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Distribution of Stream-Edge Vegetation in the Balan Stream as Related to Soil Environments

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발안천에서 토양 환경에 따른 하천 주변의 식생분포

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ABSTRACT

Seasonal and spatial distribution of vascular plants were examined and related to soil texture, pH, moisture and nutrient contents in the riparian zone of the Balan Stream. In spring the area was dominated by *Alopecurus aequalis* var. *amurensis*, was displaced by *Persicaria thunbergii* and *Humulus japonicus* in summer. From the stream channel to bank, soil texture and pH were not significantly differentiated, moisture decreased, organic matter and K increased, and TKN and available P increased in June and decreased in August. DCA ordination analysis by species distribution showed spatially and seasonally distinct patterns; seasonal difference was evident on axis 1, and spatial difference according to the distance from stream channel was clear, too. Both axis 1 and axis 2 scores were significantly correlated with biomass, pH, and phosphate. Species richness increased with increasing organic matter and phosphate, and decreased with increasing soil moisture and K. Biomass increased with increasing organic matter, but was negatively related to pH, moisture, TKN, available P and K. Available P was significantly correlated with biomass, pH, and total soil nitrogen. In conclusion, the distribution of riparian vegetation was governed by soil physico-chemical properties, which are primarily determined by how far it is from the stream channel.

Key words: Biomass, DCA ordination, Soil factors, Stream-edge, Vegetation

INTRODUCTION

Plant ecologists are still unable to explain how many species can coexist in a given community, why this should vary from one community to another and what determines the community characteristics (Keddy 1984). Recent ecological studies of plants along rivers

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have focused on whether the structure and function of riparian communities are predictable or whether they result from stochastic events (Nilsson 1987). Although the riparian vegetation along rivers is of fundamental importance in stream ecology (Swanson *et al.* 1982), and has drawn attractions for many years, the factors that control its composition and species richness are still poorly understood (Nilsson *et al.* 1989).

Most authors consider natural physical disturbance to play the most important role in shaping general community structure along streams (Nilsson 1987). The gradients of environmental factors are important in determining the composition of plant communities (Glime and Vitt 1987). Soil texture, pH, organic matter, nutrients or all these in combination are candidate factors governing riparian vegetation distribution (Nilsson 1987).

Riparian vegetation has a zonation; a species occupies different positions relative to water level. This zonation suggests that the gradient of factors varying with relative height (moisture, organic content, particle size, duration of submergence, etc) exert a major influence on plants and their associations. The variation within the region is, at the very local scale, less likely to be confounded by climate, geological history, or chance events of dispersal (Keddy 1984). The absence of apparent discontinuities makes riparian plant communities deserve a subject for a detailed analysis of the clinal characteristics of a river (Nilsson 1987).

In this paper the small-scale change in the composition of plant communities of the geolittoral belt along the stream relative to different environmental variables was examined. Whether the vegetational distribution pattern are closely associated with soil factors was focused.

MATERIALS AND METHODS

Study area

The study area, approximately 12km long, is located in the upper reach of the Balan Stream in Hwasung-Gun, Kyonggi-do, Korea (37° 10′ N, 126° 60′ E) (Fig. 1). The stream flows through two reservoirs, and the land use pattern of basin area is predominantly agricultural. The area has an annual growing season of more than 200 days and receives 858mm of annual precipitation (Anonymous 1996). Stream water level is highest in summer. Many species of riparian vegetation were disturbed by fire or other factors, mainly generated by human activities.

Vegetation

Vegetation sampling of riparian zone was conducted during March~October (4 times), 1996. Fifteen stations relatively undisturbed by human activity were selected for sampling in the riparian zone. Each station was located every 400~500 m intervals along the stream. In each station, three 1 m×1 m quadrats were laterally aligned by the distance from the stream channel in either riparian area; N (Near the stream channel), M (Middle the stream channel), and F (Far the stream channel). In each plot, the coverage of herbaceous plants was estimated by Braun-Blanquet method. Species richness was expressed simply as number of species per square meter. This index overlooks the fact that the abundance of species in a community may range from rare (low) to common (high).

Biomass

Aboveground biomass of vascular plants was harvested in June, August and October with 1m×1m quadrats. Biomass was collected from 30 plots at five stations. Plant matter was clipped to ground level and 1/10 of weighed plant matter in the field was bagged. Biomass subsamples were oven-dried at 80℃ for 48 hr and weighed.

