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Aboveground Nutrient Distribution in Pitch Pine (*Pinus rigida*) and Japanese Larch (*Larix leptolepis*) Plantations[1]

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ABSTRACT

Aboveground biomass and nutrient contents of a 31-year-old pitch pine(*Pinus rigida*) and a 31-year-old Japanese larch(*Larix leptolepis*) plantations were measured in the Chungbu Forest Experiment Station, Kyunggi Province. Aboveground biomass was 170.2ton/ha in the pitch pine and 87.2ton/ha in the Japanese larch plantations. Aboveground biomass difference between both plantations was due to the difference of stand density. Aboveground biomass in both plantations was allocated as follows : stemwood>branch>stembark>needle. The concentrations of all nutrients(N, P, K, Ca, Mg) were generally higher in the Japanese larch needle than in the pitch pine because of high nutrient uptake characteristics of larch compared with pine tree species. The nutrient concentration in different tree tissues in both tree species decreased in the order of needle>branch>stembark>stemwood. Nutrient contents of aboveground biomass were : N, 335.9 ; P, 40.4 ; K, 121.4 ; Ca, 188.6 ; Mg, 93.8kg/ha in the pitch pine plantation, while nutrient contents in the Japanese larch plantation were : N, 226 ; P, 11.5 ; K, 72.9 ; Ca, 75.7 ; Mg, 37.1kg/ha. The nitrogen use efficiency calculated as the biomass produced by one unit of nitrogen was higher in the pitch pine than in the Japanese larch plantations. This result suggests that pine with high nitrogen use efficiency could be adapted in lower site productivity area compared with larch tree species.

Key words : *Biomass,* Larix leptolepis, *Nutrient cycling, Nutrient use efficiency,* Pinus rigida

要 約

경기도 광릉의 중부임업시험장내 31년생 리기다소나무와 낙엽송조림지를 대상으로 임분별 3개의 20×10m 조사구를 선정하고 각 조사구로부터 1본씩 표본목을 선정한 후 벌도하여 지상부 현존량을 측정하고 각 부위별 양분분포를 조사하였다. 조사된 임분의 지상부 현존량은 리기다소나무의 경우 170.2ton/ha, 낙엽송은 87.2ton/ha로서 리기다소나무 임분이 낙엽송 임분에 비해 높게 나타났으며, 두 임분의 현존량의 차이는 임분 밀도의 차가 원인인 것으로 나타났다. 각 부위별 현존량 분배율은 줄기>가지>수피>잎 순이었으며, 각 부위별 조직내 양분농도는 낙엽송이 리기다소나무에 비해 높았고, 두 임분 모두 잎>가지>수피>줄기 순으로 양분농도에 차이가 있었다. 양분 축적량은 리기다소나무 임분이 질소 335.9kg/ha, 칼슘 188.6kg/ha, 칼륨 121.4kg/ha, 마그네슘 93.8kg/ha, 인산 40.4kg/ha 순이었으며 낙엽송 임분은 질소 225kg/ha, 칼슘 75.7kg/ha, 칼륨 72.9kg/ha, 마그네슘 37.1kg/ha, 인산 11.5kg/ha 으로 리기다소나무 임분에서 양분 축적량이 높게 나타났다. 양분에 대한 지상부 현존량의 비로 표시되는 양분이용효율중 질소이용효율은 낙엽송 임분이 리기다소나무 임분에 비해 낮게 나타났으며 이는 리기다소나무가 낙엽송에 비해 척박지에서 더 잘 견딜 수 있는 임목의 특성을 반영하고 있다.

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INTRODUCTION

The understanding of nutrient cycling and distribution of forest stands is one of the most important policies of forest management to sustain and enhance forest productivity. The nutrients accumulated in trees could have a significant meaning to understand tree harvesting impacts(Foster and Morrison, 1976 ; Binkley, 1986), dynamics of nutrient uptake by site and stand age class, and distribution of nutrients by tree components(Wang *et al.*, 1995 ; Lee, 1998). Several studies have carried out to understand dynamics and distribution of nitrogen and phosphorus in *Pinus rigida*, *Larix leptolepis*(Kim *et al.*, 1996), and *P. koraiensis* stands(Lee, 1998), but little is known about other macro-nutrients such as potassium, calcium and magnesium etc.

