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Soil Factors Affecting the Plant Communities of Wetland on Southwestern Coast of Korea

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한국 서남해안 습지의 식물 군집에 미치는 토양요인

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ABSTRACT

To describe the major environmental factors operating in coastal wetland and to characterize the distribution of the plant species over the wetland in relation to the major environmental gradients, 12 soil physical and chemical properties were determined. The gradient of water and osmotic potential of soil, electrical conductivity, sodium and chloride content and soil texture along the three habitat types of salt marshes, salt swamp and sand dune were occurred. The 24 coastal plant communities from principal component analysis (PCA) on the 12 variables were at designated as a gradient for soil texture and water potential related with salinity by Axis I and as a gradient for soil moisture and total nitrogen gradient by Axis Ⅱ; On Axis I were divided into 3 groups; (1) 9 salt marsh communities including *Salicornia herbacea* communities (2) 5 salt swamp communities including *Scirpus fluviatilis* communities and (3) 10 sand dune communities including *Imperata cylindrica* communities; on Axis Ⅱ were divided into 2 groups; (1) salt marsh and sand dune communities, and (2) 3 salt swamp communities. The results could account for the zonation of plant communities on coastal wetland observed along envionmental gradients.

Key words: Coastal wetland, Vegetation, Water potential, Soil moisture, PCA.

INTRODUCTION

Coastal salt wetland is vegetated area which is within the range of tidal action. Marshs on coastlines are found in sheltered areas that usually are supplied with sediments of river or marine origin (Chapman 1960, Jefferson 1975, Lee 1989). In Korea, the marshes of the eastern coast are not developed, but those of the western coast are extensively developed. The western coast is the leading tideland and is characterized by a large difference of ebb and flow of tides (about 8 m). Coastal wetland as salt marshes, salt swamp and sand dune on the Korean Peninsula are found continuously along western coast.

A better understanding of the environmental factors that determine plant community structure is a major goal of plant ecologists studying coastal wetlands. Sharp spatial boundries of plant species on coastal wetland have been observed along environmental

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gradients (del Moral and Watson 1978, Disraeli and Fonda 1979, Armstrong *et al.* 1985). In controlling the distribution and abundance of wetland plants within and across coastal wetlands types, factors related to hydrology and salinity are believed to play a major role (De Jong and Drake 1981, Ustin *et al.* 1982, Brewer and Grace 1990). Zonation is strong in coastal wetlands so that a wetland is an ideal habitat to study the relationships between the distribution of species and environmental gradients.

The objectives of this study were to describe the major environmental factors operating in the wetland and to characterize the distribution of the plant species over the wetland in relation to the major environmental gradients.

STUDY AREA

This study was conducted on salt marsh, salt swamp and sand dune dominated by twenty-four coastal vegetation communities from Yeongkwang-gun (35° 15′ N, 126° 20′ E) to Changhung-gun (34° 37′ E, 127° 5′ N), Chollanam-do Province, Korea. The coastal area is composed of salt marsh, salt swamp and sand dune.

Upper salt marsh is dominated by *Zoysia sinica, Limonium tetragonum, Aster tripolium, Suaeda asparagoides* and *Atriplex gmelini* community. *Suaeda maritima* community is occurred in sandy soil. The lower margin of the marsh is dominated by *Suaeda japonica* community on the southwestern coastal marsh, which occurred in flat coastal marsh with slow flow of sea water. *Salicornia herbacea* community is occurred in the higher margin of the marsh, which is known to a pioneer species in reclaimed land (Kim 1971, Kim and Song 1983, Ihm 1989).

Salt swamp is located in an estuary or fresh water springed salt marsh and is dominated by *Carex scabrifolia, Phragmites communis, Scirpus fluviatilis,* and *Triglochin maritimum* community. *Phragmites communis* community is broadly distributed in the estuary of River Nagdonggang (Kim *et al.* 1982), River Seomjingang (Oh and Ihm 1983) and River Youngsangang (Kim and Song 1983) and is adapted and distributed in regions of sea water or fresh water (Oh and Ihm 1983, Kim and Song 1983).

Sand dune is dominated by a shrub such as *Vitex rotundifolia* community, perennial grass such as *Imperata cylindrica* var. *koenigii, Carex kobomugi, Ixeris repens, Elymus mollis, Carex pumila* and *Ischaemum anthephoroides* community, and annual herb such as *Salsola komarovi* and *Lysimachia mauritiana* community (Ihm 1989).