Soil

Soils were collected at the five stations where biomass was harvested in June, August and October.

Soil samples were scooped 15cm deep from the quadrat center after biomass sampling. At the laboratory, fresh subsamples were used to estimate water content by mass loss at 105℃ for 24 hr. The soil samples were air-dried and then passed through a 2 mm mesh sieve for determination of soil texture, pH, organic matter, total-N, phosphate and extractable K. Soil texture was determined by hydrometer method. pH was determined by saturated soil paste method and organic matter was measured by loss on ignition at 500℃ for 12 hr. (TKN: Total Kjeldahl Nitrogen) was determined by micro-Kjeldahl method and phospate was measured by 0.5M $NaHCO_3$ extract solution of pH 8.5 (Hitachi U-2000 Spectrophotometer). The content of K was measured by Schimazu AA-680 atomic absorption spectrophotometer (Wilde *et al.* 1979)

Data analysis

Collected data for environmental factors was examined by Tukey's standardized test. The relationships between DCA axes and environmental factors in all samples were explored using Pearson correlation test. Data analysis in this study was performed using SAS (SAS 1996).

RESULTS

Soil texture varied from stream channel to bank. The fraction of sand increased along the distance from the stream channel but that of clay decreased. Silt content was greatest in the middle zone (M) from stream channel (Table 1).

Soil pH did not show any consistent tendency along the distance from the stream channel. The value of pH was above 5.5 in June, below 5.2 in

Table 1. Soil texture (±S.D.) along the distance from stream channel in the study sites

Distance from stream channel	Fraction(%) Sand	Silt	Clay
N (Near)	67.1 ± 21.2	29.8 ± 9.40	3.1 ± 1.0
M (Middle)	64.4 ± 20.4	32.3 ± 10.4	3.3 ± 1.0
F (Far)	64.0 ± 20.2	32.5 ± 10.4	3.5 ± 1.1

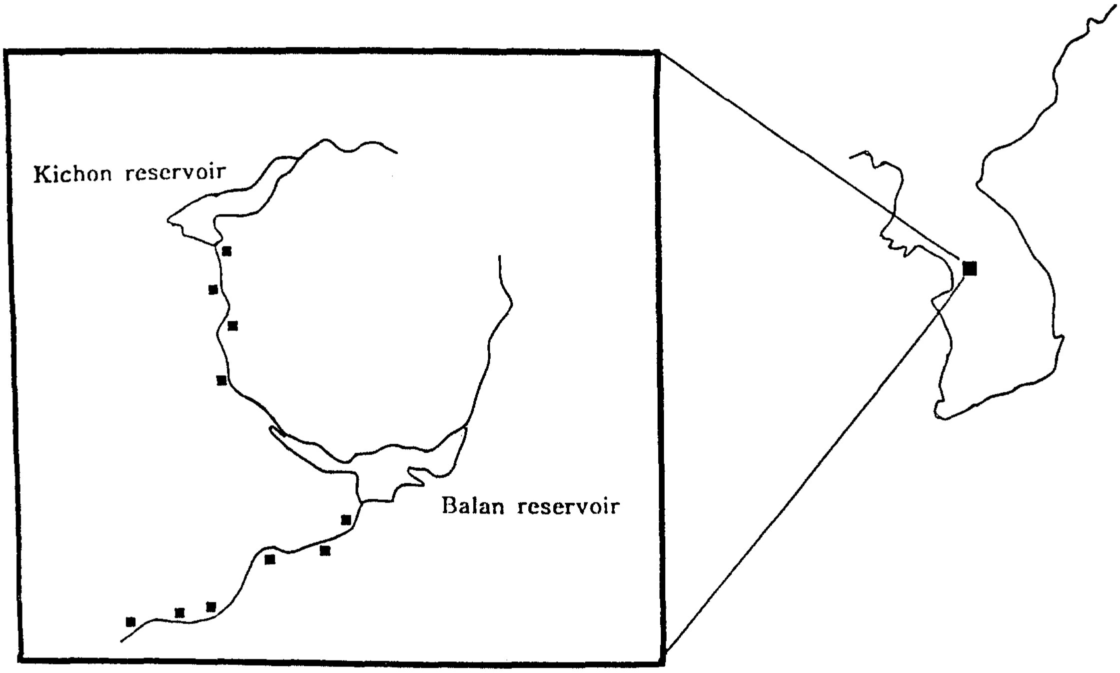

Fig. 1. Location of the sampling stations (■).

