

# *Interactions between Root System Development and Permafrost Soil Environments on Siberian Larch Forests (Extended Abstract)*

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(Received December 17, 2002)

## Introduction

Boreal forests are expected to affect significantly global carbon balance under a scenario of warming (*e.g.*, Goulden *et al.*, 1998, Schulze *et al.*, 1999). Larch forests (*Larix gmelinii*, *L. cajanderi*) in central and eastern Siberia, which are established on the continuous permafrost region, might also play a key role in the global carbon balance. However, it is still uncertain whether the Siberian larch forests will function as carbon sink or source. To predict such function precisely, we need to evaluate carbon stock and net primary production in this forest ecosystem, including not only aboveground parts but also roots and soils.

In this paper, based on our previous field studies and other published data, we discuss the following three topics focusing on interactions between root system development and permafrost soil environments in Siberian larch forests; 1) biomass allocation and productivity, 2) spatial pattern and development of individual root system, and 3) micro-scale soil temperature conditions produced by earth hummock topography.

## Materials and Methods

We used data set of sample trees (total  $n=26$ ) and biomass estimates taken from four different larch stands; two mature stands (*L. cajanderi*) located near altitudinal and northern treelines in eastern Siberia, Oymyakon (130–150 yrs-old) and Chersky (140–180 yrs-old) (Kajimoto *et al.*, 1998, 1999b), and the other two stands (*L. gmelinii*) located near the town of Tura in central Siberia, uneven-aged older stand (plot C1, 240–260 yrs-old) and almost even-aged younger stand (plot W1, 100 yrs-old) (Kajimoto *et al.*, 1999a, 2003). In each stand, six or seven larch trees with different sizes were harvested and weighed, including coarse roots (diameter > 5 mm). Above- and belowground biomass were

estimated using site-specific allometric relationships between stem diameter (DBH) and each organ's dry weight of the sample trees. For the two stands of Tura (C1, W1), we also observed spatial distribution of individual root system, and analyzed past growth and development patterns of lateral roots using ring-width data. In C1, micro-scale differences in soil-temperatures (10 cm deep) were examined in relation to earth hummock topography (*i.e.*, elevated mounds vs. depressed troughs). Details for these measurements and analysis are described elsewhere (Kajimoto *et al.*, 1998, 1999a, 1999b,

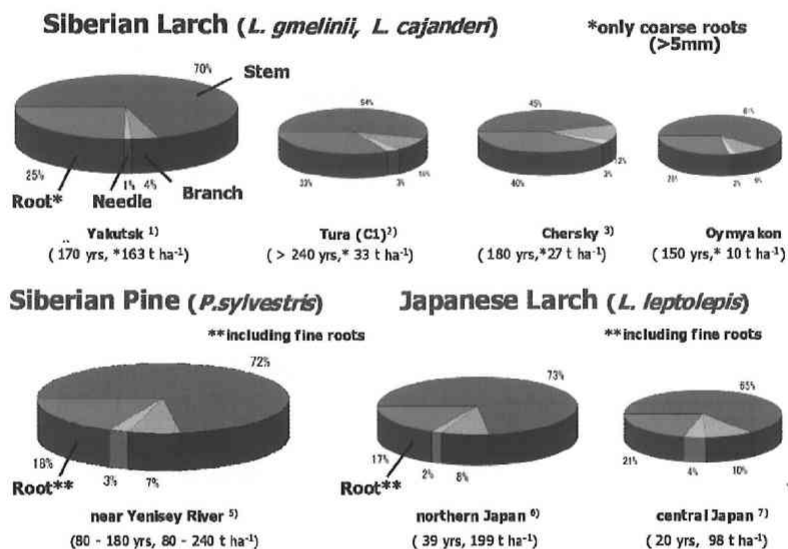


Fig. 1 Comparisons of biomass allocation patterns between Siberian larch, Siberian pine and Japanese larch forests. Data from <sup>1)</sup>Kanazawa *et al.* (1994), <sup>2),3),4)</sup> Kajimoto *et al.* (1998, 1999a, 1999b), <sup>5)</sup>Pzdynakkov *et al.* (1969), <sup>6)</sup>Satoo (1970), and <sup>7)</sup>Kurachi *et al.* (1993).

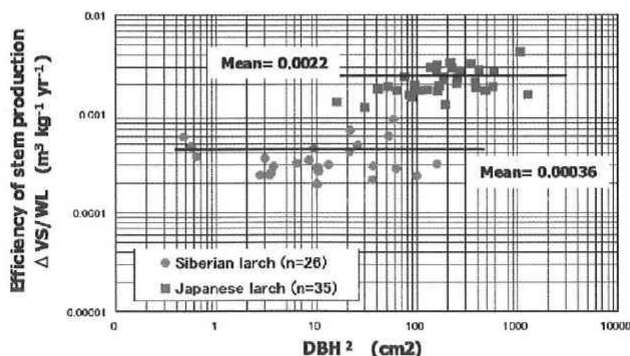


Fig. 2 Comparison of stem growth efficiency between Siberian larch and Japanese young larch trees. The efficiency was defined as annual stem volume increment ( $\Delta VS$ ; mean in recent 5-yr) per unit needle weight ( $WL$ ). Data of Japanese larch from (Shidei *et al.* 1964).

