

Distribution and Cyclings of Nutrients in *Phragmites communis* Communities of a Coastal Salt Marsh

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海岸鹽濕地 갈대 群落의 無機營養素 循環과 分配

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ABSTRACT

The aboveground production, nutrient distribution and nutrient cyclings were compared between two *Phragmites communis* communities growing in the different salt contents of soil in a coastal salt marsh.

Inorganic nutrient contents of soil for plant growth were greater at the low salt stand than at the high salt stand except for sodium(Na). Maximum aboveground biomass of the plant at the low and the high salt stands were 2,533 and 1,719 g dw/m², respectively, in August. Seasonal changes of nutrient content of biomass in dry weight decreased with growth except for Na. Nutrient contents in biomass per unit land area increased continuously as biomass increases, although the amount of potassium(K) reached the maximum content in July and thereafter decreased. Vertical distributions of total nitrogen(T-N) and phosphorus(P) increased with plant height, but Na showed the reverse trend. That of K was similar to the patterns for T-N and P in the leaves, and to the pattern of Na in the stems. The Na was greatly accumulated in underground biomass but transported scarcely to aboveground. At the low and the high salt stands, the ratios of the inorganic nutrients contained in the plant were 100 : 66 for T-N, 100 : 61 for P, 100 : 62 for K and 100 : 97 for Na. The ratios of the amounts of nutrients retrieved to soil were 100 : 242 for T-N, 100 : 408 for P, 100 : 127 for K and 100 : 269 for Na, respectively. Turnover times of the T-N, P, K and Na in the communities were 56, 1, 15 and 174 years at the low salt stand, and 75, 2, 24 and 323 years at the high salt stand, respectively. In nutrient cyclings, all of the nutrients retrieving to soil were less than uptake by plant. Among the nutrient, especially P is expected to be exhausted from soil, sooner or later, because of the harvest by men.

INTRODUCTION

The high salt concentration inhibits growth of most plants because saline condition affects plant growth in a variety of ways, i.e., higher osmotic pressure and poor quality of physical factors, toxic accumulations of sodium and chloride, and reduction of water uptake and nutrient availability of plants(Waisel, 1972). Studies on coastal salt marshes are fascinating because physicochemical and biological interactions could be approached to the blend of terrestrial, aquatic and marine community(Wiegert *et al.*, 1981).

Studies on salt marshes were begun at early 20th century and large amount of studies were performed in considerable detail in the United States and Europe. In Korea, such studies were performed by Kim(1958), Im(1967, 1969), Im and Hoang(1970a, 1970b) and Hong *et al.* (1970) but collected data are not much.

Phragmites communis is the most widely distributed plant in the world(Ridley, 1930). Many autecological studies of *P. communis* were carried out by Haslam(1968, 1969a, 1969b, 1970, 1971). *P. communis* grows in saline condition(Haslam, 1971; Waisel, 1972) and tolerates chlorinity up to 1.3‰. Production of *P. communis* varies with the salt concentration of soil(Kim, 1975). Studies on the productivity of *P. communis* were carried out by many workers(Květ and Šbovoda, 1970; Oh, 1970; Dykyjová, 1971; Ondok, 1973; Dykyjová and Přibit, 1975; Gloser, 1977; Kim *et al.*, 1972; Kim, 1975; Kim *et al.*, 1982; Oh and Ihm, 1983). The ratio of aboveground to underground biomass of *P. communis* was estimated by Fiala(1973a, 1973b, 1973c, 1976), Fiala and Květ(1971) and Fiala *et al.* (1968).

P. communis community is utilized as an important forage and as a habitat for consumers such as crabs, and supplies inorganic nutrients to river water(Westlake, 1965).

The nutrient cycling of *P. communis* community was studied by Dykyjová(1973a, 1973b) and Dykyjová and Hradecká(1976) and turnover rate of nutrients of the litter was estimated by Chang *et al.* (1978).

The purpose of this paper is to compare the nutrient cyclings, productivity, and seasonal and vertical distributions of inorganic nutrients of *P. communis* communities growing under two different salt contents of soil.

STUDY SITE

The survey was carried out at two *P. communis* communities, in high tidal salt marsh located on Namdong, Incheon, distinguished by the difference in the salt contents of soil. At the low and the high salt stands, sodium content and electric conductivity of the soils were 1.5 and 2.5 mg Na/g dry soil(1.0 : 1.7) and 0.36 and 1.39 mmho (1.0 : 3.8), respectively(Fig. 3).

The low salt stand was situated along a small tributary, where fresh water flew and the high salt stand was located between a saltpan pond filled with sea water on the sea

side and a rice paddy on the inland side(Fig. 1). Both stands were often inundated with sea water every springtide. Fig. 2 shows the climate of the study area.

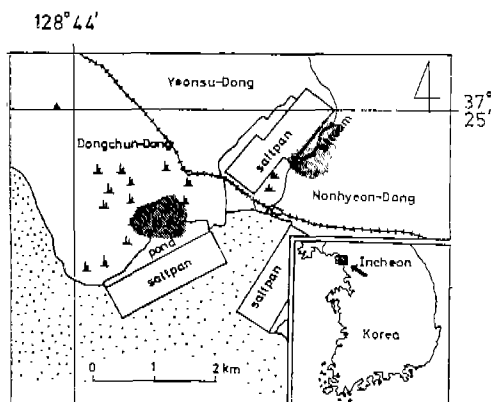


Fig. 1. Location of the study area., low salt stand; ■, high salt stand.

