

# Nitrogen and Phosphorus Cycles in the *Glyceria leptolepis* Ohwi Population at the Mt. Geumoh Basin

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金烏山 盆地の 왕미꾸리광이 (*Glyceria leptolepis* Ohwi)  
個體群의 窒素 및 磷의 循環

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## ABSTRACT

The seasonal pattern of pool size and withdrawal from senescing or storage organ, and the annual magnitude of internal- and plant-soil cycles for nitrogen and phosphorus in a *Glyceria leptolepis* Ohwi population in a marsh of the Mt. Geumoh were investigated. The population pool changed from initial size of 6.8 to the maximum of 16.1 gN m<sup>-2</sup> for N and from 1.7 to 3.9 gP m<sup>-2</sup> for P, maintaining far higher relative pool size during the first half of the growth period as compared with that for biomass. A sharp increase in N and P pool was noticed in early spring before the biomass growth was recognized. The major process supplying the demand for N and P changed as the growth progressed showing the order; absorption-withdrawal-absorption-withdrawal. The annual magnitude of internal cycle for N and P was estimated as 11.9 and 2.8 g m<sup>-2</sup>, accounting for 40 and 49 % of the annual demand, respectively. The annual magnitude of plant-soil cycle for N and P was 18.0~19.1 and 2.9~3.3 g m<sup>-2</sup>, accounting for 3 and 5 % of each nutrient pool in 0~20 cm humus layer, respectively. The higher extent of internal cycle and the lower rate of annual turnover for P(1.08) as compared with those for N may suggest that this population conserves and reuses P more efficiently than N.

## INTRODUCTION

Over the past decade it has been suggested that nutrient redistribution within the plant body including withdrawal from senescing leaves is an important pathway of ecosystem nutrient cycles. This pathway has been termed 'biochemical or internal cycle' (Switzer and Nelson, 1972; Attiwill *et al.*, 1978), which has been regarded as to be more significant in the soil of insufficient nutrient availability (Stachurski and Zimka, 1975; Turner, 1977; Westman, 1978; Gray and Schlesinger, 1983; Shaver and Melillo, 1984), though

the contrasting results were suggested by a few researchers (Ostman and Weaver, 1982; Chapin and Kedrowski, 1983). However, the study on this cycle or plant-soil cycle has been conducted in few grass lands but mainly in forest by estimating the content of nutrient of mature and dying leaves, litter fall and nutrient leaching.

We have investigated on the nutrient cycle in a grassland in the Mt. Geumoh basin (ca. 800 m altitude), and found that the phosphorus internal cycle in the *Helianthus tuberosus*, *Artemisia princeps* and *Phalaris arundinacea* populations supplied 59, 41 and 31% of the annual phosphorus demand, respectively (Lyu and Song, unpublished). The present paper reports on the seasonal trends of pool size and withdrawal, and the annual magnitude of internal and plant-soil cycles for nitrogen and phosphorus in the *Glyceria leptolepis* Ohwi population in a marsh of the Mt. Geumoh.

## MATERIALS AND METHODS

**Study site, sampling and chemical analysis** The study site was located at 800 m altitude in the Mt. Geumoh basin (Gumi, Kyungpook; 987 m altitude) (Lyu and Song, 1986). The basin had a few small marshes which were covered by a humus layer of about 20 cm in depth. A pure population of *Glyceria leptolepis*, which occurred in one (ca. 2,500 m<sup>2</sup>) of the marshes, was sampled every two weeks from March to November, 1984. Above-ground parts in three quadrats of 20·20cm<sup>2</sup> which were similar to the standard quadrat in height and density of the population were clipped at each 20 cm stratum from the surface humus layer, and separated into each organ. Below-ground part at 0~20 cm depth, most of it was distributed within the humus layer, in the quadrat was gathered and separated into live and dead fractions. All samples were dried at 80°C for three days so that the dry weight of biomass, total nitrogen (N) and total phosphorus (P) were able to be determined. Total P content in each plant fraction was determined by ascorbic acid method after burning to ashes, extracting with HCl solution and diluting procedure as described in the previous paper (Lyu and Song, 1986). Total N content was determined by micro-Kjeldahl method.