August and above 6.0 in October. The value of pH was greatest in the near zone in October (pH=6.32), and smallest in the far zone in August (pH=4.88) (Table 2). Soil water content decreased from stream channel to bank. The difference between near zone (N) and far zone (F) was greatest in August (Table 2).

Soil organic matter generally increased according to the distance from the stream channel and changed seasonally. Organic matter content was 2.28% at the near zone (N), 2.30% at the middle zone and 2.55% at the far zone (total average values). Seasonally, content of soil organic matter was highest (3.19%) in June, and lowest (1.20%) in October (Table 2). Total nitrogen content of soil gradually increased from near zone to far zone in June, while it decreased from near zone to far zone in August. The average value of estimated total nitrogen of the soil was 4.74, 4.37, and 4.70 mg/g soil in near zone, middle zone, and far zone, respectively. According to seasons, it was 4.13, 4.56, and 5.11 mg/g soil in June, August, and October, respectively (Table 2). The phosphate content of the soil showed a similar tendency to total nitrogen. It was higher in the near zone (13.06 μg/g soil) and lower in the middle zone (9.65 μg/g soil). Seasonally, it was higher in June (15.59 μg/g soil) and gradually decreased from 11.93 μg/g soil in August to 7.67 μg/g soil in October (Table 2). The potassium content of soil increased with the distance from the stream channel. It was 0.134 mg/g soil, 0.148 mg/g soil, and 0.167 mg/g soil from the near zone to the far zone. This tendency of increase with distance from the stream channel was similar to that of organic matter in the soil. The seasonal changes of potassium content, however, showed the reverse tendency with organic matter of the soil; it increased from 0.105 mg/g soil in June, to 0.220 mg/g soil in October (Table 2).

The DCA ordination analysis by species distribution showed a spatially and seasonally distinct pattern. Axis 1 scores increased, from June and August to October. The spatial difference was clear according to the distance from the stream channel. Axis 2 scores increased with the distance from the stream

Table 2. Seasonal and spatial changes of soil characteristics along the distance from the stream channel (±S.D.)

Soil characteristics	Distance from stream channel	Month		
		June	August	October
pH	N (Near)	5.86 ± 0.21	5.01 ± 0.08	6.32 ± 0.15
	M (Middle)	5.50 ± 0.14	5.18 ± 0.14	6.15 ± 0.15
	F (Far)	5.62 ± 0.15	4.88 ± 0.15	6.18 ± 0.23
Water content (%)*	N	17.6 ± 3.71	32.5 ± 12.5	34.2 ± 6.43
	M	15.1 ± 4.35	29.5 ± 5.20	17.0 ± 3.54
	F	11.1 ± 2.91	7.56 ± 1.26	20.4 ± 2.33
Loss on ignition (%)	N	2.66 ± 0.61	2.71 ± 0.50	1.46 ± 0.23
	M	3.28 ± 0.63	2.82 ± 0.25	0.79 ± 0.11
	F	3.63 ± 0.46	2.67 ± 0.46	1.36 ± 0.20
TKN (mg/g soil)	N	3.91 ± 0.38	4.52 ± 0.47	5.78 ± 1.29
	M	4.51 ± 0.32	4.00 ± 0.43	4.60 ± 0.55
	F	5.26 ± 0.29	3.88 ± 0.44	4.96 ± 0.63
P (μg/g soil)	N	14.4 ± 4.85	10.0 ± 2.24	14.8 ± 3.75
	M	13.9 ± 5.28	6.19 ± 1.25	8.81 ± 1.83
	F	18.5 ± 5.66	6.82 ± 1.16	12.1 ± 3.01
K (mg/g soil)	N	0.10 ± 0.02	0.10 ± 0.02	0.21 ± 0.05
	M	0.10 ± 0.02	0.14 ± 0.02	0.20 ± 0.04
	F	0.12 ± 0.02	0.13 ± 0.02	0.25 ± 0.04