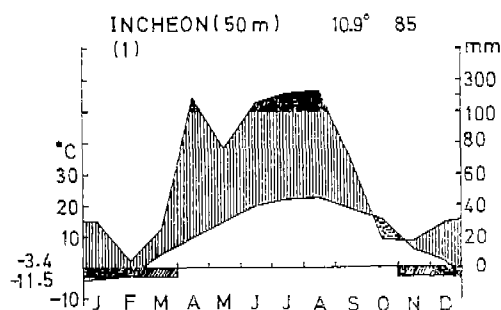


Fig. 2. Climate diagram of the study area. These data are after Incheon Meteorological Station located 12km NW apart from the study area (from Nov. 1979 to Oct. 1980).

Species composition of the low salt stand was different from that of the high salt stand: the former was nearly a pure stand of *P. communis*. In the latter, however, *Suaeda maritima*, *Scirpus triquetus*, *Atriplex tatarica* and *Salicornia herbacea* appeared as rare species as well as *P. communis* as a dominant which had about 90% biomass of whole community in summer.

MATERIALS AND METHODS

Field sampling. Sampling was begun on April (April 20, 1980), when the shoot of *P. communis* sprouted, and completed on October (October 8, 1980), when growth stopped. Sampling interval was two-week. Aboveground organs of the plants were clipped within a 25×25 cm quadrat, which was laid down randomly. After sampling, samples were carried to lab, the aboveground organs were cut at 20 cm intervals along the plant height and then each cutting was separated into leaves, stems, reproductive organs and dead part, respectively. Underground organs were dug out from the soil up to 40 cm depth and the soil was removed from the plant by hand washing and screening. Both samples were oven-dried at 80°C for 72 hrs, weighed, pulverized and then sieved through a 0.5 mm sieve. Soil was collected from surface to 40 cm in depth at 10 cm intervals, air-dried for 2 weeks and sieved through a 0.5 mm sieve. All powdered samples were stored in small, airtight bottles until analysis.

Estimation of primary production. Annual net production of the aboveground organs per unit land area (m²) was estimated from the highest standing biomass including the

aboveground dead part. The biomass of underground organs was estimated by multiplying the highest aboveground biomass by 2.5 and the annual net production of underground organs was estimated by multiplying the biomass of underground organs by 0.3(Fiala *et al.*, 1968). However, the biomass consumed by herbivores during the survey was not considered.

Chemical analyses. pH of soil was measured by glass electrode pH meter(Fisher 230 A). Electric conductivity(EC) of soil was measured by electric conductivity meter (Takemura DM 35). Organic matter(OM) of soil was determined as loss on ignition at 600°C in an electric muffle furnace for 4 hrs. Total nitrogen(T-N) both in soil and plant material was determined by micro-Kjeldahl method. In phosphorus(P) determination the plant materials were added 0.5 M MgNO_3 , burnt in a muffle furnace at 550°C and extracted with 2 N H_2SO_4 , and available phosphorus(A-P) of soil was extracted by stirring with 0.002 N H_2SO_4 solution for 1 hr, and these extractions were spectrophotometrically determined by the stannous-reduced molybdophosphoric blue color method(Jackson, 1967). Potassium(K) and sodium(Na) were measured by flame photometer(Coleman 51) with extractant of 0.2 N HCl for plant materials and 2 N ammonium acetate for soil.

RESULTS AND DISCUSSION

Soil properties. Seasonal changes of chemical properties of the soil from the surface to 40 cm depth at the low and the high salt stands are shown in Fig. 3. The concentrations of the T-N, A-P, K, OM and pH value of the soil at the low salt stand were higher than those at the high salt stand. On the contrary, the Na content of the soil at the low salt stand was continuously kept on about a half time that at the high salt stand. Moreover, the EC of the soil at the low salt stand was one fourth times of that at the high salt one. Such difference between the low and the high salt stands in the Na content or EC of the soil was especially great in spring, due to ascent of salt from underground to surface by evaporation, but it became reduced in summer, because of rain(Fig. 2).

The marked differences between the two stands for contents of the T-N and OM in spring were reduced with time. For these reasons, it might be explained that the larger amount of underground organic matter at the low salt stand than at the high salt stand was due to decomposition of organic matter and the absorption of T-N, derived from organic matter, by the rapidly growing plants. The content of the A-P of the soil at the low salt stand was very great in summer, though the very reverse trend appeared at the high salt stand in spring. The K content between the stands changed inversely each other. The value of pH was slightly higher at the low salt stand than at the high one. Kim *et al.* (1975) have also observed similar pH value at the tidal salt marsh near this experimental site.

Vertical distributions of physicochemical properties of the soil at the low and the high salt stands are shown in Fig. 4. The contents of the T-N, K and OM at the stands de-

