Primary Production Relations in a Plantation of *Larix leptolepis* in Hokkaido: Materials for the Studies of Growth in Forest Stands. 10.*

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CONTENTS

Abstract

A 21-year-old plantation having 4.5 t/ha of foliage leaf produced 14.5 t of dry matter as the aerial part of the tree layer, 0.3 t as the shrub layer, and 0.3 t as the ground vegetation, all per hectare and per year. Net production by trees depended upon leaf mass on them and was independent from the efficiency of leaf. The efficiency of leaf in net production, or net assimilation rate, was about 3.2 kg/kg leaf per year. Leaf mass, net production, and net assimilation rate were compared with forests of this and other species of larch.

1. Introduction

This paper deals with primary production relations of a planted *Larix leptolepis* forest in central Hokkaido. This species is not indigenous to Hokkaido but is planted widely there. The results of this study were partly published in a synthesis by the author (1971), and a part of them was recalculated and corrected here.

On production relations of this species, studies by SHIBAMOTO (1951), SHIDEI (1964), HATIYA et al (1966), and SATOO (1970b) were published and parts of the studies by ASADA and KAN (1967), CHIBA and NAGANO (1967), and ASADA et al (1968) were distributed as interim report of limited circulation. OHMASA and MORI (1937) published data on leaf litter of this species. Of other species of Genus *Larix*, studies by BURGER (1945) and POZDNYAKOV (1967) are available. However, most of them are concerned only with biomass of aerial parts of the overstorey larch and production of stemwood,

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but lack the measurement of production as branch. Estimation of primary production was made by SHIBAMOTO (1951), HATIYA et al (1966), CHIBA and NAGANO (1966) and SATOO (1970b). Detailed studies of production relations of other components of a woodland including roots are given only in SATOO (1970b).

Field works of this study were made in 1961 by Mr. G. YAMADA and staff of the University Forest. The author would like to express his cordial thanks to them.

2. The forest studied

Study was made on a 21-year-old plantation at the foothill of Mt. Asibetu in central Hokkaido. The forest is privately owned and history of the plantation was not recorded. The forest was on a east slope of 26°. Altitude was about 300 m. Base rock was liparite, and soil was moderately moist brown forest soil of moderate depth. According to the mean value of meteorological data (1956–1960) at the arboretum of the Tokyo University Forest (43°13′N, 142°23′E, altitude 230 m) which is located about 3 km northeast to the forest, mean annual temperature was 6.7°C with maximum and minimum monthly mean temperature of 20.8°C in August and −8.4°C in January, respectively. Annual precipitation was 1275 mm. Frost free season was generally from May to October. General description of the plot is given as Table 1. The stand density relative to the maximum density, which was calculated with REINEKE's (1933) equation with constants given for this species by SAKAGUCHI (1961), was 0.59. Understorey hardwood developed very poorly and a few trees of *Acer mono* and *Tilia japonica* were found. Their maximum height was 2.5 m. About half of the forest floor was covered by *Sasa paniculata* and the other half was covered by *Petasites japonica* and many species of herbaceous species with some ferns.

Table 1. General description of the stand.

Age	21
D. B. H.	15.1
Height (m)	15.3
Number of trees/ha	1240
Relative stand density	0.59
Basal area (sq. m/ha)	22.4
Volume (cu. m/ha)	169

3. Method

After measuring D. B. H. of all trees in the plot, 20×30 m, 10 sample trees were selected from the plot so as to cover a wide range of diameter. After felling them, they were sampled at the ground level (0.0 m), 0.3 m, 1.3 m, and then at every 2 m till the lowest living branch, and at every 1 m within the crown. Samples were used for stem analysis and for obtaining the factors for converting fresh weight and volume into dry weight. Branch was weighed separately for layers of 1 m deep and sampled for dry weight determination. One branch was sampled for each layer for the determination of growth by means of ring analysis. Leaf was weighed separately for each layer and sampled for dry weight determination. For the understorey hardwoods, 2 sample plots, each 2×2 m, were clear-cut, weighed, and sampled for determination of dry weight and relative growth rate. For the ground vegetation, 3 sample plots, each 2×2 m, were clipped clearly, weighed, and sampled for determination of dry weight. Measurements of roots were not made.

