

## Nitrogen and Phosphorus Retranslocation in Foliage and Twig of *Pinus rigida* and *Larix leptolepis*\*

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### 리기다소나무와 낙엽송 침엽 및 소지에서의 질소와 인의 재분배 연구

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#### ABSTRACT

To determine patterns of nitrogen (N) and phosphorus (P) change in foliage and twig we collected branch samples of 40-year-old *Pinus rigida* and *Larix leptolepis* plantations every month during the growing season of 1996 in Yangpyeong, Kyonggi-Do. Significant seasonal differences on N and P concentrations in foliage and twig were observed for both study species because of nutrient retranslocation. *P. rigida* and *L. leptolepis* retranslocated 40 and 37% of foliar N and 86 and 16% of foliar P, respectively. Twig N and P retranslocation rates of *P. rigida* and *L. leptolepis* were 114 and 25%, and 42 and 70%, respectively. There were no significant differences in foliar N retranslocation rates between *P. rigida* and *L. leptolepis* while P retranslocation rate in foliage of *P. rigida* was higher than that of *L. leptolepis*. Our results suggested that twigs were the main sinks for retranslocated nutrients from foliages of the both study species.

*Key words*: Foliage, *Larix leptolepis*, Nitrogen, Phosphorus, *Pinus rigida*, Retranslocation, Twig

#### INTRODUCTION

Numerous studies have reported that evergreen species have a competitive advantage over deciduous species in stressful environments or on nutrient poor soils (Small 1972, Waring and Franklin 1979). Although the dominance of evergreen species in harsh environments were related to greater carbon gain and

nutrient use efficiency by evergreen species, it is very difficult to conclude whether greater nutrient use efficiency is a genetic characteristic or a phenotypic response of evergreen species to low nutrients (Chapin and Moilanen 1991, Son and Gower 1991).

Retranslocation of foliar nutrients, especially nitrogen (N) and phosphorus (P), to perennial tissues is considered a possible nutrient conserving mechanism for temperate woody species. Foliar N and P com-

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pounds are broken down and transported out of the foliage to reserve tissues during autumnal senescence (Vogel and Dawson 1993). It is known that the majority of N lost from leaves is due to the hydrolysis of proteins to amino acids which are subsequently retranslocated to reserve tissues such as bark and root, and the quantity of foliar nutrient retranslocated in autumn can depend on site fertility and plant species (Cote *et al.* 1989). Some workers reported that foliar retranslocation was greater on poor sites (Stachurski and Zimka 1975) while others found that site fertility had little impact on the retranslocation efficiency (Chapin and Kedrowski 1983).

The objective of this study was to estimate N and P retranslocation rates in foliage and twig by *Pinus rigida* Mill. (evergreen conifer) and *Larix leptolepis* Gordon (deciduous conifer) plantations on a similar soil. We selected *P. rigida* and *L. leptolepis* because both species show rapid early growth rates in Korea and unlike many other deciduous tree species, *L. leptolepis* has a needle shape and canopy structure that are similar to those of evergreen tree species.

## MATERIALS AND METHODS

The study was conducted at the Korea University Experimental Forest in central Korea (37° 30'N, 127° 42'E, elevation 160m). For this study we selected two adjacent stands; *P. rigida* and *L. leptolepis*. The study area was dominated by *Pinus densiflora* and *Quercus* species before harvesting. Two plantations were established on a relatively homogeneous slope, aspect and soils in 1956. The soils were classified as slightly dry brown forest soils, and a detailed stand and soil description of the study site is provided in Kim *et al.* (1995) and Son and Lee (1997). The climate is humid-continental; mean January and July temperatures are -7.9°C and 24.1°C, respectively. The average annual precipitation is 1,365mm. We established two 15m × 15m replicate plots for both stands, and the distance among plots within a stand was at least 15m. As there was a very short distance among plots and stands within the study site, differences in microclimate conditions should have been minimal.