**Determination of biomass inflow and outflow** The terms 'inflow' and 'outflow' represent the sum of the gain or demand of matters and the sum of the loss of matters in each organ, respectively. Inflow and outflow of biomass in above-ground part during each sampling interval were determined by overlapping two successive vertical distribution diagrams as described in the previous papers (Monsi and Saeki, 1953; Song and Monsi, 1974). Net biomass production in the above-ground part during a time interval was estimated as the biomass inflow minus biomass withdrawal from senescing part. The withdrawal was calculated by multiplying the outflow by the withdrawal ratio. The withdrawal ratio was determined as follows: dry weight of live fraction minus that of the senescing fraction in the same organ on the basis of the same area (leaf) or volume (stem and root)/dry weight of the live fraction. Biomass mortality in the above-ground

part during a time interval was estimated as the difference between the outflow and withdrawal. In the case of below-ground part, the decrement during the first half of the growth period and the increment during the second half of the growth period were regarded as a result of the biomass withdrawal. The dead fraction taken during the sampling interval was regarded as the net loss.

**Determination of inflow and outflow of nitrogen and phosphorus** Inflow and outflow of N and P during each sampling interval were determined by the same method as used for determining the inflow and outflow of biomass. Net absorption of the nutrients by roots during each sampling interval was approximated as the inflow minus the withdrawal from senescing and storage organ during that interval. The withdrawal of the nutrients was determined by multiplying the outflow by the withdrawal ratio which was estimated by obtaining the difference between the nutrient content of senescing fraction and that of the live fraction in the same organ (Hirose, 1971). The nutrient decrement in below-ground part during the first half of the growth period was regarded as a result of translocation toward above-ground part, because little amount of dead fraction was found during that growth period. The increment during the second half of the growth period was also regarded as a result of withdrawal from the above-ground part. The N and P in the fraction of below-ground part died during each sampling interval were regarded as net losses.

## RESULTS

### Seasonal changes of biomass, nitrogen and phosphorus pools

**Biomass pool** The biomass pool changed from initial dry weight of 260 to 1,436 g DM m<sup>-2</sup> in late August (Fig. 1). The increase was very slow for the first half of the growth period, and the vigorous increase began in mid-July. The peak of biomass for leaf, stem and reproductive organ reached by late July, early September and mid-August, respectively. Below-ground part tended to decrease until mid-July, and then it began to increase.

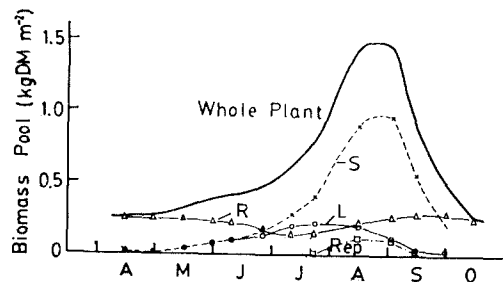


Fig. 1. Seasonal changes of biomass pool in the *G. leptolepis* population. L, leaf; S, stem; R, below-ground part; Rep, reproductive organ.

**Content of nitrogen and phosphorus** The N content in leaf increased at the first stage of growth and then decreased as the growth progressed, showing the variation range of 22.3~42.8 mgN g<sup>-1</sup>DM (Fig. 2). The N content in stem decreased sharply from the initial high value of 40.0 to 6.5 mgN g<sup>-1</sup>DM in late growth stage. In the case of below-ground part, the N content showed the change pattern of high-to-low-to-high, following a sharp increase during the soil thaw in early spring. The variation

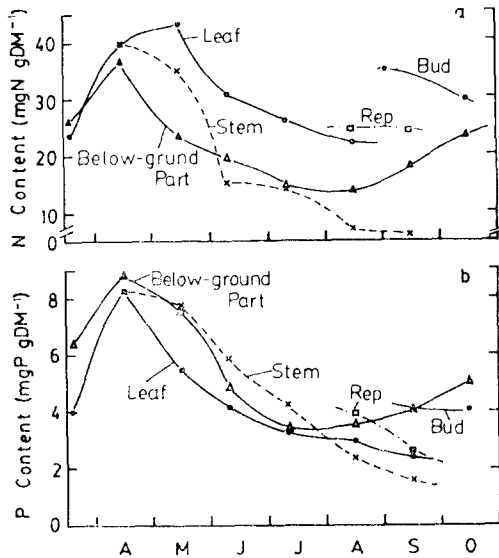


Fig. 2. Seasonal changes of N(a) and P(b) contents in each organ in the *G. leptolepis* population.