4. Biomass aboveground

Three methods were used for conversion of the values for sample trees into unit ground area basis: allometry (aD^b), the ratio of basal area to sum of cross sectional area at breast height of sample trees (G/g), and trees of mean cross-sectional area ($\bar{D}$). These methods were compared already (SATOO 1966, 1968, and 1970a). Constants for the allometric equations using D.B.H. as the independent variable are shown in Table 2. The estimates of aboveground biomass by the three methods are given in Table 3. The differences by the methods were not too large.

Table 2. Constants for the allometric equation: $\log W_{kg} = b \log D_{cm} - a$

	b	a
Biomass		
stem	2.377	1.709
branch	2.778	2.319
leaf	2.252	2.108
aboveground	2.695	1.347
Net production		
stem	2.443	2.182
branch	2.283	2.325
leaf	2.252	2.108
aboveground	2.661	2.080

There are some comparable data on phytomass of Japanese larch overstorey (SHIBAMOTO 1951, SHIDEI 1964, HATIYA et al 1966, CHIBA and NAGANO 1967, ASADA and KAN 1967, ASADA et al 1968, and SATOO 1970b) and on leaf litter (OHMASA and MORI 1937), but as stem mass is rather a function of age of the stand and branch mass is also affected by age (SATOO 1971), only leaf mass was compared. Mean value of dry weight of leaf of 13 plantations of Japanese larch, not including this one, was 3.8 t/ha, varying from 2.8 to 5.3 t/ha in dry weight. The value for this stand, 4.3-4.9 t/ha is rather large. As for the other species of larch, BURGER (1945) reported that 50-, 105-, and 220-year-old stands of European larch in Switzer-

Table 3. Biomass (t/ha)

Method	aD^b	G/g	$\bar{D}$	Mean	Distribution: within tree layer	Distribution: as forest
Tree layer						
leaf	4.9	4.3	4.4	4.5	5.4	5.2
branch	12.2	12.0	12.3	12.1	14.4	14.1
stem	69.2	66.8	66.5	67.5	80.2	78.4
total	86.3	83.1	83.2	84.1	100	97.7
aboveground	91.2					
Shrub layer				1.3		1.5
Ground vegetation				0.7		0.8
Total				86.1		100

land had 4.2, 2.8, and 3.0 t/ha of leaf, respectively. POZDNYAKOV (1967) reported that 60- and 140-year-old Dahurican larch stands in Yakutia had 2.2 and 2.7 t/ha of leaf, respectively. These values are shown in Fig. 1. POZDNYAKOV also reported 0.7 and 0.9 t/ha of leaf mass for 350- and 150-year-old stands, respectively, which seemed not to be closed well.

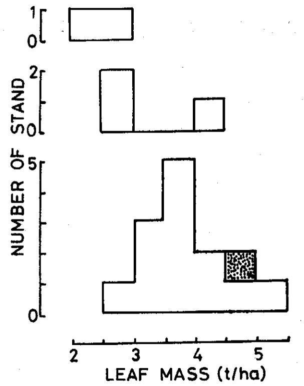

Fig. 1. Leaf mass of larch forests. From bottom to top: Japanese larch (ASADA and KAN 1967, ASADA et al 1968, CHIBA and NAGANO 1967, HATIYA et al 1966, SATOO 1970b, SHIDEI 1964, SHIBAMOTO 1951), European larch (BURGER 1945), and Dahurican larch (POZDANYAKOV 1967). Dotted: the plantation reported here.

Aerial parts of the tree layer made about 98% of the total aboveground biomass of the forest. Biomass of aerial parts of undergrowth was about 2 t/ha which is about 2.3% of the biomass of the forest. Undergrowth biomass was smaller than a 39-year-old plantation of this species (SATOO 1970b) which had 3.6 t/ha of overstorey leaf mass with 6.6 t/ha of undergrowth biomass. This difference of undergrowth biomass could be partly due to the difference of overstorey leaf mass which intercepts incident light energy.

