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Plant Distribution in Relation to Soil Properties of Reclaimed Lands on the West Coast of Korea

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Plant species distribution was studied on five reclaimed lands and one intertidal flat (control) on the western coast of Korea. Nineteen soil properties were analyzed. Of these, soil moisture, electrical conductivity, and levels of Na and Cl had the greatest effect on plant distribution. The plant species were divided into four groups, according to the amount of soil moisture found at their habitats. *Triglochin maritimum* and *Typha angustata* were found on the wettest sites; *Phragmites communis, Carex scabrifolia, Suaeda japonica, Zoysia sinica,* and *Salicornia herbacea* in places with relatively high moisture; *Aster tripolium* and *Phacelurus latifolius* in areas with medium levels of moisture; and *Atriplex subcordata, Chenopodium virgatum,* and *Trifolium repens* in the driest areas. The species also were divided into four groups, according to the degree of soil electrical conductivity: Highest, *S. herbacea, Limonium tetragonum, Suaeda asparagoides,* and *S. japonica;* Relatively high, *A. tripolium, C. scabrifolia, P. communis, Artemisia scoparia,* and *Z. sinica;* Relatively low, *Setaria viridis, C. virgatum, Sonchus brachyotus, A. subcordata, Calamagrostis epigeios,* and *T. angustata;* and Lowest, *Imperata cylindrica* var. *koenigii, Aeschynomene indica, Lotus corniculatus* var. *japonicus,* and *T. repens.* On reclaimed land, plant species were found in zones, according to the degree of desalinization (i.e., levels of Na and Cl).

Keywords: Desalinization, Electrical conductivity, Moisture content, Reclaimed land, Soil properties

Tidal flats on the western coast of Korea are being converted to reclaimed land (Min and Kim, 1997a). This reclaimed land has characteristics of both coastal soils, i.e., similar ion composition (Ungar, 1974) and inland salt marshes, (tide cutoff; Ranwell, 1972; Disraeli and Fonda, 1979; Noordwijk-Puijk et al., 1979). After reclamation, sediment becomes the common soil as soil salts leach over time (Agricultural Development Corporation (ADC), 1986; Min and Kim, 1997a, 1997b). The rate of leaching is proportional to rain intensity, soil texture, and topography (Chang and Lee, 1978; Noordwijk-Puijk et al., 1979; ADC, 1986; Min and Kim, 1997a).

Plant species growing in intertidal flats or reclaimed lands differ in their inherent salt tolerance (Waisel, 1972; Ihm and Lee, 1985, 1986; Ihm, 1987; Ihm et al., 1995a, 1995b). Therefore, vegetative zonations follow lines of topography or according to the distance from the high water mark to sites farther inland. This is because soil salt concentrations vary by altitude or by the amount of inundating seawater (Penfound, 1952; Mall, 1969; Jefferies, 1972).

Changes in soil properties and vegetation have been studied on reclaimed lands (Feekes, 1936, 1943; Zuur, 1961; van der Toorn et al., 1969; Beeftink, 1975; Gray, 1974, 1977). Joenje (1979) monitored the invasion of plant species and accompanying changes in soil properties in the early stages after reclamation. In Korea, several aspects involved in land reclamation have been investigated, including soil properties and desalinization patterns (Chang and Lee, 1978; Min et al., 1989; Min and Kim, 1997a, 1997b); ecological properties of halophytes and soil amelioration (Hong et al., 1969a, 1969b, 1970); crop cultivation (Cha and Choi, 1966; Im, 1969, 1970a, 1970b; Im et al., 1969, 1971a, 1971b; Im and Hoang, 1970, 1977; Im and Lim, 1970; Kim, 1971, 1980, 1982); the relationship between halophyte distribution and soil environment (Kim and Song, 1983); plant productivity and mineral cycling (Kim and Min, 1983; Min and Kim, 1983; Ryu and Kim, 1985); and energy flow (Kim and Ryu, 1985).

Plant distribution has been studied on intertidal flats (Hong, 1956; Kim et al., 1975; Ihm, 1987; Lee, 1990), but little research has been done for plant populations on reclaimed lands. The purpose of this study was to identify the patterns of plant distribution as they are influenced by soil properties and soil environment on reclaimed land.

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STUDY AREA AND METHODS

This study was conducted at one intertidal flat and five reclaimed sites on the western coast of Korea (Fig. 1). One additional research area was added to those described by Min and Kim (1997a, 1997b).

1) Intertidal flat (control): The Namdong area (Nonhyen-dong, Nam-gu, Incheon city, 37° 24′ N, 126° 42′ E) contained a vast intertidal flat to the south, embankments west and east, and a low, hilly area to the north. The main research site comprised the intertidal flat and a band 3 m wide along the mean high water mark. This land had not been reclaimed, but was selected for study as being representative of the prereclamation condition.

