Experimental Studies on Vegetating Potential on Bare Ground in Antarctica

Eri S. AYUKAWA*, Satoshi IMURA** and Hiroshi KANDA**

Abstract

A field experiment designed to enhance the *in situ* conditions in order to stimulate the development of the potential community lying dormant in the soil, using acrylic domes (chamber) was made at the Yukidori Valley, Langhovde, Antarctica The 19 chambers were placed on the bare ground for 38 days in austral summer. The average temperature in the chambers recorded was 8.2°C higher than that of the control. Except chambers located near stream, water contents were low before and after the experiment. After the experiment, new bryophyte cover of *Bryum pseudortiquetrum* emerged from the buried old bryophyte clump in the chamber located in the middle of the stream. The soil had relatively high water content in this chamber. When some environmental factors such as temperature are altered, bryophyte colonization from buried moss clump may be possible at the wet site. Diaspores of *B. pseudotriquetrum* and *Ceratodon purpureus* were observed in the sampled surface soils, and some diaspores germinated already before the experiment. No significant differences were observed in the germination rates between before and after the experiments. Considering the result of our field experiment, the possibility for the bryophyte colonization on dry ground seems to be low.

Key words : field experiment, bryophyte, Antarctica, colonization, diaspore bank

Introduction

Knowledge regarding plant colonization process is important for understanding the succession of plant communities. Seeds and spores continuously emigrate from their existing vegetation habitats to new habitats (Harper 1977[1)]). The remaining populations composed of the ungerminated seeds and spores in soils are termed "seed bank" or "diaspore bank." In the Antarctic fellfields, the completely cryptogamic ecosystem is dominated by bryophytes and lichens (e.g., Kanda 1981[2)], Lewis Smith 1993[3)]). During the clarification of the colonization process of plants in Antarctica, we have to focus on the germination from the diaspore bank.

Bryophyte propagule bank in the temperate zone or in the arctic region has been reported in some articles (e.g., Rydgren and Hestmark 1997[4)], Sundberg and Rydin 2000[5)], During 2001[6)]). The colonization process of bryophytes has been clarified by studies on bryophyte propagule banks in Antarctic fellfields (Lewis Smith 1987[7)], 1993[3)], Imura et al. 1993[8)], Ayukawa et al. 2001[9)]). In most of these studies, soils were incubated under laboratory conditions and focus was laid on the diaspores stored in the soils. In these experiments, the sampled soils were

---

Received December 17, 2004

* Department of Chemical Engineering on Biological Environment, Hachinohe Institute of Technology, 88-1, Ohbiraki, Myo, Hachinohe, Aomori, 031-8501
** National Institute of Polar Research, 1-9-10, Kaga, Itabashi, Tokyo, 173-8515

provided adequate conditions, such as correct temperature and moisture levels, to facilitate germination of diaspores. These previous studies clarified the germination potential of sampled diaspores.

Using these approaches, it is difficult to observe the *in situ* colonization process in Antarctica. Sampled soil cannot retain its physical characteristics, such as vertical moisture distribution or layer distribution of each soil particle or gravel. It is not possible to discern the response of diaspores or unknown sources of new vegetation only by incubation of the sampled soils. The objective of this study is to clarify the vegetation potential on bare ground in Antarctica, by a field experiment that enhanced the colonization conditions from diaspore bank or another vegetating source.

Study site and method

Study site

This study was conducted midway of the stream flowing through the Yukidori Valley (69° 14′ 30″ S, 39° 46′ 00″ E, Fig. 1), Langhovde, Antarctica, which is 20 km south of Syowa Station. This area is one of the richest in terms of vegetation in the vicinity of Syowa Station. The terrestrial vegetation was composed of bryophytes, algae, and lichens. In the Yukidori Valley, the dominant bryophyte species are *Bryum pseudotriquetrum* and *Ceratodon purpureus*, which are the most widely distributed and form the vegetation cover in the vicinity of Syowa Station (Kanda 1981[2]).

