Eurasian J. For. Res. 2: 39-44 , 2001

Comparison of Needle Mass Density in The Tree Crowns of *Larix gmelinii* and *Larix kaempferi* Trees

SHIBUYA Masato[1]*, SUGIURA Tetsuya[1], TAKAHASHI Kunihide[1], SAWAMOTO Takuji[1], HATANO Ryusuke[1], CHA Joo Young[2], FUKUYAMA Kenji[3], ISAEV Alexander P.[4] and MAXIMOV Trofim C.[4]

[1] Graduate School of Agriculture, Hokkaido Univ., Sapporo 060-8589, Japan
[2] Wakayama Experimental Forest, University Forests of Hokkaido Univ., Kozagawa 649-4563, Japan
[3] Hokkaido Reseach Center, Forestry and Forest Products Research Institute, Sapporo 062-8516, Japan
[4] Institute of Biological Problems of Cryolithozone, Russian Academy of Science, Yakutsk 677891, Republic of Sakha, Russia

Abstract

In order to explain the smaller stand needle mass in Siberian *Larix* stands comparing with that in Japanese *Larix* and deciduous broadleaved stands, we examined needle mass density against cross-sectional stem area at live crown base (*i.e.* pipe-model relationship) of Siberian and Japanese *Larix* (*Larix gmelinii* and *L. kaempferi*, respectively) trees sampled from a young stand in each area. The results showed no significant difference in allometries between needle mass and cross-sectional stem area at live crown base between the two species. However, basal area and aboveground biomass in the Siberian *Larix* stand were 1.6- and 1.3-times larger than those in the Japanese *Larix* stand, respectively. Consequently, it was concluded that causes inducing loosely closed canopy in Siberian *Larix* stands and other factors such as competition for resources than needle mass density against cross-sectional stem area need to be examined to explain the smaller stand needle mass in Siberian *Larix* stands.

Key words: *Larix gmelinii, Larix kaempferi*, needle mass density, stand needle mass

Introduction

Needle mass in many *Larix gmelinii* stands in the eastern Siberian permafrost zone generally ranges from around 150 to 250 $g \cdot m^{-2}$ (Osawa *et al.* 1993, Kanazawa *et al.* 1994, Schulze *et al.* 1995, Yajima *et al.* 1998), and tends to be less than that in *Larix kaempferi* and deciduous broadleaved stands in the cool-temperate zone in Japan (around 300 $g \cdot m^{-2}$; Kira and Shidei 1967, Tadaki 1976). Although this may result in part from the loosely closed canopy of the Siberian *Larix* stands (Schulze et al. 1995), we hypothesize that the difference in stand needle mass is due to the needle mass density in the crown of Siberian *Larix* trees being less than that of Japanese *Larix* trees.

In this study, we compared needle mass density between the crowns of Siberian and Japanese *Larix* trees based on the pipe-model relationship (Shinozaki *et al.* 1964) to test the hypothesis that the smaller stand needle mass in Siberian *Larix* stands is the result of smaller needle mass density in the tree crowns. The relationship between individual leaf mass and a tree dimension such as diameter at breast height generally differs between stands, that is called as the stand segregation (Tadaki 1966). However, the stand segregation in leaf mass estimation is disappeared by the application of the pipe-model theory of tree form which predicts a close relationship between individual leaf mass and cross-sectional area of conducting tissue in stem at live crown base (Shinozaki *et al.* 1964). Therefore, we can use stem diameter at live crown base as an explanatory variable of individual leaf mass (Shinozaki *et al.* 1964). Consequently, in this study, we compared the relationship between individual needle mass and stem diameter at live crown base, *i.e.* the pipe-model relationship, between Siberian and Japanese *Larix* trees.

Study sites and Methods

The Siberian *Larix* stand studied (N62° 13′ , E129° 11′) is located near the Kenkeme river about 40 km northwest of Yakutsk, in eastern Russia. This stand is composed almost purely of *Larix gmelinii* trees that has regenerated after a forest fire about 25 years ago. The site was located on a flat plateau in the permafrost zone and about 220 m in altitude. Soil was sandy Spodosls and the depth of active layer was 100 cm in the stand (Sawamoto *et al.* 1999). Lichens and *Vaccinium* species were dominant on the forest floor of the stand. Annual mean temperature and precipitation in Yakutsk are −10.0 ℃ and 237 mm, respectively. Monthly mean temperature more than 5 ℃ is observed from May to September.