2) Reclaimed land: The five areas included Hyundai A (1 year since reclamation), Hyundai B (2 years), Jangdeog (8 years), Mado (12 years), and Baegseog (30 years). These sites were described previously (Min and Kim 1997a, 1997b).

Soil and plant samples were taken in July of 1984. Selection of the sampling sites was based on topography and vegetation. The criteria for choosing plants was that the vegetation should be homogeneous and found in pure stands >2 m in diameter. Each patch also had to contain at least five plants of a particular species. As a result, 17 sites were chosen at Namdong, 17 at Hyundai A, 51 at Hyundai B, 60 at Jangdeog, 64 at Mado, and 58 at Baegseog. At each site, 10 subsamples were chosen within a 25 × 25-cm quadrant. The amount of coverage was determined for each species and the aboveground portions of the sample plants were removed. These samples were oven-dried at 80°C for 48 h and then weighed.

Soil samples were taken at depths of 2 cm to 15 cm, and the topsoil was discarded. Moisture content was measured immediately, and then the soil samples were air-dried in the shade. Samples to be used for bulk density, porosity, and aerated porosity determinations were placed in plastic sleeves 10 cm long and 1 cm wide. The following steps were taken to analyze soil properties:

1) Moisture content was calculated from fresh and dry weights after the samples were oven-dried at 105°C for 72 h.

