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Effect of Understory Dwarf Bamboo on Seasonal Changes in Soil Temperature in a *Betula ermanii* Forest, Northern Japan

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Abstract

The effect of understory dwarf bamboo (*Sasa kurilensis*) on the seasonal changes in soil temperature was studied in a dense secondary forest of *Betula ermanii* in northern Japan. Four plots were established in the *Betula ermanii* forest with *Sasa kurilensis* in the understory, and *Sasa* was removed in two plots of the four. The soil temperatures at 5 cm below the surface were monitored in the four plots from May 1999 to September 2000, and were compared between the plots with and without *Sasa*. The daily maximum soil-temperature was ca. 0.5℃ lower in the plots without *Sasa* than in the plots with *Sasa* during the snow-cover period. On the contrary, the daily maximum soil-temperature was ca. 3~4℃ higher in the plots without *Sasa* than in the plots with *Sasa* just after the snowmelt in mid-May 2000. The difference in soil temperature between the plots with and without *Sasa* decreased gradually from the snowmelt toward the snow-cover period. The solar radiation was highest at around late May or early June 2000, and decreased toward winter. In addition, much solar radiation penetrated through the overstory layer from the snowmelt till early June when the leaf emergence of overstory trees started. Therefore, the absolute difference in solar radiation on the soil surface between the plots with and without *Sasa* was thought to be highest after the snowmelt, and gradually decreased till the snow cover period. Thus, this study showed that the impact of *Sasa* on the seasonal changes in soil temperature relates to the snow cover on the forest floor, the leaf phenology of overstory trees and the seasonal changes in solar radiation.

Key words: *Betula ermanii*, *Sasa kurilensis*, Soil temperature, Uryu Experimental Forest

Introduction

Dwarf bamboos, the genus *Sasa*, form dense undergrowth in Japanese forests (Suzuki 1961, 1962). Soil surface is heavily shaded when dwarf bamboo is abundant: the relative light intensity is only a few percent under the dense foliage of *Sasa* canopy (Makita 1992, Makita *et al.* 1993, Konno 2001). Therefore, many ecologists have focused on the effects of dwarf bamboo on early phase of regeneration as seedling establishment, in relation to the light conditions on the forest floor (Nakashizuka 1988, Taylor and Qin 1988, Takahashi 1997, Kudoh *et al.* 1999). A low light level due to vegetation cover also reduces soil temperature by reducing the heat stored in soil (Körner 1999). Soil temperature is an important abiotic factor affecting nutrient cycling and nutrient availability for trees because high soil-temperature enhances decomposition rate of organic matter (Van Cleve *et al.* 1983, Bonan and Shugart 1989, Illeris and Jonasson 1999, Karlsson and Weih 2001). Therefore, not only the light intensity but also the soil temperature should be examined to reveal the effect of *Sasa* on the forest dynamics in Japan, where *Sasa* is abundant. However, little information is available about how *Sasa* affects the soil temperature.

In this study, we evaluated the effects of understory dwarf bamboo (*Sasa kurilensis* Makino et Shibata) on the seasonal changes in soil temperature in a dense secondary forest of *Betula ermanii* Cham. in northern Japan. We established experimental plots with and without *Sasa*, and compared the seasonal changes in the soil temperature at 5 cm below the surface between the plots with and without *Sasa*. In this study, we report the impact of *Sasa* on the seasonal changes in soil temperature relates to the snow cover on the forest floor, the leaf phenology of overstory trees and the seasonal changes in solar radiation.

Materials and methods

Study site

This study was carried out at the Uryu Experimental Forest of Hokkaido University in northern Japan (44° 20' N, 142° 15' E). The mean monthly temperatures ranged between 21.2 ℃ and –13.8 ℃ during the examined period (Fig. 1). The mean annual temperature and the annual precipitation were 4.6℃ and 1652 mm, respectively, during 1999–2000.