After foliages were fully expanded, we collected one or two branches, depending on branch size, from the lower crown of five dominant or codominant trees per plot (total 10 trees per stand) every 4~5 weeks from June through December (until October for *L. leptolepis*). Collections were made on June 22, July 27, August 31, September 30, October 26, November 30, and December 28, 1996. Samples were placed on ice immediately on collection and stored at -20°C prior to analyses. In the laboratory, branches were separated into current-year foliage, 1-year-old foliage (*P. rigida* only), current twig, and 1-year-old twig (*P. rigida* only). Specific leaf area (SLA, cm<sup>2</sup>/g) was determined on at least 100 current-year and 1-year-old foliages from each tree sample to measure seasonal weight loss. After measuring leaf area, foliage samples were dried at 70°C to a constant mass and weighed. Foliage and twig samples were ground, digested (Lachat block digester BD-46) and analyzed colorimetrically for total N and P concentrations (Bran-Luebbe autoanalyzer).

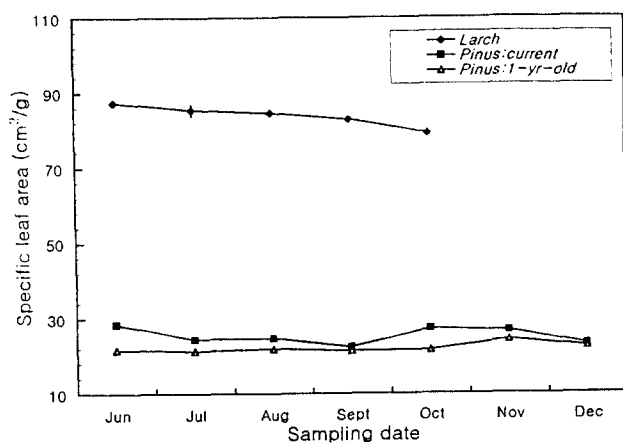
Percent retranslocation was calculated as retranslocation (%) =  $(C_{\max} - C_{\min}) / C_{\max} \times \Delta SLA \times 100$ .  $C_{\max}$  is the seasonal maximum foliar (August) and twig (October) nutrient concentrations, and  $C_{\min}$  is the seasonal minimum foliar (October) and twig (June) nutrient concentrations.  $\Delta SLA$  refers to the ratio of SLA changes (Son and Gower 1991). We only included  $\Delta SLA$  in the calculations when SLA changed significantly between  $C_{\max}$  and  $C_{\min}$  sample periods. Foliage leaching can be an important flux in forest ecosystems for certain nutrients (e.g. K). However, canopy leaching are generally nil or relatively small for N and P (Gholz *et al.* 1985, Helmisaari and Malkonen 1989, Nelson *et al.* 1995), and furthermore autumn weather in the study region is typically very dry. Thus, the values for the retranslocation of N and P reported here are assumed to include no or very little leaching losses.

## RESULTS AND DISCUSSION

The average SLA for current-year foliages of *P. rigida* and *L. leptolepis* were 25.3 and 83.9cm<sup>2</sup>/g, re-

**Table 1.** Mean SLA( $\text{cm}^2/\text{g}$ ) and nutrient concentrations(%) for *P. rigida* and *L. leptolepis* during the growing season of 1996. One standard error of the mean is in parentheses

Species	Tissue	Age(yr)	SLA( $\text{cm}^2/\text{g}$ )	N(%)	P(%)
<i>P. rigida</i>	Foliage	Current	25.3(0.4)	1.63(0.07)	0.106(0.008)
		1	22.1(0.3)	1.64(0.07)	0.120(0.007)
	Twig	Current	—	0.83(0.05)	0.060(0.005)
		1	—	0.76(0.06)	0.083(0.006)
<i>L. leptolepis</i>	Foliage	Current	83.9(0.8)	2.02(0.09)	0.192(0.014)
	Twig	Current	—	1.02(0.04)	0.125(0.009)



