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The Energy Flow and Mineral Cycles in a *Zoysia japonica* and *Miscanthus sinensis* Ecosystem on Mt. Kwanak 2. Organic Matter Synthesis and Decomposition Balance

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관악산의 잔디와 억새 생태계에 있어서 에너지의 흐름과 무기물의 순환 2. 유기물의 합성과 분해의 평형

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ABSTRACT

An investigation was performed to reveal the relation of the production and decomposition of the *Zoysia japonica* and *Miscanthus sinensis* litters on Mt. Kwanak.

The decay constant k of litters was as follows; k of *Zoysia japonica*, k=0.44, k of *Miscanthus sinensis*, k=0.33. The time required for the decomposition of half of the accumulated organic matter of *Zoysia japonica* and *Miscanthus sinensis* was 1.6 and 2.1 years, respectively. The amount of mineral nutrients returned annually to soil is faster in the *Zoysia japonica* grassland than in the *Miscanthus sinensis* grassland on Mt. Kwanak.

Key words: Organic matter synthesis, Decomposition balance.

INTRODUCTION

The ratio of annual production and decomposition of litters affords a reliable index to evaluate the mineral nutrient cycles. Acording to Jenny, Gessel and Bingham(1959), Olson(1963), Chang *et al.*(1987a, b), Chang *et al.*(1990), and Chang *et al.*(1991), the annual production of organic matter in the form of the litter of leaves and twigs is much higher in the tropical than in the temperate vegetations, but the rate of turnover of the litters is in inverse relation. Consequently, the storage of organic carbon on the top soil of the tropical vegetations is low in spite of the high production of the litter in comparison to the high level of carbon accumulation in the less productive temperature vegetations. According to Olson(1963), this inverse relation is due to the decomposition rate of the annual dead organic matter, and the chemical composition of the litter as well as low temperature is a reason for the decomposition of turnover of the litter on forest and grassland floors. The direct object of this study was to reveal the relation of the production and decomposition of the *Zoysia japonica* and *Miscanthus sinensis* litters and to trace the amount of mineral nutrients returned to the mineral soils.

EXPERIMENTAL METHODS

Litters of *Zoysia japonica* and *Miscanthus sinensis* are collected from one square meter of the ground surface on Mt. Kwanak at the end of the growing season, 1995. The annual production of the litter and the accumulation of humus on the F, H, A1 layers were measured.

Two grams of litter was heated at 450℃ for 24 hours. After ashing the litter, N, P and K have been analyzed by the methods as follows ;

Soil organic matter was determined by the loss on ignition. Total nitrogen was determined by the Kjeldahl method. Phosphorus was precipitated as the standard molybdate method and determined by using colorimeter. Potassium was determined by using flame photometer.

RESULTS

1. The decopostion of litters

In the decomposition of litters, let the amount of organic matter or organic carbon in the litter per square meter of the ground surface be O, the annual increment of organic matter be L, and the varing amount of O per unit time(Δt) be ΔO. If Δt and ΔO approach zero, then

$$\frac{dO}{dt} = L - kO \quad \cdots\cdots (1)$$

In the above equation k is a decay constant.

If the accumulation of the litter shows no variation and reaches a steady state level, Oss, then the rate of change in the equation (1) is zero. Therefore,

$$L = kOss$$

In this case, the decay constant k can be estimated by the following equation.

$$k = \frac{L}{Oss} \quad \cdots\cdots (2)$$

L is an annual production of the dead leaves(Lf), stems(Ls), twigs(Lt) and barks(Lb),

Table 1. Decay constants of organic matter for the accumulation and decomposition of litters of *Zoysia japonica* and *Miscanthus sinensis* grasslands on Mt. Kwanak

Grassland	Unit	L	F	H	A1	k
Zoysia japonica	g / m^2	560.2	105.1	91.5	1,081.5	0.44
Miscanthus sinensis	g / m^2	654.1	1,315.1	488.9	192.7	0.33