Chambers and climate measurement

Nineteen acrylic transparent domes (chamber, $\phi=50$ cm, Fig. 2) were placed on the bare ground at the site. The chambers were fixed by steel rings weighing 5 kg, to prevent the movement of the domes by strong winds (Fig. 2). Temperature and humidity sensors (9630, Hioki E. E. corporation, Nagano, Japan) were set 15 cm above the ground in each dome, the temperature and the humidity in each dome were recorded by the temperature and humidity logger 3631 (Hioki E. E. corporation) at 5 min intervals. Data was collected by the data

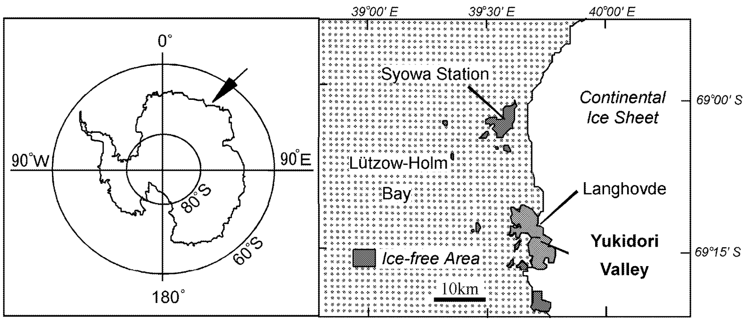

Fig. 1. Map of the study site, Yukudori Valley, Langhovde, Antarctica.

collector 3911 (Hioki E. E. corporation). Temperature and humidity at the control site without chambers were measured for the same methods.

Data collection

Nineteen subsites that had no vegetation on the surface ground as well as less than 3 cm beneath the surface were selected for recording the vegetation changes caused due to the experiment. Table 1 shows the details of each chamber. Chamber Nos. 9 and 10 were set on a polygon. The chambers had been placed from December 31st, 2000 to February 6th, 2001 (38 days). At the start of the experiment, four quadrates (17×17 cm) were set in each chamber (Fig. 3). Prior to the experiment, the surface soils upto a depth of 1 cm were sampled, using a scoop, from quadrates A and D (Fig. 3). After the experiment, the soils were sampled from quadrates B and C in the same manner. The surface status, before and after the experiment, was recorded. The sampled soils were placed in plastic bags, that were sealed immediately and stored in the dark at −20°C until the

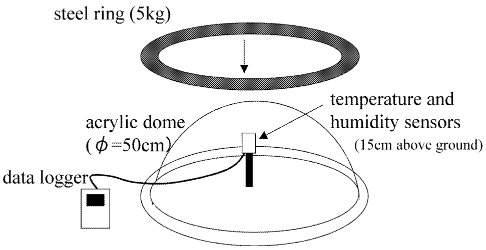

Fig. 2. The chamber placed on the bare ground. The temperature and humidity sensors were set in the chambers and data loggers were set outside the chambers.

Table 1. Conditions of chambers and the changes in the surface of the ground.

No.	Distance from the present vegetation (m)	Substrate	Change of the surface on the ground
1	1	sand	New moss shoots
2	1	sand	—
3	1	sand	—
4	1	sand	—
5	4	sand	—
6	4	sand	—
7	4	sand	—
8	4	sand	—
9	4	gravel (on polygon)	Pool by melt water
10	4	gravel (on polygon)	Pool by melt water
11	7	gravel	—
12	7	gravel	—
13	7	sand	—
14	7	sand	—
15	70	gravel	—
16	70	gravel	New moss shoots
17	70	gravel	—
18	70	gravel	New moss shoots
19	70	gravel	—

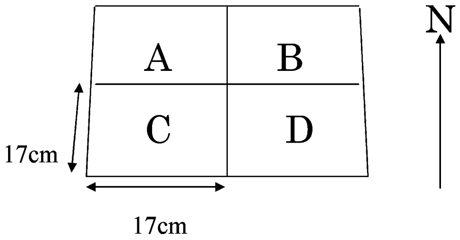

Fig. 3. Placement of the quadrates (17× 17 cm) in the chambers. Quadrates were placed in a fixed direction in each chamber.

analysis. In May 2001, soils were thawed at 5°C and divided into volumes of 10 cm^3 and were then placed in petri dishes ($\phi = 10$ cm) in a laboratory. The diaspores in each soil sample were counted and identified under a stereomicroscope. When the new shoots germinated from the diaspores, they were counted as “germinating.” When the new shoots did not germinate, they were counted as “ungerminating.”