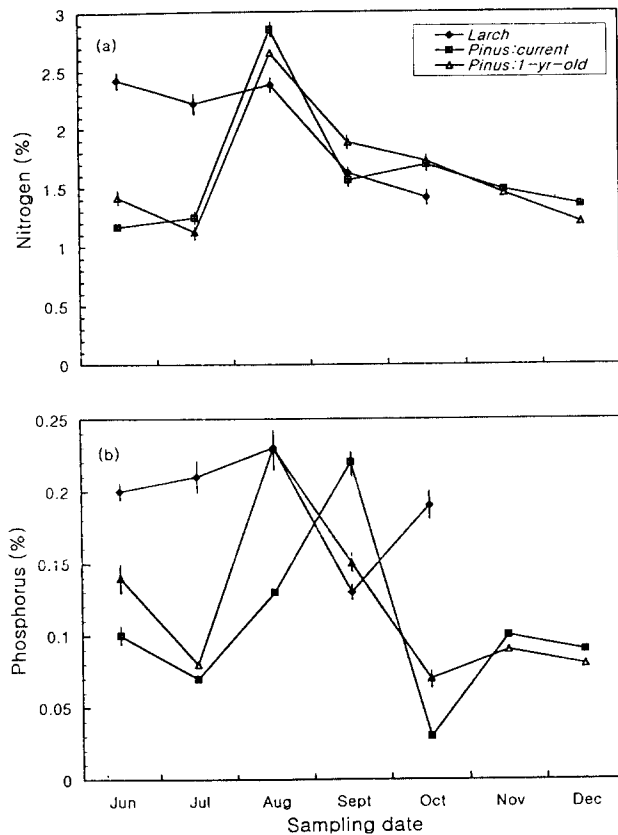
**Fig. 1.** Seasonal foliar specific leaf area ( $\text{cm}^2/\text{g}$ ) for 40-year-old *P. rigida* and *L. leptolepis* plantations. Vertical bars denote one standard error.

spectively (Table 1), and these values were very similar to the values reported for other *Pinus* and *Larix* species (Gower *et al.* 1989). The greater SLA of *Larix* species has been related to lower proportion of structural material such as lignin in foliages compared to *Pinus* species by Gower *et al.* (1989). Significant seasonal differences on SLA were observed for both species (Fig. 1). The SLA of current-year foliages for *P. rigida* decreased significantly from  $28.4\text{cm}^2/\text{g}$  in June to  $22.3\text{cm}^2/\text{g}$  in September, and increased in October ( $p < 0.05$ ). However, the SLA of 1-year-old foliages of *P. rigida* increased significantly from June through October ( $p < 0.05$ ) and remained constant until the end of the growing season. The SLA of *L. leptolepis* significantly decreased from  $84.4\text{cm}^2/\text{g}$  by late October ( $p < 0.05$ ), and the SLA of senescent foliage of *L. leptolepis* averaged  $79.2\text{cm}^2/\text{g}$  (Fig. 1). Similar seasonal patterns

in SLA were observed for other conifer species (Gower *et al.* 1989, Son unpublished data).

Average N and P concentrations in current-year foliage for *L. leptolepis* (2.02 and 0.192%) were significantly ( $p < 0.05$ ) higher than those for *P. rigida* (1.63 and 0.106%) during the growing season (Table 1). Previous studies also reported higher foliar nutrient concentrations in *Larix* species compared to other conifers (Gower *et al.* 1989, Son and Gower 1992). Average N and P concentrations in twig for *L. leptolepis* (1.02 and 0.125%) were significantly ( $p < 0.05$ ) higher than those for *P. rigida* (0.83 and 0.060%) during the growing season (Table 1). Twig N and P concentrations in *P. rigida* from this study were very similar to those reported by Woodwell *et al.* (1975). We did not observe any significant differences in foliar and twig nutrient concentrations with needle and twig ages for *P. rigida* in this study (Table 1). It is difficult to find consistent patterns between foliar nutrient concentrations and needle age from the literature for evergreen conifers (Son and Gower 1992, Bockheim *et al.* 1983).