*Water content was calculated by (fresh soil weight (g) − dry soil weight (g)) / (dry soil weight (g)) × 100

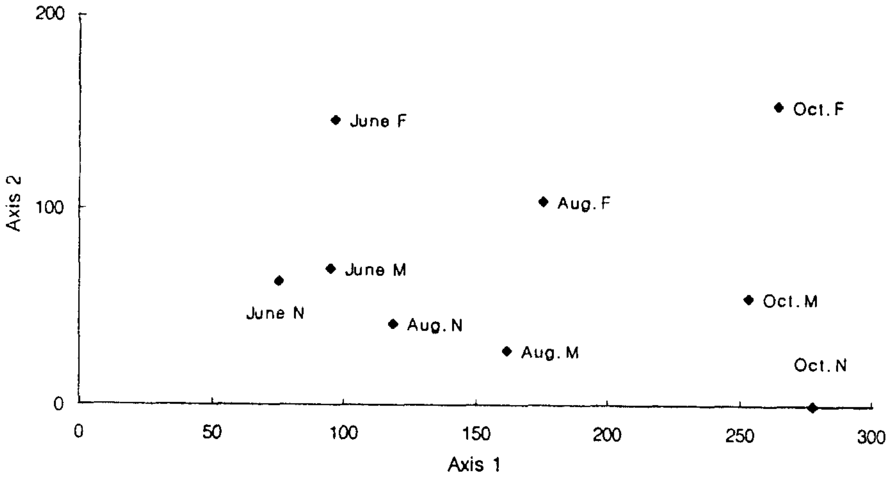

Fig. 2. Seasonal and spatial scatter diagram of DCA axis 1 versus axis 2 sample scores for vegetation distribution from Balan stream region. (N, M and F is Near, Middle and Far zone, respectively from the stream channel).

Table 3. The correlation between environmental factors and the DCA axis scores in Fig. 2. ($P < 0.5$: *, $P < 0.01$: **, $P < 0.001$: ***, not significant: $^{n.s.}$)

Environmental factors	Pearson correlation coefficient	
	Axis 1	Axis 2
Biomass (D.M. g/m^2)	0.449^{**}	-0.450^{**}
pH	-0.475^{**}	0.587^{***}
Water content (%)	$0.079^{n.s.}$	$0.199^{n.s.}$
Loss on ignition (%)	$0.224^{n.s.}$	$0.187^{n.s.}$
TKN (mg/g soil)	$-0.283^{n.s.}$	$0.310^{n.s.}$
P (μg/g soil)	-0.536^{***}	0.431^{**}
K (mg/g soil)	$0.162^{n.s.}$	$-0.115^{n.s.}$

channel (Fig. 2). Axis 1 score was significantly correlated with biomass (P = 0.0037), pH (P = 0.0020), and phosphate (P = 0.0004) (Pearson correlation). Especially, pH and phosphate were negatively correlated with axis 1 score. This species distribution was closely related to the biomass. Axis 2 scores showed a similar correlation to axis 1 score; it was correlated with biomass (P = 0.0036), pH (P = 0.0001), and phosphate (P = 0.0055). Biomass was negatively correlated with axis 2 (Table 3).

The relationship between species richness and soil characteristics was variable as in Fig. 3. Species richness was not correlated with pH and TKN (Fig. 3. b, f). However, species richness increased with increasing organic matter and phosphate (Fig. 3. c, e), but decreased with increasing soil moisture and K (Fig. 3. b, f).

The relationship between biomass and soil characteristics was clear as in Fig. 4. Biomass increased with increasing organic matter (Fig. 4. c). In contrast,

Table 4. Pearson correlation coefficient between environmental facors ($P < 0.01$: **, $P < 0.001$: ***, not significant: $^{n.s.}$)

	Biomass	pH	Water content	Loss on ignition	Total-N	Phosphate	K
Biomass	1						
pH	$-0.208^{n.s.}$	1					
Water content	$0.156^{n.s.}$	$0.193^{n.s.}$	1				
Loss on ignition	$-0.107^{n.s.}$	$0.057^{n.s.}$	$0.127^{n.s.}$	1			
TKN	$-0.295^{n.s.}$	$0.206^{n.s.}$	$-0.167^{n.s.}$	$0.019^{n.s.}$	1		
P	-0.642^{***}	0.415^{**}	$-0.104^{n.s.}$	$-0.221^{n.s.}$	0.475^{**}	1	
K	$0.078^{n.s.}$	$-0.056^{n.s.}$	$0.092^{n.s.}$	$0.240^{n.s.}$	$0.142^{n.s.}$	$-0.178^{n.s.}$	1