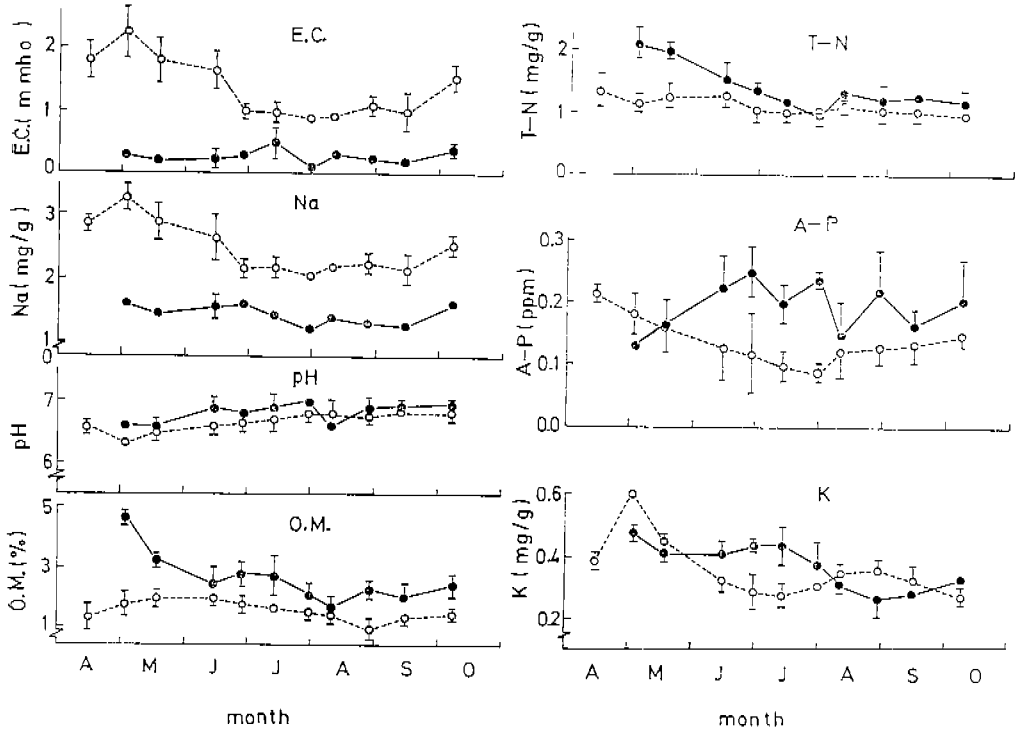


Fig. 3. Physicochemical properties of soil at sampling stands as change of season. ●—●, low salt stand; ○—○, high salt stand; E.C., electric conductivity; pH, pH value; Na, sodium; O.M., loss on ignition; T-N, total nitrogen; A-P, available phosphorus; K, potassium.

creased with soil depth from the surface to 40 cm deep. However, the contents of the Na, A-P and the value of EC were constant vertically regardless of soil depth.

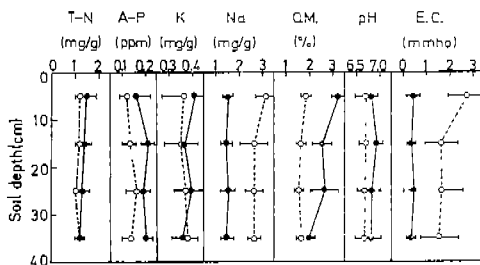


Fig. 4. Physicochemical properties of soil with soil depth at sampling stands. ●—●, low salt stand; ○—○, high salt stand. See Fig. 3 for abbreviation.

Seasonal changes of primary production. Seasonal changes of biomass at both stands are shown in Fig. 5. The highest amounts of aboveground biomass at the low and the high salt stands were 2,533 and 1,710 g dw/m², respectively, in mid-August. In August occurring when biomass shows a maximum value, average heights of *P. communis* communities were 210 and 150 cm and the density was 367 and 485 individuals/m² at the low and the high salt stands, respectively.

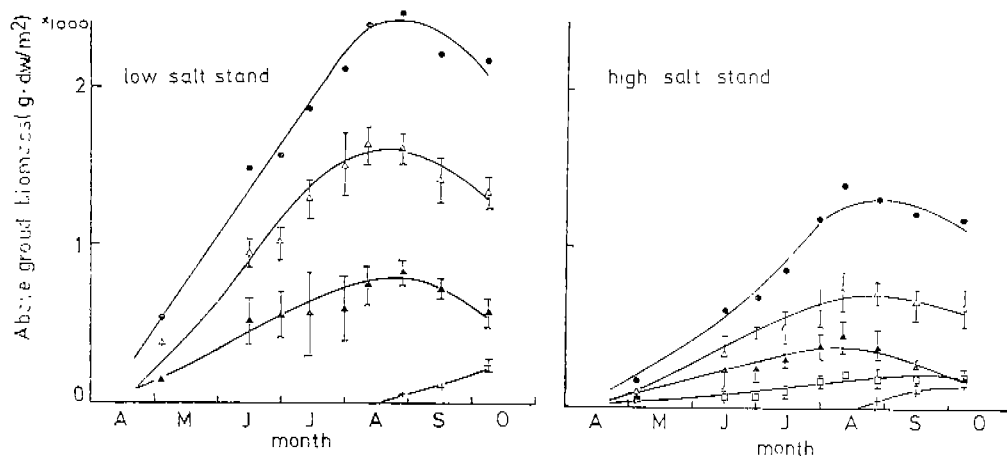


Fig. 5. The aboveground biomass in dry weight in each organ of *P. communis* communities. ●—●, total; ▲—▲, leaves; △—△, stems; +—+, reproductive organs. □—□, other plants.

Aboveground biomass of *P. communis* communities studied by Kim *et al.* (1975), Oh (1970), Kim (1975), Kim *et al.* (1982) and Oh and Ihm (1983) at various sites in Korea was within a range from 406 g dw/m² at Gunja which was flooded with the sea water at coast to 6,461 g dw/m² at Eulsugdo which was flooded with brackish water at the estuary of the Nagdong river as shown Fig. 6. Although Kim *et al.* (1975) have suggested that the local difference of the biomass of *P. communis* community was due to grazing, the difference of biomass between the low and the high salt stands in this study might be caused by the difference of the soil properties such as the Na content and EC. Ranwell (1972) had reported that 1.3‰ of chlorinity, about one third concentrations of the sea water, of soil solution became a limit of growth for *P. communis* plant.

