Kor. Turfgrass Sci., 9(4), 343～350, 1995

The Removal Rate of the Constituents of the Litters in the Aquatic Plant Ecosystems
Ⅱ. N, P, K, Ca and Na of the Litter in *Phragmites longivalvis* Grassland in the Delta of the Nakdong River

Chang, Nam-Kee and Byeong-Ha Ahn

Dept. of Biology, College of Education, Seoul National University

수생식물 생태계에 있어서 낙엽의 구성성분의 유실률
Ⅱ. 낙동강 삼각주 지역의 갈대초지에 있어서 낙엽의 N, P, K, Ca 및 Na

장 남 기 · 안 병 하

서울대학교 사범대학 생물교육과

ABSTRACT

Samples from the L, F, H and A_1 horizons of the *Phragmites longivalvis* grassland were collected in a delta of the Nakdong River and the removal rates of N, P, K, Ca and Na were investigated. The results obtained in this study can be abstracted as follows;

The removal fractions of N, P, K, Ca and Na of the litter were 0.56, 1.22, 1.95, 0.65 and 0.53, respectively. The half times of N, P, K, Ca and Na required for the remove or accumulation of the litter on the grassland floor were 1.23, 0.57, 0.36, 1.06 and 1.32 years, respectively. The increasing order of the turnover parameters of the elements was Na, N, Ca, P and K.

Key words : Removal rate, Accumulation, *Phragmites longivalvis*, Nakdong River

INTRODUCTION

The amount of production of a *Phragmites longivalvis* grassland is closely related to the levels of available mineral nutrients when soil humidity is sufficient. According to Kim and Chang(1975), the ratio of production and decomposition of the litter affords a reliable index to evaluate the soil conditions. Men who manage a grassland must not only understand the transformation and remove of mineral nutrient elements into grassland soils are not clearly defined. Also, investigations are needed to elucidate the amount of sufficient supply of mineral nutrients for the maximum productivity in the grasslands.

Numerous investigators(Greenland and Nye, 1956; Jenny *et al.*, 1959; Olson, 1963; Oohara *et al.*, 1971; Chang and Yoshida, 1973; Kim and Chang, 1975; Chang *et al.*, 1987; Chang and Oh, 1995) have used the mathematical model to describe the changes of mineral nutrient elements in soil as a function of time.

Since in the grasslands of the steady state the net velocity of change in the annual addition of N, P, K, Ca and Na into soil or water is equal to the rate of the annual removal, this study has been performed to elucidate the accumulation and mineralization of organic N, P, K, Ca and Na on the grassland floor of the *P. longivalvis* in a delta of the Nakdong River.

EXPERIMENTAL METHODS

1. Study area

As shown in the paper of Chang and Oh(1995), the study area is a delta of the Nakdong River and is located 13 km southeast of Kimhae, Gyungsangnam-do(E 128°57′, N 35°06′).

The climate of the study area is a continental one with hot wet summer and cold dry winter and the rainfall of the same area hovers between 1,300mm and 1,400mm annually. About 59% of the rainfall has been recorded during summer, from June to September (Chang and Oh, 1995).

2. Methods

The litter samples were collected by the quadrat method from the L, F, H and A_1 horizons in the *P. longivalvis* grassland of a delta of the Nakdong River in August, 1976 and 1994. The litter production was calculated on a dry weight basis. Total nitrogen was determined by the Kjeldahl method. Organic P, K, Ca and Na were estimated as the difference between the inorganic P, K, Ca and Na extracted from comparable ignited at 550℃ and unignited samples. Available phosphorus was determined by the molybdenum blue stanmous chloride method.

Exchangeable K, Ca and Na were extracted with in 1N NH_4OAC solution of pH 7.00. The levels of K, Ca and Na in these extracts were determined by the flame photometry and an atomic absorption spectro-photometer(Model 303).