2) Bulk density was calculated from dry weight and

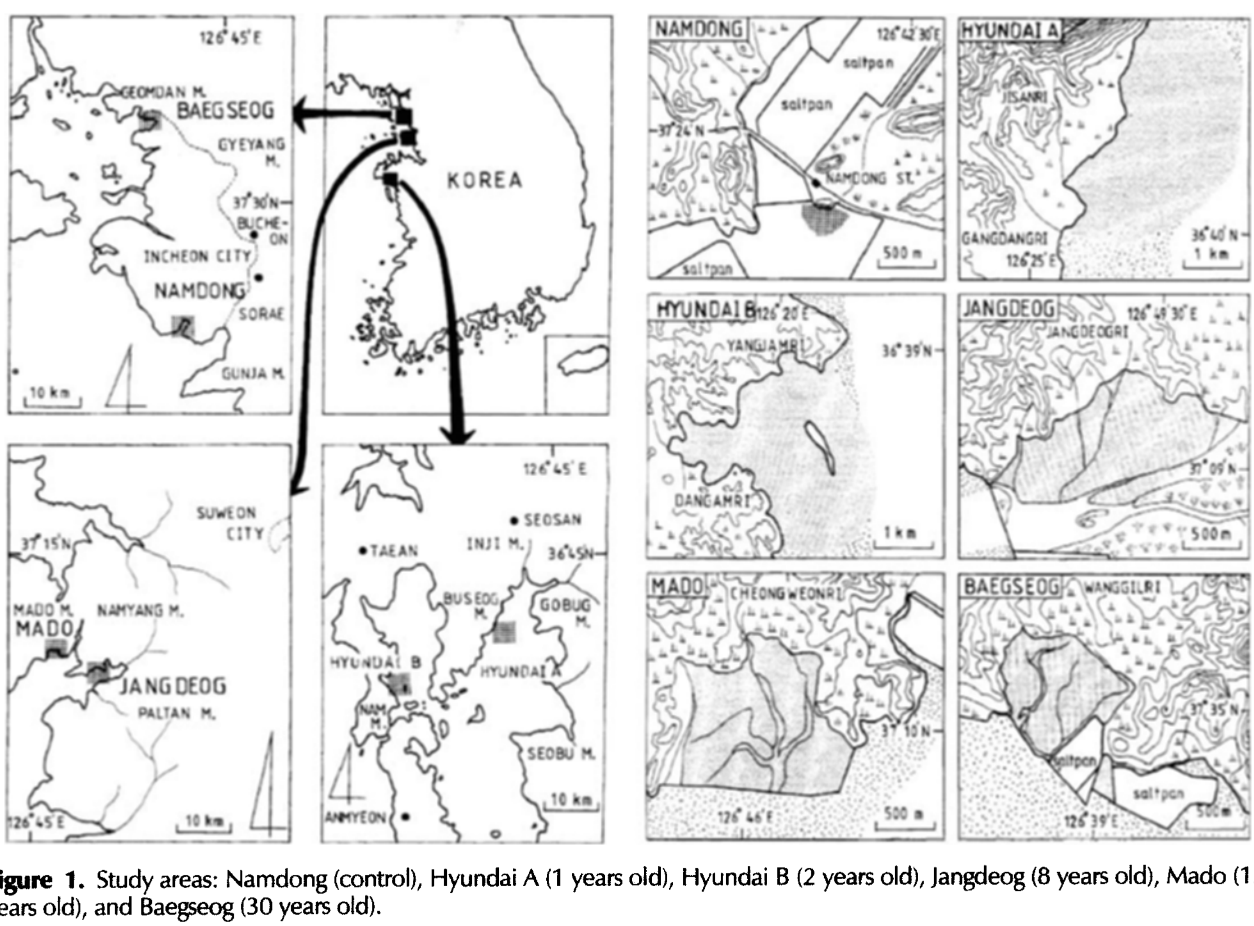
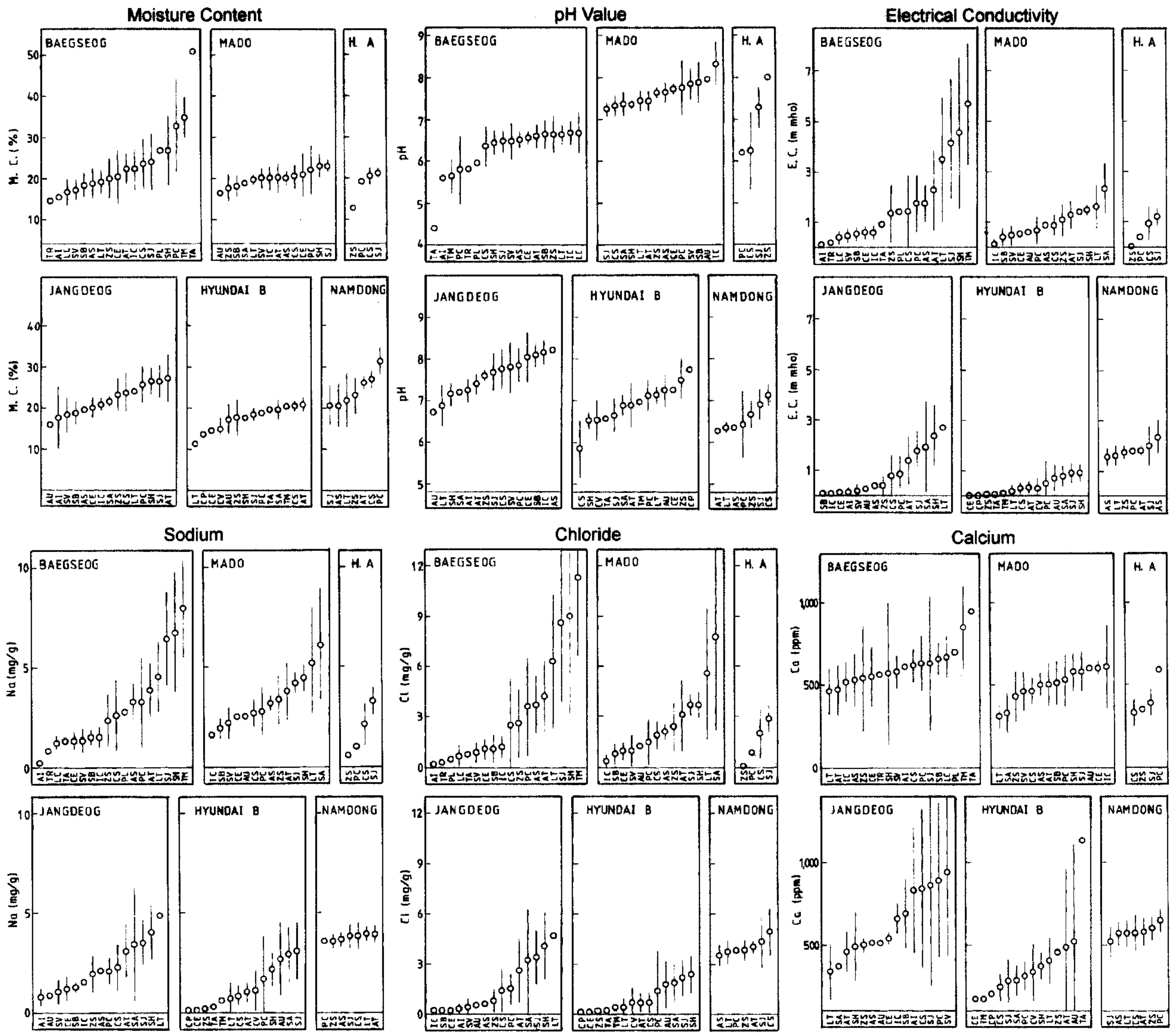


Figure 1. Study areas: Namdong (control), Hyundai A (1 years old), Hyundai B (2 years old), Jangdeog (8 years old), Mado (12 years old), and Baegseog (30 years old).