We set out a 100 m^2 plot and made a tree inventory in early August 1998. To examine the relationship

(Received; Oct. 16, 2000: Accepted; Jan. 17, 2001)

* Corresponding author: shibuya@for.agr.hokudai.ac.jp

between the masses of crown components and tree dimension, nine trees within the large size range (height: 1.6-6.1 m, diameter at breast height: 0.2- 5.5 cm) for the stand were sampled around the plot. They were separated into stem, branches and needles, and the dry mass of each component was determined after the measurement of stem diameter at breast height (1.3 m, DBH), tree height (H), height of live crown base and stem diameter at live crown base (D_b). We took a small sample of each component to determine its dry mass. Needle and branch samples were dried at 80 ℃ for 48 hrs, which was sufficient because branches were thin. Stem samples were dried at 80 ℃ until their masses became constant.

Tree measurement was also conducted in a Japanese *Larix* stand (N42° 51′, E140° 57′), an 11-year-old *L. kaempferi* plantation, located in Kyogoku Town in Hokkaido, Japan. The stand dominant height of this stand was similar to that of the *L. gmelinii* stand. The site was located on a gentle slope less than 5° and about 400 m in altitude. Soil is forest brown soil and *Sasa senanensis* completely covered the forest floor of the stand. Annual mean temperature and precipitation are 7.0 ℃ and 1505 mm, respectively, in the record of the closest meteorological station (N42° 54′, E140° 46′). From May to October, monthly mean temperature are more than 5 ℃.

We set out two 400 m^2 plots and made tree inventories in early September 1998. Nine trees within the large size range (height: 2.5-7.1 m, diameter at breast height: 1.9-10.9 cm) for the stand were sampled around the plots to compare relationships between the masses of crown components and tree dimensions between the stands. The mass of each component and the dimension of the sampled trees were determined in the same way as for the *L. gmelinii* trees.

Results and Discussion

Table 1 shows the stand conditions of the two *Larix* stands. Tree density in the *L. gmelinii* stand was 1.00 trees·m^{-2} and approximately ten times larger than that in the *L. kaempferi* stand. *L. gmelinii* trees accounted for 99 % of the basal area and were accompanied by *Pinus sylvestris*, *Betula platyphylla* and *Salix bebianna*. Mean DBH and H were larger in the *L. kaempferi* stand than in the *L. gmelinii* stand.

The pipe-model relationships between masses of crown components and D_b (Shinozaki *et al.* 1964) in the sampled *Larix* trees are shown in Fig. 1. In all relationships, significant regressions were obtained on a log-log scale ($p<0.01$ for all regressions). There were no significant differences in regression coefficients and intercepts of the W_l-D_b^2 (W_l: needle mass) and W_b-D_b^2 (W_b: branch mass) regressions between the stands (ANCOVA, $p>0.05$). Further, there were no significant differences in the allometric relationships between needle mass and branch mass between the stands (ANCOVA, $p>0.05$, Fig. 1). Therefore, needle mass density against supporting organs, W_b and D_b, of the *Larix* trees was statistically equivalent in the two stands. The smaller needle mass in a *L. gmelinii* stand, therefore, is not attributable to differences in needle mass density against supporting organs. Stand needle masses estimated from the allometry between W_l and $DBH^2 \cdot H$ (Append. 2) were 151 g·m^{-2} and 167 g·m^{-2} in the *L. gmelinii* and *L. kaempferi* stands, respectively. However, basal area and aboveground biomass, which was estimated from the allometry between aboveground mass and $DBH^2 \cdot H$ (Append. 2), in the Siberian *Larix* stand were 1.6- and 1.3-times larger than those in the Japanese *Larix* stand (Table 1). It is suggested that

Table 1. Stand conditions in Siberian and Japanese *Larix* stands

Species	Density	DBH[2]	H[3]	BA[4]	Aboveground biomass[5]
	(trees·m^{-2})	(cm)	(m)	(cm^2·m^{-2})	(kg·m^{-2})
L. gmelinii	1.00	3.0	4.7	8.91	1.62
		0.5–7.0	1.8–7.4		
L. kaempferi[1]	0.11	7.0	5.4	5.68	1.27
		0.8–13.2	1.5–8.4		

1) Mean values of two plots.
2) Diameter at breast height. Values indicate mean (upper) and range (lower).
3) Tree height. Values indicate mean (upper) and range (lower).
4) Basal area.
5) Estimated from allometries between individual aboveground mass and $DBH^2 \cdot H$ (Append. 2).

the individual crown size of *L. gmelinii* trees tends to be limited smaller for the tree size and stand density compared to that of *L. kaempferi* trees.