The study site was located at a flat ridge on Mt. Jinja (580 m above sea level) in the Uryu Experimental Forest. This area was a dense secondary forest of *Betula ermanii* where self-thinning was occurring. The forest floor was

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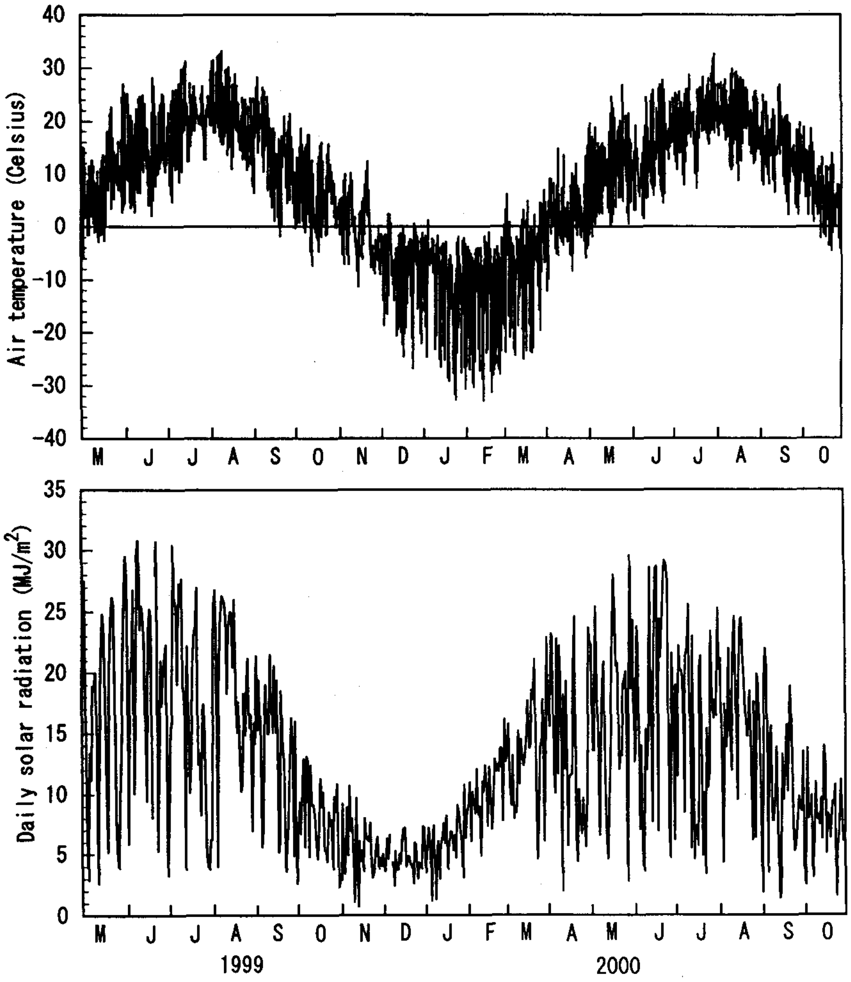

Fig. 1. The seasonal changes in the air-temperature recorded at the office of the Uryu Experimental Forest (upper figure), and he seasonal changes in the daily solar radiation recorded at Asahikawa Weather Station (lower figure). The daily maximum and minimum air-temperatures were expressed by a vertical bar for each day in the upper figure. The solar radiation was not recorded between August and December 2000 at the office of Uryu Experimental Forest.

densely covered with dwarf bamboo (*Sasa kurilensis*). The height of *Sasa kurilensis* was up to ca. 2.5 m. Leaf area index (total leaf area per ground area) of the understory *Sasa* layer and that of the overstory tree layer were ca. 0.9 and 4, respectively (our unpublished data). Leaves of *Betula ermanii* emerge in early June, and completely fall until mid-October (personal observation).