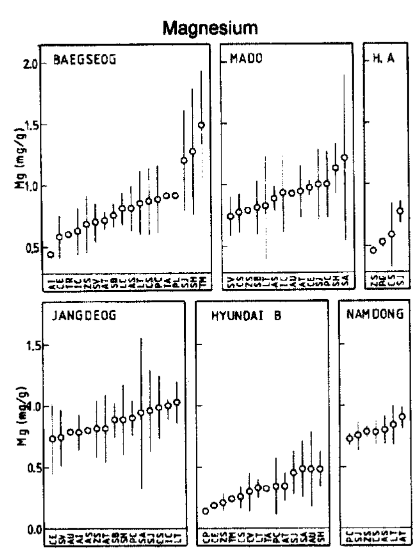


Figure 2. The distribution range for plant species in relation to seven soil attributes at the six study areas. AI, *Aeschynomene indica*; AS, *Artemisia scoparia*; AT, *Aster tripolium*; AU, *Atriplex subcordata*; CE, *Calamagrostis epigeios*; CP, *Carex pumila*; CS, *Carex scabrifolia*; CV, *Chenopodium virgatum*; IC, *Imperata cylindrica* var. *koenigii*; LC, *Lotus corniculatus* var. *japonicus*; LT, *Limonium tetragonum*; PC, *Phragmites communis*; PL, *Phacelurus latifolius*; SA, *Suaeda asparagoides*; SB, *Sonchus brachyotus*; SH, *Salicornia herbacea*; SJ, *Suaeda japonica*; SV, *Setaria viridis*; TA, *Typha angustata*; TM, *Triglochin maritimum*; ZS, *Zoysia sinica*.

volume. Particle density, porosity, and aerated porosity were measured, using a 100-mL volumetric flask and H_2O in a 4°C cold room.

3) Organic matter was calculated according to the amount of weight lost after the samples were kept in a muffle furnace for 4 h at 550°C.

4) Total nitrogen was measured by the micro-Kjeldahl method. Available phosphorus was determined according to the stannous-reduced molybdophosphoric blue color method, in which samples were extracted with a 0.002 N H_2SO_4 solution and shaken for 30 min. Measurements of pH, soil texture, and ions were made as described previously (Min and Kim, 1997a, 1997b).

RESULTS AND DISCUSSION

Plants Distribution as Influenced by Soil Properties

The plant distribution ranges and mean values for soil properties are shown in Figure 2. The seven main soil properties that affected plant distribution were soil moisture content, electrical conductivity, pH, and chloride, sodium, calcium, and magnesium contents.

At Namdong (control, not reclaimed), plant species were distributed in the order of (from wettest to driest site): *Phragmites communis, Carex scabrifolia, Aster tripolium, Zoysia sinica, Limonium tetragonum, Artemisia scoparia,* and *Suaeda japonica.* However, most of these plants grew in a wide range of soil, and differences in moisture content were minimal among species. This was probably because the area was an intertidal flat, continually inundated with seawater at high tides.

At Hyundai A (1 year post-reclamation), the soil moisture content for all sites was similar, except where *Z. sinica* grew. However, at Hyundai B (2 years), species were divided among three habitat groups, according to soil moisture content: Low, *L. tetragonum, Carex pumila, Calamagrostis epigeios,* and *Chenopodium virgatum;* Medium, *Atriplex subcordata, Z. sinica, Salicornia herbacea, S. japonica, S. asparagoides, P. communis,* and *Typha angustata;* and High, *Triglochin maritimum, C. epigeios.* and *A. tripolium.* The differences in moisture content among groups, however, were below 10%.

At Jangdeog (8 years) and Mado (12 years), the range of plant distribution was narrow, and differences in species habitats were few. At Baegseog (30 years), however, the distribution range was distinct and conspicuous. The order of species, from xeric to wet habitat, was: *Trifolium repens, Aeschynomene indica, Lotus corniculatus* var. *japonicus, Setaria viridis, Sonchus brachyotus, A. scoparia, L. tetragonum, Z. sinica, C. epigeios, A. tripolium, Imperata cylindrica* var. *koenigii, C. scabrifolia, S. japonica, Phacelurus latifolius, S. herbacea, P. communis, L. tetragonum,* and *T. angustata.*

The distribution ranges for plant species across soil moisture content are shown in Figure 3 (left). First, *T.*

