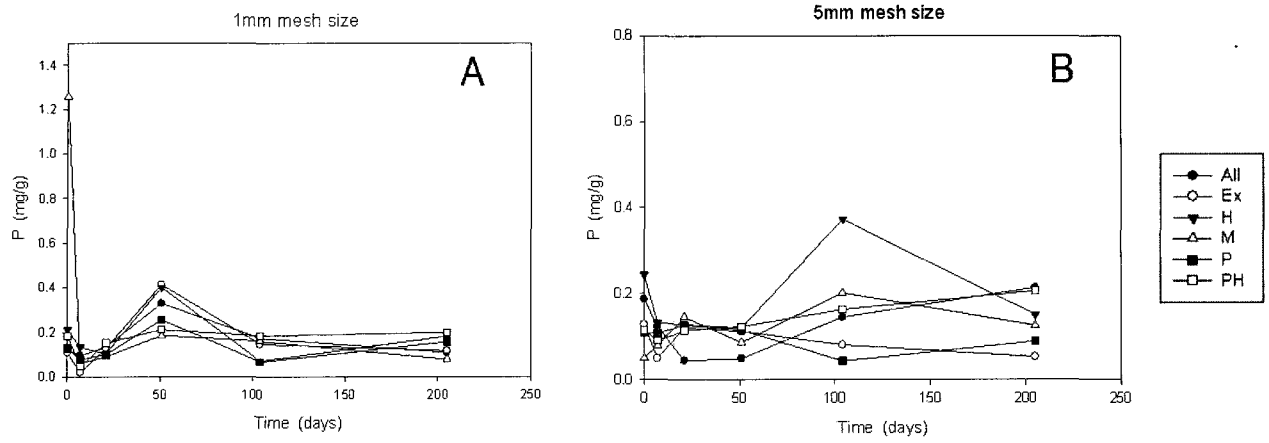

Fig. 7. The change of P concentration with time in 1 mm (A) and 5 mm (B) mesh size litterbags. Abbreviation is the same as in Fig. 1.

the end of incubation, remaining P of *H. japonicus* and *M. sacchariflorus* in 1mm mesh size litterbags were the lowest as 86.2 % and the highest as 128.1% after 204 days. The remaining P in mixed plants including *H. japonicus,* mixed plants without *H. japonicus, P. communis,* and *P. communis* and *H. japonicus* were 88.9, 107.7, 122.3 and 107.9% after 204 days incubation. The changing pattern of P remaining was different between 1 mm and 5 mm mesh size litterbags and the reason for this difference should be studied further.

The initial Na concentrations of *H. japonicus*, *M. sacchariflorus*, and *P. communis* in 1mm and 5mm mesh size litterbags were 0.15 ~0.30, 0.39~0.22 and 0.20~0.30 mg/g, respectively (Table 2). *Humulus japonicus* contained relatively lower Na than *P. communis* and *M. sacchariflorus*. At the end of study, Na concentrations of *H. japonicus*, *M. sacchariflorus*, and *P. communis* were 0.76~0.74, 0.78~0.74 and 1.13~0.59 mg/g, respectively.

Remaining Na in *H. japonicus* and mixed plants including *H. japonicus* except in 5mm mesh size litterbags of mixed plant including *H. japonicus* and *P. communis* only increased rapidly until 105 days and decreased slowly to the end of the study (Fig. 8C, D). That in 1 mm mesh size litterbags of *P. communis* constantly increased to 204 days. From the fact that percentages of remaining Na of mixed plants including and without *H. Japonicus* in 1 mm mesh size litterbags were 252% (190% in 5 mm mesh size litterbag) and 38% (110% in 5 mm mesh size litterbag), respectively, we knew that *H. japonicus* absorbs sodium better than others.

The initial concentrations of Ca in *H. japonicus*, *M. sacchariflorus* and *P. communis* were 87.5~94.59, 14.47~22.13 and 20.41~22.49 mg/g, respectively. After 204 days incubation, Ca concentration of *H. japonicus*, *M. sacchariflorus* and *P. communis* were 40.5~42.9, 34.6~42.56 and 13.86~30.45 mg/g, respectively (Table 2).

The remaining Ca of *H. japonicus* decreased more rapidly than other plants. The immobilization of Ca was observed in *M. sacchariflorus* after 50 days (Fig. 8E, F) and remaining Ca were 156.4~294.2% after 204 days.

The initial concentration of K in *H. japonicus*, *M. sacchariflorus* and *P. communis* were 175.52~240.31, 91.99~97.94 and 225.18 ~235.59 mg/g, respectively (Table 2). The concentrations of potassium fluctuated with time and there was no general trend. Brinson (1977) reported potassium disappearance of aquatic macrophytes was rapidly occurred within two weeks. Although *H. japonicus* was not aquatic macrophyte, its potassium was rapidly disappeared. Remaining K diminished to about 30~40% within two weeks (Fig. 8G, H). Also, Planter (1970) reported that K leaches more rapidly than calcium and our results showed the same trend.