Result

Temperature

Temperatures in the chambers are shown in Fig. 4. Temperatures in chambers were higher than that of the control, and the temperature was particularly higher during the day. The average temperature of the 19 chambers recorded during the experimental period (38 days), was 8.2°C higher than that of the control.

Soil water contents

Fig. 5 illustrates soil water content before and after the experiment. Except chambers Nos. 1-4, located near the stream, and No. 9 located on the polygon, water levels were quite low (0%-2.9%) before the experiment. In chamber Nos. 1-4, the water content was 6.9%-16.0% before and after the experiment. The water status did not change in most chambers after the experiment. In chamber No. 9, a round pool (diameter ca. 2 m, depth ca. 8 cm) was found after the experiment and the soil sampling was not carried out. In chamber Nos. 10, 15, 17, and 18,

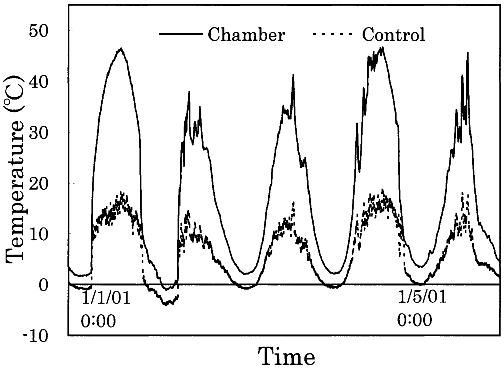

Fig. 4. Temperature 15 cm above soil inside the chambers (chamber No. 8) and outside the chambers (control) at the study site. Data recorded at 5 min intervals. No shade was used for data collection except the one with the installed loggers.

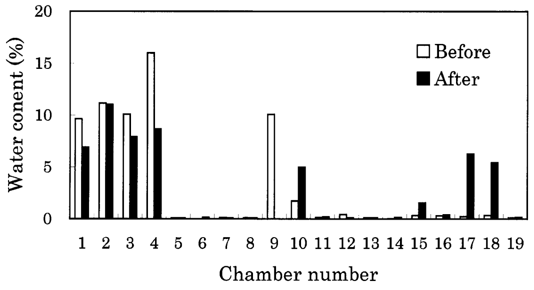

Fig. 5. Soil water content in 19 chambers before and after the experiment. At subsite No. 9, the soil sampling was not carried out because of the emergence of a pool.

the water contents increased after the experiment.

Changes in the soil surface

The *in situ* changes in the soil surface are shown in Table 1. No vegetation was found on the surface in all the subsites before the experiment, vegetation consisting of bryophytes emerged in the chamber Nos. 1, 16, and 18 after the experiment. In quadrate C under chamber No. 1, most of the surface was covered by *Bryum pseudotriquetrum* (Fig. 6 (a)) and no change was observed in quadrate B. We observed a small moss clump composed of shoots of *C. purpureus* under chamber No. 16, and clumps of *B. pseudotriquetrum* under chamber No. 18. At the base of the emerged moss cover, there was a small (ca. 1.0×1.0 cm), buried moss clump, which was brown in color and appeared to be old (Fig. 6 (b), (c)). It was ca. 5 cm beneath the soil surface. The length of the newly grow-shoots were ca. 4.6 cm. Thin sand layer (ca. 0.4 cm in depth) was observed on the surface of the new vegetation. The new shoots formed one segment and the color of the segment was quite fresh.

