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A PRELIMINARY REPORT ON PHENOLOGICAL MONITORING USING EXPERIMENTAL CHAMBERS IN MT. KISOKOMAGATAKE, CENTRAL JAPAN

Ikuko NAKASHINDEN[1], Tadashi MASUZAWA[2], Satoshi FUKUYO[2], Keiji KIMURA[1], Satoko YAMAMOTO[2], Yoshihiro IIJIMA[3], Kazuharu MIZUNO[3], Shingo KOBAYASHI[4], Takahito YAMAMOTO[4], Hiroyuki MACHIDA[5] and Sadao TAKAOKA[3]

[1]*Department of Geography, Graduate School of Science, the University of Tokyo, 3–1, Hongo 7-chome, Bunkyo-ku, Tokyo 113*
[2]*Department of Agriculture, University of Tokyo Agricultural and Technology, 5–8, Miyuki-cho 3-chome, Fuchu-shi, Tokyo 183*
[3]*Department of Geography, Faculty of Science, Tokyo Metropolitan University, 1–1, Minami-Osawa, Hachioji-shi, Tokyo 192–03*
[4]*Ehime Prefectural Science Museum, 2133–2, Daishoin, Niihama 792*
[5]*Sano Junior and High School of Nihon University, 2555, Ishizuka-cho, Sano 327–01*

Abstract: To predict the influence of global warming on high-mountain plants, we have started an experiment on Mt. Kisokomagatake (2956 m), the Central Japanese Alps, using the ITEX (International Tundra Experiment) method. Four small greenhouses (OTC: open-top-chamber) were set up in May 1995 to cover two alpine species: *Arctous alpinus* var. *japonica* and *Diapensia lapponica*. The temperatures at plant height and the ground were measured in each OTC as well as a control plot without OTC. The average temperature in OTCs was higher than that in the control plot by 0.9°C. In accordance with the temperature enhancement, the plants in OTCs underwent some phenological changes during the summer of 1995. The duration from the leaf emergence to the beginning of coloring in OTCs was longer than that in the control plot by 33 days. Leaf wilting was also delayed in OTCs. Thus, alpine plants responded sensitively to the environmental change in the OTC.

1. Introduction

Global warming may cause significant environmental changes in cold areas such as polar regions and high mountains. In Spitsbergen (78°30′N), for example, a recent increase in temperature led to less snow cover, marked retreats of most glaciers, and advancement of plant seedlings onto recently exposed moraines (CRAWFORD *et al.*, 1993). To address the prediction of vegetation dynamics in arctic and alpine regions, a long term monitoring project on tundra plants (ITEX: International Tundra Experiment) has been conducted in circum-polar regions since 1990. ITEX attempts to understand the response of tundra plant species through simple manipulation and transplant experiments at multiple arctic and alpine sites (MOLAU, 1994). Although many arctic species have circumpolar distributions, some species occur in restricted habitats with narrow geographic ranges. For example, the temperate alpine flora in the Alps or the Rocky Mountains has a similar number of species to the arctic flora, although their distribution is confined within a narrow area (CHAPIN and KÖRNER, 1994). In Japan, tundra species occur above timberline in high mountains of Hokkaido and the Chubu district of Honshu. In the Taisetsu Mountains of Hokkaido, an ITEX site has been set up since 1994 to monitor phenological and physiological responses of ericaceous plants to temperature enhancement (G. KUDO, Hokkaido Univ., personal communication). The central mountain area of Honshu is located near the southern margin of tundra-plant distribution and it is expected that plants will respond sensitively to future climatic changes, but little attention has been paid to the ecology of tundra plants. In this context, three groups have started a long term experimental study on three different mountains, Mt. Kisokomagatake (2956 m), Mt. Fuji (3776 m) and Mt. Tateyama (3015 m) in 1995. On Mt. Kisokomagatake, we have started to monitor the phenological and climatological response of tundra species to temperaure enhancement. This paper describes the setting up of the study site and reports the preliminary result of the experiment in the first year.