THEORETICAL MODELS

The basic concepts of the decay of the litter can also be applied to the mineralization of organic N, P, K, Ca and Na(Chang and Yoshida, 1973; Chang and Oh, 1995). Therefore, the net velocities of change in amounts of N, P, K, Ca and Na in a grassland ecosystem of a delta of the Nakdong River are equal to the rate of addition minus the rate of mineralization and remove.

For the model of the steady addition of minerals such as N, P, K, Ca and Na to an unit area of soil sampled in the depth the fundamental equation is

$$\frac{dM}{dt} = A - rM \quad \cdots\cdots (1)$$

where t is time, M is the amount of a mineral nutrient elements per unit area in soil sampled in the depth d, A is the annual addition of a mineral nutrient element to an unit area of soil sampled in depth d and r is the removal constant of the mineral nutrient elements per year.

1. The storage by continuous addition of a mineral nutrient elements

To calculate the yield of a mineral nutrient, the equation(1) can be rewritten as integrating and transposing,

$$M = \frac{A}{r}[1-\exp(-rt)] \quad \cdots\cdots (2)$$

where $\frac{A}{r}$ is the steady state of the storage of the mineral nutrients on the floor soil.

2. The remove with no addition of a mineral nutrient elements

For the special case of A=0, the equation(1) can be rearranged to express the removal as fraction of the residue mineral nutrient currently remaining.

$$\frac{dM}{dt} = -rM \quad \cdots\cdots (3)$$

The integrated equation(3) is

$$M = Mo\ \exp(-rt) \quad \cdots\cdots (4)$$

It permits the calculation of the time required to remove 50, 95 and 99% of an initial level. That is, these are expressed as $t_{\frac{1}{2}}=0.693/r$ in the case of 50%, as $t_{\frac{1}{20}}=3/r$ in the case of 95% and as $t_{\frac{1}{100}}=5/r$ in the case of 99%.

3. The evaluation of the removal constant r

The radio-tracer and dating techniques have been used to show that various fractions of organic mineral nutrients removed in various velocities. When the accumulation of mineral nutrient elements reaches the steady state condition, Mss, in a grassland ecosystem, the rate of annual addition A is the same with the rate of removal. Therefore, dM/dt is equal to zero.

$$A - rMss = 0 \qquad (5)$$

In this case, the removal constant r can be estimated by

$$r = \frac{A}{Mss} \qquad (6)$$

where A and r can be estimated independently upon M, then their ratio might be used to predict the steady state level in a grassland ecosystem which has not yet come to a balance of addition and remove.

$$Mss = \frac{A}{r} \qquad (7)$$

RESULTS AND DISCUSSION

The site selected for this study is the grassland of *P. longivalvis* in a delta of the Nakdong River. The annual production and removal of N, P, K, Ca and Na on the grassland floor were estimated in this area.

1. Annual production of organic minerals

Table 1 shows the annual production and accumulation of dry weight, organic matter

Table 1. The annual production of dry weight, organic matter and ash of the litter in the *P. longivalvis* grassland in a delta of the Nakdong River

Horizon	Dry weight(g/m^2)	Loss on ignition(%)	Organic matter(g/m^2)	Ash and soil(g/m^2)
L	1,090.8	93.55	1,020.4	70.4
F	907.9	80.05	726.8	181.1
H	511.1	42.55	217.5	293.6
A1	167.4	30.15	210.7	116.9

Table 2. The annual production and accumulation of N, P, K, Ca and Na of the litter in the *P. longivalvis* grassland in a delta of the Nakdong River

Horizon	N (g/m^2)	P (g/m^2)	K (g/m^2)	Ca (g/m^2)	Na (g/m^2)
L	7.068	1.320	2.480	1.031	1.286
F	8.516	0.572	0.590	0.620	1.534
H	3.281	0.388	0.517	0.698	0.583
A1	0.785	0.124	0.163	0.273	0.322

and ash of the litter. Table 2 presents the amount of the annual production of N, P, K, Ca and Na of the litter on the grassland floor of *P. longivalvis*. Oohara *et al.*(1971a) have reported that the amount of the litter production of a *P. longivalvis* grassland in Obihro was 95,811g /m². As shown in Table 1, the litter production of *P. longivalvis* grassland in a delta of the Nakdong River is higher than in Obihiro, Japan.