Inorganic nutrients per unit weight of biomass. The contents of the T-N, P, K and

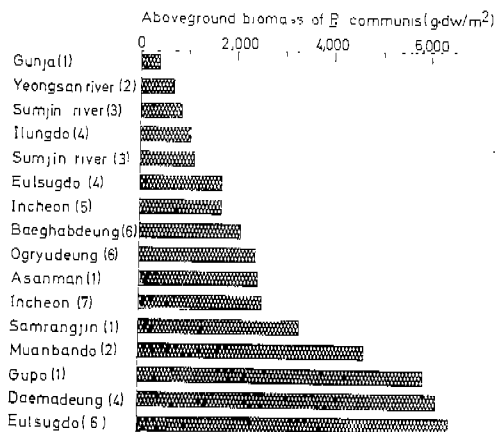


Fig. 6. The aboveground biomass of *P. communis* communities in Korea in gram dry weight per square meter.

- (1) Kim *et al.* (1972)
- (2) Kim (1975)
- (3) Oh and Ihm (1983)
- (4) Oh (1970)
- (5) high salt stand
- (6) Kim *et al.* (1982)
- (7) low salt stand

Na per gram dry weight of each organ at the low and the high salt stands during growth season are shown in Fig. 7. In the aboveground organs, the contents of the T-N, P and K per gram dry weight of leaves and stems were the highest at early growth period in May, thereafter, decreased rapidly and then kept constant for 2 months at both stands. The content of the Na, however, was rather constant during growth season.

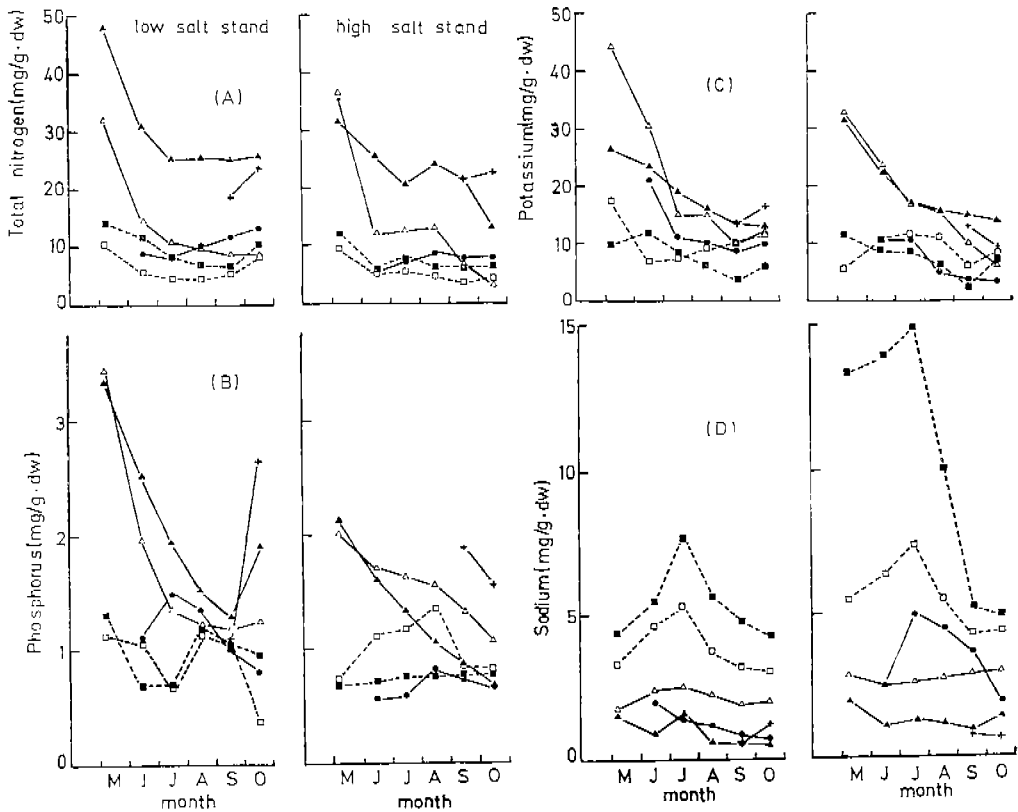


Fig. 7. Seasonal changes of total nitrogen(A), phosphorus(B), potassium(C) and sodium(D) contents per gram dry weight in different parts of *P. communis* communities. \blacktriangle — \blacktriangle , leaves; \triangle — \triangle , stems; \blacksquare — \blacksquare , roots; \bullet — \bullet , dead parts; \square — \square , rhizomes; $+$ — $+$, reproductive organs.

In underground organs, the T-N content decreased gradually at early growth stage and thereafter increased at the low salt stand but maintained a constant value at the high salt stand. The P content fluctuated widely during growth season, with minor exception of root having a constant value at the high salt stand. The K content of root decreased until late growth stage on September and thereafter increased slightly, but that of rhizomes showed different trends between both stands. The Na contents of both roots and rhizomes reached the highest on mid-July and thereafter decreased.