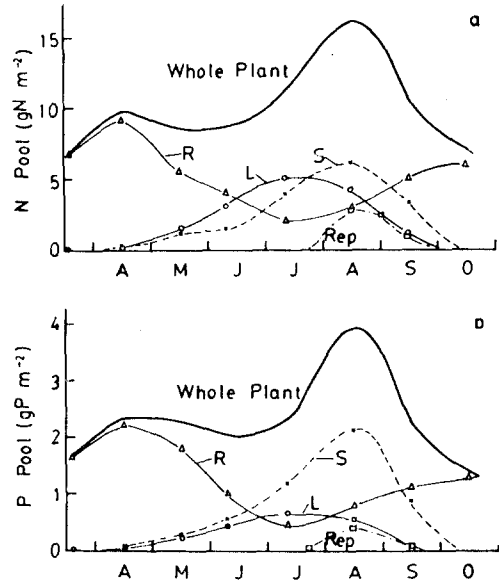


Fig. 3. Seasonal changes of N(a) and P(b) pools in the *G. leptolepis* population. L, leaf; S, stem; R, below-ground part; Rep, reproductive organ.

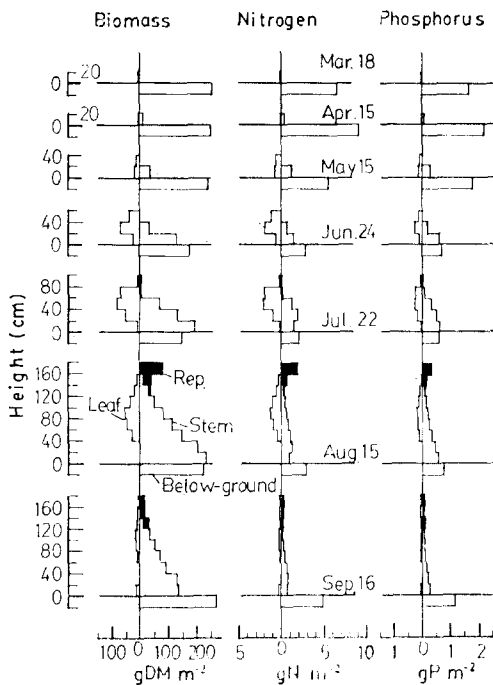


Fig. 4. Vertical distribution of biomass, N and P in the *G. leptolepis* population in 1984.

range of the N content was 13.6~36.6 mgN g<sup>-1</sup>DM.

The P content in above ground part decreased as the growth progressed following the sharp increase in early spring, showing the variation ranges of 2.41~8.45 and 1.30~8.45 mgP g<sup>-1</sup>DM for leaf and stem, respectively. The P content in below-ground part showed a sharp increase in early spring just as the case of N and then decreased showing the variation range of 3.40~8.83 mgP g<sup>-1</sup>DM.

**Nitrogen and phosphorus pools** The pools for N and P were determined by multiplying the biomass pool by each nutrient content. The population pool for N changed from initial size of 6.8 to the maximum of 16.1 gN m<sup>-2</sup> in mid-August (Fig. 3). The N pool of the below-ground part decreased continuously by late July and then increased gradually. The season-

nal pattern of population pool for P was similar to that for N, changing from initial level of 1.7 to the maximum of 3.9 gP m<sup>-2</sup> in mid-August. The pool of below-ground part showed the same seasonal pattern as the pattern of N pool.