Consequently, factors inducing the loosely closed canopy of *L. gmelinii* stands other than individual needle mass density against supporting organs must cause the smaller needle mass of the stands. Schulze *et al.* (1995) reported that the canopy of Siberian *Larix* stands became more open with decrease in tree density. We found a similar trend in *Larix* stands aged 23, 50, 120 and over 230 years old near the Kenkeme river (Unpublished data). These results mean that the loosely closed canopy is related to the self-thinning dynamics of a stand. Schulze *et al.* (1995) also suggested that nitrogen availability might affect stand structure and density dynamics of *Larix* stands in eastern Siberia. If nutrient and/or water availability is severely limited, a loosely closed canopy results from competition between trees for those resources. On the other hand, Wirth *et al.* (1999) reported that crown cover in Siberian pine forest stands was small, and competition for light and nutrients affected tree growth and self-thinning dynamics in the stands. Furthermore, Oker-Blom and Kellomäki (1982) demonstrated that thinner crowns were more effective in absorbing light at high latitudes. Therefore, it is neccessary to take competition for light and nutrients into account when examining the cause of the loosely closed canopy of the Siberian *Larix* stands.

This study was supported by an International Scientific Research (Field Research) Grant (No. 09041140) to Kunihide Takahashi from the Ministry of Education, Culture, Sports, Science and Technology of the Japanese Government.

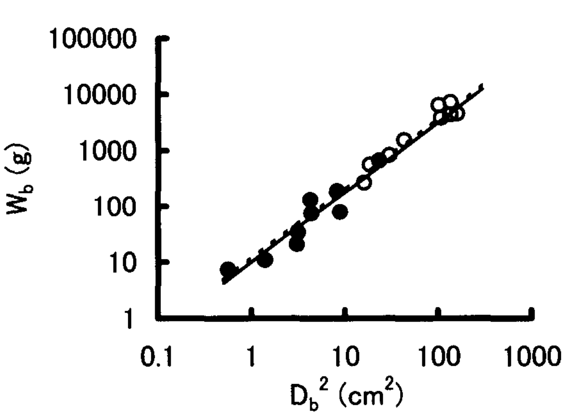
References

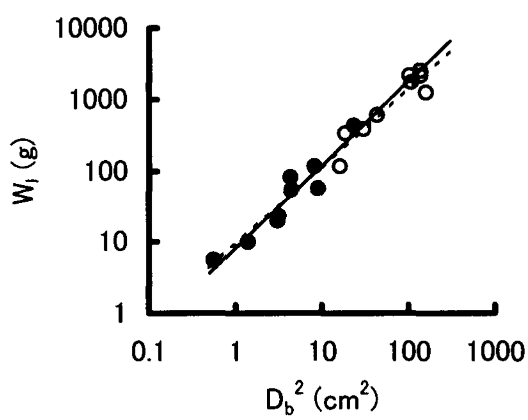
Kanazawa, Y., Osawa, A., Ivanov, B.I. and Maximov, Kira, T. and Shidei, T. 1967. Primary production and turnover of organic matter in different forest ecosystems of the western Pacific. Jpn. J. Ecol., 17: 70-87.

Oker-Blom, P. and Kellomäki, S. 1982. Theoretical computations on the role of crown shape in the absorption of light by forest trees. Math. Biosci., 59: 291-311.

Osawa, A., Takahashi, K., Maksimov, T.C. and Ivanov, B.I. 1993. Forest biomass in east Siberia. Trans. Mtg. Hokkaido Br. Jpn. For. Soc., 41: 238-239.