Field methods

In 1998, two 15-m × 15-m plots (Plot-1a and Plot-1b) were established in a dense secondary *Betula ermanii* stand with ca. 5.5-m trunk height. A second pair of 20-m×30-m plots (Plot-2a and Plot-2b) were established in another dense stand with ca. 9.2-m trunk height (ca. 1 km away from the first pair of the plots). There were no canopy gaps in the four plots. The distance between Plot-1a and Plot-1b and that between Plot-2a and Plot-2b were ca. 60 m and 30 m, respectively. Size structure and species composition were similar between the two plots in each stand (our unpublished manuscript). Stand basal area and tree density were 15.6 m^2/ha and 15755 trees/ha, respectively, in Plot-1a and Plot-1b, and those were 18.2 m^2/ha and 5165 trees/ha, respectively, in Plot-2a and Plot-2b. *Betula ermanii* occupied 96% of the total density in both Plot-1a and Plot-1b, and 72% in both Plot-2a and Plot-2b. Subordinate trees were all deciduous broad-leaved species: *Phellodendron amurense* Rupr., *Sorbus commixta* Hedland, *Salix bakko* Kimura and *Aralia elata* (Miq.) Seem.

All *Sasa* within Plot-1b, Plot-2b and a 5-m buffer were removed in October 1998. The soil temperature at 5 cm below the surface was automatically recorded in each plot at 1-hour intervals from late May 1999 to September 2000, by using the thermometer involving data logger (TidbiT, Onset Computer Corporation, Pocasset, MA, USA). This thermometer is completely sealed in epoxy, and very durable. A thermistor is placed inside the thermometer, and its accuracy is ±0.5℃. Two thermometers were buried at 5 cm below the soil surface at around the center of each plot, with a distance of a few meters between the two thermometers. The soil temperatures recorded by the two thermometers in each plot were averaged in each hour, and the averaged temperature was used for the comparison between the plots with and without *Sasa* for each pair of the plots (i.e., Plot-1a versus Plot-1b, and Plot-2a versus Plot-2b).

Results and discussion

An example of the seasonal changes in the soil temperature at 5 cm below the surface is shown in Figure 2. The snow cover on the forest floor lasted from late November 1999 to mid-May 2000 because the seasonal changes as well as the diurnal changes in soil temperature during this period were considerably small (cf. Masuzawa *et al.* 1991, Körner 1999). The soil temperature at 5 cm below the surface decreased slightly from the start of the snow-cover period to the snowmelt. A similar pattern was also observed at different soil depth deeper than 50 cm near our study site (Ishii and Kobayashi 1994).

The mean difference in the daily mean soil-temperature was small between the two thermometers in each plot during the examined period (at least smaller than 0.5℃). The effect of *Sasa* on the seasonal changes in the soil temperature at 5 cm below the surface was examined by comparing the soil temperatures between the plots with and without *Sasa*. As for each of the daily mean, maximum and minimum soil-temperatures, the two pairs of the plots (Plot-1a versus Plot-1b, and Plot-2a versus Plot-2b) showed similar seasonal trends in the difference in soil temperature between the plots with and without *Sasa* (Fig. 3). The daily mean soil-temperature was ca. 0.5℃ lower in the plots without *Sasa* than in the plots with *Sasa* during the snow-cover period probably because the presence of air within the *Sasa* layer had an adiabatic effect (i.e., the soil surface is less cooled by the snow cover if *Sasa* is present). Although the soil temperature increased abruptly just after the snowmelt (Fig. 2), this increase was found several days earlier in the plots with *Sasa* than in the plots without *Sasa* (i.e., the abrupt increase of $[T_{+sasa} - T_{-sasa}]$, Fig. 3). This suggests that the snow cover disappeared several days earlier in the plots with *Sasa* than in the plots without *Sasa*. However, the degree of the increase in soil temperature just after the snowmelt was higher in the plots without *Sasa* than in the plots with *Sasa* (i.e., the negative values of $[T_{+sasa} - T_{-sasa}]$, Fig. 3). This tendency was more conspicuous in the maximum soil-temperature than in the daily mean and minimum soil-temperatures. The maximum soil-temperature was ca. 3~4℃ higher in the plots without *Sasa* than in the plots with *Sasa* just after the snowmelt in mid-May, but this difference was only ca. 1℃ for the minimum soil-temperature. These thermal conditions are ascribed to the difference in solar radiation on the soil surface in daytime between the plots with and without *Sasa*.