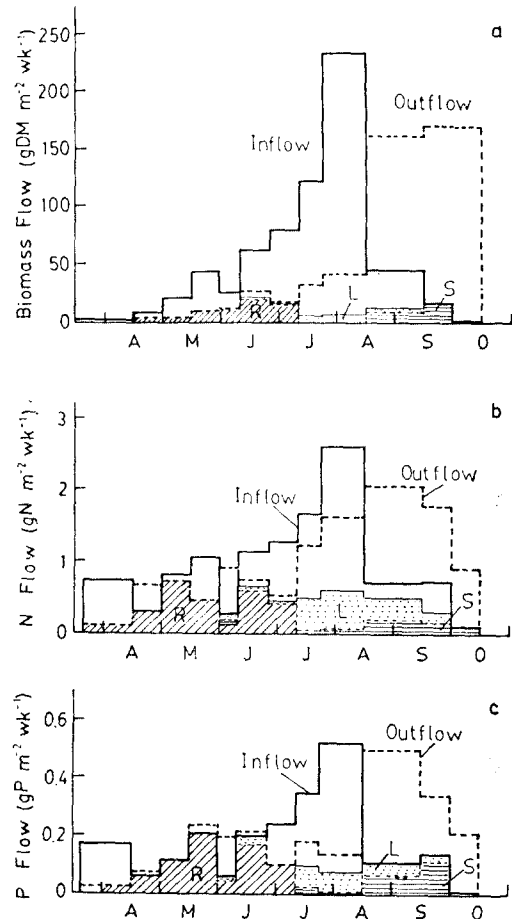
### Seasonal changes of biomass, nitrogen and phosphorus flows

**Vertical distribution of biomass, nitrogen and phosphorus** Fig. 4 showed the seasonal changes of vertical distributions for biomass, N and P, which were illustrated by determining standing crops of each organ at each 20 cm stratum in 1 m<sup>2</sup> area. We could see, from these diagrams, that N and P were distributed less in stem as compared with biomass. These diagrams were used for determining the inflow and outflow rates of the matters.

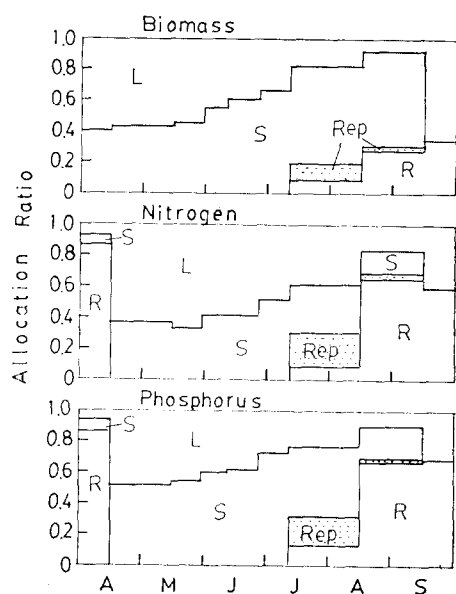
**Flow of biomass, nitrogen and phosphorus** The peak of biomass inflow rate was 232 gDM m<sup>-2</sup> wk<sup>-1</sup> in early August. The net production at that time was 226 gDM m<sup>-2</sup> wk<sup>-1</sup>. Most of the biomass withdrawal was derived from whole below-ground part in early growth period, from leaf in mid-growth period and from stem in late growth period. The extent to which the withdrawal contributed to the demand (or inflow) was lower in mid-growth period than in the other growth periods (Fig. 5a).

The maximum of N inflow rate was 2.6 gN m<sup>-2</sup> wk<sup>-1</sup> in early August. At that time the net absorption rate from soil was 2.0 gN m<sup>-2</sup> wk<sup>-1</sup> (Fig. 5b). It was noticed that ca. 14% of the annual N absorption of 18.0 gN m<sup>-2</sup> was absorbed in early spring before the growth of above-ground part was recognized.

The seasonal pattern of P inflow rate including withdrawal was similar to that of N inflow rate. The peak values were 0.52 gP m<sup>-2</sup> wk<sup>-1</sup> for inflow rate and 0.45 gP m<sup>-2</sup> wk<sup>-1</sup> for net absorption rate in early August (Fig. 5c). The P absorption in early spring prior to the above-ground growth was ca. 20% of the annual P absorption of 2.9 gP m<sup>-2</sup>.