5. Aboveground net production

For the conversion of the values for the sample trees into unit ground area basis, the three methods mentioned for biomass were also used here. The constants for the allometric equation with D.B.H. as the independent variable are shown in Table 2. Aboveground net production of this forest is given in Table 4; the differences by the methods of conversion were not too large. Aboveground net production by the three methods was within the range of 14–15 t/ha/year. As the measurement of growth of branch is rather laborious, there are very few data

Table 4. Net production (t/ha)

Method	aD^b	G/g	$\bar{D}$	Mean	Distribution	
					within tree layer	as forest
Tree layer						
leaf	4.9	4.3	4.4	4.5	31.0	29.8
branch	3.0	3.1	3.4	3.2	22.1	21.2
stem	6.7	6.7	7.1	6.8	46.9	45.0
total	14.6	14.1	14.9	14.5	100	96.0
aboveground	15.3					
Shrub layer				0.3		2.0
Ground vegetation				0.3		2.0
Total				15.1		100

on net production. Mean of aboveground net production in published data other than this one (SHIBAMOTO 1951, HATIYA et al 1966, CHIBA and NAGANO 1967, SATOO 1970b) was 12.7 t/ha/year, ranging from 7.6 to 17.9 t/ha/year. The value for this plantation, 14–15 t/ha is within the range of the variation of these values. Comparisons of the net production of this forest with plantation of other species of conifer and broad-leaved trees within a few kilometers at the same altitudinal zone as well as with agricultural crops of adjacent fields are reported elsewhere (SATOO 1970a). The under-storey tree layer produced 0.3 t/ha/year of dry matter which is far less than the production of understorey tree and shrub layer, 1.5 t/ha/year, of another plantation (SATOO 1970b). Production of the ground vegetation was not estimated accurately; it was 0.3 t/ha/year if biomass of herbaceous plants and a quater of biomass of *Sasa* were assumed as production. This value is also far less than the production by the ground vegetation of other plantations (SHIBAMOTO 1951, SATOO 1970b). This difference could partly be due to the difference of leaf mass of the overstorey trees of them. As shown in Table 4, about 96% of net production by this forest was by the tree layer and less than half of the net production by the tree layer distributed into stem.

6. Efficiency of leaf to produce dry matter

The relationships between net production and leaf mass of trees within this stand as well as of stands including this one were reported already (SATOO 1971). Similar trend was also reported for trees and stands of *Betula maximowicziana* (SATOO 1970a) and *Pinus densiflora* (SATOO 1968). Net production of trees and stands was linearly proportional to their leaf mass. Net assimilation rate of this plantation determined from the regression between net production and leaf dry weight was 3.154 kg/kg/year, 3.222 kg as calculated by dividing net production by leaf dry weight of the forest, and 3.165 kg as mean of net assimilation rate of sample trees. There was not much difference by the method. Mean net assimilation rate calculated from the published data of net production and leaf mass of stands (SHIBAMOTO 1951, HATIYA et al 1966, CHIBA and NAGANO 1967, and SATOO 1970b) was 3.080 kg/kg/year, ranging from 2.307 to 3.521. Net assimilation rate of this species was reported to be largest among conifers, due to the small leaf mass (SATOO 1971).

7. Relationship between stem wood production and leaf mass

As seen from Fig. 2, production of stem wood of sample trees was linearly proportional to leaf mass on it ($r=0.98^{**}$), while it did not have any clear relation with the "efficiency of leaf to produce stem wood" as the distribution ratio of produced matter into stem was not much different among trees except a few of them. The "efficiency of leaf to produce stem wood" is a product of net assimilation rate times distribution ratio, as discussed before (SATOO 1974). Stem wood production per 1 kg of needle leaf was 1.572 kg from the regression of Fig. 2, 1.565 kg from stemwood production and leaf mass per unit ground area, and 1.553 kg as the mean of the

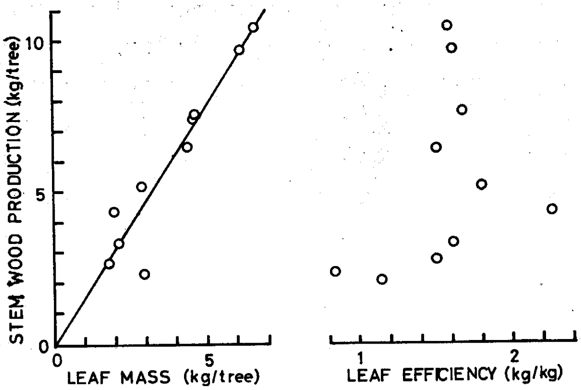

Fig. 2. Relations between stemwood production and leaf mass and the "efficiency of leaf to produce stemwood" of individual trees within the stand.