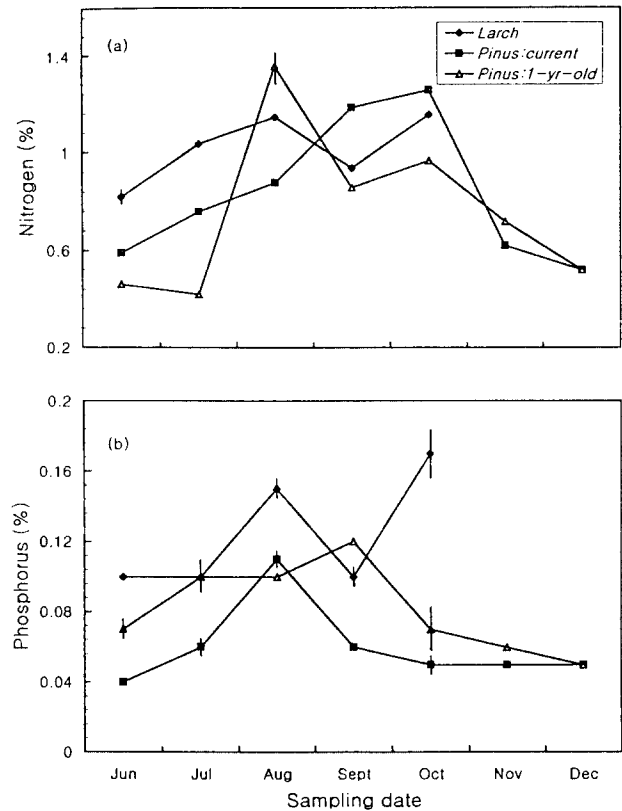
Generally foliar nutrient concentrations significantly decreased from June to July, increased and peaked in August, decreased rapidly prior to leaf senescence, and remained relatively constant through December (Fig. 2, 3). Decreases in foliar nutrient concentrations during the early growing season (June and July) was a well-documented dilution effect of needle growth (Adams *et al.* 1987). Seasonal patterns of foliar N and P concentrations for *P. rigida* in this study were similar to the trends for other *Pinus* species (Son and Gower 1991). Also seasonal foliar N concentration for *L. leptolepis* in this study was very similar to N



**Fig. 2.** Seasonal foliar (a) nitrogen and (b) phosphorus concentrations (%) for the two study species. Vertical bars denote one standard error.

concentration by Matyssek (1986). Nutrient concentrations in twig of both species significantly increased from the early growing season through foliage senescence and remained relatively stable through December (Fig. 3).

Autumnal decrease in foliar N and P concentrations was due to retranslocation of foliar nutrients rather than to leaching because there was a corresponding increase in N and P concentrations of twig tissue during this period (Fig. 2, 3 and Table 2). These results suggest that twigs are the main sinks for retranslocated nutrients, and other studies also supported the same conclusions (Cote *et al.* 1988, Helmisaari 1992). However, the increases in twig nutrient concentrations might be also related to greater nutrient availability in the soil during autumn (Son and Lee 1997). In autumn, nutrients retranslocated



**Fig. 3.** Seasonal twig (a) nitrogen and (b) phosphorus concentrations (%) for the two study species. Vertical bars denote one standard error.

**Table 2.** Foliar and twig N and P retranslocation rates (%) for *P. rigida* and *L. leptolepis*

Species	Tissue	Age(yr)	N	P
<i>P. rigida</i>	Foliage	Current	40.4	86.4
		1	34.7	69.6
	Twig	Current	113.6	25.0
		1	131.0	0.0
<i>L. leptolepis</i>	Foliage	Current	37.2	15.6
	Twig	Current	41.5	70.0

and taken-up must be stored in twigs or old foliages because there are no strong nutrient sinks such as growing foliages (Helmisaari 1992).