Fig. 1 shows a wide range in N, P, K, Ca and Na production, plotted along the vertical axis in terms of grams of N, P, K, Ca and Na per square meter per year.

Under the assumption that the grassland floor in the study area may approximate a steady state, one method of estimating the fraction r can be made from the ratio of the vertical and horizontal coordinates of each point in Fig. 1.

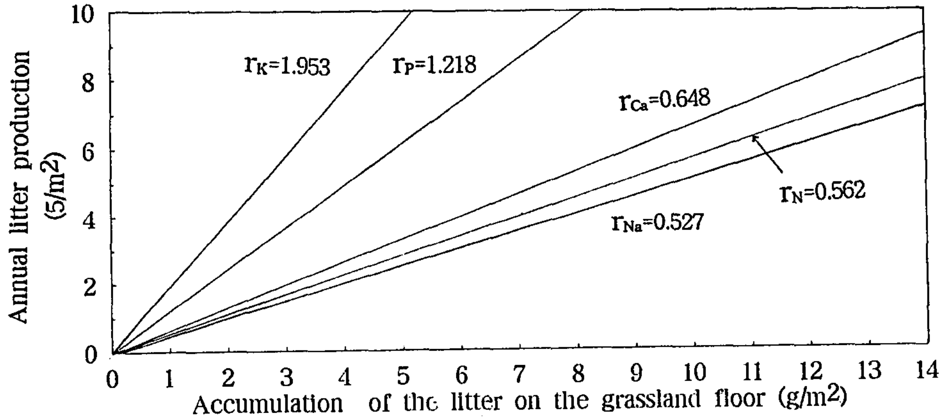

Fig. 1. Estimates of removal fraction r for N, P, K, Ca and Na in the *P. longivalvis* grassland from the ratio of annual addition, A, to the approximately steady state accumulation of the grassland floor, Mss.

2. Estimate of removal fraction r

The estimates of the removal fraction r for N, P, K, Ca and Na are collected in Fig. 1 and Table 3. It was determined by the equation(6) or Fig. 1 from the data of Table 2. These values of N, P, K, Ca and Na show 0.562, 1.218, 1.953, 0.648 and 0.527 on the *P. longivalvis* grassland floor, respectively.

Oohara *et al.*(1971a,b,c, 1972) reported that the turnover fractions of N, P, K, Ca and Na in the *P. longivalvis* grassland in Obihiro in Japan were 0.148, 0.393, 0.322, 0.114 and 0.033, respectively. These values are less than those in a delta of the Nakdong River in Korea. It seems to be the result of the fact that the climate of the delta of the Nakdong River in Korea is warmer than that of Obihiro, Japan. The fractions of N, P, K, Ca and Na corresponds not only to the wide variation between N, P, K, Ca and Na contents and annual productions of the litter but their contents of the soil profiles and their levels of

Table 3. Duration of accumulation and remove of N, P, K, Ca and Na on the grassland floor of *P. longivalvis* in the delta of the Nakdong River

Elements	r	1/r	$t_{\frac{1}{2}}$(years)	$t_{\frac{1}{20}}$(years)	$t_{\frac{1}{100}}$(years)
N	0.562	1.779	1.23	5.34	8.90
P	1.218	0.821	0.57	2.46	4.11
K	1.953	0.512	0.36	1.54	2.56
Ca	0.648	1.543	1.07	4.63	7.72
Na	0.527	1.898	1.32	5.67	9.49

the annual litter(Oohara *et al.*, 1971b).

3. Accumulation and remove of mineral nutrient elements

Accumulation of N, P, K, Ca and Na on the *P. longivalvis* grassland floor are expressed in Table 2. Amounts of the total storages of N, P, K, Ca and Na in this grassland were 19.65, 2.40, 3.71, 2.62 and 3.73 g/m^2, respectively. As the fraction r increases or decreases, the steady state level, Mss=A/r, decreases or increases accordingly.