2. Study Site

Mt. Kisokomagatake (2956 m a.s.l.) is located in the central mountain area of Honshu (35°47′N,137°49′E) (Fig. 1a). Above the timberline (*ca.* 2600 m a.s.l.), glacial and periglacial landforms such as cirques, moraines, block fields, and fellfields with patterned grounds were formed during 10000–80000 BP (YANAGIMACHI, 1983). Fellfields with turf-banked terraces mainly occur on a gentle SE-facing slope near the summit. An experimental site was set up on the slope at 2850 m a.s.l. (Fig. 1b). Wind-blown fellfield vegetation dominated by *Diapensia lapponica, Potentilla matsumurae, Stellaria nipponica, Leontopodium shinanense,* and *Vaccinium uliginosum* (KOIZUMI, 1980) is formed on the banks of the terraces. Dwarfed *Pinus pumila*

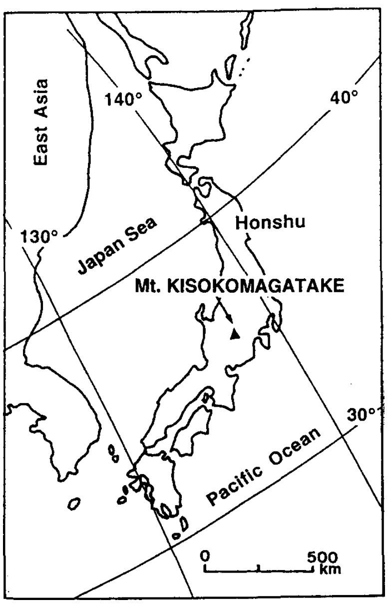

Fig. 1a. Location of Mt. Kisokomagatake.

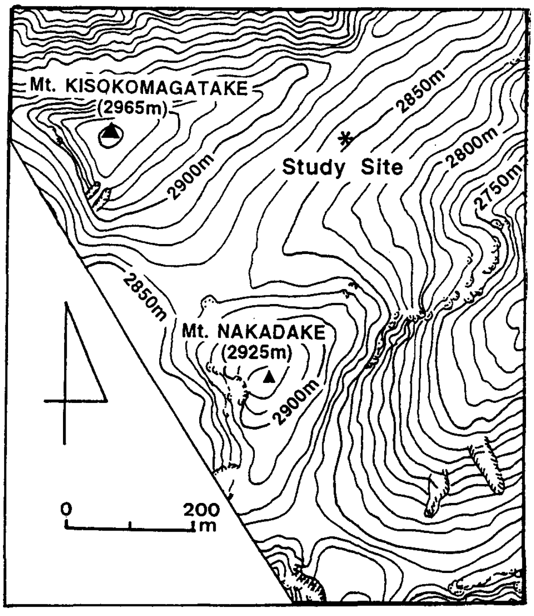

Fig. 1b. Map of study site.

scrubs also grow around the slope. Some of these species were originated from arctic regions during the glacial period (MURATA, 1995). Mean monthly temperature near the experimental site (*ca.* 2650 m a.s.l.) ranged from −12.1°C (January) to 11.9°C (August), and mean annual temperature was 0.8°C (1990 to 1992; measured by Mr. T. KINOSHITA, Chuo Alps Kanko Co., Ltd.). Snow covers a large part of the mountain from early November to early May. The experimental site, however, has sparse snow cover due to strong westerly wind during winter. Maximum snow depth at the site is at most 20–40 cm (KOIZUMI, 1974).

3. Method

Experimental surveys on plant phenology and measurements of temperatures were carried out during the growing season from May 28 to October 15, 1995. Four pentagon Open Top Chambers (called OTC-A to D), made of transparent acrylic resin boards, were set up over plants for temperature enhancement (Fig. 2). The basal diameter of each OTC was about 70 cm and the height was 30 cm. One quadrat