Nitrogen and P retranslocation rates in current-year foliage for *P. rigida* and *L. leptolepis* were 40 and 86%, and 37 and 16%, respectively (Table 2). There were no significant differences in current-year foliar N retranslocation rates between *P. rigida* and *L. leptolepis* ( $p > 0.05$ ), and these results were in dis-

agreement with the studies by Gower *et al.* (1989) and Son and Gower (1991) who concluded that *Larix* species had a higher foliar N retranslocation rate than evergreen conifers. Phosphorus retranslocation rate in current-year foliage of *P. rigida* was higher than that of *L. leptolepis*. Foliar N and P retranslocation rates for *P. rigida* compared closely with values for other *Pinus* species (Gower *et al.* 1989, Helmisaari 1992, Son and Gower 1991, Switzer and Nelson 1972). As previous studies indicated (Helmisaari 1992, Son and Gower 1991), there were no significant differences in N and P retranslocation rates between current-year and 1-year-old foliages for *P. rigida*.

Foliar N retranslocation value determined for *L. leptolepis* in this study was lower than values for other species of *Larix* (48~90%) (Chapin and Kedrowski 1983, Gower *et al.* 1989, Son and Gower 1991). However, foliar P retranslocation rate was within the range of 0~80% for other *Larix* species (Gower *et al.* 1989). In contrast with N retranslocation, foliar P retranslocation in *Larix* species was known to be less efficient than in evergreen conifers (Gower *et al.* 1989). To calculate retranslocation, most researchers have compared green foliages with litterfall foliages. However, we used October branch samples to estimate nutrient changes in foliage and twig although litterfall typically occurs in early to mid November in the study region. This would result in low foliar retranslocation values for *L. leptolepis* in this study. Assuming the same growth rate of foliage based on SLA measurements, we speculated that the absolute amounts of N translocated to twig would be greater in *L. leptolepis* because *L. leptolepis* had a higher foliar N concentration than *P. rigida* with the same foliar N retranslocation rates. It seemed difficult to conclude that leaf habit (evergreen vs. deciduous) influences nutrient use efficiency from this study with the limited number of species.

Our results on the percentage accumulation of N in current-year and 1-year-old twigs for *P. rigida* during foliage senescence (114 and 131%) were comparable with >200% N increases in the bark by Cote

and Dawson (1986) and Cote *et al.* (1989). Although foliar P concentration of *P. rigida* decreased during autumn, P concentrations in 1-year-old twig did not change significantly during the same period of time (Table 2). The apparent lack of accumulation of P in the twig of *P. rigida* might be due to the translocation of P to other stem and/or root tissues or increases in dry weight of the twig causing a dilution effect. Other tissues have been implicated in the storage of nutrients (Cote *et al.* 1989, Vogel and Dawson 1993), but our experimental design did not allow to evaluate specifically the contribution of foliar N and P retranslocation to the increase of N and P in other tissues during autumn.

## 적 요

리기다소나무와 낙엽송의 침엽과 소지 내 질소 및 인의 농도변화를 연구하기 위하여 경기도 양평지역의 40년생 인공림에서 1996년 생장기간 동안 매월 시료를 채취하여 분석하였다. 양분의 재분배때문에 침엽과 소지 내 질소와 인의 농도는 두 수종 모두에서 계절에 따라 큰 변화를 보이고 있었다. 침엽 내 질소와 인의 재분배율은 리기다소나무의 경우 40%와 86%, 낙엽송의 경우 37%와 17%를 보였다. 한편 소지 내 질소와 인의 재분배율은 리기다소나무에서 114%와 25%, 낙엽송에서 42%와 70%를 보였다. 침엽 내 질소의 재분배율에서는 두 수종간 차이가 없었으나, 인의 재분배율은 리기다소나무에서 낙엽송보다 높게 나타났다. 본 연구에서 소지는 침엽으로부터 재분배되는 양분의 주요 저장장소가 됨을 보이고 있다.

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