Since N, P, K, Ca and Na are $N_o=0$, $P_o=0$, $K_o=0$, $Ca_o=0$ and $Na_o=0$ at t=0, the models of accumulation expressed by the equation(2) are given by

$$N = 12.58\,[1-\exp(-0.562\,t)] \quad \cdots (8)$$
$$P = 1.08\,[1-\exp(-1.218\,t)] \quad \cdots (9)$$
$$K = 1.27\,[1-\exp(-1.953\,t)] \quad \cdots (10)$$
$$Ca = 1.59\,[1-\exp(-0.648\,t)] \quad \cdots (11)$$
and
$$Na = 2.44\,[1-\exp(-0.527\,t)] \quad \cdots (12)$$

Since the removal fraction r has been determined by the equation(6), the removal models of N, P, K, Ca and Na for the *P. longivalvis* grassland in a delta of the Nakdong River can be obtained from the equation(4);

$$N = 12.58\,\exp(-0.562\,t) \quad \cdots (13)$$
$$P = 1.08\,\exp(-1.218\,t) \quad \cdots (14)$$
$$K = 1.27\,\exp(-1.953\,t) \quad \cdots (15)$$
$$Ca = 159\,\exp(-0.648\,t) \quad \cdots (16)$$
and
$$Na = 2.44\,\exp(-0.527\,t) \quad \cdots (17)$$

The graphical changes of accumulation and remove of N, P, K, Ca and Na on the grassland floor were expressed in Fig. 2. The removal curve is the mirror image of the curve for accumulation of N, P, K, Ca and Na on the grassland floor.

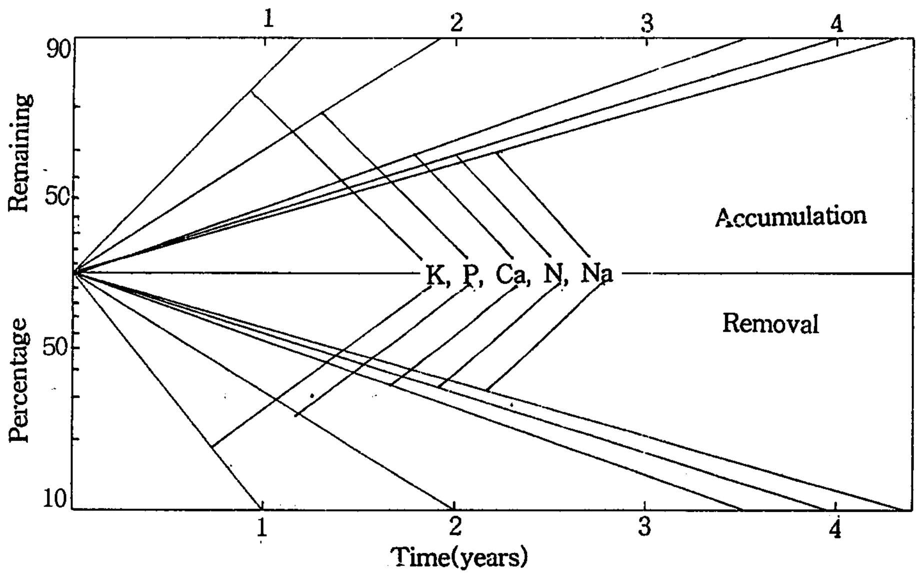

Fig. 2. Exponential models of accumlation and remove for N, P, K, Ca and Na of the litter in the *P. longivalvis* grassland in the delta of the Nakdong River.

4. Annual remove cycles of N, P, K, Ca and Na

The convenient virtue of the exponential model is that the time required to reach 50, 95 and 99 percent to the steady state level is the same as that required for removal of accumulated N, P, K, Ca and Na. These periods are given by the solution of the equation (4) substituting the values of the fraction r. These data are shown in Table 3.