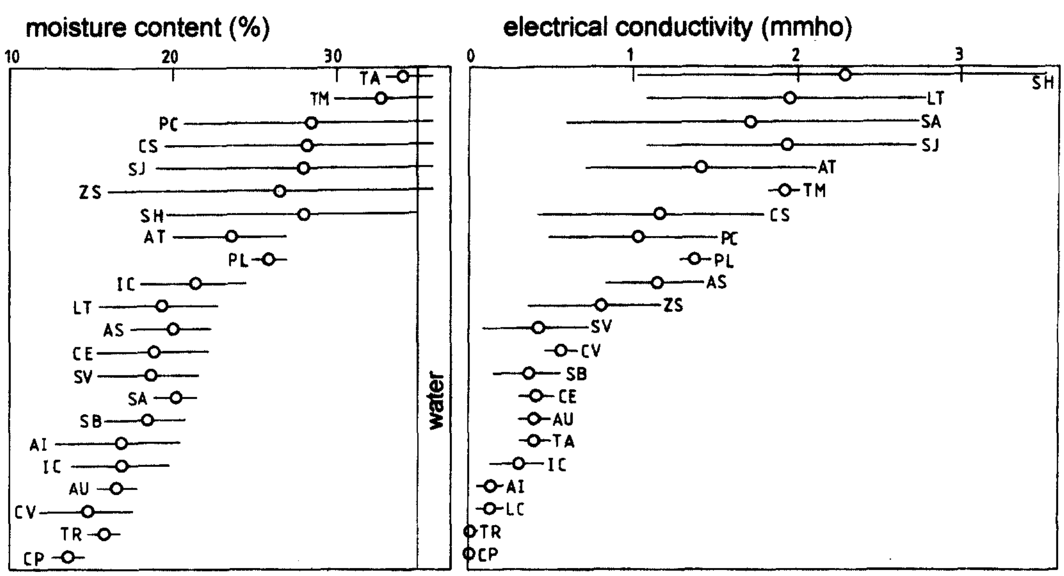


Figure 3. Mean (circle) and range (line) of distribution for plant species in relation to moisture content (left) and electrical conductivity (right) of the soil. Abbreviations of species are defined in Figure 2.

angustata and *T. maritimum* grew in stagnant water, and low soil moisture content was a limiting factor. Second, *P. communis, C. scabrifolia, S. japonica, Z. sinica*, and *S. herbacea* were found in a broad range of soil moisture contents, but preferred wet habitats. Third, *A. tripolium, L. tetragonum, A. scoparia, C. epigeios, S. viridis, Suaeda asparagoides, S. brachyotus, A. indica*, and *L. corniculatus* var. *japonicus* grew in a mesic habitat. Fourth, *A. subcordata* and *C. pumila* were found in a xeric habitat, where high soil moisture was a limiting factor.

Salicornia grows well in wetlands (Waisel, 1972) or intertidal flats (Hinde 1954, Beeftink 1977), and prefers non-flooding areas (Brereton, 1971). *S. japonica* is a species characteristic of the Sino-Japanese group (Chapman, 1975), and grows in the intertidal flat (Hong, 1956), preferring inundation by seawater (Walter, 1968; Reimold and Queen, 1974). *T. maritimum* and *P. communis* are found in various habitats, including seawater, brackish or fresh water, and areas with periodic inundation or stagnant water (Waisel, 1972; Ungar, 1974). In contrast, *Aster, Atriplex*, and *Limonium* grow in non-flooding habitats (Branson et al., 1967; Waisel, 1972; Beeftink, 1977). Because the species preference for habitat shown in our study resulted from a narrow range of tolerance to seawater, zonations were formed according to altitude from the mean high water mark.

Distribution patterns were also determined, in part, by pH, although these species ranges varied by area. Most plants grow well in soils with pH from 4.0~ to 9.0 (Arron and Johnson, 1942; Small, 1946). In addition, *Salicornia* and *Suaeda* grow especially well in salt marshes where pH is between 7.0 and 9.0 (Ungar and Capilupo, 1968). The pH at our study sites ranged from 6.37~ to 7.70; soil pH, therefore, was not a limiting factor.

The distribution range varied for absolute value of soil electrical conductivity (EC) by species and by area, but the relative order of distribution for each species with a particular value was similar in all six areas (Fig. 1). The differences in EC values among plant species were small at Namdong (control), Hyundai A (1 year), and Hyundai B (2 years), but large at Jangdeog (8 years), Mado (12 years), and Baegseog (30 years).

The distribution ranges for each species, by EC value, are summarized in Figure 3 (right). Four groups of soil EC values were identified, based on plant distribution patterns at reclaimed sites. First, very high values (>1.52 mmho) were found at sites where *S. herbacea, S. asparagoides, S. japonica*, and *L. tetragonum* grew. These species, especially *S. herbacea*, are tolerant of high soil salinity. Second, *A. tripolium, C. scabrifolia, P. communis, A. scoparia*, and *Z. sinica* grew in areas with relatively high EC values (0.50 to 1.51 mmho). Third, relatively low EC values (0.20 to 0.50 mmho) were found in areas with *S. viridis, C. virgatum, S. brachyotus, C. epigeios, A. subcordata*, and *T. angustata*. These species appeared during the early stage following reclamation. In the fourth group, the glycophytic species *I. cylindrica* var. *koenigii, A. indica, L. corniculatus* var. *japonicus*, and *T. repens* grew in areas with very low EC values (<0.20 mmho).