**Fig. 5.** Seasonal changes of flow rate for biomass (a), N (b) and P (c) in the *G. leptolepis* population. R, L and S represent the withdrawal rate from below-ground part, leaf and stem, respectively.



**Fig. 6.** Seasonal changes of allocation ratio of biomass, N and P to each organ in the *G. leptolepis* population. L, leaf; S, stem; R, below-ground part; Rep, reproductive organ.

represent the amount of total N and P at 0~20 cm depth. The figures on arrows show the annual amount of matter flow. The dotted arrows mean the internal cycles.

The annual net biomass production was estimated as  $1,476 \text{ gDMm}^{-2}$ , but the sum of annual biomass growth of each organ became  $1,713 \text{ gDMm}^{-2}$  because the withdrawal from senescing or storage organ ( $237 \text{ gDMm}^{-2}$ ) was added to the net production. In the cycle schema, the amount of biomass growth of each organ was regarded as the amount of biomass allocated to each organ; the biomass annually allocated to leaf, stem, reproductive organ and below-ground part was 428, 1,015, 119 and  $151 \text{ gDMm}^{-2}$ , respectively. On the other hand, the annual biomass loss by death or shedding was  $1,508 \text{ gDMm}^{-2}$ .

The annual amount of N absorption was estimated as  $18.0 \text{ gNm}^{-2}$ . If the N withdrawal from senescing or storage organs ( $11.9 \text{ gNm}^{-2}$ ) was added to this absorption, the sum of the N allocated to each organ became  $29.9 \text{ gNm}^{-2}$ . The N loss by death or shedding was  $19.1 \text{ gNm}^{-2}$  which was a little more than the absorption.

In the case of P, the annual amount of absorption and withdrawal was 2.9 and  $2.8 \text{ gP m}^{-2}$ , respectively. And the annual loss by death or shedding was  $3.3 \text{ gP m}^{-2}$  which was also a little more than the annual absorption.

Conclusively the annual magnitude of plant-soil cycle was  $18.0\sim 19.1 \text{ gNm}^{-2}$  for N and  $2.9\sim 3.3 \text{ gPm}^{-2}$  for P, which account for only about 3 and 5% of each nutrient pool respectively in the 0~20 cm humus layer, and the annual internal cycle (i.e., annual withdrawal) supplied 40% of the annual demand for N and 49% for P, which were far higher than

### Allocation of biomass, nitrogen and phosphorus

The seasonal pattern of allocation of N and P inflow was different to that of biomass, showing a remarkable increase of allocation to below-ground part in early spring and late growth period (Fig. 6). The annual allocation to leaf, stem, below-ground part and reproductive organ was 40.2, 28.8, 9.7 and 21.3% of total inflow for N and 25.9, 41.3, 8.0 and 24.8% for P, respectively.

### Nitrogen and phosphorus cycles

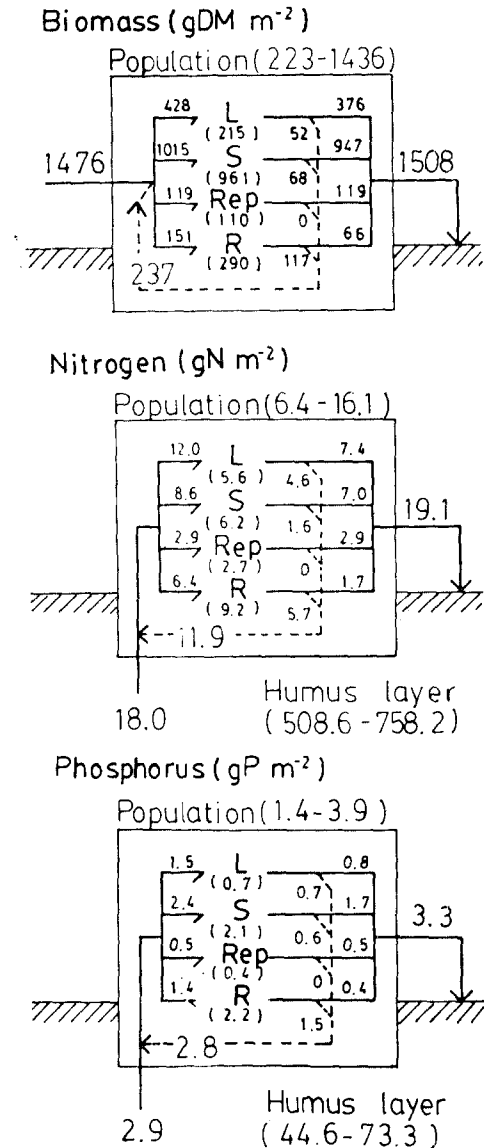
If the standing crop of each matter in plant population is regarded as a pool at the population or organ level, the annual amount of matters flowed through the pool can be expressed in cycle schema (Fig. 7). The figures in parentheses represent the maximum or variation range of each pool size. The N and P pools in humus layer