METHODS

In order to examine the soil environment near the roots, samples were taken at a depth of 10 cm from the surface.

Air-dried samples of soils were used for physico-chemical analysis. Water potential (ψ_{soil}) and osmotic potential (ψ_o) of soils were determined by the method of Ihm (1989). Soil texture were determined by the Köhn's apparatus method. Organic matter content of soil was determined by ashing the samples at 550℃ for 4hr. Electrical conductivity and pH of soil were measured by S-C-T meter (YSI Model 33) and Orion Ion-analyser (Model 407A), respectively. Total nitrogen of soil was determined by micro-Kjeldahl method (Allen *et al.* 1986). Cl^- content of soil was measured by argentometric method (Kalthoff and Stenger 1947) and Na^+ content of soil was measured by flame photometer (Coleman 51).

Principal component analysis (PCA) in the SAS package (1987) was carried out on the 12 variables; soil water potential, soil osmotic potential, soil moisture content, soil texture (sand, silt and clay content), organic matter content of soil, soil electrical conductivity, soil pH, total nitrogen of soil, Cl^- content and Na^+ content of soil.

RESULTS AND DISCUSSION

The gradient in water and osmotic potential along the three habitat types was occurred (Fig. 1). Water

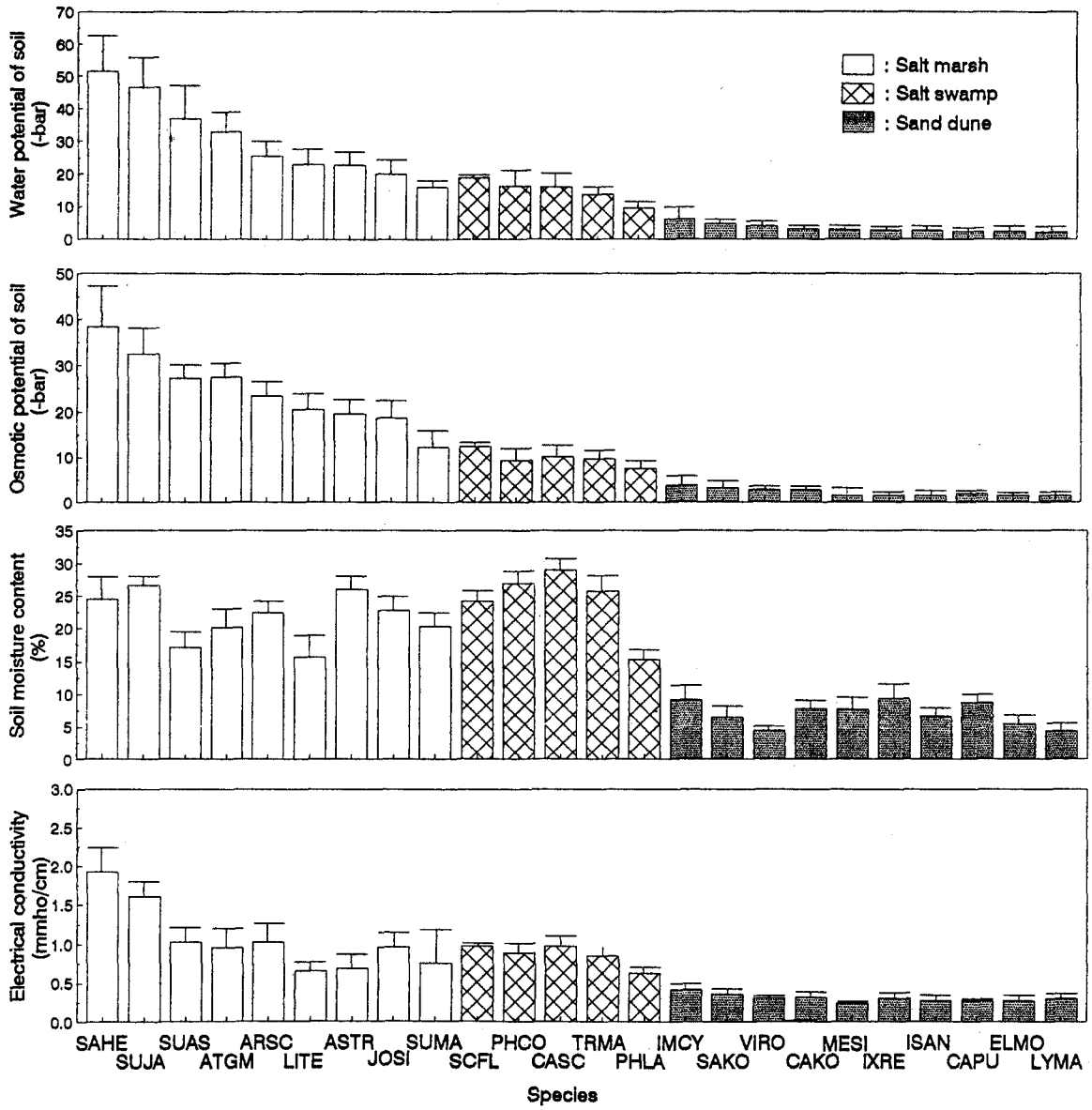