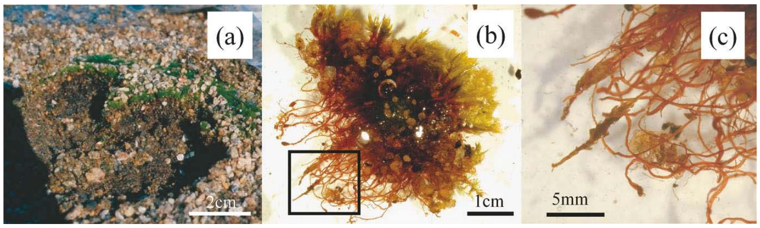

Fig. 6. Bryophyte clump appeared after the experiments in chamber No. 1. (a) Vertical section at the site. (b) Vertical section after removing the soil particles. (c) Magnification of the basal part of the emerged shoots, magnification of the black square part on (b).

Table 2. Diaspore germination of *B. pseudotriquetrum* and *C. purpureus* before and after the experiment. The numerals show the total numbers of diaspores counted under stereomicroscope.

B. pseudotriquetrum

	Ungerminated	Germinated	Germination rate (%)
Before	76	8	9.5
After	107	13	10.8
Total	183	21	11.5

C. purpureus

	Ungerminated	Germinated	Germination rate (%)
Before	26	1	3.7
After	33	1	3.7
Total	59	3	5.1

Germination rate

Diaspores of two species, *B. pseudotriquetrum* and *C. purpureus*, were identified from the sampled soil. Table 2 shows the diaspore germination status of *B. pseudotriquetrum* and *C. purpureus*. The numbers of diaspores were much higher in *B. pseudotriquetrum* than in *C. purpureus*. The germination rate before and after the experiment was 9.5% and 10.8% respectively, in the case of *B. pseudotriquetrum*, and 3.7% and 5.7%, respectively, in the case of *C. purpureus*. In the case of both species, no significant differences were observed in the germination ratio between before and after the experiments (Fisher's exact probability test, $p=0.63$ and $p=0.67$ for *B. pseudotriquetrum* and *C. purpureus*, respectively).

Discussion

The experiment was designed to enhance the *in situ* conditions in order to stimulate the development of the potential community lying dormant in the soil. Lewis Smith (1993)[3] installed polystyrene cloches for the same type of experiments on Jane Col, Signy Island. He reported the annual changes in the soil surface in the cloches. Only after the completion of 1 year, moss cover was observed, on the previously barren soil at the site. This study focused on the changes in one summer (38 days, from the end of December to the beginning of February). Despite an experimental period of 38 days, an enormous change in the soil surface was observed in chamber No. 1. The moss cover in this chamber was composed of *B. pseudotriquetrum*, which is the dominant species around the stream flowing through the Yukidori Valley. At the base of the emerged moss cover, a buried moss clump, which was brown and aged, was observed. Based on the morphology, i.e., one long segment and color of the new segments, these shoots could potentially elongate within the period of the experiment. The newly appeared moss cover at the surface showed the importance of buried vegetation cover for colonization at the soil surface and of the diaspores stored in and on the soil. The subsites, where chamber Nos. 1-4 were placed, were in the middle of the stream. Sand flowing from upstream may often cover the vegetation in such habitats. This result indicates that buried moss clump or vegetation is a potential source of vegetation, despite being ca. 5 cm beneath the soil surface when environmental changes occurred.

Prior to the experiment, 9.5% and 3.7% diaspores of *B. pseudotriquetrum* and *C. purpureus*, respectively, germinated in the surface soil. However, no significant difference was observed, and the ratio of germinated diaspores of *B. pseudotriquetrum* and *C. purpureus increased* to 10.8% and 5.7%, respectively. Several shoots had germinated at the site prior to the experiment. It is possible that the diaspores were easily carried with the dry sand by strong winds since they did not enroot into the soil surface. They will begin colonization only when they fall on a wet and stable habitat.

By the experimental treatment, the temperature in all the chambers increased. It is not possible to state what factors may be responsible for the enhanced regrowth of buried bryophytes in the experiment. Temperature increase may be one of the possible factors.