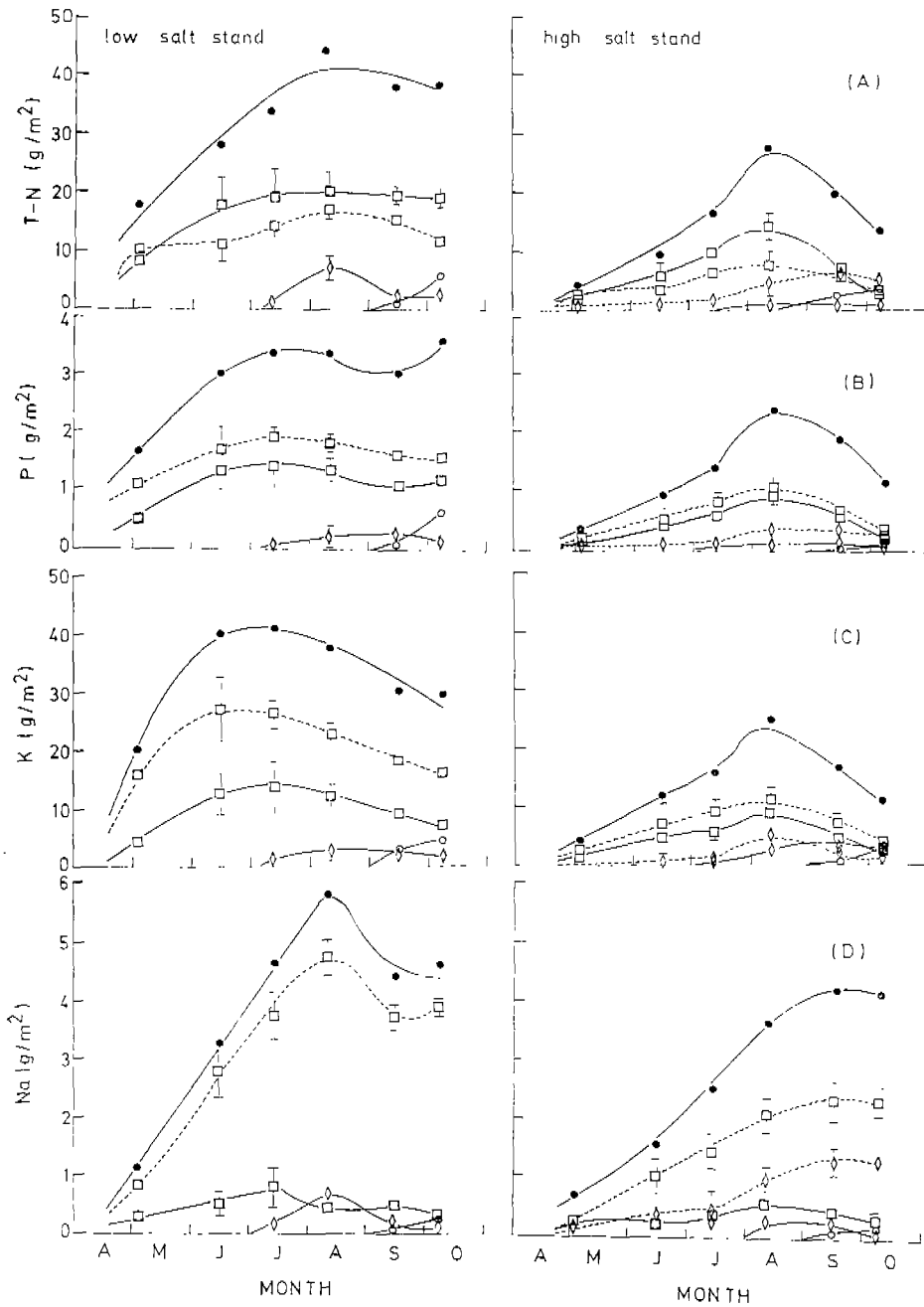


Fig. 8. Seasonal changes of total nitrogen(A), phosphorus(B), potassium(C) and sodium(D) content per square meter in different parts of *P. communis* communities. ●—●, total; □—□, leaves; □—□, stems; ◇—◇, dead parts; ○—○, reproductive organs; ◇—◇, other plants.

The contents of the T-N and K per unit weight of each organ at the low salt stand were similar to those at the high salt stand. The P content of leaves, however, was greater at the low stand than at the high salt one. In a comparison of the nutrient content between the above- and under-ground organs, the contents of the T-N, P and K for both leaves and stems were obviously greater than those for both roots and rhizomes, except for late growth stage. In the Na contents, however, such distribution between above- and under-ground organs were showed inversely. The reproductive organ contained large amounts of the T-N, P and K except for Na. The nutrient contents per unit dry weight of biomass in this study agree well with data obtained from *P. communis* by Dykyjová(1971, 1973a, 1973b). According to Ihm *et al.* (1971), the seed of rice plant contained only little amount of the Na even though the rice plants were grown in reclaimed soil with very high salt concentration.

Inorganic nutrients of biomass per unit area. Standing inorganic nutrients in plants were estimated by multiplying the amount of nutrient element per unit weight by biomass per m². Seasonal changes of the contents of the T-N, P, K and Na for biomass per m² are shown in Fig. 8. All of the nutrient contents of biomass are markedly greater at the low salt stand than the high salt stand, because of difference in biomass.

The curves of seasonal changes of the standing nutrients were similar to those of the aboveground biomass(Fig. 5) with minor exception of the K content at the low salt stand.

Ratios of the maximum standing nutrient in biomass at the low salt stand to that at the high salt stand were 100 : 80 for the T-N in mid-August, 100 : 71 for the P in mid-August, 100 : 62 for the K in July and August, and 100 : 74 for the Na in August and October. Ratios of the standing nutrients obtained here are similar to the results reported