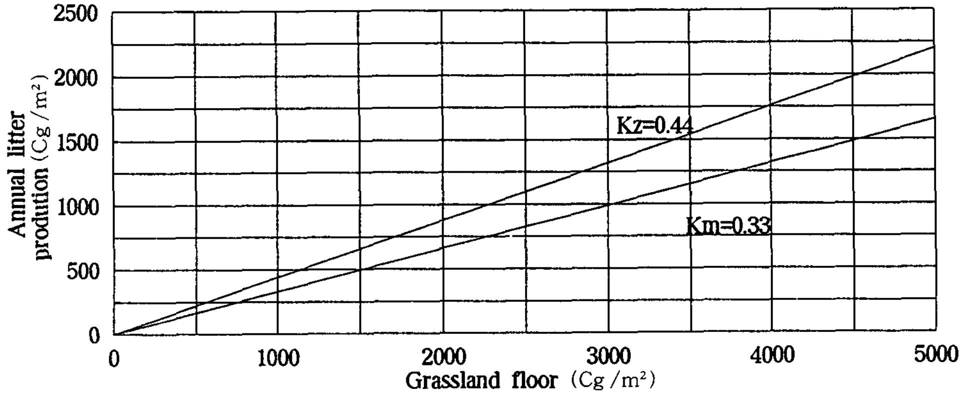

Fig. 1. The decay constant k for organic matter in the *Zoysia japonica* and *Miscanthus sinensis* litters on Mt. Kwanak.

so

$L = Lf + Ls + Lt + Lb.$

Oss is the total amount of organic matter of F, H, and A1 layers on the mineral soil, that is,

$Oss = Of + Oh + Oa1$

If the accumulation of the *Zoysia japonica* and *Miscanthus sinensis* litters on Mt. Kwanak reaches a steady state level, the decay constant k can be calculated by the equation (2).

The decay constant k is 0.44 and 0.33 for the *Zoysia japonica* and *Miscanthus sinensis* litters, respectively(Table 1). The decay constant k for organic matter in the *Zoysia japonica* and *Miscanthus sinensis* litters is illustrated in Fig. 1.

If the artificial case in which there is no litter fallen, L=0, the organic matter accumulated on the top of mineral soil would be gradually decreased by the lapse of time. So the equation (1) can be rewritten as follow ;

$$\frac{dO}{dt} = -kO \qquad (3)$$

Multiplying by dt / O, the equation (3) becomes

$$\frac{dO}{O} = -kdt \qquad (4)$$

The decoposition represented by the equation (4) is a mere fraction of the organic matter currently remaining. Let the initial amount of organic matter at t=0 be Oo, and the amount remaining after a certain period of time t be O, the equation (4) can be rearranged as follow in estimating the decay constant,

$$\ln\left(\frac{O}{Oo}\right)= -kt \quad \cdots\cdots (5)$$

Antilogarithms of both sides of the equation (5) give the fraction remaining as a negative exponetial function.

$$\frac{O}{Oo} = \exp(-kt) \quad \cdots\cdots (6)$$

Tne example of this curve is shown in Fig. 3a.

The time t which required for the organic matter O to decrease up to half(50%) of Oo can be calculated from the equation (6).

$$\frac{\frac{Oo}{2}}{Oo} = \exp(-kt)$$

$$\frac{1}{2} = \exp(-kt)$$

Taking logarithms of both sides, the above equation becomes $\ln 1/2 = -kt$

$$t = -\frac{\ln\frac{1}{2}}{k} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

Let t 0.50 be the value of t above, then

$$t_{0.50} = \frac{0.693}{k} \quad \cdots\cdots (7)$$

Then the O decreases to 95% and 99% of Oo, the value of t is as following respectively;

$$t_{0.95} = \frac{3}{k} \quad \cdots\cdots (8)$$

$$t_{0.99} = \frac{5}{k} \quad \cdots\cdots (9)$$

The equation (7) may be viewed as a half time in the accumulation or the decomposition of litters. This half time has an analogy with the radioactive half time. The time period 3/k means the time required for attaining 95% of the final level of accumulation or decomposition of the litters, while 5/k should appoximate the time needed to reach 99% of the final level. The reciprocal can be viewed as the time constant for the cycle of organic matter and mineral nutrients in the grassland and the forest ecosystems, and such numbers are readily obtainable from the tables of logarithms (Table 2).