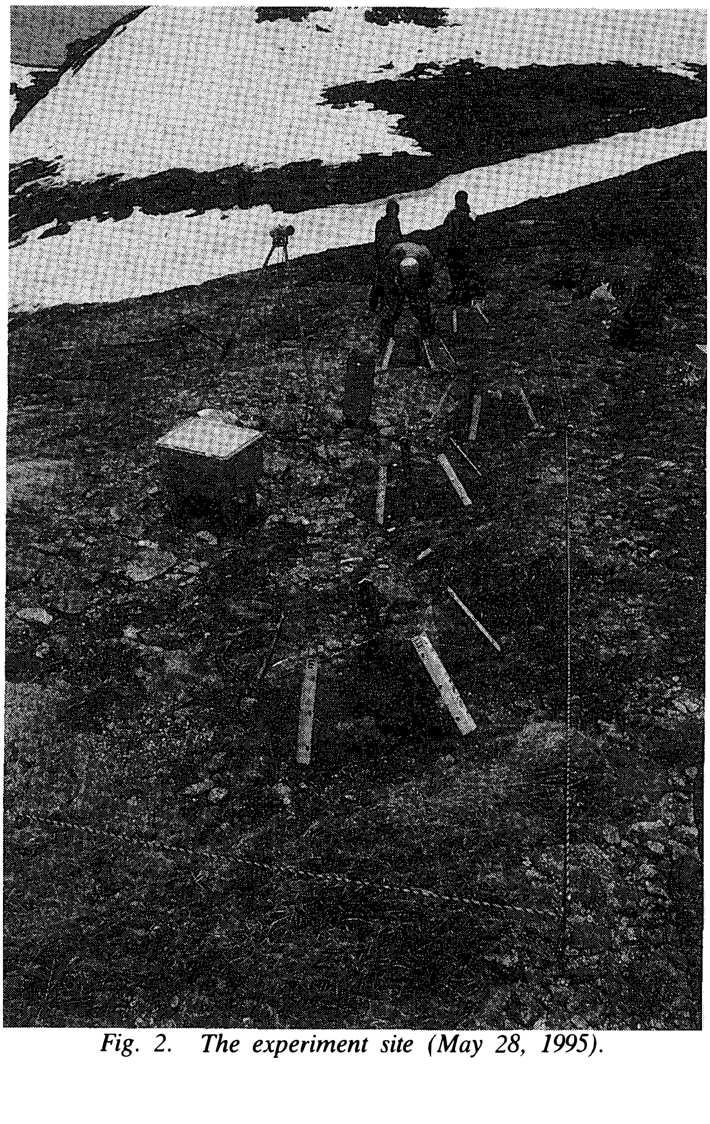

Fig. 2. The experiment site (May 28, 1995).

Table 1. Vegetation at the study site.

Species	Open top chambers				Control
	A	B	C	D	
Plant cover (%)	80	70	70	65	70
Arcterica nana	2.2	2.3	1.2	1.2	1.2
Arctous alpinus var. *japonica*	+	+	2.2	2.2	2.2
Gentiana algida	+	1.2	+	+	+
Loiseleuria procumbens	+	2.2	3.3	3.3	
Potentilla matsumurae	+	+	+	+	
Empetrum nigrum	4.4		4.4		
Pinus pumila	+		+		
Diapensia lapponica		2.3		4.4	3.3
Cladonia stellaris			1.2		
Vaccinium uliginosum					2.2
Carex sp.	2.2	2.2	2.2	2.2	3.2

Surveyed on May 28, 1995 (BRAUN-BLANQUET, 1964).

(50 cm × 50 cm) without an OTC was also selected as a control (called CTRL) next to OTC-D for comparison. These OTCs and CTRL were set in a line west to east on a large south-facing turf-banked terrace (*ca.* 2 m×5 m), where fairly dense wind-blown fellfield vegetation was growing, permission from the prefectural park office. Two thermistor sensors (Kona-System Co., Ltd., Sapporo, Japan) for temperature were set inside each OTC and CTRL. One sensor without shield was set at the height of vegetation (5 cm above ground) for measurement of air temperature and the other was set at 3 cm below the ground surface for measurement of soil temperature. The temperatures at the 10 points were recorded every one hour by automatic recorders (Kadec-U2, Kona-System Co., Ltd.) during the experiment. Air temperature at the height of 1.2 m near the OTCs and CTRL was also measured and recorded.