Pitch pine(*Pinus rigida*) originated from USA was introduced from Japan in the early 1900's and planted to rehabilitate eroded and erosion areas. This tree was planted about 700 thousand hactares between 1960 and 1994(Forestry Administration, 1994). Japanese larch(*Larix leptolepis*) was planted about 600 thousand hactares between 1957 to 1990 (Forestry Administration, 1994). In addition, both tree species were the most major planting species for afforestation throughout the country during last thirty years. It is needed to understand information to evaluate distribution and accumulation of nutrients in the pine and larch plantations with increasing of matured plantations. Consequently, this study was performed to provide estimates of biomass and nutrient distributions in pitch pine and Japanese larch plantations.

MATERIALS AND METHODS

The study was conducted in the Chungbu Forest Experiment Station in Kwangnung, Kyunggi Province, Korea. The study sites were classified as slightly dry brown forest soils(mostly Inceptisols). Annual precipitation in the sites averages 1,365㎜ and slightly higher than the average of the country(1,274㎜). Dominant understory species in the study site were *Carpinus laxiflora*, *Quercus serrata*, *Styrax japonica*, *Q. acutissima*, *Sorbus alnifolia*, and *Cornus kousa* etc. in the pitch pine plantation. *Carpinus laxiflora*, *Quercus serrata*, *Styrax japonica*, *Stephanandra incisa*, and *Prunus sargentii* were dominated in the Japanese larch plantation. Stand tree densities were from 1,800trees/ha to 2,200trees/ha in the pitch pine and from 400trees/ha to 500trees/ha in the Japanese larch plantations. Mean diameter at breast height was 15.3cm in the pitch pine and 22.1cm in the Japanese larch plantations. Stand basal area was 41.1m^2/ha in the pitch pine and 16.6m^2/ha in the Japanese larch plantations.

Three sampling plots of 20×10m from the pitch pine and the Japanese larch plantations were chosen and a median sample tree from each plot was harvested between 20 and 22 Oct. 1997. Each sample tree was cut at the ground level, separated into needles, branches and stem, and weighed fresh. The subsamples were oven-dried at 65℃ for chemical analysis and at 105℃ for obtaining the factors for converting fresh weight into oven dry weight.

The biomass of each component in the pitch pine plantation was estimated by allometric equations developed from a 37-year-old pitch pine plantation in Yangpyeong, Kyunggi Province(Kim *et al.*, 1995). The biomass of each component in the Japanese larch plantation was obtained by the basal area ratio method using the relationship : Estimated stand biomass weight=(sum of sample tree weights/sum of sample tree basal area)× stand basal area. Nutrient content of each component was estimated by mean concentration of nutrients in the samples. All nutrients(N, P, K, Ca, Mg) were analyzed by the standard method of Natural Institute of Agriculture and Technology (1988).

RESULTS AND DISCUSSION

The mineral soil in both plantations consisted of a relatively similar particle size distribution (Table 1). Soil pH was higher in the Japanese larch than in the pitch pine plantations. Higher soil pH in the Japanese larch plantation on similar site condition may be due to the difference of acidic organic matter accumulation(Binkley, 1995)

Table 1. Soil properties in the study site (n=3)

Depth (㎝)	Stand	Bulk density (g/㎤)	>2㎜ coarse fragment (%)	Sand	Silt	Clay	pH (H_2O)	OM (%)	TN (%)	P_2O_5 (ppm)	CEC	K^+	Na^+	Ca^{2+}	Mg^{2+}
				(%)							(me/100g)				
0 - 10	Pine	0.72	17.8	38.5	43.7	17.9	4.6	5.23	0.20	46	12.5	0.17	0.28	1.09	0.17
	Larch	0.80	26.7	47.5	37.2	15.3	5.1	4.19	0.21	17	10.2	0.18	0.28	1.77	0.41
10 - 30	Pine	1.02	19.9	40.5	36.9	22.5	4.9	1.97	0.09	12	10.5	0.13	0.21	0.56	0.06
	Larch	1.04	17.5	46.2	36.8	17.0	5.2	2.27	0.11	5	9.4	0.16	0.21	1.24	0.23
30 - 50	Pine	1.13	18.2	36.7	40.3	22.9	5.0	1.09	0.05	3	10.0	0.14	0.22	0.54	0.08
	Larch	1.17	19.6	50.8	30.1	19.1	5.3	1.80	0.08	3	9.2	0.13	0.24	1.06	0.20