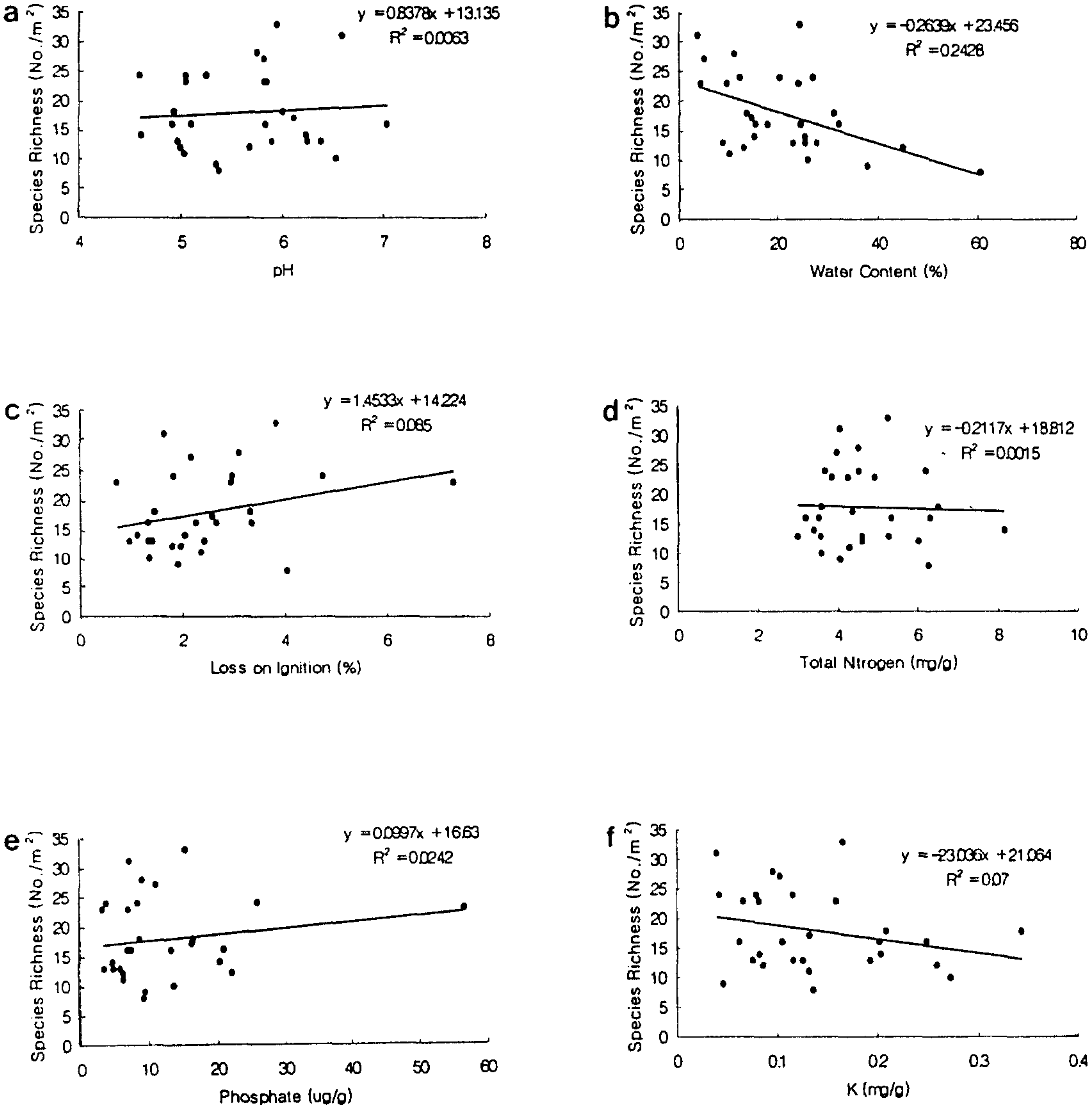

Fig. 3. Relationship between species richness and soil characteristics in the riparian zone of the Balan stream. The different shapes of each plot show that several points have similar coordinates. a: pH, b: Water content, c: Loss on ignition, d: Total nitrogen, e: Phosphate and f: K.

biomass was negatively related to pH, moisture, TKN, available P and K (Fig. 4. a, b, d, e, f, Table 4). Available P was significantly correlated with biomass, pH, and total nitrogen.