Table 2. The decay constant for exponential decomposition of organic matter in the *Zoysia japonica* and *Miscanthus sinensis* grasslands on Mt. Kwanak

Grassland	Loss constant 1/k	Half-time 0.693/k	99% time 3/k	99% time 5/k
Zoysia japonica	2.27	1.6	6.8	11.4
Miscanthus sinensis	3.03	2.1	9.1	15.2

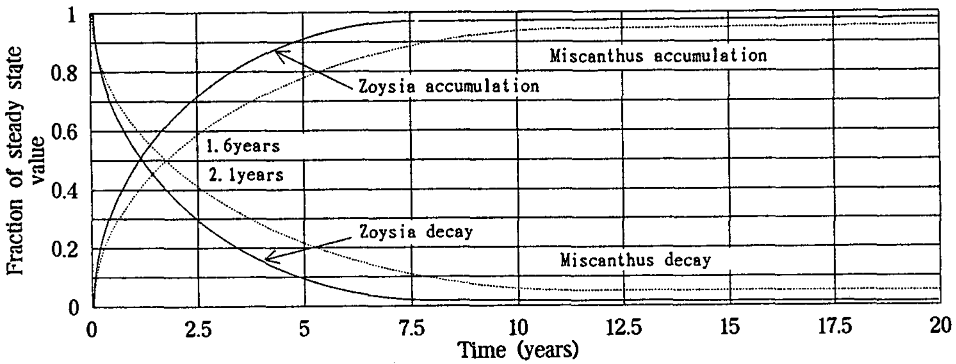

Fig. 2. The showing relation of the accumulation and decomposition of the litters of the *Zoysia japonica* and *Miscanthus sinensis* grasslands on Mt. Kwanak. Dashed lines for accumulation toward the steady state and solid lines for decrease from the steady state.

As the Table 2 shows, the time needed to reach half loss of organic matter are 1.6 and 2.1 years while for 95% and 99% loss, 6.8, 11.4 and 9.1, 15.2 years in the *Zoysia japonica* and *Miscanthus sinensis* grasslands, respectively. However, the final level of the steady state should vary with the increase or decrease of k values. Therefore, the time needed to reach the steady state is different not only among different grass species, but also according to the levels of nutrient, moisture and temperature of the grasslands. Fig. 2 illustrates the lines for accumulation and decomposition of litters of the *Zoysia japonica* and *Miscantus sinensis grasslands* on Mt. Kwanak.

If litters fall with an almost constant level, the equation (1) can be rewritten after dividing all terms by k ;

$$\frac{dO}{kdt} = \frac{L}{k} - O$$

This equation has been integrated ;

$$\ln(\frac{L}{k} - O) = -kt + \text{constant} \quad \cdots\cdots (10)$$

The initial quantity of litters on grassland and forest floors at t=0, O is zero, then