Fig. 1. Water potential and osmotic potential, moisture content, electrical conductivity of soil of 24 coastal plant communities in southwestern coast of Korea. SAHE: *Salicornia herbacea*, SUJA: *Suaeda japonica*, SUAS: *Suaeda asparagoides*, ATGM: *Atriplex gmelini*, ARSC: *Artemisia scoparia*, LITE: *Limonium tetragonum*, ASTR: *Aster tripolium*, JOSI: *Zoysia sinica*, SUMA: *Suaeda maritima*, SCFL: *Scirpus fluviatilis*, PHCO: *Phragmites communis*, CASC: *Carex scabrifolia*, TRMA: *Triglochin maritimum*, PHLA: *Phacelurus latifolius*, IMCY: *Imperata cylindrica*, SAKO: *Salsola komarovi*, VIRO: *Vitex rotundifolia*, CAKO: *Carex kobomugi*, MESI: *Messerschmidia sibirica*, IXRE: *Ixeris repens*, ISAN: *Ischaemum anthephoroides*, CAPU: *Carex pumila*, ELMO: *Elymus mollis*, LYMA: *Lysimachia mauritiana*.

potential of soil in salt-marsh, salt-swamp and sand dune communities was −51.4∼−16.1, −19.0∼−9.5 and −6.2∼−2.3 bar and osmotic potential of soil was −38.3∼−12.3, −12.4∼−7.5 and −3.8∼−1.4 bar, respectively. Soil moisture content in salt-marsh, salt-swamp and sand dune communities was 26.7∼15.7, 29.0∼15.3 and 9.4∼4.4%, respectively (Fig. 1). The gradient in electric conductivity along the three habitat types was occurred (Fig. 1) Electrical conductivity in salt-marsh, salt-swamp and sand dune com-

munities was 1.92~0.65, 0.98~0.63 and 0.42~0.24 mmho/cm, respectively. Organic matter in salt-marsh, salt-swamp and sand dune communities was 4.9~2.6, 4.3~2.8 and 2.3~0.4% respectively (Fig. 2). Total