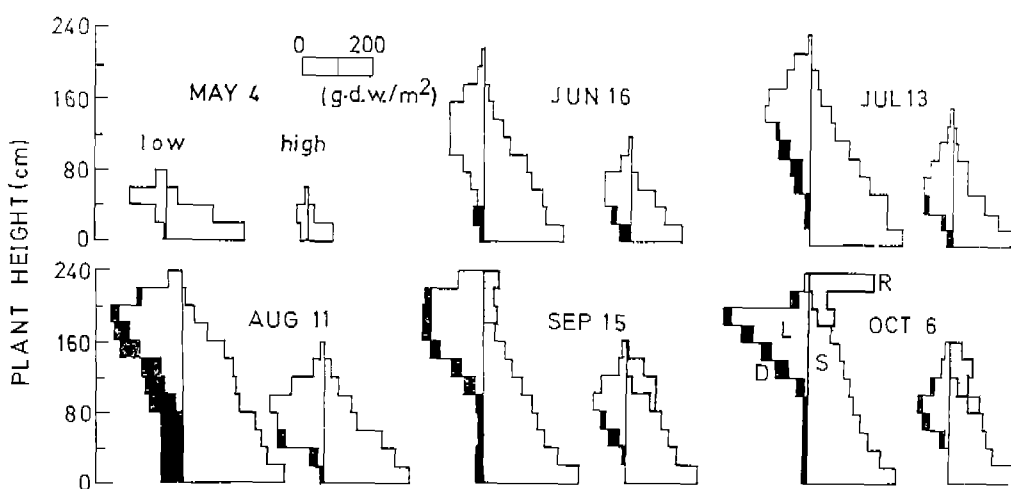


Fig. 9. Seasonal changes of productive structure of *P. communis* communities. L, leaves; S, stems; R, reproductive organs; D, dead parts.

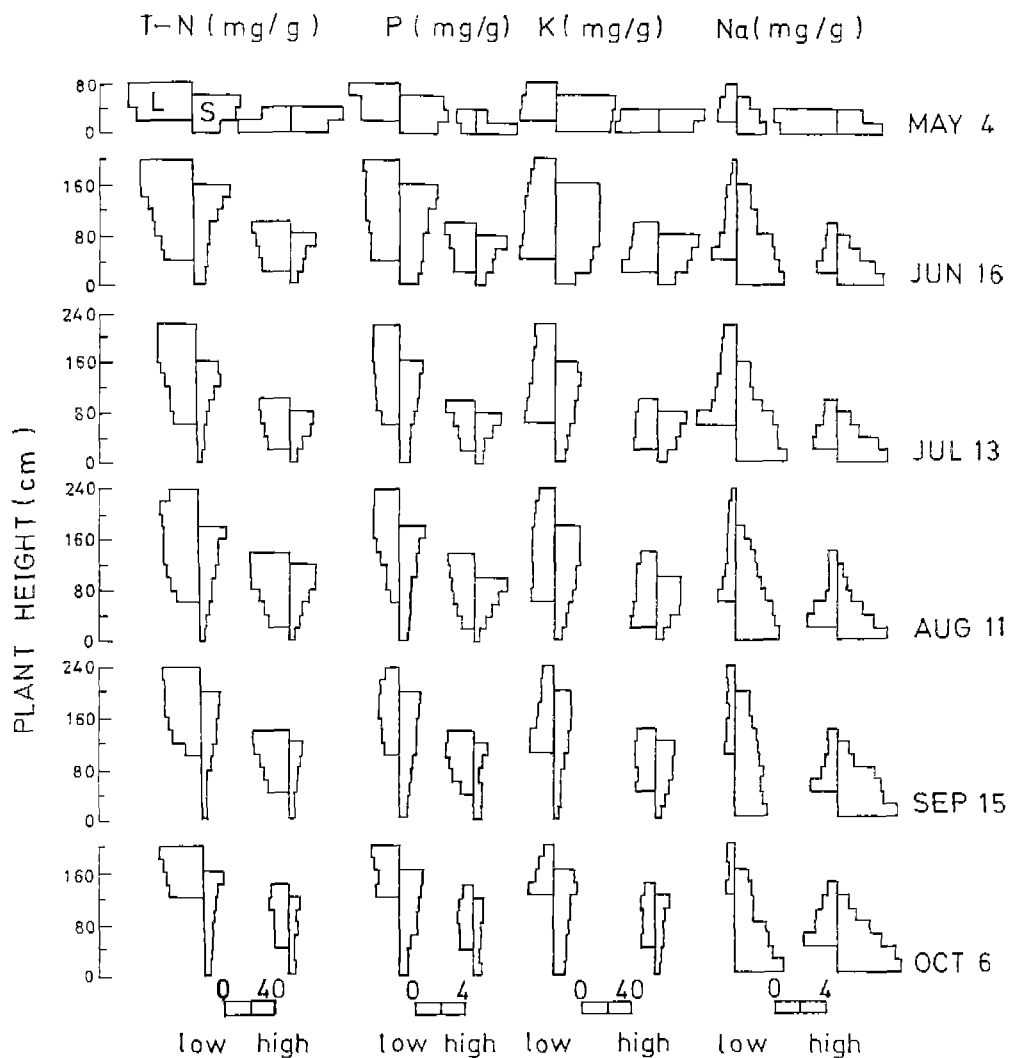


Fig. 10. Seasonal changes of vertical distribution of total nitrogen(T-N), phosphorus(P), potassium (K) and sodium(Na) with growth season. L, leaves; S, stems.

by Dykyjová and Hradecká(1976), and Mason and Bryant(1975), but are less than those by Květ(1973).

Vertical distribution of nutrients with plant height. To investigate the vertical distribution of nutrients productive structure of the *P. communis* community was analyzed by means of stratified clip technique(Monsi and Saeki, 1953) (Fig. 9). Although leaves of the lower part of the plant were shaded earlier at the low salt stand than the high salt stand. Productive structures between stands were similar in both photosynthetic and non-photosynthetic part at corresponding sampling period.

The contents of the T-N and P were increased with the plant height (Fig. 10). Such trends of the vertical distributions of the T-N and P were conspicuous in the stems compared with the leaves.

The vertical distribution of the K content in the stems was different from that in the leaves. The former was similar to the pattern of the T-N and P in both leaves and stems but the latter was nearly homogeneous throughout the whole leaves. These results on the vertical distribution of inorganic nutrients well agree with the data obtained from *P. communis* community by Dykyjová and Hradecký (1976).