We observed the component of plant species both in OTCs and CTRL (Table 1). Two dwarf shrub species, *Diapensia lapponica* L. (evergreen) and *Arctous alpinus* Niedenzu var. *japonica* OHWI (deciduous) (MAKINO, 1961) were selected for phenological observation. *Diapensia* occured in OTC-B, OTC-D and CTRL. *Arctous* was found in all OTCs and CTRL. Phenological events such as flowering, leaf bud emergence, leaf opening, and leaf coloring and wilting were monitored in each OTC and CTRL every six to eight days. We recorded the date of the beginning of each event in OTCs (mean date) and CTRL as phenological changes. For *Diapensia*, we observed leaf phenology irrespective of whether the leaf was old or current.

4. Results

4.1. Air temperature at the site

On May 28, snow at the site had already disappeared. Mean air temperature at the site during the observation period (May to October, 1995) was 8.7°C (Table 2).

Table 2. Mean temperature (°C) of the site during observation period, 1995.

Location/Period	May to October	July & August
Air (1.2 m)	8.7	11.0
Vegetation height (5 cm)		
OTC (A–D)	12.7±0.43	15.4±0.48
CTRL	11.8	14.3
Ground (−3 cm)		
OTC (A–D)	10.0±0.52	12.4±0.67
CTRL	9.5	11.8

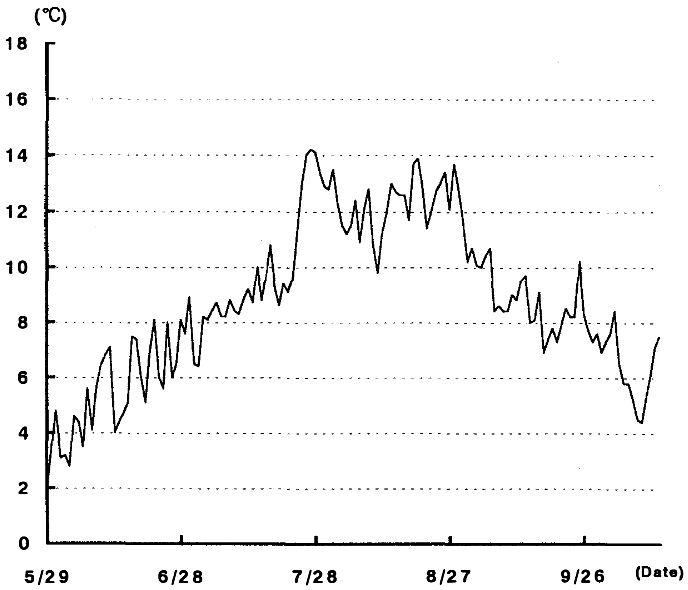

Fig. 3. Mean air temperature of study site during observation period (May to October, 1995).

The temperature increased gradually from May to late July, then it rose rapidly because of the termination of the rainy season (June to mid July) and remained high until mid-August (Fig. 3). Mean temperature between mid-July and mid-August was more than 11°C. Air temperature decreased gradually from late August to October.

4.2. Temperature at the height of vegetation and ground

Mean temperature at vegetation height during the observation period was 12.7°C in the OTCs, whereas it was 0.9°C lower in CTRL (Table 2). During summer (July and August), OTC was elevated 1.1°C from the CTRL value. Mean ground temperature for 5 months was 10.0°C in OTCs and 9.5°C in CTRL. These results indicate that the OTC treatment actually raised temperatures of vegetation height and the ground. The difference of vegetation height temperature between OTCs and CTRL was maximum at the end of July (Fig. 4). The diffrence of ground temperature between OTCs and CTRL was most distinct at the beginning of June. The