DISCUSSION

Heterogeneous environments have an effect on the vegetative structure such as species richness (Gabrielle 1997). In the current study, seasonal and spatial variations of plant distribution were observed in a riparian zone. The species established early in the growing season are *Cardamine flexuosa* and *Alopecurus aequalis* var. *amurensis*. These dominant species are displaced by *Persicaria thunbergii*, *Equisetum arvense*, and *Humulus japonicus* in early summer. The species of early growing season terminate their life history before summer to keep out of the competition

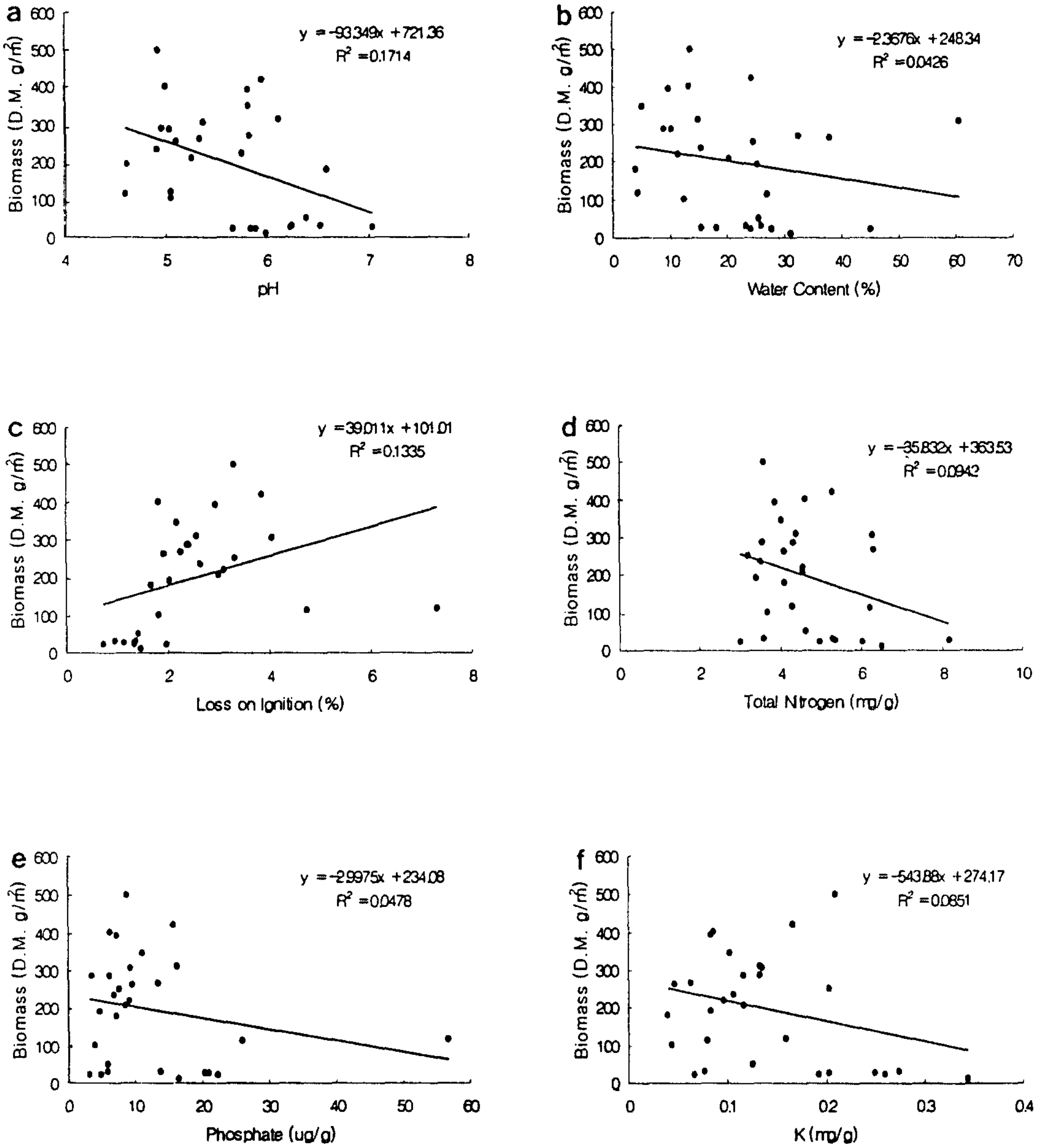

Fig. 4. Relationship between biomass and soil characteristics in the riparian zone of the Balan stream. The different shapes of each plot show that several points have similar coordinates. a: pH, b: Water content, c: Loss on ignition, d: Total nitrogen, e: Phosphate and f: K.

with later species. *P. thunbergii* during the vigorous growing season occurred in the near zone from the water channel. In contrast, *H. japonicus* occurred in middle and far zone from stream channel (data not shown). It is considered that this dominance of species to different habitat is due to habitat preference in the early stages such as germination and establishment stage (Keddy and Ellis 1984). This indicates that variation existed between species for microhabitat preference (Gabrielle 1997).

The distribution of vegetation can be predicted through the relationship between species richness and habitat environment. This study shows that the relationship between richness and soil characteristics is more important than that between evenness and soil characteristics (Day *et al.* 1988). Microtopography in wetland communities affects more than simply spatial variation of water levels (Ehrenfeld 1995). It may interact with temporal fluctuations in water levels, affecting factors such as the duration of flooding and soil nutrient dynamics (Gabrielle 1997). Soil pH and phosphate were main factors regulating plant distribution in the study area. Other factors did not show