Salicornia is a characteristic halophyte that grows only in saline areas because of its tolerance to high salinity. However, it shows weak competition with other species (Rawson and Moore, 1944; Ungar, 1965; Waisel, 1972; Reimold and Queen, 1974). This genus inhabits intertidal flats, inland salt marshes, and inland salt deserts (Chapman, 1975; Ferrari et al., 1985). *Suaeda, Atriplex*, and *Triglochin* also grow in high-saline areas (Svenson, 1927; Beadle, 1952; Waisel, 1972; Ungar, 1974) and are highly salt-tolerant (Hong, 1956; Ihm and Lee, 1986; Ihm, 1987).

The plant distribution patterns, as influenced by levels of soil Na and Cl, were similar to those associated with EC. This was because the correlation coefficients between EC and Na or Cl were very high, as reported by Min and Kim (1997a, 1997b). In addition, Mg and Ca were constituents in the saline soil, but at levels less than for Na or Cl ions. Mg and Ca contents did not influence plant distribution in the reclaimed areas.

In this study, the distribution patterns for most species were not influenced by bulk density, porosity, aerated porosity, organic matter, total nitrogen, available phosphorus, or soil texture.

Standing Crops in Relation to Soil Moisture Content and EC

To verify the performance of each species that invaded the reclaimed lands, we calculated correlation coefficients between standing crops and soil factors (i.e., moisture content and EC value). Those traits common to our six study areas are shown in Table 1.

Correlation coefficients (CC) between phytomass and EC were positive in populations of *S. japonica, S. asparagoides, S. herbacea, and A. subcordata*, but negative in *C. epigeios, P. communis, A. scoparia*, and *S. brachyotus* populations. The CCs between phytomass and soil moisture content were positive for *S. japonica, S. asparagoides, L. tetragonum, C. epigeios,*

Table 1. Growth of plant species along the gradients of electrical conductivity (EC) and moisture content (WC) of the soil.

CC between EC And phytomass	CC between WC and phytomass		
	+	0	–
+	*S. japonica, S. asparagoides, A. subcordata*	*S. herbacea*	
0	*L. tetragonum*	*C. scabrifolia*	*I. cylindrica* var. koenigii, *A. indica*
–	*C. epigeios*	*P. communis*	*A. scoparia, S. brachyotus*
N	*A. tripolium*		

+, positive; 0, unaffected; –, negative; N, normal distribution curve.

and *A. tripolium,* but negative for *I. cylindrica* var. *koenigii, A. indica, A. scoparia,* and *S. brachyotus.* In particular, the phytomass of *A. tripolium* showed a normal distribution curve for EC value. This species probably appeared during the early stage after reclamation.

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LITERATURE CITED

Agricultural Development Corporation (ADC) (1986) On the desalination drainage and soil ripening. ADC, 201p

Arron DI, Johnson CM (1942) Influence of hydrogen in concentration on growth of higher plants under controlled conditions. Plant Physiol 17: 525-539

Beadle NCW (1952) Studies in halophytes. Germination of the seeds and establishment of the seedlings of five species of *Atriplex* in Australia. Ecology 33: 49-62

Beeftink WG (1975) The ecological significance of embankment and drainage with respect to the vegetation of the Southwest Netherlands. J Ecol 63: 423-458

Beeftink WG (1977) The coastal salt marshes of Western and Northern European ecological and phytosociological approach, *In* VJ Chapman, ed, Wet Coastal Ecosystem, Elsevier, Amsterdam, pp 109-155

Branson FA, Miller RF, McQueen IS (1967) Geographic distribution and factors affecting the distribution of salt desert shrubs in the United States. J Range Manage 20: 287-296

Brereton AJ (1971) The structure of the species populations in the tidal stages of saltmarsh succession. J Ecol 59: 321-338

Cha JW, Choi SJ (1966) Effect of saline and alkaline salts on the phosphorus content of vegetable plants. J Plant Biol (Korean J Bot) 9: 46-50

Chang NK, Lee WS (1978) The salt accumulation model on the soil surface by evaporation, transpiration and rainfall. Korean J Ecol 2: 31-37

Chapman VJ (1975) The salinity problem in general, its importance, and distribution with special reference to natural halophytes, *In* A Poljakoff-Mayber, J Gale, eds, Plants in Saline Environments, Springer-Verlag, New York, pp 7-24