The Na content was decreased with plant height in contrast to three other nutrients. Ratios of the Na contents at the low salt stand to that at the high salt stand were 100 : 185 for the soil, 100 : 182 for the roots, 100 : 239 for the rhizomes, 100 : 117 for the stems, and 100 : 181 for the leaves as shown in Fig. 11. At the high salt stand, even though the Na content of the plant became conspicuously decreased with the height of *P. communis* plant and its absorption was directly proportional to the Na concentration of the soil, a part of the Na absorbed was transported from roots to rhizomes and the transport of Na in the shoots might be inhibited. Pitman *et al.* (1968) have observed that barley seedlings absorb Na element from a culture solution in proportion to the concentration of Na element and accumulate greater, it in the root than in the shoot. It might be recommended to use the shoot, especially leaves of *P. communis* plants with a small quantity of salt, as a forage.

Nutrient cyclings in salt marsh community. Distributions of biomass among the plant part of *P. communis* communities are shown in Fig. 12. Although annual net productions of each organ were larger at the low salt stand than the high salt stand, the amount of litter remained in the stands was larger at the high salt stand than the low salt stand because the litter at the low salt stand was removed by men to other place for their needs. Thus it was observed that the amount of detritus remaining at the low salt stand

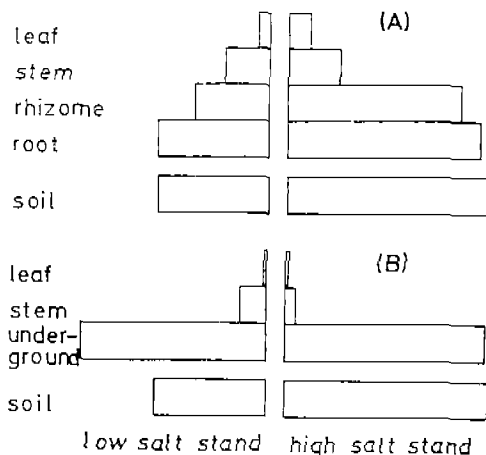


Fig. 11. Comparison of relative sodium content of the low and the high salt stands in each organ, (A) per unit weight. (B) per unit area (m²).

was only one half of that at the high salt stand.

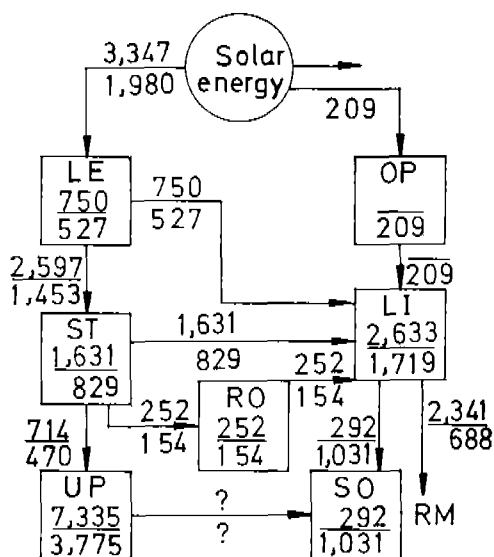


Fig. 12. Distributions of biomass among the components in *P. communis* communities. Numbers on arrow indicate the flux quantities and those in compartments indicate the maximum standing quantities in g/m²/yr. Numerators mean the values of low salt stand and denominators mean those of high salt stand. LE, leaves; ST, stems; UP, underground parts; RO, reproductive organs; LI, litters; OP, other plants; SO, soil; RM, harvested by men.

Annual cyclings of various nutrients in *P. communis* community at the different salt soils are shown in Fig. 13. Uptakes of the T-N by whole plants were 57.27 and 31.80 g N/m²/yr and its restitutions to soil as the litter were 44.51 and 31.78 g N/m²/yr at the low and the high salt stands, respectively.

The cyclings of the T-N between the soil and biomass were considerably balanced at both salt stands. However, restitutions from litter to soil in fact were 8.41 and 19.20 g N/m² because of the biomass removed. Ratios of restitution to uptake for the T-N were 14% and 51% at the low and the high salt stands, respectively. Maintenance of nitrogen balance in these communities would be made by supply from the stream water, flood tide water, rain water and nitrogen fixation by soil microorganisms (Green and Edmisten, 1974).

In the cycling of the community, the A-P content in the soil was meager compared with other nutrients. P absorption by the plants was as much as 6.39 and 3.89 g P/m²/yr and the return of the absorbed P to the soil under a steady condition was 17 and 82% (1.0 : 1.7) at the low and the high salt stands, respectively. Because biomass was continually harvested by men, deficiency of P element was expected to occur soon in these communities.

In the K cycling, uptakes of the K were made as much as 54.51 and 33.91 g K/m²/yr, and 53 and 73% (1.0 : 1.4) of the amounts were returned to the soil at the low and the high salt stands, respectively. In the Na cycling, however, the amounts of the Na in biomass were similar in both salt stands, for example, absorbed amounts of the Na were