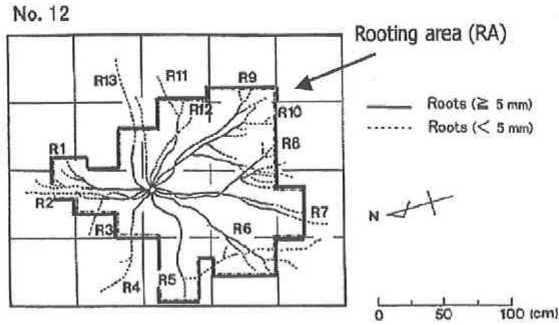


Fig. 3 Example of horizontal distribution of individual root system for Siberian larch (*L. gmelinii*) sample tree (No. 12 in W1, Tura) (from Kajimoto *et al.* 2003).

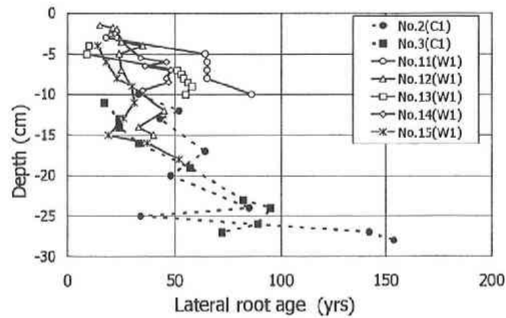


Fig. 4 Relationship between age and vertical depth of lateral roots for some larch sample trees in C1 and W1, Tura. Tree ages are 266 and 207 yrs-old (No. 2, 3 in C1), and 92–100 yrs-old (No. 11–15 in W1) (Kajimoto *et al.* 2003).

2003).

## Results and Discussion

### *Biomass allocation and productivity*

Siberian larch forests had relatively high root/total biomass ratio, *e.g.*, the ratios of four mature stands reached 30–40%, even excluding fine roots (Fig. 1). This ratio was much higher than the root/total ratios (including fine roots) for Scots pine (*Pinus sylvestris*) forests in Siberia (18%) and Japanese young larch (*L. leptolepis*) stands (17–21%).

Net primary production rates (NPP) of *L. gmelinii* forests were considerably low, *e.g.*, 1.8 and 2.7 ton ha<sup>-1</sup>y<sup>-1</sup> for the old stands in Tura (C1) (Kajimoto *et al.*, 1999a) and Yakutsk (Kanazawa *et al.*, 1994), respectively. These estimates were less than 20% of NPP for Japanese young larch plantation, 12.6 ton ha<sup>-1</sup> y<sup>-1</sup> (Satoo 1970). However, net assimilation rates (*i.e.*, NPP/needle biomass ratio) of these two Siberian larch stands (1.6 and 1.8 y<sup>-1</sup>) reached 40–50% of the Japanese larch stand (3.5 y<sup>-1</sup>). On a tree basis, mean stem growth efficiency (*i.e.*, stem volume increment per unit needle weight) of Siberian

mature larches was only about 17% of that of Japanese young larch trees (Fig. 2), indicating that annual carbon gain was largely invested into roots for Siberian larch than Japanese larch trees.

#### *Spatial distribution and development of root system*

Mature Siberian larch trees developed superficial, asymmetric root system consisting of horizontally well-spread lateral roots (Fig. 3). Lateral roots expanded within upper soils (<10 cm deep), mostly grew into elevated mounds than surrounding troughs (Kajimoto *et al.*, 1999a). Horizontal rooting areas (RA) of the sample trees were about four times crown projection areas. On a stand level, total RA per unit land area ( $\text{m}^2 \text{m}^{-2}$ ) exceeded an unity, e.g., 1.2 in the old stand (C1) and 1.1 in the younger stand (W1) of Tura, indicating that root networks were almost fully closed in these stands (Kajimoto *et al.*, 2003).

For each tree, lateral roots occurred successively from each tap root, and older roots often started to expand simultaneously, e.g., ages of older roots were almost the same for some trees (No. 12–15) of the younger stand (W1) (Fig. 4).

#### *Micro-scale soil temperature conditions*

Earth hummock topography produced conspicuous gradient of soil-temperature conditions. Mean summer soil-temperatures were much higher ( $>5^\circ\text{C}$ ) on the mounds than inside troughs, and cumulative soil-temperatures ( $>0^\circ\text{C}$ ) decreased from the top of mounds (800–1,200°C days) to the bottom of troughs ( $<400^\circ\text{C}$ , days) (Kajimoto *et al.* 2003).

#### *Interactions between tree growth, root system development and permafrost dynamics*

For Siberian larch, annual carbon gain is highly invested into root growth, resulting in relatively large belowground carbon pool. This root-oriented carbon allocation is also linked with construction of superficial root system. The fact that lateral roots extend horizontally into warmer mounds than colder troughs indicates that the micro-scale gradient of soil-temperature produced by the earth hummock primarily affects individual root system development. Consequently, root network is likely to be fully expanded on a stand level ( $>100$  years), irrespective of no evidence of canopy closure. These features suggest that growth of Siberian larch is controlled by constraint of soil-nutrients uptake.

Root system development might be also affected by changes of soil environments following past fire disturbance, e.g., gradual declines of active layer depth and nutrient availability due to vegetation recovery. In *L. gmelinii* forests in central Siberia, tree dieback often occurs intensively at relatively early growth stage ( $<100$  yrs-old), including both smaller and larger trees (Abaimov & Sofronov 1996, Osawa *et al.*, 2000), implying that tree mortality is caused by the decline of soil-nutrient uptake than so-called inter-tree competition for irradiance. Corresponding to such growth stage, individual root system may change drastically from vertical growth of tap root to horizontal growth of lateral roots, as seen in the trees of 100 yrs-old stand (W1):

simultaneous occurrence of older lateral roots in the period of 30–50 years after tree establishment (Fig. 4). To discuss more this linkage between tree growth, root system development, and post-fire dynamics of permafrost soil environments, we need further studies on various growth-stage forests.

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