Sawamoto, T., Hatano, R., Takahashi, K., Shibuya, M., Isaev, A. P., Desyatkin, R. M., Maximov, T. C. and Ivanov, B. I. 1999. Soil respiration and fluxes of N_2O and CH_4 in Siberian-taiga ecosystems with different histories of forest fire. In M. Shibuya, K. Takahashi and G. Inoue eds., Proceedings of the Seventh Symposium on the Joint Siberian Permafrost Studies between Japan





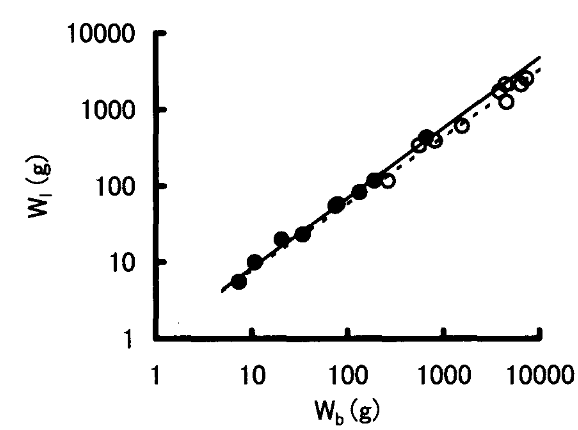


Fig.1. Allometric relationships for the crown components of *Larix gmelinii* and *L. kaempferi* trees. Solid and open circles indicate *L. gmelinii* and *L. kaempferi* trees, respectively. Solid and dotted lines are regressions for *L. gmelinii* and *L. kaempferi*, respectively.
Abbreviations: W_b, branch mass; W_l, needle mass; D_b, stem diameter at live crown base.

and Russia in 1998, Isebu, Ibaraki, pp. 77-89.

Schulze, E.-D., Schulze, W., Kelliher, F.M., Vygodskaya, N.N., Ziegler, W., Kobak, K.I., Koch, H., Arneth, A., Kusnetsova, W.A., Sogatchev, A., Issajev, A., Bauer, G. and Hollinger, D.Y. 1995. Aboveground biomass and nitrogen nutrition in a chronosequence of pristine Dahurian *Larix* stands in eastern Siberia. Can. J. For. Res., 25: 943-960.

Shinozaki, K., Yoda, K., Hozumi, K. and Kira, T. 1964. A quantitative analysis of plant from-The pipe model theory Ⅱ. Further evidence of the theory and its application in forest ecology. Jpn. J. Ecol., 14: 133-139.

Tadaki, Y. 1966. Some discussions on the leaf biomass of forest stands and trees. Bull. Gov. For. Exp. Sta., Tokyo, 184: 135-161.

Tadaki, Y. 1976. Biomass of forests, with special reference to the leaf biomass of forests in Japan. J. Jpn. For. Soc., 58: 416-423.

Wirth, C., Schulze, E.-D., Schulze, W., von Stünzner-Karbe, D., Ziegler, W., Miljukova, I. M., Sogatchev, A., Varlagin, A.B., Panvyorov, M., Grigoriev, S., Kusnetzova, W., Siry, M., Hardes, G., Zimmermann, R. and Vygodskaya, N.N. 1999. Above-ground biomass and structure of pristine Siberian Scots pine forests as controlled by competition and fire. Oecologia 121: 66-80.

Yajima, T., Takahashi, K., Sasaoka, E., Hatano, R., Sawamoto, T., Ivanov, B.I. Isaev, A.P. and Maximov, T.C. 1998. Stand structure and biomass of *Larix* cajanderi forest in the Siberian taiga. In S. Mori, Y. Kanazawa, Y. Matsuura and G. Inoue eds., Proceedings of the Sixth Symposium on the joint Siberian Permafrost Studies between Japan and Russia in 1997, Isebu, Ibaraki, pp. 72-80.