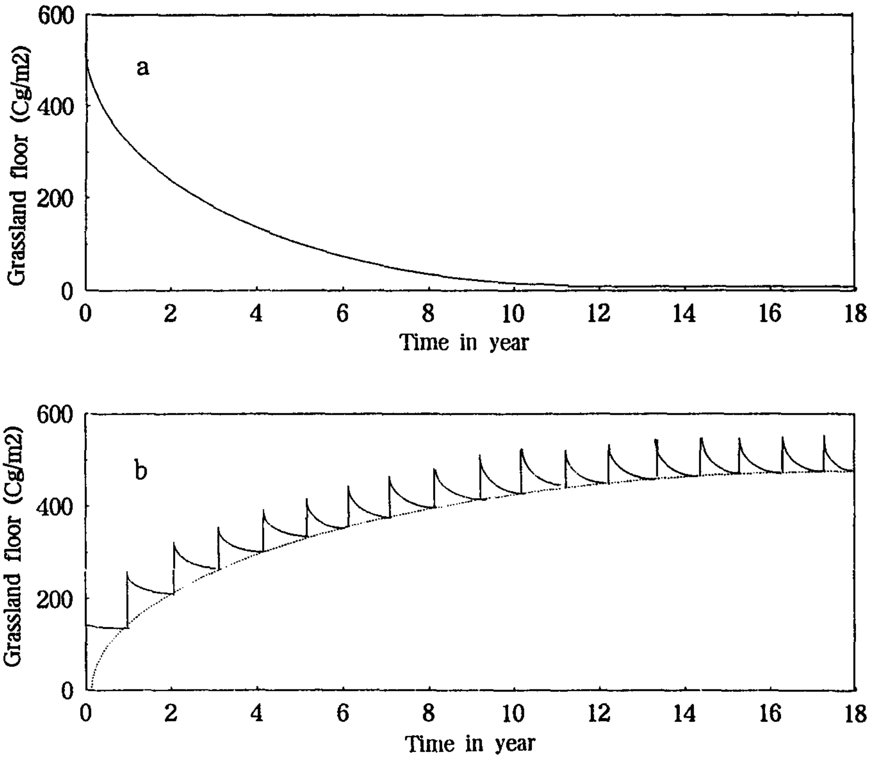

Fig. 3. Decay and accumulation of litters in *Zoysia japonica* grassland.
a. Negative exponential curve for the *Zoisia japonica* litter decay assuming weight loss proportional to the amount remaining at any one time.
b. Gradually rising exponential curve for the accumulation under conditions of fall and loss of litters in a *Zoysia japonica* grassland.

$$\ln \frac{L}{k} = \text{constant}$$

Therefore, the antilog of the equation (10) gives the solution a rising curve like that shown in Fig. 3b.

$$O = \frac{L}{k}[1 - \exp(-kt)] \quad \cdots\cdots (11)$$

Litter falls at the end of the growing season, hence the loss rate kC is determined by the below equation.

$$kO = L[1 - \exp(-kt)] \quad \cdots\cdots (12)$$

The equation (11) is the mirror image of the curve for the decay shown in Fig. 3a and 4a, which, as the time lapses, still is rising up to the steady state with a zigzag path caused by the accumulation and the decay of the litters.