Table 2. Dry weight (㎏) of the sampled trees in *P. rigida* and *L. leptolepis*

Species	Sample No.	DBH (㎝)	Height (m)	Stemwood	Stembark	Branch	Needle	Total
Pine	1	15.4	14.5	62.4	9.6	10.9	4.2	87.1
	2	16.5	13.5	62.2	12.4	18.7	3.8	97.1
	3	17.0	14.0	66.8	8.8	14.1	4.3	94.0
	Mean	16.3	14.0	63.8(69%)	10.3(11%)	14.6(16%)	4.1(4%)	92.7(100%)
Larch	1	15.4	14.5	57.1	3.9	16.7	5.9	83.6
	2	18.8	20.5	108.2	7.8	11.4	2.2	129.5
	3	23.5	16.5	198.9	9.1	41.4	9.1	258.5
	Mean	19.2	17.2	121.4(77%)	6.9(4%)	23.1(15%)	5.7(4%)	157.2(100%)

and/or less acidic throughfall and stem flow inputs compared with the pitch pine plantation(Kim, personal observation). Soil properties such as organic matter, phosphorus, and cation exchange capacity were generally better in the pitch pine than in the Japanese larch plantations.

The dry weight of sample tree(sample No.1) in the same DBH(15.4㎝) and height(14.5m) was higher in the pitch pine than in the Japanese larch because of more stem and bark mass compared with the larch(Table 2). However, branch and needle mass were higher in the larch than in the pine because of the difference of stand densities between both plantations. Tree crown in the Japanese larch may be more expanded due to stand open space available compared with the pitch pine.

Aboveground biomass was allocated as follows : stemwood > branch > stembark > needle(Table 2). The biomass distribution of sampled trees in the pitch pine was 69% in stemwood, 16% in branch, 11% in stembark, and 4% in needle. In contrast, the biomass distribution in the Japanese larch was 77% in stemwood, 15% in branch, 4% in stembark, and 4% in needle. Both tree species showed similar branch and needle distribution, while stembark was higher in the pitch pine than in the Japanese larch. Other studies reported biomass distribution that was 71% in stemwood, 16% in branch, 8% in stembark, and 5% in needle in a 37-year-old pitch pine plantation in Yangpyeong(Kim *et al.*, 1996), and 77.6% in stem, 15.7% in branch, and 6.7% in needle of a 29-year-old larch pine plantation(Lee *et al.*, 1997) in Kwangju, Kyunggi Province.

The concentrations of all nutrients(N, P, K, Ca, Mg) were generally higher in the Japanese larch than in the pitch pine(Table 3). Similar results were observed in pine and larch plantations of Yangpyung(Kim *et al.*, 1996). Higher nutrient concentrations in the larch may be due to high uptake characteristics of larch compared with pine tree species(Son and Gower, 1992). Nutrient concentrations varied considerably among tree components. The concentrations of all nutrients in both tree species were highest in the needle, followed by branch, stembark, and stemwood(Table 3). Nitrogen concentration from each

Table 3. Nutrient concentration(% of dry weight) of *P. rigida* and *L. leptolepis* components

Component	Species	N	P	K	Ca	Mg
Stemwood	Pine	0.085(0.006)a	0.013(0.003)a	0.027(0.007)a	0.066(0.002)a	0.034(0.005)a
	Larch	0.139(0.023)a	0.018(0.002)a	0.0531(0.013)a	0.085(0.01)a	0.037(0.01)a
Stembark	Pine	0.220(0.005)b	0.02(0.003)b	0.033(0.007)b	0.167(0.045)a	0.062(0.010)a
	Larch	0.36(0.05)a	0.03(0.0007)a	0.073(0.007)a	0.246(0.03)a	0.053(0.007)a
Branch	Pine	0.437(0.025)a	0.053(0.001)a	0.200(0.001)a	0.238(0.057)a	0.068(0.036)a
	Larch	0.575(0.11)a	0.069(0.009)a	0.289(0.103)a	0.342(0.061)a	0.106(0.01)a
Needle	Pine	0.98(0.05)b	0.092(0.009)b	0.360(0.053)b	0.254(0.036)b	0.175(0.01)a
	Larch	1.70(0.04)a	0.126(0.005)a	0.587(0.37)a	0.501(0.053)a	0.205(0.01)a