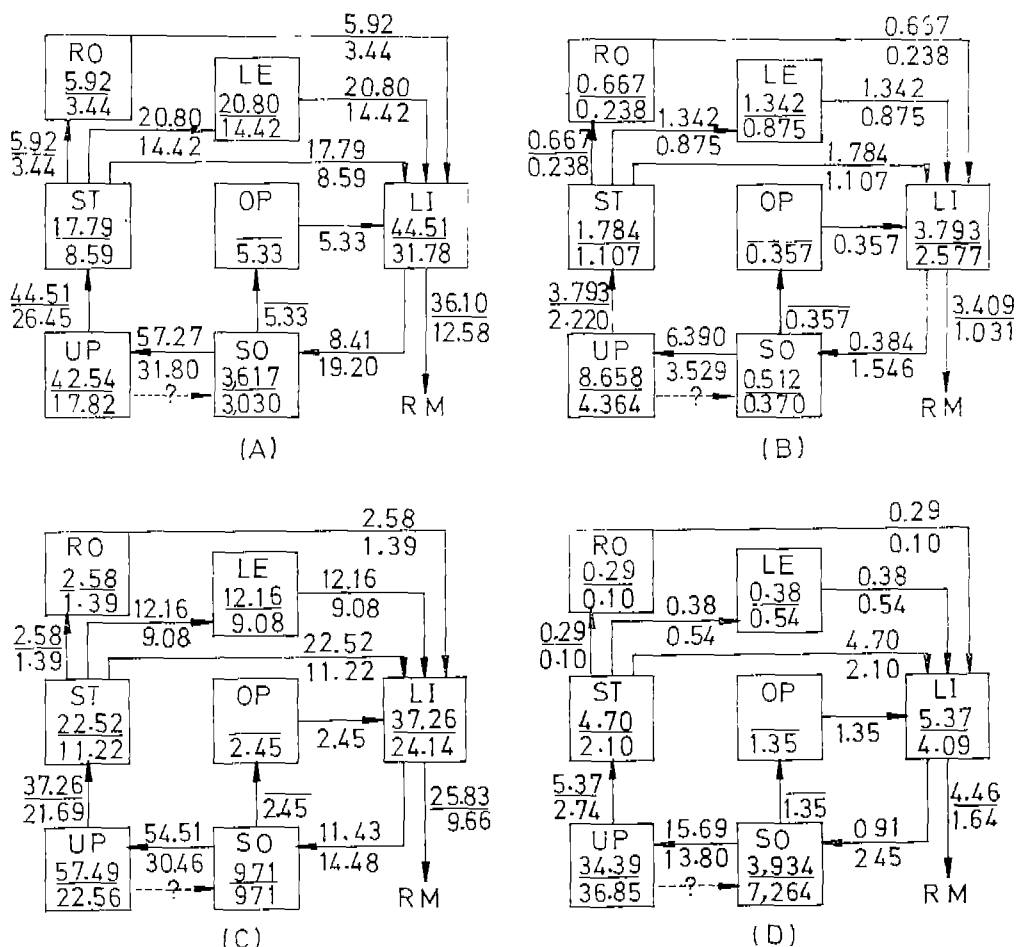


Fig. 13. Flow chart showing the total nitrogen(A), phosphorus(B) potassium(C) and sodium(D) contents of *P. communis* communities. Units are g/m² in soil and g/m²/yr in the plant materials. See Fig. 12 for abbreviation.

15.6% and 15.15 g Na/m²/yr(1.00 : 0.97), although the ratios of biomass (1.0 : 1.7) and the Na content in the soil (1.0 : 1.8) at the low and the high salt stands. 72 and 89% (1.0 : 1.2) of the amount of absorbed Na were returned to the soil owing to harvest of biomass. Never will bring out the lack of the Na in the salt marsh because of enough amount of the Na in the soil.

Turn-over times, defined as ratio of the amount of nutrient in the soil to that of uptake by the plant, of the T-N, P, K and Na were estimated to be 56, 1, 15 and 174 years at the low salt stand and 75, 2, 24 and 323 years at the high salt stand, respectively. Furthermore, if we consider leaching of the nutrients from the biomass by rainfall and recycling during the growth season, the actual turnover time would be shorter than the estimated turnover time. Out of all the nutrients, the P had the shortest turnover time

because the A-P content in the soil was too small for the growth of plants in the study area. If such tidal salt marshes are reclaimed, the supply of P element should be inevitable.

摘 要

海岸鹽濕地에서 土壤의 鹽分含量이 다른, 두 갈대(*Phragmites communis* Trin.) 群落의 地上部 生産性, 식물의 높이에 따른 無機營養素의 分布 및 循環을 比較하였다.

土壤의 高나트륨 地所는 低나트륨 地所보다 空氣傳導度는 크고 pH, 유기물함량, 질질소, 인, 칼리 와 같은 物理化學的 特性은 낮았다. 地上部는 8월에 最大 乾物生産量을 나타냈는데 低나트륨 地所에서 는 2,533 g·dw/m²이고, 高나트륨 地所에서는 1,719 g·dw/m²이었다. 植物體 各 器官의 單位 乾物重量 當의 全窒素, 磷, 加里의 季節變化는 時間이 경과함에 따라 減少하였지만 나트륨은 7월에 最大値를 보 였다. 單位 地面積當 植物體內의 無機營養素 現存量의 季節變化는 生物量의 變化와 대체로 一致하였 다. 植物體內의 單位 重量當의 全窒素와 磷의 含量은 植物體의 上部로 올라갈수록 증가하였고, 칼리는 앞에서 下部로 내려갈수록, 줄기에서는 上部로 올라갈수록 增加하였지만 나트륨은 地下部에 많이 蓄 積되고 地上部에는 적게 含有되었다. 低·高나트륨 地所에서 植物群落의 年 無機營養素 吸收量 比는 全 窒素가 100 : 66, 磷이 100 : 61, 칼리는 100 : 62, 나트륨이 100 : 97이었다. 그리고 植物體로부터 土壤 으로의 年 回收量 比는 全窒素가 100 : 242, 磷이 100 : 408, 칼리가 100 : 127, 나트륨이 100 : 269이었 다. 특히 磷은 外部로부터 流入되지 않을 경우 그것은 곧 枯渴된 것으로 예상되었다. Turnover time은 全窒素, 磷, 칼리 및 나트륨이 低나트륨 地所에서 55, 1, 및 175년이고, 高나트륨 地所에서 75, 2, 24 및 322년이었다.

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