The initial concentrations of Mg in *H. japonicus*, *M. sacchariflorus* and *P. communis* were 13.66~18.98, 6.99~10.61 and 16.90 ~19.53 mg/g, respectively (Table 2). Mason and Bryant (1975) reported that loss of K, Mg and P in emergent hydrophytes take place within the first month during the decomposition process. In this study, about 43% of Mg leached out in 7 days. Davis and Valk (1978) reported that Mg leached out rapidly as K in the decomposition process of macrophytes. This study supports the findings of Mason and Bryant (1975) and Davis and Valk (1978) that Mg rapidly disappeared as rapidly as K.

The Mg concentration in *H. japonicus*, *M. sacchariflorus* and *P. communis* decreased continuously with time and became 13.49~15.59, 15.75~8.27 and 11.47~7.46 mg/g after 204 days, respectively. The remaining K in *H. japonicus*, *M. sacchariflorus* and *P. communis* was 92.6%, 133.5% and 51.5% after 204 days, respectively (Fig. 8 I, J).

CONCLUSION

The decrease of dry weight in the litterbags was revealed with

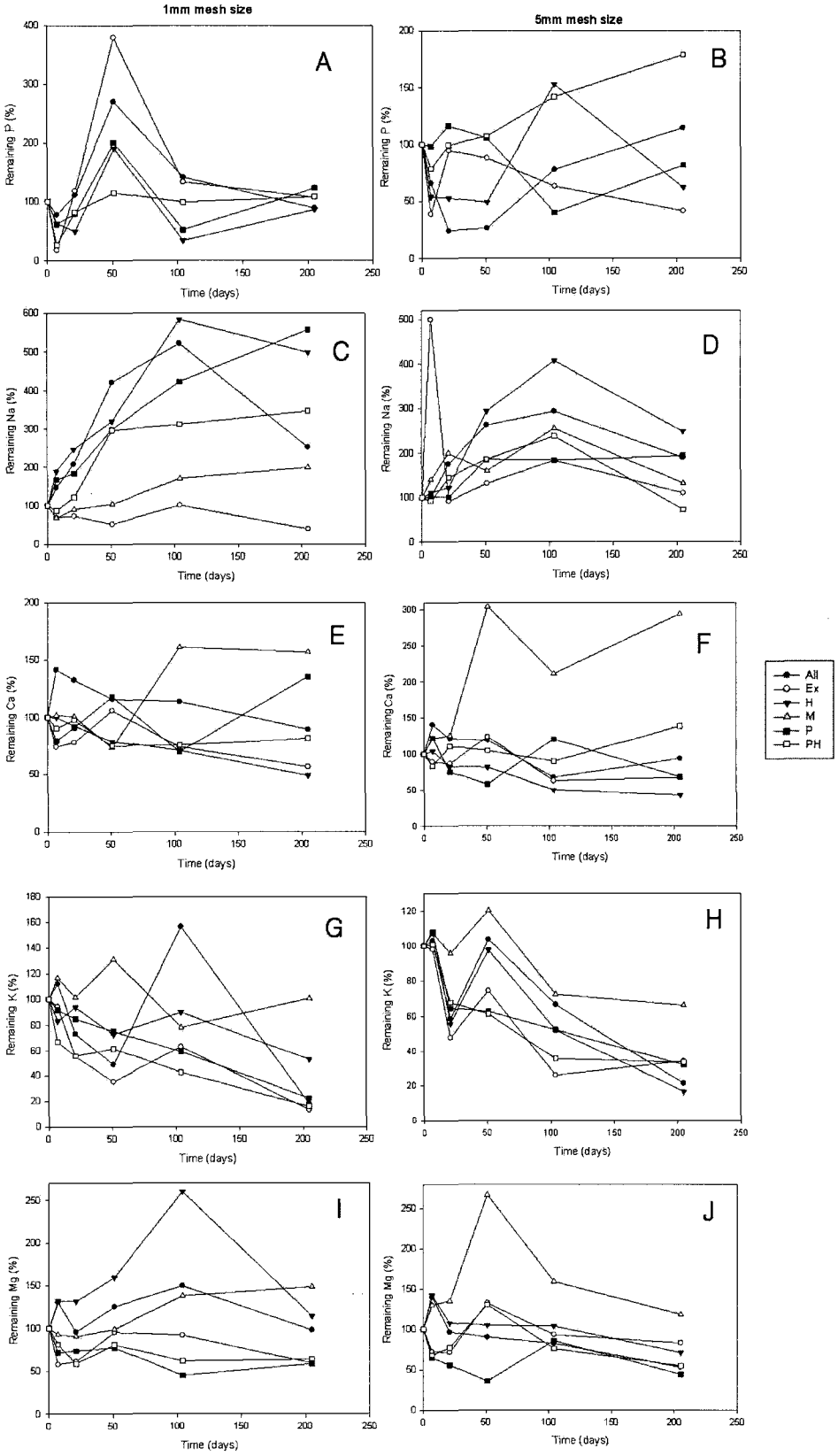

Fig. 8. The change of remaining P (A and B), Na (C and D), Ca (E and F), K (G and H) Mg (I and J) with time in 1 mm and 5 mm mesh size litterbags. Abbreviation is the same as in Fig. 1.