* Values in the parentheses are standard errors of the means (n=3)

Table 4. Aboveground biomass(ton/ha) and nutrient content(kg/ha) of the tree component of *P. rigida* and *L. leptolepis* plantations

Component	Stand	Biomass	N	P	K	Ca	Mg
Stemwood	Pine	120.8(71)	102.7(31)	15.7(39)	32.1(26)	79.7(42)	41.6(44)
	Larch	67.4(77)	89.7(40)	5.6(49)	26.6(37)	32.1(42)	19.3(52)
Stembark	Pine	14.2(8)	31.3(9)	2.8(7)	4.7(4)	23.7(13)	8.8(10)
	Larch	3.8(4)	13.2(6)	0.5(4)	2.1(3)	6.0(8)	1.8(5)
Branch	Pine	26.4(16)	115.4(34)	14.0(35)	52.8(44)	62.8(33)	28.0(30)
	Larch	12.8(15)	70.7(31)	3.7(32)	29.4(40)	27.0(36)	11.8(32)
Needle	Pine	8.8(5)	86.5(26)	7.9(19)	31.8(26)	22.4(12)	15.4(16)
	Larch	3.2(4)	51.4(23)	1.7(15)	14.8(20)	10.6(14)	4.2(11)
Total	Pine	170.2(100%)	335.9(100%)	40.4(100%)	121.4(100%)	188.6(100%)	93.8(100%)
	Larch	87.2(100%)	225(100%)	11.5(100%)	72.9(100%)	75.7(100%)	37.1(100%)

tree component in the pitch pine was 0.98% in needle, 0.437% in branch, 0.22% in stembark, and 0.085% in stemwood, while the nitrogen concentration in the pitch pine plantation of Yangpyeong(Kim *et al.*, 1996), was 1.43% in needle, 0.35% in branch, and 0.13% in stembark, and 0.06% in stemwood. Nitrogen concentration in the Japanese larch was 1.70% in needle, 0.575% in branch, 0.36% in stembark and 0.139% in stemwood, while the nitrogen concentration in the Japanese larch plantation of Yangpyeong(Kim *et al.*, 1996) was 1.97% in needle, 0.37% in branch, and 0.38% in stembark, and 0.04% in stemwood. The values were higher in the pitch pine and Japanese larch of Kwangnung than in the pitch pine and Japanese larch of Yangpyeong, except for needle nitrogen concentrations. The phosphorus concentration from each tree component showed similar trends. The difference of nutrient concentrations from each tree component between Kwangnung and Yangpyung may be due to retranslocation of nutrients by the seasonal variation of tree nutrient concentration and/or the difference of site quality between two areas. The nutrients in Yangpyeong were analyzed from samples collected in August, while the samples in this study were collected in late of October. Considerable amount of nutrients may be translocated from needle to branch and stem during heavy litterfall season in October(Woodwell, 1974).

The aboveground biomass was 170.2ton/ha in the pitch pine and 87.2ton/ha in the Japanese larch plantations(Table 4). Aboveground biomass was higher in the pitch pine than in the Japanese larch plantations. The difference of biomass between both plantations may be due to stand density(pine, 2,150trees/ha ; larch, 450trees/ha), although the difference of aboveground biomass in the same species was due to site productivity or provenance(Keyes and Grier, 1981, Zavitkovski

Table 5. Aboveground biomass(ton/ha) and nutrient content(kg/ha) of *Pinus* spp. and *Larix* spp. stands of comparable ages