any clear effect on the species distribution. It is not consistent with the fact that organic matter content is correlated with nutrient levels on wetlands (Keddy 1985). It is due to the fact that the width of the riparian zone was too small to differentiate the limited variation of species composition (Keddy 1984) or that natural pattern was interfered with the effects of intensive human land use (Samson and Fritz 1996).

Plants themselves often provide clearer evidence of how environments control plant production (Clements 1935). Evidence that soil nutrient affects species richness at low biomass sites comes not only from the correlations of soil nutrient measurements but from the morphology and life histories of the species themselves. The difficulties with interpreting direct physical measurement of environmental factors were stressed long ago by Clements (1935). In this study, biomass was significantly correlated with DCA axis scores, and biomass increased as species richness increased (data not shown). Without knowing in advance where maximum richness will be found, it is not possible to specify which range of biomass values will produce positive or negative relationships (Wisheu and Keddy 1989). In wetlands, biomass is greatly enhanced by eutrophication (Moore *et al.* 1989). Eutrophication, however, is not a prerequisite for competitive exclusion. In this study area, biomass was greatest in near zone from the stream channel in spring and fall but was greatest in far zone in summer. This indicates that biomass is affected by water nutrient levels. In the Balan stream, water level dramatically increases in summer. It is considered that the near zone from the stream channel was diluted and its soil was eroded by increasing water (Anonymous 1996). In this study, the distribution of riparian vegetation was affected by various physico-chemical environmental factors, however, interspecific competition and human disturbance can be as important as such environmental factors. Future studies on these issues will explain the riparian vegetation distribution pattern.