the value of biomass withdrawal (ca. 14%). On the other hand, the fact that the annual loss by death or shedding for these materials was larger than the annual net production or absorption may indicate that this plant population was in a state of degradation.

**DISCUSSION**

The differences between inflow rate and outflow rate of matters in a plant population result in the increment or decrement of the matter pools. Before the start of biomass growth, the relative pool size(i.e., the ratio of pool of each time to the maximum pool) of N(0.42) and P(0.42) was larger than that of biomass(0.18) (Fig. 8). Moreover the abrupt absorption of these nutrients prior to the biomass growth made the relative pool size of the nutrients far larger than that of biomass. It is also noticeable that the N and P pools of below-ground part decreased sharply in comparison with its biomass pool. These results suggest that this plant has a tendency to secure N and P in the early growing season and then translocate them toward above-ground part intensively. The same result for P in a few herbaceous plant populations as this has been reported in the previous paper (Lyu and Song, 1986).

The turnover rate of inflow(i.e., the ratio of net production or absorption rate to pool size) for biomass was higher than that for N and P over the growth period except for the early spring when the abrupt nutrient absorption occurred, showing the peak of 0.21 wk<sup>-1</sup> in early August, 0.15 wk<sup>-1</sup> in mid-July and 0.14wk<sup>-1</sup> in early August for biomass, N and P, respectively(Fig. 9). The annual turnover rate expressed in the ratio of annual production or absorption to annual mean population pool for each matter was 1.74, 1.57 and 1.08 for biomass, N and P, respectively. In a few perennial herbaceous populations



**Fig. 7.** Annual magnitude of internal and plant-soil cycles for biomass, N and P in the *G. leptolepis* population. L, leaf; S, stem; R, below-ground part; Rep, reproductive organ.

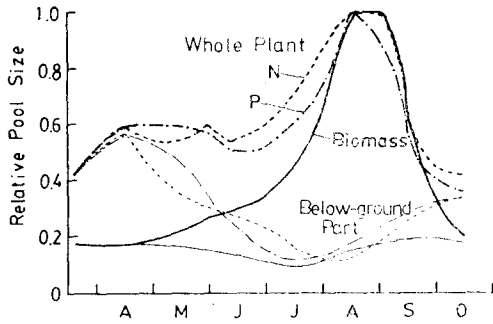


Fig. 8. Seasonal changes of relative pool size of whole plant population and below-ground part for biomass, N and P in the *G. leptolepis* population.

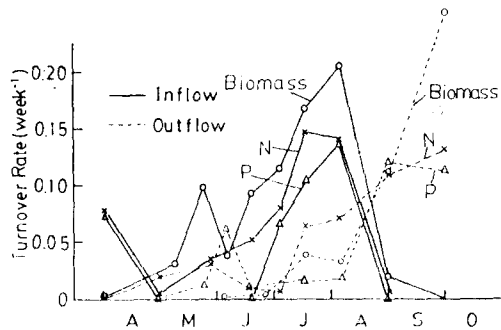


Fig. 9. Seasonal change of turnover rate for biomass, N and P in the *G. leptolepis* population.

occurred in the Mt. Geumoh basin, the mean annual turnover rate for N was larger than that for P, but in the *Solidago altissima* population occurred in the flood plain, Toride, Japan, the result was in contrast (Table 1).