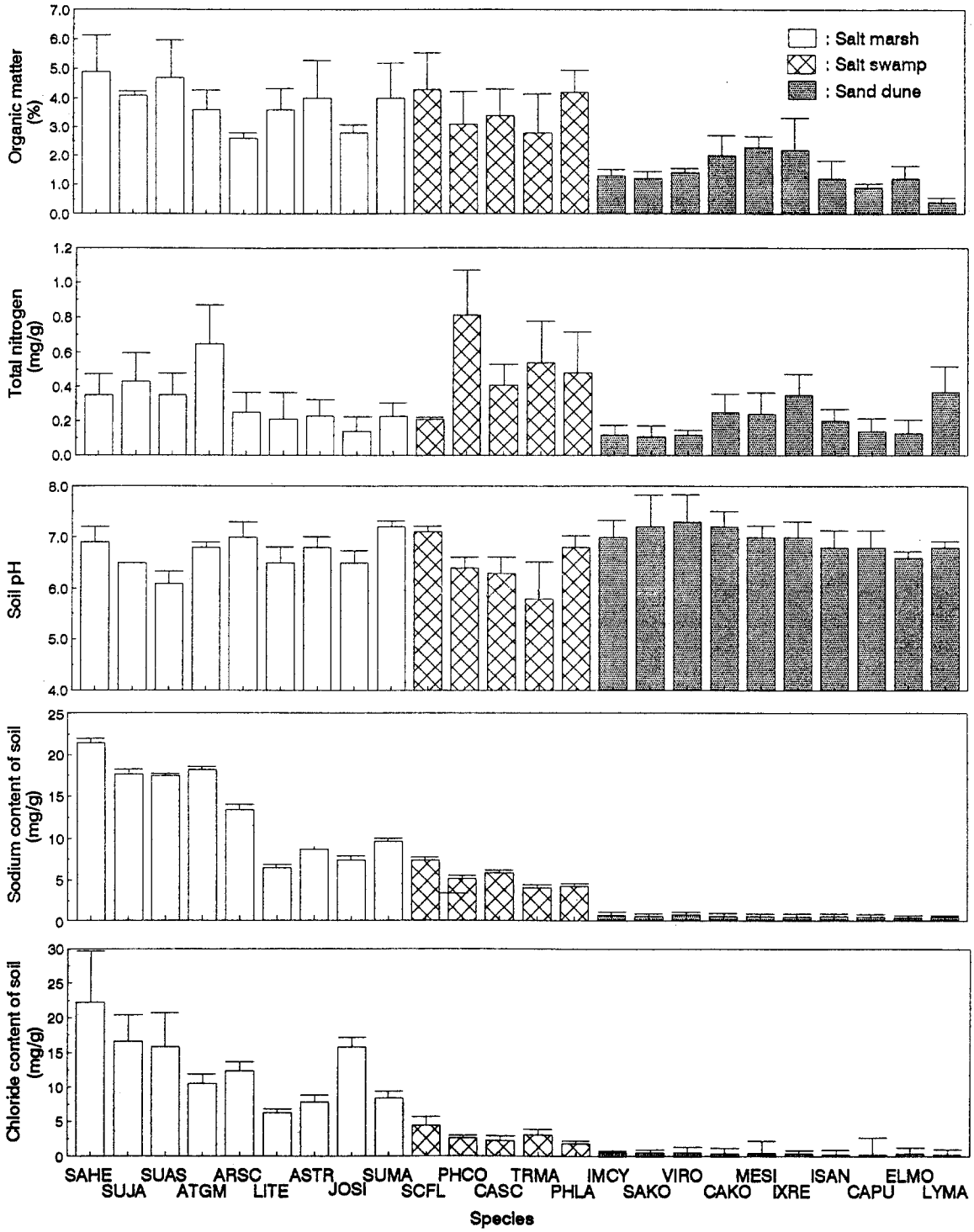

Fig. 2. Contents of organic matter and total nitrogen, pH, contents of sodium and chloride of soil of 24 coastal plant communities in southwestern coast of Korea. Abbreviations of species name are the same in Fig. 2.

nitrogen in salt-marsh, salt-swamp and sand dune communities was 0.65~0.14, 0.81~0.21 and 0.35~0.11 mg/g, respectively (Fig. 2). Soil pH in salt-marsh, salt-swamp and sand dune communities was 7.2~6.1, 7.1~5.8 and 7.3~6.6, respectively (Fig. 2). The gradient in sodium and chloride content of soil along the three habitat types were occurred (Fig. 2). Sodium content of soil in salt-marsh, salt-swamp and sand dune communities was 21.3~6.3, 7.2~3.9 and 0.65~0.36 mg/g, respectively. Chloride content of soil in salt-marsh, salt-swamp and sand dune communities was 22.2~6.2, 4.4~1.8 and 0.6~0.3 mg/g, respectively. The gradient in soil texture along the three habitat types was occurred (Fig. 3). Clay content of soil in salt-marsh, salt-swamp and sand dune communities was 31~8, 19~9 and 16~5%, respectively. Silt content of soil in salt-marsh, salt-swamp and sand dune communities was 62~11, 30~22 and 28~11%, respectively. Sand content of soil in salt-marsh, salt-swamp and sand dune communities was 76~8, 66~51 and 83~56%, respectively.

Water potential is probably determined by soil salinity, i.e. increasing salinity produces more negative water potential (Kuramoto and Brest 1979, Ihm 1989, Upkong 1991). The gradient of water and osmotic potential of soil, electrical conductivity, sodium and chloride content and soil texture along the three habitat types of salt marshes, salt swamp and sand dune was occurred. This indicates that the distribution and abundance of plant communities among salt marsh, salt swamp and sand dune were related to environmental gradients in soils. Table 1 shows the correlation coefficients among the 12 soil properties of 24 coastal plant communities. Except for total nitrogen and pH, the other properties correlated among them at 0.05 level.