Disraeli DJ, Fonda RW (1979) Gradient analysis of the vegetation in brackish marsh in Bellingham Bay, Washington. Canadian J Bot 57: 465-475

Feekes W (1936) De ontwikkeling van de natuurlijke vegetalie in de Wieringermeer polder de eerste groote droogmakerij van de Zuiderzee. Ned Kruidk Arch 46: 1-29

Feekes W (1943) De Piamer kooiwaard en Makkumer waard. Ned Kuidk Arch 53: 288-330

Ferrari C, Gerdol R, Piccoli F (1985) The halophilous vegetation of Po Delta (northern Italy). Vegetatio 61: 5-14

Gray AJ (1974) The genecology of salt marsh plants. Hydro Bull 8: 152-165

Gray AJ (1977) Reclaimed land, *In* RSK Barnes, ed, The Coastline, John Wiley & Sons, London, pp 253-270

Hinde HP (1954) The vertical distribution of salt marsh phanerogams in relation to tide levels. Ecol Monogr 24: 209-225

Hong S-W, Hah YC, Choi YK (1969a) Biological improvement of reclaimed tidal land (1). Desalination effects of saline soil by the growth of certain halophytes. J Plant Biol (Korean J Bot) 12: 7-14

Hong S-W, Hah YC, Choi YK (1969b) Biological improvement of reclaimed tidal land (4). Changes of saline soil by addition of organic acids. J Plant Biol (Korean J Bot) 12: 151-160

Hong S-W, Hah YC, Choi YK (1970) Ecological studies of certain halophytes on the high saline soil. J Plant Biol (Korean J Bot) 13: 25-32

Hong WS (1956) Research of west coasts' plant community in Korea (I). J Biology 1: 17-24

Ihm B-S (1987) The distribution and growth of halophytes at the coastal marsh. Bull Inst Litt Biota 4: 71-80

Ihm B-S, Lee J-S (1985) The effects of salt on plant growth. Bull Inst Litt Biota 2: 33-40

Ihm B-S, Lee J-S (1986) Adjustment of *Salicornia herbacea* and *Suaeda japonica* for environment change in the salt marsh. Bull Inst Litt Envi 4: 15-25

Ihm B-S, Lee J-S, Kim H-S, Kwak A-K, Ihm H-B (1995a) Distribution of coastal plant communities at the salt marshes of Mankyung and Dongjin River estuary. Bull Inst Litt Environment 12: 11-28

Ihm B-S, Lee J-S, Woo J-C, Kwak A-K, Ihm H-B (1995b) Adjustment of three halophytes to changes of NaCl concentration. Bull Inst Litt Environment 12: 1-10

Im HB (1969) Study on the salt tolerance of rice and other crops in reclaimed soil areas (II). On the salt tolerance of Chinese cabbage and cabbage in various salty conditions. J Plant Biol (Korean J Bot) 12: 100-106

Im HB (1970a) Study on the salt tolerance of rice and other crops in reclaimed soil areas (III). On the optimum ratio of phosphate and potash to N fertilization for rice plant in the reclaimed salty areas. J Plant Biol (Korean J Bot) 13: 21-31

Im HB (1970b) Study on the salt tolerance of rice and other crops in reclaimed soil areas (X). Response of rice population to varying plant density and N levels in reclaimed salty area. J Plant Biol (Korean J Bot) 13: 1-16

Im HB, Hoang CS (1970) Study on the salt tolerance of rice and other crops in reclaimed soil areas (II). On the histological differences between the roots of salt land and water bed seedlings of rice and their rooting in saline soil. J Plant Biol (Korean J Bot) 13: 13-22

Im HB, Hoang CS (1977) A basic study on sugar beet culture in reclaimed salty area. 1. On the sugar accumulation of sugar beet in reclaimed salty area. J Pland Biol (Korean J Bot) 20: 23-27

Im HB, Lim UK (1970) Study on the salt tolerance of rice and other crops in salty areas. J Plant Biol (Korean J Bot) 13: 1-12

Im HB, Lim UK, Hoang CS (1971a) Study on the salt tolerance of rice and other crops in reclaimed soil areas. 15. The effects of salt on the efficiency of sunlight utilization of rice canopy in reclaimed saline soils. J Plant Biol (Korean J Bot) 14: 60-65

Im HB, Lim UK, Shim JS (1969) Study on the salt tolerance of rice and other crops in reclaimed soil areas. 3. Response of rice to plant population and spacing in the salty soil area. J Plant Biol (Korean J Bot) 12: 28-42

Im HB, Shim JW, Lim UK (1971b) Study on the salt tolerance of rice and other crops in reclaimed soil areas. 13. On the absorption of the mineral elements of rice and the components of rice grains in reclaimed saline soils. J Plant Biol (Korean J Bot) 14: 25-31