Table 2. Changes of P, Na, Ca, K, and Mg concentration with incubation time

		Mesh size	0	7	21	51	104	204
Na	All		0.26 ± 0.02	0.38 ± 0.03	0.53 ± 0.15	1.08 ± 0.24	1.34 ± 0.21	0.65 ± 0.21
(mg/g)	Ex		1.91 ± 0.13	1.32 ± 0.11	1.39 ± 1.11	0.99 ± 0.30	1.92 ± 1.34	0.74 ± 0.12
	H		0.15 ± 0.05	0.29 ± 0.07	0.38 ± 0.06	0.49 ± 0.31	0.90 ± 0.09	0.77 ± 0.16
	M	1	0.39 ± 0.22	0.27 ± 0.05	0.36 ± 0.06	0.41 ± 0.15	0.67 ± 0.10	0.79 ± 0.32
	P		0.20 ± 0.09	0.34 ± 0.06	0.37 ± 0.10	0.61 ± 0.01	0.86 ± 0.30	1.14 ± 0.20
	PH		0.27 ± 0.01	0.24 ± 0.05	0.34 ± 0.09	0.81 ± 0.50	0.85 ± 0.16	0.95 ± 0.41
	All		0.34 ± 0.11	0.35 ± 0.10	0.60 ± 0.16	0.90 ± 0.46	1.00 ± 0.33	0.65 ± 0.06
	Ex		0.64 ± 0.17	3.19 ± 4.34	0.59 ± 0.22	0.84 ± 0.61	1.17 ± 0.30	0.70 ± 0.08
	H	5	0.30 ± 0.10	0.34 ± 0.22	0.37 ± 0.11	0.89 ± 0.40	1.23 ± 0.67	0.75 ± 0.16
	M		0.22 ± 0.09	0.31 ± 0.07	0.44 ± 0.09	0.35 ± 0.16	0.56 ± 0.13	0.29 ± 0.19
	P		0.31 ± 0.07	0.31 ± 0.10	0.31 ± 0.07	0.57 ± 0.62	0.56 ± 0.08	0.59 ± 0.14
	PH		0.30 ± 0.15	0.27 ± 0.12	0.43 ± 0.05	0.55 ± 0.28	0.70 ± 0.13	0.21 ± 0.21
Ca	All		56.1 ± 10.3	79.3 ± 0.3	74.2 ± 19.2	64.9 ± 15.5	63.6 ± 30.7	50.2 ± 9.7
(mg/g)	Ex		47.4 ± 7.2	35.1 ± 4.2	37.1 ± 4.0	50.1 ± 3.3	35.1 ± 2.4	26.8 ± 2.7
	H		87.6 ± 20.7	87.4 ± 71.4	81.2 ± 15.1	69.2 ± 14.6	62.2 ± 10.6	42.9 ± 21.5
	M	1	22.1 ± 7.6	22.5 ± 6.9	22.2 ± 4.3	16.3 ± 1.6	35.6 ± 35.5	34.6 ± 33.9
	P		22.5 ± 1.2	17.9 ± 3.2	20.5 ± 5.1	26.5 ± 21.5	15.7 ± 3.2	30.5 ± 25.3
	PH		55.6 ± 10.2	50.2 ± 17.8	54.3 ± 5.7	41.7 ± 11.1	42.1 ± 12.7	45.4 ± 10.9
	All		53.7 ± 1.5	75.4 ± 26.3	65.2 ± 17.9	64.2 ± 25.3	36.0 ± 12.6	50.2 ± 14.0
	Ex		51.4 ± 18.0	45.7 ± 7.1	44.5 ± 15.1	63.8 ± 37.6	32.1 ± 5.0	34.4 ± 8.4
	H	5	94.6 ± 26.0	98.3 ± 32.5	78.1 ± 10.8	77.1 ± 27.1	47.1 ± 24.7	40.5 ± 20.3
	M		14.5 ± 4.6	17.6 ± 2.2	18.2 ± 5.7	44.0 ± 44.7	30.5 ± 31.8	42.6 ± 9.7
	P		20.4 ± 1.4	25.0 ± 13.3	15.2 ± 6.6	11.8 ± 44.0	24.6 ± 19.6	13.9 ± 2.8
	PH		53.7 ± 12.3	44.7 ± 27.5	59.5 ± 30.9	56.3 ± 38.9	48.2 ± 17.9	74.7 ± 53.6
K	All		166 ± 42	186 ± 15	122 ± 19	81 ± 24	260 ± 339	30 ± 8
(mg/g)	Ex		182 ± 40	171 ± 36	101 ± 33	64 ± 12	114 ± 107	24 ± 2
	H		173 ± 99	143 ± 40	162 ± 53	126 ± 21	155 ± 73	91 ± 76
	M	1	92 ± 16	107 ± 51	93 ± 24	120 ± 30	72 ± 35	92 ± 27
	P		225 ± 82	206 ± 27	191 ± 32	169 ± 99	133 ± 99	50 ± 31
	PH		295 ± 34	198 ± 63	165 ± 24	182 ± 78	126 ± 83	47 ± 47
	All		189 ± 61	195 ± 48	111 ± 17	196 ± 209	126 ± 122	40 ± 9
	Ex		166 ± 34	162 ± 28	79 ± 9	123 ± 117	43 ± 23	57 ± 70
	H	5	240 ± 86	260 ± 34	134 ± 29	235 ± 156	125 ± 94	40 ± 14
	M		98 ± 8	105 ± 53	94 ± 10	118 ± 103	71 ± 8	65 ± 9
	P		236 ± 67	253 ± 66	152 ± 25	148 ± 310	123 ± 130	75 ± 40
	PH		239 ± 35	240 ± 51	162 ± 30	146 ± 93	85 ± 66	80 ± 37