Principal component analysis (PCA) was carried out on 12 soil properties. The 24 coastal plant communities were plotted in the space defined by the first two PCA axes (Fig. 4). The correlation matrix between eigen values and 12 variables related with the distribution of coastal plant communities was shown in Table 2. Total variances accounted for by the Axes I and II were 70% and 14%, respectively. In PCA, Axis I was designated as a gradient for soil texture and water potential related with salinity (Ustin *et al.* 1982, Brewer and Grace 1990), and Axis II as a gradient for soil moisture and total nitrogen

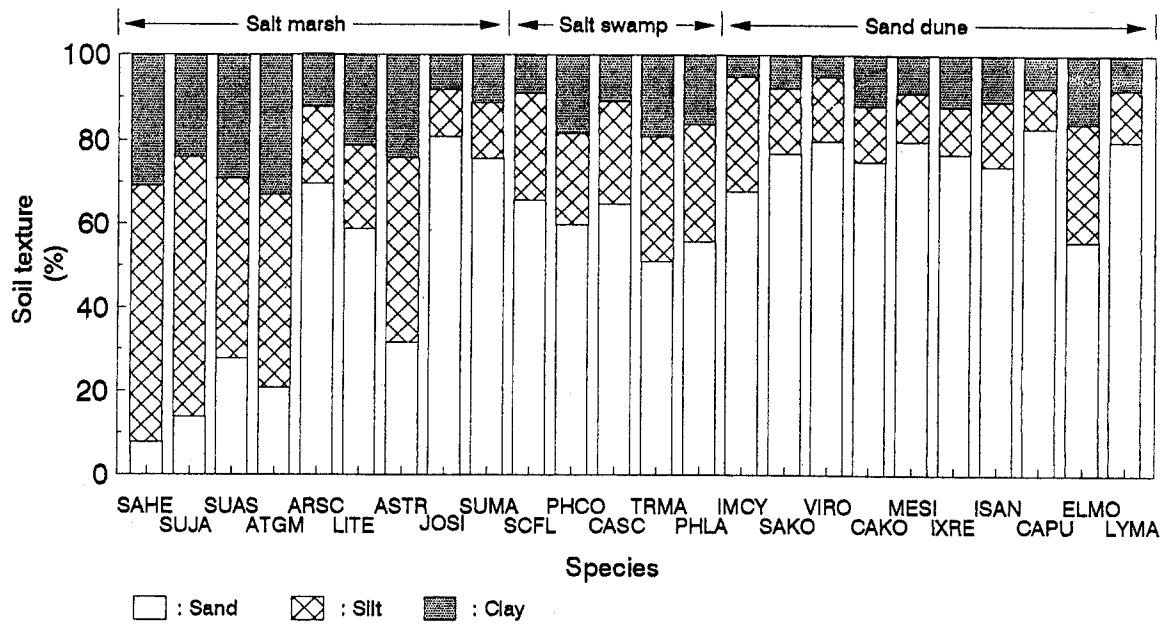

Fig. 3. Contents of sand, silt and clay of soil of 24 coastal plant communities in southwestern coast of Korea. Abbreviations of species name are the same in Fig. 2.

Table 1. Correlation coefficients among soil properties of coastal plant communities in southwestern coast in Korea. E.C. means electrical conductivity of soil

	Water potential	Osmotic potential	Moisture content	E.C.	Organic matter	Total nitrogen	pH	Sodium	Chloride	Sand	Silt
Osmotic potential	0.99**										
Moisture content	0.71*	0.69*									
E.C.	0.94**	0.90**	0.81**								
Organic matter	0.79*	0.77**	0.78**	0.78**							
Total nitrogen	0.34	0.29	0.51	0.40	0.40						
pH	−0.31	−0.28	−0.48	−0.33	−0.28	−0.49					
Sodium	0.97**	0.97**	0.67*	0.89**	0.78**	0.36	−0.24				
Chloride	0.93**	0.95**	0.61*	0.87**	0.69*	0.15	−0.23	0.92**			
Sand	−0.85**	−0.81**	−0.54*	−0.75**	−0.67*	−0.44	0.38	−0.81**	−0.69*		
Silt	0.83**	0.78**	0.52*	0.76**	0.62*	0.36	−0.33	0.78**	0.67*	−0.98**	
Clay	0.78**	0.78**	0.49	0.64*	0.67*	0.54*	−0.44	0.79**	0.65*	−0.91**	0.83**

* $P<0.05$; ** $P<0.01$.