Table 1. Annual demand, absorption(Absorp.), withdrawal(Withd.), the ratio of withdrawal to demand(W/D) and turnover rate(TR) for N and P in herbaceous plant populations

Species	Nut.	Demand	Absorp.	Withd.	W/D	TR	Ref.
		g m <sup>-2</sup> yr <sup>-1</sup>				yr <sup>-1</sup>	
<i>Glyceria leptolepis</i>	N	29.9	18.0	11.9	0.40	1.57	
	P	5.7	2.9	2.8	0.49	1.08	
<i>Helianthus tuberosus</i>	N	38.3	16.3	22.0	0.58	1.71	Lyu & Song unpub.
	P	11.4	4.7	6.7	0.59	1.18	
<i>Phalaris arundinacea</i>	N	39.7	24.8	14.9	0.38	1.82	Lyu & Song unpub.
	P	7.6	5.2	2.5	0.32	1.42	
<i>Solidago altissima</i>	N	33.5	14.3	19.2	0.57	1.29	Hirose 1971 & 74
	P	3.7	2.3	1.4	0.39	1.56	

The major process of contribution to the demand for N and P, that is, whether the demand was supplied mainly by withdrawal or by absorption, changed as the growth progressed, showing the order: absorption—withdrawal—absorption—withdrawal (Fig. 10). The same seasonal pattern as this for P has been observed in the *Artemisia princeps* and *Phalaris arundinacea* populations occurred in a grassland near the *Glyceria leptolepis* population (Lyu and Song, unpublished). The extent to which the P withdrawal supplies the P demand was higher and longer as compared with the extent to which N withdrawal supplies the N demand. The annual magnitude of internal cycle of N and P expressed in the ratio of withdrawal to demand varied with plant species, and the

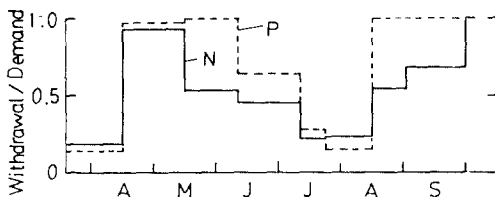


Fig. 10. Seasonal changes of the ratio of withdrawal to demand for N and P in the *G. leptolepis* population.

The extent to which the P withdrawal supplies the P demand was higher and longer as compared with the extent to which N withdrawal supplies the N demand. The annual magnitude of internal cycle of N and P expressed in the ratio of withdrawal to demand varied with plant species, and the



two nutrients in the same plant were also different in the annual magnitude of the internal cycle (Table 1). In the *G. leptolepis* population, the ratio of annual withdrawal to annual demand was 0.40 for N and 0.49 for P. The leaching of N and P from plant surface is small as compared with that of the other nutrients (Attiwill, 1968; Tukey, 1970; Luxmoore *et al.*, 1981), therefore a large magnitude of the internal cycle of the nutrients in a plant population is supposed to represent a high efficiency in reuse and conservation of the nutrients in the plant population. The larger magnitude of internal cycle with the lower annual turnover rate for P in this population as compared with those for N may indicate this population conserves and reuses P more efficiently than N.

### 摘 要

金烏山 盆地の 왕미꾸리광이 (*Glyceria leptolepis* Ohwi) 個體群을 對象으로 窒素(N) 및 燐(P)의 流出入의 계절변화와 植物—土壤間의 年間 循環량을 조사하였다.