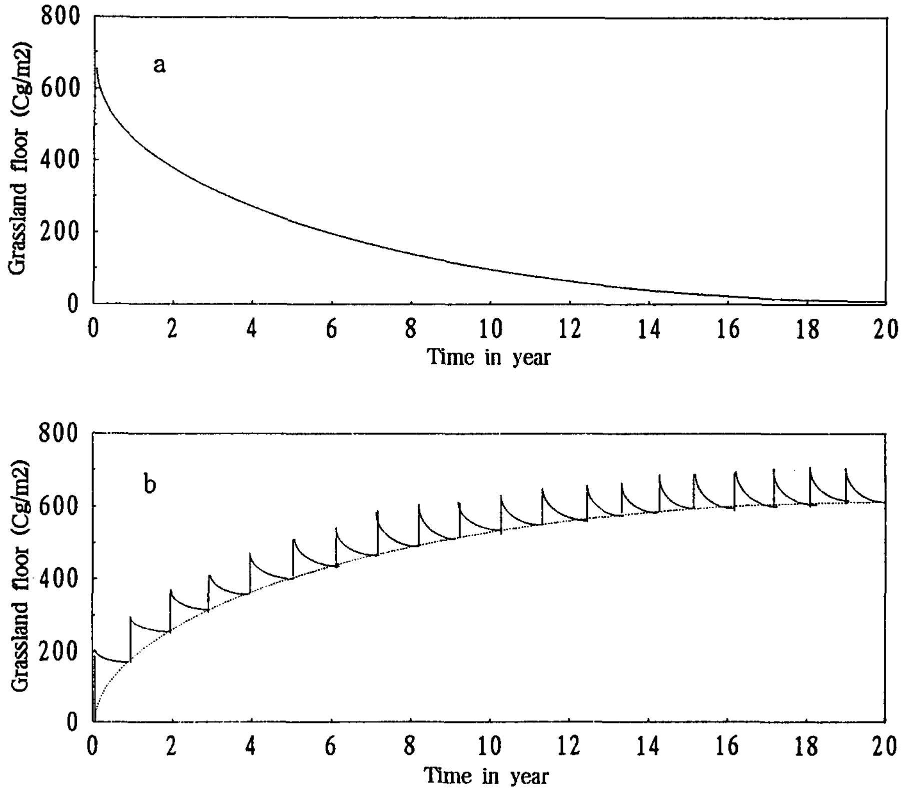

Fig. 4. Decay and accumulation of litters in *Miscanthus sinensis* grassland.

a. Negative exponential curve for the *Miscanthus sinensis* litter decay assuming weight loss proportional to the amount remaining at any one time.

b. Gradually rising exponential curve for the accumulation under conditions of fall and loss of litters in a *Miscanthus sinensis* grassland.

DISCUSSIONS

Since the litter is generally related to the quantity of photosynthetic organs such as leaves, it can be an index showing poductivity of grass and tree species. According to Ovington and Heitkamp(1960), when the amount of organic matter of energy fixation on the forest floor is considered, conifers tend to be more efficient than hardwoods. In this experiment it is recognized that the amount of freshly fallen leaves and twigs are higher in the oak forest floor. However, the total organic matter on the top soil including humus of A1 layer is higher in the pine forest. The major reason for this fact is the slow decomposition of pine residues. Thus, the production and decomposition of organic matter are not closely related. The depth of humus on the ground surface in the temperature region is different among tree species. According to Olson(1963), when the value of parameter k nears 0.003, about 1,000 years would be needed to attain 95% of the steady state level. Jenny, Gessel and Bingham(1959) reported that the time required to reach near-equilibrium accumulation of the forest floor is calculated to be less than a decade in tropical forests, 30 to 60 years under California oak, and 100 to 200 years under Ponderosa pine in temperate forests.

Comparing the production and decomposition of the *Zoysia japonica* and *Miscanthus sinensis* grasslands at the Kwanak, it is clear that the amount of annual litter fall is higher in the *Miscanthus sinensis* grasslands than in the *Zoysia japonica* grasslands, and the rate at which the litter breaks down is lower in the *Miscanthus sinensis* grasslands. Consequently more mineral nutrients would be returned to soil from dead organic matter of *Zoysia japonica*. Hence, the change in production or decomposition of litters controlled by grass species may modify the amount of mineral nutrients returned to soil and lead in turn to the soil conditions. Kim(1965) has reported that nutrient holding capacity of woodland soils is affected by tree species. According to Daubenmire(1956), The change of forest type may contribute to modifying the soil profile within a few decades in northeastern regions of America. Such change in the soil conditions may in some cases facilitate the introduction of new species during succession.

적 요

본 연구는 관악산의 남사면에 발달하여 있는 잔디와 억새초지의 낙엽의 연생산과 분해와의 관계를 연구하였다. 그 결과는 다음과 같다.

잔디와 억새의 낙엽이 초지생태계 속에서 분해하는 분해상수 k의 값은 각각 0.44 및 0.33으로 잔디의 낙엽의 분해상수가 억새의 낙엽의 분해상수보다 컸다. 초지토양에 축적된 유기물이 50%로 분해하는 데 필요한 시간은 잔디와 억새초지에서 각각 1.6년 및 2.1년이 였다. 축적된 유기물이 95%와 99% 분해하는 데 필요한 시간은 각각 잔디와 억새초지에서 6.8년과 9.1년 및 11.4년과 15.2년이 였다. 그러므로 매년 토양으로 되돌아가는 식물의 무기양분은 억새초지에서 보다도 잔디초지에서 더 빠르다는 것을 알 수 있었다.

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