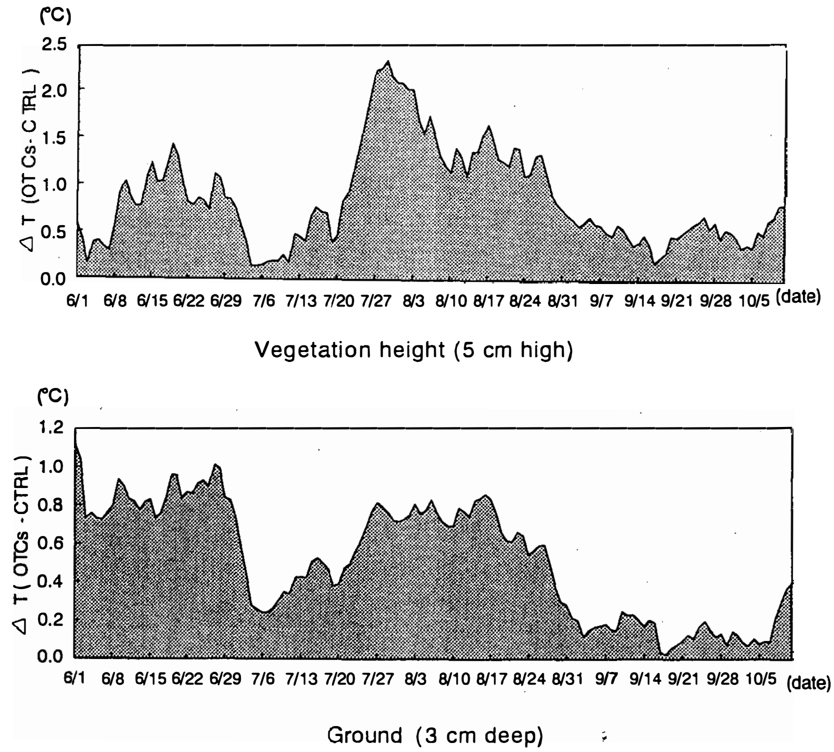

Fig. 4. Differences of mean temperatures between OTCs and CTRL (7 day running mean). Mean value of 4 OTC's data was compared to the control value.

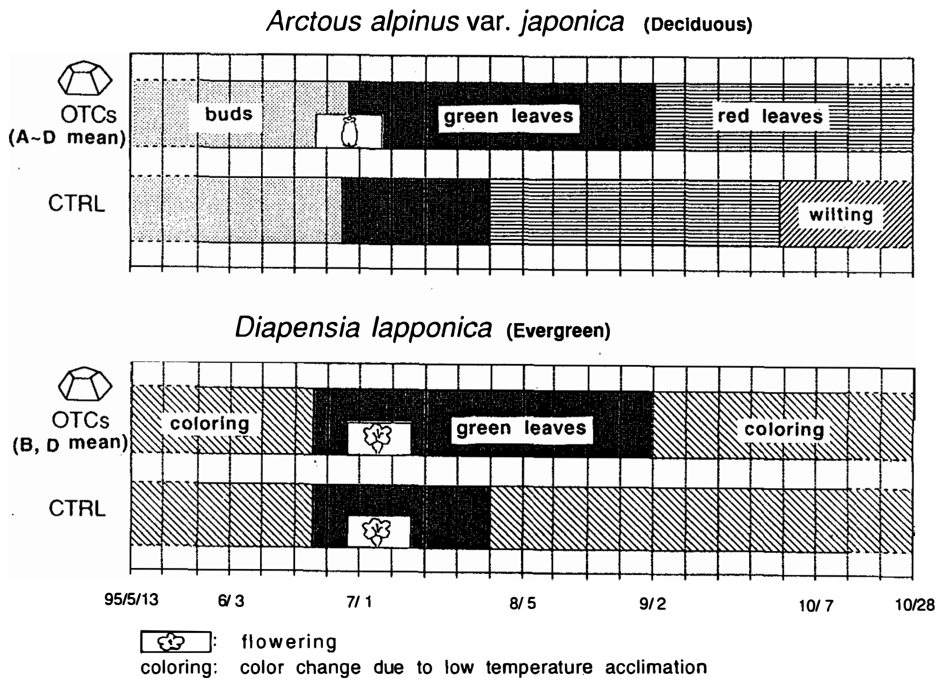

Fig. 5. Phenophase diagrams for two wind-brown dwarf shrub species.

temperature differences during the rainy season and autumn were less distinct.