적 요

발안천 주변의 식물을 대상으로 시간적, 공간적 식생 분포와 환경요인 간의 관계를 조사하였다. 생장기간 초기에는 황새냉이 (*Cardamine flexuosa*)같은 종이 우점하였으나 여름철로 접어들수록 고마리 (*Persicaria thunbergii*)와 환삼덩굴 (*Humulus japonicus*)이 우점하게 되었으며, 특히 하천에 가까울수록 고마리가 우점하였다. 토양 pH는 공간적인 분포에는 큰 차이를 보이지 않았으나 계절적으로는 뚜렷한 차이를 보였다. 토양 수분 함량은 하천에서 거리가 멀어질수록 감소하였다. 유기물 함량은 대체적으로 하천으로부터 멀어질수록 증가하였다. 토양의 총 질소와 유효인 함량은 6월에 하천에서 멀어질수록 그 값이 증가하였다. 반대로 8월에는 하천에서 멀어질수록 감소하였다. 토양 내 칼륨은 하천으로부터 멀어질수록 증가하였다. 이러한 토양 특성의 변화와 더불어 서열법에 의한 종 분포의 분석 결과도 시간적, 공간적으로 뚜렷하게 구별되었다. 축 1의 값이 증가함에 따라 계절적 차이가 분명하였으며, 공간적 차이는 축 2의 값에 따라 분포되었다. 축 1과 축 2의 값은 생물량, 토양 pH, 그리고 토양의 인 함량과 유의하게 연관되었다. 종풍부도는 유기물과 유효인 증가에 의해서 증가했지만 토양 수분과는 음의 상관관계를 보였다. 식물량은 유기물과 양의 상관관계를, 그러나 pH, 수분, 총 질소, 유효인 그리고 칼륨 함량과는 음의 상관관계를 보였다. 유효인 함량은 생물량, pH, 그리고 총 질소와 유의하게 연관되었다. 결론적으로 하천변 식생의 분포는 토양의 이화학적 특성에 의해서 조절되었고 이 특성은 수로로부터의 거리와 관계가 있었다.

LITERATURE CITED

Anonymous. 1996. Monitoring agro-ecological environments and developing comprehensive agricultural environmental management systems. Korea Ministry of Agriculture. 306p.

Clements, F.E. 1935. Experimental ecology in the public service. Ecology 16: 342-363.

Day, R.T., P.A. Keddy and J. McNeill. 1988. Fertility and disturbance gradients: a summary model for riverine marsh vegetation. Ecology 69: 1044-1054.

Ehrenfeld, J.G. 1995. Microsite differences in surface substrate characteristics in *Chamaecyparis* swamps of the New Jersey Pinelands. Wetlands 15: 183-189.

Gabrielle, V.S. 1997. Microtopographic heterogeneity and floristic diversity in experimental wetland communities. J. Ecol. 85: 71-82.

Glime, J.M. and D.H. Vitt. 1987. A comparison of bryophyte species diversity and niche structure of montane streams and stream banks. Can. J. Bot. 65: 1824-1837.

Keddy, P.A. 1984. Plant zonation on lakeshores in Nova Scotia: a test of the resource specialization hypothesis. J. Ecol. 72: 797-808.

Keddy, P.A. 1985. Wave disturbance on lakeshores and the within-lake distribution of Ontario's Atlantic coastal plain flora. Can. J. Bot. 63: 656-660.

Keddy, P.A. 1989. Effects of competition from shrubs on herbaceous wetland plants: a 4-year field experiment. Can. J. Bot. 67: 708-716.

Keddy, P.A. and T.H. Ellis. 1984. Seedling recruitment of 11 wetland plant species along a water level gradient: shared or distinct response? Can. J. Bot. 63: 1876-1879.

Moore, D.R.J., P.A. Keddy, C.L. Gaudet and I.C. Wisheu. 1989. Conservation of wetlands: do infertile wetlands deserve a higher priority? Biol. Conserv. 47: 203-217.

Nilsson, C. 1987. Distribution of stream-edge vegetation along a gradient of current velocity. J. Ecol. 75: 513-522.

Nilsson, C., G. Grelsson, M. Johansson and U. Sperens. 1989. Patterns of plant species richness along riverbanks. Ecology 70: 77-84.

Nilsson, C. and G. Grelsson. 1990. The effects of litter displacement on riverbank vegetation. Can. J. Bot. 68: 735-741.

SAS. 1988. SAS User's guide. Version 6. SAS Institute, Cary, NC.

Swanson, F.I., S.V. Gregory, J.R. Sedell and A.G. Campbell. 1982. Land-water interactions: the riparian zone in analysis of coniferous forest ecosystems in the western United States. *In* R.L. Edmonds (ed.), US/IBP Synthesis Series No. 14. Dowden, Hutchinson and Ross, Streudsburg, PA. pp. 267-291.

Wilde, S.A., R.B. Corey, J.G. Iyer and G.K. Voigt. 1979. Soil and plant analysis for tree culture. Oxford Univ. Press. 224p.

Wisheu, I.C. and P.A. Keddy. 1989. Species richness-standing crop relationships along four lakeshore gradients: constraint on the general model. Can. J. Bot. 67: 1609-1617.

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