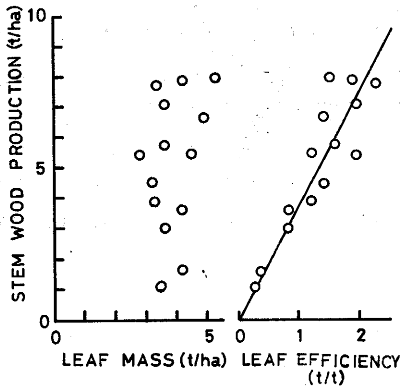

Fig. 3. Relations between stemwood production and leaf mass and "efficiency of leaf to produce stemwood" of stands of Japanese larch (sources: see the explanation of Fig. 1.)

values for sample trees; there was not much difference by the method. BURGER (1945) reported that in stands of European larch in Switzerland 1 kg of needle leaf produced 1.9 kg of stem wood in 50- and 105-year-old stands and 0.4 kg in a 220-year-old stand at a higher elevation.

In Fig. 3, production of stemwood per unit ground area of forest in published data (SHIDEI 1964, HATIYA et al 1966, CHIBA and NAGANO 1967, ASADA and KAN 1967, ASADA et al 1967, SATOO 1970b) was related to their leaf mass and "efficiency of leaf". Production of stem wood per unit ground area of forest was, on the contrary to the relationships among trees within this stand, not proportional to the leaf mass but to the efficiency of leaf (r=0.83**). There was not much variation in leaf mass per unit ground area while the difference of stemwood production was rather large among the forests. This does not necessarily mean that photosynthetic efficiency of leaf largely differs by the stand. For the four stands, which are included in Fig. 3, net production per unit ground area of forest was linearly proportional to their leaf mass (SATOO 1971). As stated before (SATOO 1974), "the efficiency of leaf to produce stem wood" is a product of net assimilation rate and distribution ratio of produced matter to the stem. The variation in the "efficiency of leaf" may be caused by the differences in the distribution ratio by stand. Distribution ratio was influenced by relative stand density, or intensity of competition among trees, for example (SATOO et al 1955). The coefficient of variation in net assimilation rate of the four stands mentioned above was 4.8% while it was 21.2% in the "efficiency of leaf to produce stem wood", for the same four stands. Among forests of *Fagus crenata* and *Betula* spp., stem wood production per unit ground area was proportional to their leaf mass (SATOO 1970a). Among plantations of *Cryptomeria japonica* (SATOO 1967), stem wood production had close connection with both leaf mass and efficiency of leaf.

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* in Japanese with English summary

** in Japanese only

Titles in parentheses are tentative translation from Japanese originals by the present author.

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北海道のわかいカラマツの植栽林の物質生産
― 林分生長論資料 10 ―

佐　藤　大七郎

あ　ら　ま　し

1 ha あたり 4.5 t の葉をもつた 21 年生の植栽林は，1 年 1 ha あたり，カラマツの高木層が 14.5 t，低木層が 0.3 t，林床植生が 0.3 t，しめて 15.1 t の乾物を生産した。林木の純生産量はそれについている葉の量に比例し，葉の能率 (NAR) とは関係がなかつた。葉の能率は乾葉 1 kg あたり 1 年 3.2 kg だつた。カラマツおよびほかの種のカラマツの林と葉の量，純生産量および NAR をくらべた。

Appendix 1. Sample tree data

Tree	D. B. H. (cm)	Height (m)	Dry weight (kg)			Production (kg)		
			stem	branch	leaf	stem	branch	leaf
1	14.8	16.0	51.50	7.54	2.12	3.40	2.04	2.12
2	11.3	14.6	26.21	4.89	1.86	2.13	1.12	1.86
3	12.9	14.6	38.38	6.04	2.01	4.54	1.70	2.01
4	14.9	13.9	40.06	11.03	4.39	6.59	2.58	4.39
5	12.3	14.0	31.56	5.25	2.89	2.40	1.54	2.89
6	19.9	17.1	97.97	18.39	6.62	10.54	4.25	6.62
7	12.5	14.3	33.14	4.32	1.85	2.79	1.26	1.85
8	20.9	16.8	110.83	23.11	6.12	9.84	4.61	6.12
9	16.4	15.5	70.18	13.28	4.59	7.71	5.01	4.59
10	13.8	15.6	46.93	5.47	2.94	5.31	1.31	2.94

Appendix 2. Stand table

D.B.H.	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
n/ha	50	17	67	17	17	34	134	84	151	134	84	84	185	84	34	17	34	17