4.3. Phenology of two species (Fig. 5)

(1) *Arctous alpinus* var. *japonica*

When we started the experiment on May 28, 1995, current buds had already formed. Green leaves began to open on June 28 both in OTCs and CTRL. Flowers were observed from June 21 to July 6 in OTCs but flowering was not observed in CTRL. Leaves in CTRL began to turn red on July 30 and to wilt on September 29. All leaves in OTCs, however, remained green until August 31. In other words, the duration from leaf emergence to the beginning of coloring in OTCs was extended by 33 days over that in CTRL. Colored leaves in OTCs did not wilt even on October 15, the end of the observation period. The maximum leaf height of *Arctous* became 4.9 cm in OTCs, compared to 2.5 cm in CTRL by August 4.

(2) *Diapensia lapponica*

At the beginning of the experiment, leaves of *Diapensia* were purple, probably because of low temperature acclimation for overwintering. They began to turn green on June 21 in both OTCs and CTRL. The flowering season was from June 28 to July 13 both in OTCs and CTRL. On July 30, leaves in CTRL began to turn purple, whereas leaves in OTCs remained green until September 1. Thus, the green leaf period was extended 33 days in OTCs.

5. Disscussion

The OTC treatment enhanced mean temperature at vegetation height by 0.9°C during the growing season in this study, whereas more effective warming has been reported in other studies by OTC. At ITEX sites in the circumpolar arctic, the OTC devices made average temperature 2.3°C higher (Molau, 1994). Despite the small increase in temperature in OTCs, both evergreen and deciduous shrubs in OTCs underwent phenological changes soon after the experimental warming. Especially, the green leaf periods of both *Arctous* and *Diapensia* were extended almost one month. This observation indicates that leaf phenology is highly controlled by current temperature and is sensitive to slight temperature changes. In Fennoscandia, an increase of 1°C in mean temperature significantly affected leaf development and insect growth (Debevec and MaClean, 1993). In this context, an increase of 0.9°C in mean temperature may be enough to affect tundra plants in temperate Japanese mountains. A report from ITEX sites in Canada has also shown that both *Eriophorum* and *Cassiope* are very responsive to temperature changes (Molau, 1994). In Denmark, experimental warming led to early flowering and a extended growing season for *Papaver* (Molau, 1994). Thus, the two species we observed have responded to warming in the same manner as different species in other ITEX sites.

In contrast, we could not find any difference of the beginning of leaf bud emergence and flowering between OTCs and CTRL this year (1995). As mentioned before, there was no snow when we started the experiment, indicating that snow disappeared almost simultaneously on slopes with OTCs and without them. These facts suggest that the primordias of new leaves and flowers were already provided in the previous year, and their initiation was controlled mainly by the snow disappearance time of current year. In alpine tundra of Colorado, U.S.A., the disappearance of snow cover also affects the onset of plant growth (MAY and WEBBER, 1982). Therefore, it is expected that the phenology of initiation and flowering in OTCs will differ from that in CTRL in the next summer, because of different snow accumulation and snowmelt.

The plant height was also affected by the OTC treatment. *Arctrous* in OTCs grew twice as tall as that in CTRL. In Sweden, the leaf size of *Cassiope* sp. is also determined by temperature in the current year (MOLAU, 1994). It should be noted, however, that the wind shield effect by OTCs may have also accounted for the prolonged growing season and the morphological changes in platns. In addition, we observed small waterdrops adhering to the inner walls of OTCs. In arctic Alaska, a clear plastic greenhouse provided relatively moist environment in soil (CHAPIN and SHAVER, 1985), which may also be favorable for plant growth. Indeed, phenological development in the Rocky Mountains is influenced by the moisture regime within a single growing season (MAY and WEBBER, 1982). Therefore, we need to assess wind shield effects and moisture controls of the OTC treatment in future studies to evaluate the effects of temperature enhancement.

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