Appendix 1. Size and organ mass of sampled *Larix* trees in Siberia and Japan

a) Siberian *Larix* trees (*Larix gmelinii*)

No.	DBH (cm)	D_0 (cm)	$D_{0.1}$ (cm)	D_b (cm)	H (m)	H_b (m)	W_s (g)	W_b (g)	W_l (g)	Age (yrs)
1	5.5	8.1	6.3	4.8	6.1	2.3	3708	670	432	22
2	3.0	3.9	3.3	2.9	5.1	1.3	914	193	116	22
3	2.1	4.1	3.0	2.4	4.0	1.1	532	133	82	19
4	2.5	4.1	3.1	3.0	3.6	1.0	481	79	57	22
5	2.1	3.0	2.6	2.1	3.4	1.2	376	75	54	19
6	1.3	2.3	2.2	1.8	2.7	1.1	149	21	20	18
7	1.1	2.9	2.2	1.8	2.3	0.9	148	35	23	17
8	0.8	1.8	1.4	1.2	1.7	0.3	63	11	10	20
9	0.2	1.1	0.9	0.8	1.6	0.5	27	7	6	20

b) Japanese *Larix* trees (*Larix kaempferi*)

No.	DBH (cm)	D_0 (cm)	$D_{0.1}$ (cm)	D_b (cm)	H (m)	H_b (m)	W_s (g)	W_b (g)	W_l (g)	Age* (yrs)
1	10.9	16.0	12.0	11.7	7.1	0.8	10751	7332	2549	11
2	9.3	13.3	9.7	11.7	6.6	0.4	7456	4472	2149	11
3	8.0	12.9	9.7	10.4	5.8	0.3	5652	3859	1747	11
4	8.4	13.8	10.2	10.1	5.4	0.5	6362	6496	2150	11
5	7.6	16.0	10.3	12.7	4.8	0.3	5135	4560	1259	11
6	4.0	7.9	6.5	6.6	3.8	0.3	1661	1562	606	11
7	4.4	7.4	5.7	5.5	4.1	0.5	1481	832	388	11
8	1.9	4.2	2.9	4.0	2.5	0.1	253	268	117	11
9	3.1	5.9	4.4	4.3	3.5	0.5	799	566	339	11

* Stand age.

Abbreviations; DBH: diameter at breast height, D_0: diameter at stem base, $D_{0.1}$: diameter at 1/10-tree height, D_b: diameter at crown base, H: tree height, H_b: height of crown base, W_s: dry mass of stem (including bark mass), W_b: dry mass of branches, W_l: dry mass of needles.

Appendix 2. Parameters of allmetries ($\log y = a + b \log x$) for *Larix* trees in Siberia and Japan

x	y	Species	*a*	*b*	r^2	n
$DBH^2 \cdot H$	W_t	*L. gmelini*	-1.143^a	0.768^a	0.977	8*
		L. kaempferi	-0.932^b	0.779^a	0.976	9
$DBH^2 \cdot H$	W_s	*L. gmelinii*	-1.272^a	0.772^a	0.982	8*
		L. kaempferi	-1.346^a	0.821^a	0.991	9
D_b^2	W_b	*L. gmelinii*	-1.996^a	1.249^a	0.878	9
		L. kaempferi	-1.932^a	1.257^a	0.933	9
D_b^2	W_l	*L. gmelinii*	-2.092^a	1.174^a	0.909	9
		L. kaempferi	-2.036^a	1.099^a	0.884	9
W_b	W_l	*L. gmelinii*	-0.002^a	0.921^a	0.993	9
		L. kaempferi	-0.002^a	0.884^a	0.969	9

* One tree was excluded from a regression analysis because of its extremely irregular trend.
All regressions are significant ($p<0.01$). Different superscripts with parameters, *a* and *b*, dicate significant difference ($p<0.05$).
Abbreviations; W_t: dry mass of aboveground parts, the others: the same to Append. 1.

Photo. 1. Siberian *Larix gmelinii* stand. Stand age was 22 years old in 1998. The stand was crowded for its stand age, but the canopy closed loosely and forest-floor vegetation such as shrubs and lichens were abundant. Canopy closure was 63% estimated from the crown projection diagram (Photo. by M. Shibuya).

Photo. 2. Soil profile in the Siberian *Larix gmelinii* stand. All horizons were sandy soil. Organic matter accumulated at O- and A-horizons from top to the depth of 10 cm. Below the A-hrizon, a white-colored horizon with 5 cm in thickness could be E-hrizon, from which iron and aluminum has been eluviated. Soil temperature was 20 and 10 ℃ at 5 and 10 cm depth, although air temperature was 30 ℃. Permafrost layer was recognized below the depth of 100 cm, where soil temperature was minus in centigrade (Photo. by T. Sawamoto).