Jefferies RL (1972) Aspects of salt-marsh ecology with particular reference to inorganic plant nutrition, *In* RSK Barnes, J Green, eds, The Estuarine Environment, Applied Science Publisher, London, pp 61-85

Joenje W (1979) Plant succession and nature conservation of newly embanked tidal flats in the Lauerszeepolder, *In* RL Jefferies, AJ Davy, eds, Ecological Processes in Coastal Environments, Blackwell Scientific, Oxford, London, pp 617-634

Kim CM, Chang NK, Lee SK, Woo TK (1975) A continuum of plant communities on the gradient of the tidal land in Namdong. Commemoration Papers Celebrating Sixtieth Birthday of Professor Choon Min Kim, pp 150-157

Kim CS (1971) An ecological study on the process of plant community formation in tidal land. J Plant Biol (Korean J Bot) 14: 163-169

Kim CS (1980) Study on the seed germination and salt tolerance of plants in reclaimed salt area. J Plant Biol (Korean J Bot) 23: 27-33

Kim CS (1982) A study on the germination and salinity tolerance of plant seeds. J Mokpo Natl College 4: 449-460

Kim CS, Song TG (1983) Ecological studies on the halophyte communities at western and southern coasts in Korea (IV)-The halophyte communities at the different salt marsh habitats. Korean J Ecol 6: 167-176

Kim J-H, Min BM (1983) Ecological studies on the halophyte communities at western and southern coast in Korea (III). On the soil properties, species diversity and mineral cycling in reclaimed soil in Incheon. J Plant Biol (Korean J Bot) 26: 53-71

Kim J-H, Ryu BT (1985) Energy flow in coastal salt marsh ecosystem. Korean J Ecol 8: 153-161

Lee J-S (1990) On the establishment of halophytes along tidal level gradient at salt marshes of Mankyong and Dongjin river estuaries. Ph.D. thesis. Seoul Natl Univ, Seoul

Mall RE (1969) Soil-water-salt relationships of waterfowl food plants in the Suisum marsh of California. Calif Dept Fish Game, Wildl Bull 1: 1-59

Min BM, Kim J-H (1983) Distribution and cyclings of nutrients in *Phragmites communis* communities of a coastal salt marsh. J Plant Biol (Korean J Bot) 26: 17-32

Min BM, Kim J-H (1997a) Soil texture and desalination after land reclamation on the West coast of Korea. Korean J Ecol 20: 133-143

Min BM, Kim J-H (1997b) Desalinization characteristics after reclamation of reclaimed lands on the Western coast of Korea. Korean J Ecol 20: 275-283

Min BM, Kim J-H, Kimura M, Kikuchi E, Suzuki T, Takeda S, Kurihara Y (1989) Soil and plant community of reclaimed lands on the west coast of Korea. Ecological Review 21: 245-257

Noordwijk-Puijk K, Beeftink van WG, Hogeweg P (1979) Vegetation development on salt-marsh flats after disappearance of the tidal factors. Vegetatio 39: 1-13

Penfound WT (1952) Southern swamps and marshes. Bot Rev Sci 4: 59-64

Ranwell DS (1972) Ecology of salt marshes and sand dunes. Chapman and Hall, London

Rawson DS, Moore JE (1944) The saline lakes of Saskatchewan. Canadian J Res 22: 141-201

Reimold RJ, Queen WH (1974) Ecology of halophytes. Academic Press, New York

Ryu BT, Kim J-H (1985) Comparison of estimation methods for primary net production at herbaceous coastal marsh vegetation. Korean J Ecol 8: 133-140

Small J (1946) pH and Plants. Van Nostrand Co, New York

Svenson HK (1927) Effects of post pleistocene marine submergence in eastern North America. Rhodora 29: 41-48

Ungar IA (1965) Soil-vegetation relationships in saline soils of Kansas and Oklahoma. Bull Ecol Soc Amer 46: 90

Ungar IA (1974) Inland halophytes of the United States, *In* RJ Reimold, WH Queen, eds, Ecology of Halophytes, Academic Press, New York, pp 235-305

Ungar IA, Capilupo F (1968) An ecological life history study of *Suaeda depressa* (Pursh.) Wats. Adv Front Plant Sci 23: 137-158

van den Tooren J, Brandsma M, Bates WB, Penny MG (1969) De vegetatie van Zuidelijk Flevoland in 1968. De levende Natuur 72: 56-61
Waisel Y (1972) Biology of Halophytes. Academic Press, New York
Walter H (1968) Die vegetation der Erde in kologischer Betrachtung. Band I, Fischer Verlag, Jena
Zuur AJ (1961) Initicle bodemborming bij marien gronde. Me. van Laudbouwhogeschool en de opzoekingsstations van de Staat te Gent 24: 7-33