Table 2. Continued

		Mesh size	0	7	21	51	104	204
Mg	All		16.0 ± 1.2	20.8 ± 2.8	15.3 ± 2.0	20.0 ± 4.2	23.9 ± 14.3	15.6 ± 8.1
(mg/g)	Ex		17.5 ± 2.8	10.1 ± 2.7	10.7 ± 2.5	16.7 ± 6.5	16.0 ± 7.5	10.4 ± 5.1
	H		13.7 ± 5.3	18.1 ± 15.5	18.0 ± 4.5	21.8 ± 5.2	35.5 ± 21.2	15.6 ± 5.9
	M	1	10.6 ± 3.9	9.8 ± 2.7	9.6 ± 2.6	10.5 ± 1.6	14.6 ± 8.0	15.8 ± 8.8
	P		19.5 ± 6.8	14.1 ± 6.7	14.4 ± 2.4	15.1 ± 10.5	8.8 ± 1.4	11.5 ± 8.9
	PH		20.7 ± 4.2	16.8 ± 2.0	12.2 ± 2.2	16.8 ± 7.4	12.8 ± 4.6	13.3 ± 7.2
	All		15.2 ± 2.5	21.3 ± 12.0	14.7 ± 3.0	13.7 ± 5.0	12.5 ± 3.8	8.0 ± 1.2
	Ex		16.6 ± 5.6	12.0 ± 3.8	11.9 ± 1.9	21.9 ± 17.8	15.4 ± 9.0	13.7 ± 9.3
	H	5	19.0 ± 10.9	27.0 ± 11.3	20.4 ± 2.6	19.9 ± 4.4	19.7 ± 16.3	13.5 ± 2.2
	M		7.0 ± 1.2	9.1 ± 2.0	9.4 ± 2.6	18.6 ± 18.9	11.1 ± 5.4	8.3 ± 7.2
	P		16.9 ± 2.6	10.9 ± 2.4	9.4 ± 7.5	6.0 ± 21.1	14.5 ± 9.5	7.5 ± 4.7
	PH		17.9 ± 4.4	12.2 ± 5.7	13.8 ± 4.0	23.4 ± 18.7	13.6 ± 6.7	9.8 ± 1.2

the following order: *H. japonicus* > mixed plants including *H. japonicus* > *P. communis* and *H. japonicus* > mixed plant without *H. japonicus* > *M. sacchariflorus* > *P. communis*. The mass disappearance of *H. japonicus* (44~55%) was higher than *P. communis* (6~48%) and *M. sacchariflorus* (26~28%). During the period of the decomposition, the mineral nutrients except Na decreased to around 40~80% of the initial, while Na in the litters of *H. japonicus* nearly tripled. There was no significant difference between 1mm and 5mm mesh size litterbags in decomposition and this indicates that mainly microbes rather than small invertebrates decomposed plant litters in this study. The relatively fast nutrient cycling of *H. japonicus* and the subsequent unbalance of nutrients might constrained the growth of other wetland plants and facilitate the spread of *H. japonicus*. Our results suggest that *H. japonicus* accelerate the nutrient circulation for its more competitive growth. Therefore, it is required to control *H. japonicus* for the healthy structure and function of the riverside wetland ecosystem.

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