Stand	Age	Location	Biomass	N	P	K	Ca	Mg	Reference
P. rigida	31	Korea	170.3	335.9 (0.51)*	40.4 (4.20)	121.4 (1.40)	188.6 (0.90)	93.8 (1.83)	present study
P. rigida	37	Korea	138.2	202 (0.68)	38 (3.64)	–	–	–	Kim *et al.*, 1996
P. koraiensis	34	Korea	95.7	423.7 (0.23)	81.3 (1.18)	119.5 (0.80)	184.7 (0.52)	35.9 (2.67)	Lee, 1998
P. resinosa	39	USA	207.1	356 (0.58)	41 (5.05)	180 (1.15)	302 (0.69)	–	Perala and Alban, 1982
P. banksiana	39	USA	151.2	264 (0.57)	26 (5.82)	99 (1.53)	203 (0.74)	–	"
P. banksiana	30	Canada	81.3	157 (0.52)	13 (6.25)	77 (1.06)	102 (0.80)	16 (5.08)	Foster and Morrison, 1976
P. taeda	25	USA	169.3	257 (0.81)	28 (6.77)	155 (1.75)	231 (0.86)	80 (2.69)	Pehl *et al.*, 1984
L. leptolepis	31	Korea	87.2	225 (0.39)	11.5 (7.58)	72.9 (1.20)	75.7 (1.15)	37.1 (2.35)	present study
L. leptolepis	37	Korea	127.2	205.3 (0.62)	30 (4.24)	–	–	–	Kim *et al.*, 1996
L. decidua	28	USA	191	≈360 (0.53)	≈41 (4.65)	–	–	–	Son and Gower, 1992

* Values in the parentheses are the nutrient use efficiencies (ton/kg) calculated as the biomass produced by one unit of nutrient.

et. al., 1981). The aboveground biomass of the pitch pine plantation was comparable to 163.8ton/ha for *P. resinosa* on similar stand density (2,032trees/ha)(Gower and Son, 1992), but this value was higher than 138.2ton/ha in a 37-year-old pitch pine plantation(667trees/ha) in Yangpyung(Kim *et al.*, 1996). In a 37-year-old Japanese larch plantation(Kim *et al.*, 1996), aboveground biomass was 127.2ton/ha with higher stand density(548trees/ha) compared with the Japanese larch plantation in this study(450trees/ha). Kim *et al.*(1996) reported that aboveground biomass on similar stand density(pine : 667trees/ha, larch : 548trees/ha) was not different between pitch pine and Japanese larch plantations.

The nutrient content in both plantations was higher in the pitch pine than in the Japanese larch plantations. The difference of nutrient content between both plantations may be due to the difference of biomass rather than the difference of nutrient concentration of each component. The nutrient content of each tree component in both plantations was generally highest in stemwood, followed by branch, needle, and stembark, while potassium content was highest in branch among tree components(Table 4). Total needle biomass was about 4~5% of total aboveground biomass in both plantations, but nutrient content in needle was between 11 and 26% of total nutrient content. In contrast, stemwood biomass was 71~77% of total aboveground biomass, while nutrient content in stemwood was between 26 and 52% of total nutrient content. Similarly, stemwood biomass in *P. koraiensis* plantations was 66% of total aboveground biomass, while nutrient content in stemwood was between 25 and 44% of total nutrient content(Lee, 1998). This result indicates that the *in situ* return of branches, needles, and bark after tree cutting in both plantations may act to minimize the loss of nutrient resulted from tree harvest.

The most abundant nutrient in both plantations was nitrogen, followed by calcium, potassium, magnesium and phosphorus(Table 5). Other pine stands showed similar trends with the highest value of nitrogen and the lowest value of phosphorus(Lee, 1998). The nitrogen use efficiency calculated as the biomass produced by one unit of nitrogen(Ranger *et al.*, 1995) was higher in the pitch pine than in the Japanese larch plantations(Table 5). High nitrogen use efficiency of the pitch pine compared with the Japanese larch plantations may be related to inherent adaption characteristics in low site productivity area. This result suggests that larch with low nitrogen use efficiency should be planted in more fertile site compared with pine. However, other nutrient use efficiency such as phosphorus and nitrogen, except for potassium was generally higher in the Japanese larch than in the pitch pine plantations. The nutrient use efficiency in the pitch pine plantation was similar to the values obtained in other *Pinus* spp. studies, except for *P. koraiensis* stands(Table 5).

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