個體群의 N푸울은 6.8에서 16.1 gN m<sup>-2</sup>로, P푸울은 1.7에서 3.9 gP m<sup>-2</sup>로 증가했으며, 生長前半期동안 植物量푸울보다 높은 相對푸울(各 時期의 푸울/最大 푸울) 값을 보였다. 生長期間中 P 및 N要求量에 대한 주요공급방법은 吸收—回收(또는 translocation)—吸收—回收의 순서를 보였다. N 및 P의 體內回收에 의한 年間 공급량은 각각 11.9 및 2.8 gm<sup>-2</sup>로서 年間 총요구량의 40 및 49%에 해당되었다. N 및 P의 年間 植物—土壤間 循環량은 각각 18.0~19.1 및 2.9~3.3 g m<sup>-2</sup>로서 土壤(깊이 20 cm이내) N·P푸울의 3~5%에 해당되었다. 이들 영양염과 植物量의 年間 손실량이 흡수량 및 生産量보다 많은 것으로 보아 이 個體群이 쇠퇴하고 있음을 알 수 있었다. N에 비해 P의 年間 內部循環(internal cycle) 率이 높고 年間 轉換(turnover) 率이 낮다는 것은 이 個體群의 P에 대한 보존성이 N에 대한 보존성보다 크다는 것을 의미하는 것으로 해석된다.

### LITERATURES CITED

- Attiwill, P.M. (1968). The loss of elements from decomposing litter. *Ecology*, **49** : 142~145.
- Attiwill, P.M., H.B. Guthrie and R. Leuning. (1978). Nutrient cycling in a *Eucalyptus obliqua* (L'Herit) forest. I, litter production and nutrient return. *Aust. J. Bot.*, **26** : 79~91.
- Chapin, F.S. III and R.A. Kedrowski. (1983). Seasonal changes in nitrogen and phosphorus fractions and autumn retranslocation in evergreen and deciduous taiga trees. *Ecology*, **64** : 376~391.
- Gray, J.T. and W.H. Schlesinger. (1983). Nutrient use by evergreen and deciduous shrubs in southern California. *J. Ecol.*, **71** : 43~56.
- Hirose, T. (1971). Nitrogen turnover and dry matter production of a *Solidago altissima* population. *Jap. J. Ecol.*, **21** : 18~32.
- Luxmoore, R.J., T. Grizzard and R.H. Strand. (1981). Nutrient translocation in the outer canopy and understory of an eastern deciduous forest. *For. Sci.*, **27** : 505~518.
- Lyu, S.W. and S.D. Song. (1986). Biomass production and phosphorus inflow in three perennial herb population in the basin of the Mt. Geumoh. *Korean J. Bot.*, **29** : 95~107.
- Monsi, M. and T. Saeki. (1953). Über den Lichtfaktor in den Pflanzen Gesellschaften und seine Bedeutung für die Stoffproduction. *Jap. Bot.*, **14** : 22~52.

- Ostman, N.L. and G.T. Weaver. (1982). Autumnal nutrient transfer by retranslocation, leaching, and litter fall in a chestnut oak forest in southern Illinois. *Can. J. For. Res.*, **12** : 40~51.
- Shaver, G.R. and J.M. Melillo. (1984). Nutrient budgets of marsh plants: efficiency concepts and relation to availability. *Ecology*, **65** : 1491~1510.
- Song, S.D. and M. Monsi. (1974). Studies on the nitrogen and dry matter economy of a *Lespedeza bicolor* var. *japonica* community. *Journ. Fac. Sci. Univ. Tokyo*, **III**, **11** : 283~332.
- Stachurski, A. and J.R. Zimka. (1975). Methods of studying forest ecosystems: leaf area, leaf production, and withdrawal of nutrients from leaves of trees. *Ekologia Polska*, **23** : 637~648.
- Switzer, G.L. and L.E. Nelson. (1972). Nutrient accumulation and cycling in loblolly pine (*Pinus taeda* L.) plantation ecosystem: the first twenty years. *Soil Sci. Soc. Amer. Proc.*, **36** : 143~147.
- Tukey, H.B., Jr. (1970). The leaching of substances from plants. *Annu. Rev. Plant Physiol.*, **21** : 305~324.
- Turner, J. (1977). Effect of nitrogen availability on nitrogen cycling in a Douglas-fir stand. *For. Sci.*, **23** : 307~316.
- Westman, W.E. (1978). Inputs and cycling of mineral nutrients in a coastal subtropical eucalypt forest. *J. Ecol.*, **66** : 513~531.

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