The increasing order of the turnover parameters for mineral nutrient elements was Na, N, Ca, P and K(Table 3). As compared with the results of Oohara *et al.*(1971a,b,c and 1972), the removal rate parameter for Na was least of those mineral nutrient elements. According to Chang and Yoshida(1973), the turnover rate of k was greater than any of the other elements mentioned above.

In agreement with the results of Oohara *et al.*(1971a and 1972) organic K was decomposed faster than any other elements such as N, P, Ca and Na. Generally the turnover rate of organic N in the litter on the grassland floor is less than the decay rates of other organic minerals except Na.

요 약

낙동강 하구 삼각주의 갈대초지에 있어서 낙엽의 N, P, K, Ca 및 Na의 유실률을 조사한 결과

는 다음과 같다.

1. N, P, K, Ca 및 Na의 유실률과 유실에 소요되는 시간은 이론적 model에 의해 계산하였다.
2. N, P, K, Ca 및 Na의 removal constant는 각각 0.5672, 1.218, 1.953, 0.648 및 0.527이었다.
3. 낙동강 하구 삼각주의 갈대초지에 있어서 낙엽의 N, P, K, Ca 및 Na의 유실과 축적에 대한 점근선의 절반에 도달하는데 소요되는 시간은 각각 1.23, 0.57, 0.36, 1.06 및 132년이었다.

REFERENCE

1. Chang, N.K. and S. Yoshida. 1973. Studies on the gross metabolism in a Sasa paniculata type grassland Ⅲ. The decay system of the litter. J. Japan Grassl. Sci. 19:341-357.
2. Chang, N.K. and K.H. Oh. 1995. The removal rate of the constituents of the litters in the aquatic plant ecosystems 1. *Phragmites longivalvis* grasslands in a delta of the Nakdong River(in press).
3. Chang, N.K., S.K. Lee, B.S. Lee and H.B. Kim. 1987. The litter accumulation, decay and turnover models and their varidation. Korean J. Ecol. 10(3);139-149.
4. Grassland, D.J., and P.H. Nye. 1956. Increases in the carbon and nitrogen content of tropical soils under natural fallows. J. Soil sci. 10;284-299.
5. Jenny Hans, S.P. Gessel and P.T. Bingham. 1959. comparative study of decomposition rates of organic matter in temperature and tropical regions. Soil Sci. 10;400-432.
6. Kim, C.M., and N.K. Chang. 1975. The decomposition rate of pine and oak litters affecting the amount of mineral nutrients of forest soil in Korea. The collection of papers in commemoration of the sixty anniversary of Dr. Kim's birth;104-111.
7. Olson, J.S. 1963. Energy storage and the balance of producers and decomposers in ecological system. Ecology 44;322-330.
8. Oohara, H., N. Yoshida and N. K. Chang. 1971a. Balance of producers and decomposers in a grassland ecosystem in Obihiro. Ⅳ. Nitrogen cycle. J. Japan Grassl. Sci. 17;97-105.
9. Oohara, H., N. Yoshida and N. K. Chang. 1971b. Balance of producers and decomposers in a grassland ecosystem in Obihiro. V. Phosphorus cycle. Res. Bull. Obihiro Univ. 7;165-175.
10. Oohara, H., N. Yoshida, K. Ito and N. K. Chang. 1971c. Balance of producers and decomposers in a grassland ecosystem in Obihiro. Ⅵ. Cycles of potassium, calcium and magnesium. Res. Bull. Obihiro Univ. 7;176-188.
11. Oohara, H., N. Yoshida and N. K. Chang. 1972. Balance of producers and decomposers in a grassland ecosystem in Obihiro. Ⅶ. Movement of Na, Fe, Mn, Zn, Cu, Co and Ni. J. Japan Grassl. Sci. 18;75-84.

Annual litter production (5/m²) Accumulation fo the litter on the grassland floor (g/m²)

10 8 6 4 2 0 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 r_K=1.953 r_P=1.218 r_{Ca}=0.648 r_N=0.562 r_{Na}=0.527

Percentage Remaining Time(years) 90 50 50 50 1 2 3 4 1 2 3 4 K, P, Ca, N, Na Accumulation Removal