As for each of the daily mean, maximum and minimum soil-temperatures, the difference in soil temperature between the paired plots decreased gradually from the snowmelt toward the snow-cover period. These seasonal trends in the difference in soil temperature between the paired plots are probably attributable to the leaf phenology of overstory trees and to the seasonal changes in solar radiation. Although the highest peak of the solar radiation in the year 2000 was observed in June,

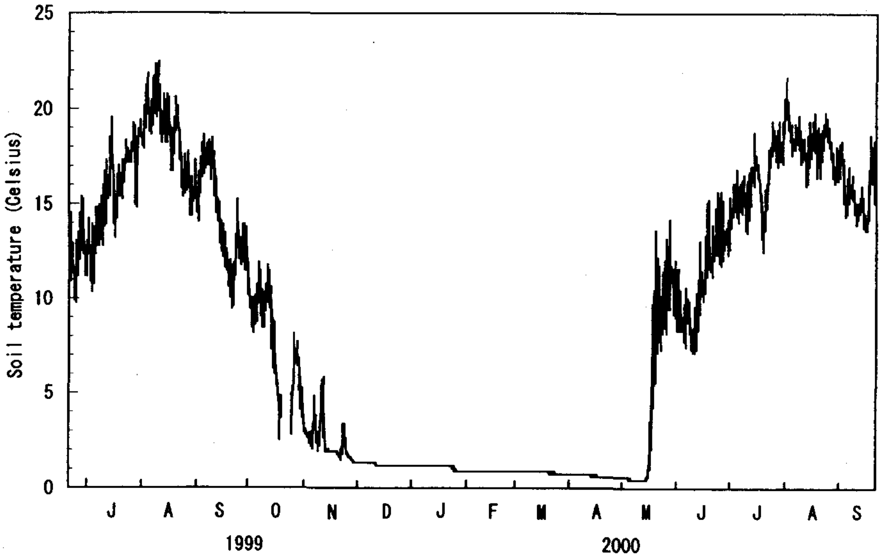

Fig. 2. The seasonal changes in the soil-temperatures at 5 cm below the surface in Plot-2a with *Sasa* in a dense secondary *Betula ermanii* forest. The daily maximum and minimum values were expressed by a vertical bar for each day.

the solar radiation was also high in mid-May when the snow cover disappeared (Fig. 1). In addition, the leaf emergence of overstory trees started from early June. Thus, much solar radiation reached the understory layer after the snowmelt till the leaf emergence of overstory trees. Even if the *Sasa* layer intercepts the same ratio of solar radiation throughout a year, the absolute difference in solar radiation on the forest floor between the plots with and without *Sasa* is expected to be large between the snowmelt and the leaf emergence of overstory trees. This resulted in the large difference in soil temperature between the paired plots. On the contrary, the leaf emergence of overstory trees and the decreased solar radiation from the summer solstice to the winter solstice brought about the small difference in soil temperature between the paired plots (i.e., the solar radiation on the soil surface was small irrespective of the presence/absence of *Sasa*).