The extremely dry habitat in Antarctica is one of the factors responsible for only a few species being able to survive on this continent (Hooker 1847(10), Longton 1967(11), Claridge and Campbell 1985(12)). At the study site, the soil water content was very low. The effects of the experiments on diaspore germination appear to be small in such dry habitat because of the paucity of water. Ayukawa et al. (1998)(13) reported the water content along the transect crossing the stream in the Yukidori Valley and identified the presence of extremely dry soil only within 3 m from the center of the stream. The water content data in the present study indicated that subsite Nos. 1-4, 9, and 10 had relatively high water content levels; however, at all the other subsites, they were extremely low as Ayukawa et al. (1998) reported. Following the experiment, the water content increased in chamber Nos. 9 and 10, which were set on a polygon, and had unique water content because of its freeze-thaw cycle. Except for the areas where vegetation exists, such as near a stream, snow beds, lakes or ponds and soil polygons, most of the ground is dry in Antarctica as in the case of the soils in the chamber Nos. 5-8 and 11-14, 16, and 19. Considering the result of our field experiment, the possibility for the bryophyte colonization on dry ground appears to be low. On the contrary, when some environmental factors such as temperature are altered, bryophyte colonization from both diaspores and buried moss vegetation or clump is possible at the wet site.

Acknowledgements

We wish to express our sincere gratitude to the members of the 42nd and 41th Japanese Antarctic Research Expedition teams for their devoted support to the field survey.

Reference

1) Harper, J. L. (1977) Population biology of plants. Academic Press, London, pp. 892
2) Kanda, H. (1981) Flora and vegetation of mosses in ice-free areas of Soya Coast and Prince Olav Coast, East Antarctica. Hikobia Supplement 1 (H. Suzuki commemoration Volume): 91-100
3) Lewis Smith, R. I. (1993) The role of bryophyte propagule banks in primary succession: case study of an Antarctic fellfield soil. *In* Miles, J. & Walton, D.W. (eds.), Primary Succestion on Land. Blachwell Scientific Publications, Oxford; 55-78
4) Rydgren, K. and Hestmark, G. (1997) The soil propagule bank in a boreal old-growth spruce forest; changes with depth and relationship to aboveground vegetation. Can. J. Bot. 75: 121-128
5) Sundberg, S. and Rydin, H. (2000) Experimental evidence for a persistent spore bank in *Sphagnum*. New Phytol. 148: 105-116
6) During, H. J. (2001) New frontiers in Bryology and Lichenology. Diaspore bank. Bryologist 104: 92-97
7) Lewis Smith, R. I. (1987) The bryophyte propagule bank of Antarctic fellfield soils. Symposia Biologica Hungarica 35: 223-245
8) Imura, S., Higuchi, M. Kanda, H. and Iwatsuki, Z. (1993) Vegetative reproduction of mosses in soil around the Antarctic moss community (extended abstract). Proc. NIPR. Symp. Polar Biol. 6: 179-181
9) Ayukawa, E., Imura, S. and Kanda, H. (2001) Bryophyte propagule bank in the Yukidori Valley, Langhovde, Antarctica. Antarctic Record 45: 320-328

10) Hooker, J. D. (1847) The botany of the Antarctic voyage of H. M. Discovery Ships Erebus and Terror in the years 1839-1843, vol. 1. Frola of Antarctica. Cramer, Weinheim, 503pp.

11) Longton, R. E. (1967) Vegetation in the maritime Antarctic. *In* Smith, J. E. (Organizer), A discussion on the terrestrial Antarctic ecosystem. Philos. Trans. R. Soc. London, Ser. B. 252 ; 213-235.

12) Claridge, G. G. C. and Campbell, I. B. (1985) Physical geography-Soils. In Bonner, W. N. and Walton, D. W. H. (ed.), Key environments Antarctica : 62-70, Pergamon Press Oxford.

13) Ayukawa, E., Imura, S. and Kanda, H. (1998) Soil property and distribution of vegetation in the Yukidori Valley, Antarctica. Bryol. Res. 7 : 109-115