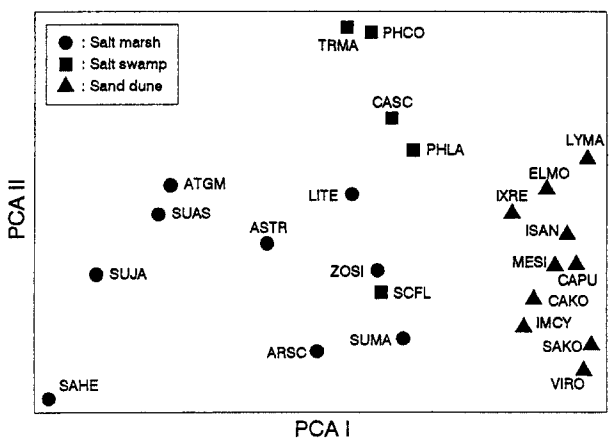

Fig. 4. Principal component analysis of 24 coastal plant communities based on 12 soil factors. Axis I (70% of total variance) is water potential related with salinity-gradient. Axis II (14% of total variance) is soil moisture and total nitrogen content-gradient. Abbreviations of species name are the same in Fig. 2.

Table 2. Correlation coefficients among twelve soil properties and community scores of the first and the second axes by principal component analysis in coastal plant communities in southwestern coast of Korea

Soil properties	Community scores	
	Axis I	Axis II
Water potential	−0.973	−0.535
Osmotic potential	−0.952	−0.536
Moisture content	−0.757	−0.700
Electrical conductivity	−0.935	−0.567
Organic matter	−0.897	−0.443
Total nitrogen	−0.421	−0.628
pH	0.367	0.374
Sodium	−0.930	−0.475
Chloride	−0.916	−0.435
Sand	−0.881	−0.510
Silt	−0.840	−0.448
Clay	−0.910	−0.650
Variance (%)	70	14

gradient (Boucaud and Billard 1985). Figure 4 showed that on Axis I the 24 coastal plant communities were divided into 3 groups; (1) 9 salt marsh communities including *Salicornia herbacea* communities, which was characterized by low water and osmotic potential, high electrical conductivity and high sodium and chloride content (2) 5 salt swamp communities including *Scirpus fluviatilis* communities, which showed moderate character, and (3) 10 sand dune communities including *Imperata cylindrica* var. *koenigii* communities, by high water and osmotic potential, low electric conductivity and low sodium and chloride content; on Axis II the 24 coastal plant communities were divided into 2 groups; (1) 9 salt marsh and 10 sand dune communities, which was characterized by low soil moisture and total nitrogen

content (Boucaud and Billard 1985), and (2) 3 salt swamp communities except for *Scirpus fluviatilis* communities, which was characterized by high soil moisture and total nitrogen content. Species distribution modes appear to reflect a spatial transition along gradients from fresh water zone to the saline zone. The vegetation communities in southwestern coast in Korea consisted of three communities modes and plant species were occurred along environmental gradients.

적 요

해안습지의 주요 환경요인의 구배와 관련된 식생의 분포를 밝히기 위하여 24 종의 해안습지 군집에서 토양의 물리화학적 요인을 조사하였다. 염습지, 염소택지 및 사구의 3가지 생육지 타입은 수분포텐셜, 삼투포텐셜, 전기전도도, Na^+와 Cl^-함량 및 토양입도의 구배를 보였다. 12가지 변수에 대한 24 해안 식물 군집의 주성분 분석 (PCA)에서 제 1축은 토성과 염도와 관련된 수분포텐셜과 관련되는데 3그룹, 즉 (1) 퉁퉁마디군집을 포함하여 9가지 염습지식물군집 (2) 매자기군집을 포함하여 5가지 염소택지식물군집 및 (3) 띠군집을 포함하여 10 가지 사구식물군집으로 구분되었고, 제 2축은 토양함수량 및 전질소함량과 관련되는데 2 그룹, 즉 (1) 염습지식물군집과 사구식물군집, (2) 3가지 염소택지식물군집으로 구분되었다. 이 결과는 해안 습지에서 식물군집의 분포가 토양 수분포텐셜, 토성 및 수분함량 같은 환경구배와 관련됨을 잘 설명하고 있다.

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