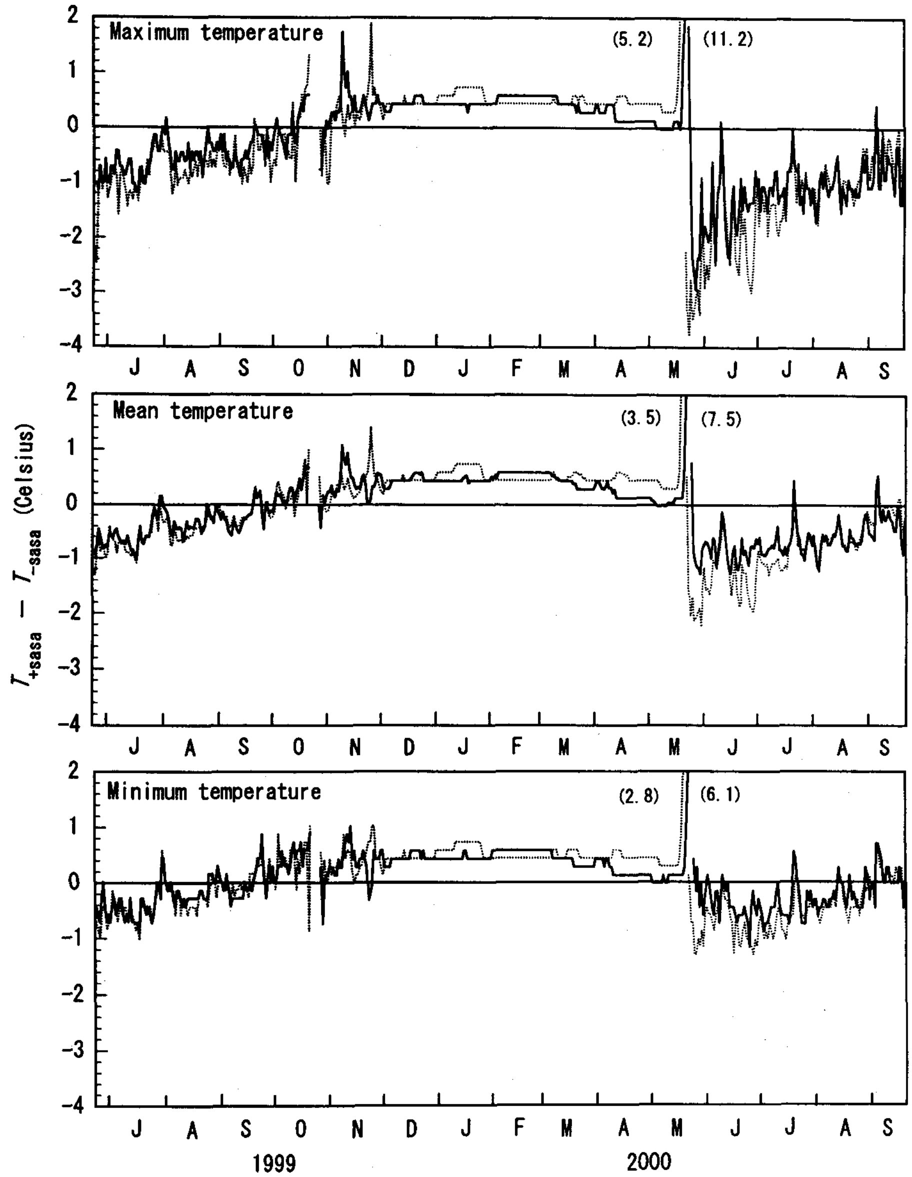

Fig. 3. The difference in the soil temperature at 5 cm below the surface between the plot with *Sasa* (T_{+sasa}) and the plot without *Sasa* (T_{-sasa}) for each pair of the plots in a dense secondary *Betula ermanii* forest. The difference in soil temperature between the plots with and without *Sasa* was expressed as [$T_{+sasa} - T_{-sasa}$: the soil temperature in Plot-1a (or Plot-2a) minus that in Plot-1b (or Plot-2b)]. Solid and dotted lines represent the pair of Plot-1a and Plot-1b and the pair of Plot-2a and Plot-2b, respectively. Values in right and left parentheses indicate the maximum differences found in the pair of Plot-1a and Plot-1b and the pair of Plot-2a and Plot-2b, respectively.

Thus, this study experimentally showed that the impact of *Sasa* on the seasonal changes in soil temperature relates to the snow cover on the forest floor, the leaf phenology of overstory trees and the seasonal changes in solar radiation. The high soil-temperature due to the *Sasa* removal might enhance the decomposition rate of organic matter and influence the nutrient cycling in this stand. To reveal this expectation, further experimental studies are necessary.

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