Proc. NIPR Symp. Polar Biol., 3, 245-253, 1990

COMPARISON OF NET PHOTOSYNTHESIS AND DARK RESPIRATION OF ANTARCTIC MOSSES MEASURED IN THE ANTARCTIC AND IN JAPAN

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Abstract: Net photosynthesis and dark respiration (CO_2 uptake) of Antarctic mosses were measured to investigate the effects of transportation in a frozen condition from the Antarctic to Japan.

Moss blocks were collected from some *Ceratodon purpureus* communities in different habitats at the Yukidori Valley (69°14′30″S, 39°46′00″E) in Langhovde, East Antarctica, on January 16, 1988.

The CO_2 uptake activities of the surface layer of the moss blocks were measured in the laboratory on the research ship SHIRASE with two infrared CO_2 gas analyzers and an assimilation chamber within a month after the collection. The relationships of net photosynthesis and dark respiration to water content, illumination intensity, and temperature were determined. After the measuring, the samples were frozen at −20°C and transported to Japan. From May to August of 1988, each sample was defrosted in the laboratory of Waseda University and the same measurements were undertaken with the same equipment that had been used in the Antarctic.

There was little difference between the optimum water content for net photosynthesis measured in the Antarctic and that measured in Japan. In some samples, the net photosynthetic rate at saturated illumination intensity and the dark respiration rate measured in the Antarctic differed from those measured in Japan. A little difference was recognized in the optimum temperature for net photosynthesis in some samples.

It was concluded that storage in a frozen condition for a long period produced some undesirable effects on the photosynthetic and respiration activities of some Antarctic mosses.

1. Introduction

The response of the net photosynthetic activity and dark respiration to environmental features is one of the very important keys to estimate the primary production of plants and to study their adaptation to the habitats. But there are some difficulties in measuring these activities in the Antarctic, *i.e.*, transportation of equipment for the measurements to the field, maintenance of equipment, techniques of measurements, limited time, and so on.

Few studies, therefore, have been made concerning net photosynthesis and dark respiration of mosses in the Antarctic. DAVIS and HARRISSON (1981) reported CO_2 uptake (net photosynthesis and respiration) of *Drepanocladus uncinatus* and *Polytrichum alpestre* with an infrared CO_2 gas analyzer (IRGA) in Signy Island in a maritime Antarctic region. INO (1983a) measured the CO_2 uptake of some species of mosses with an IRGA at East Ongle Island, East Antarctica, and roughly estimated the primary production of the moss community at the Island (INO, 1983b). RASTORFER (1970) measured the photosynthesis of two *Bryum* species at McMurdo Station. His results were useful just in the area of plant physiology because his measurement was done with a manometric method.

The estimations of photosynthetic activities of Antarctic mosses in the habitats have been derived by extrapolation of domestic laboratory results using climatic data in the Antarctic field. In such studies, attention has to be paid to extrapolation errors. These are caused by the difficulties in creating environmental conditions in the laboratory which are comparable with the field, the acclimation effects by laboratory culture (COLLINS, 1977), the effects of storage, etc. These problems must be solved by the comparison of the results measured carefully in the Antarctic and in domestic laboratories.

When investigators of the Japanese Antarctic Research Expedition want to measure some physiological activities of Antarctic organisms in Japan, the organisms must be transported by ship from the Antarctic. Therefore, it is important to keep the organisms in good condition in order to be measured accurately. If the effects of storage and transportation on the organisms' activities are negligible, investigators can obtain much information about physiological activities with transported samples from the Antarctic.

Some moss blocks were sampled at Langhovde, East Antarctica, in the austral summer of 1988. The CO_2 uptake of the surface layer of moss block was measured in the laboratory on the research ship SHIRASE in the Antarctic Ocean within a month after the collection. After the measurements were taken, these samples were frozen at $-20°C$ and transported to Japan. Their CO_2 uptake activities were measured again at Waseda University in Japan from May to August of 1988, with the same analyzing equipment.

In this paper, the results measured under the laboratory condition in the Antarctic and the results measured in Japan were compared to investigate the effects of long-period storage.

2. Materials and Methods

Moss blocks were collected at a place tentatively named Magoke-Daira (in English "the plain where many mosses live") on January 16, 1988. This plain is situated between the Yukidori Valley (69°14′30″S, 39°46′00″E) and the Yatsude Valley in Langhovde on the east coast of Lützow-Holm Bay, East Antarctica (Fig. 1). The Yukidori Valley is designated as No. 22 SSSI (Sites of Special Scientific Interest) for the study of terrestrial ecosystem and the conservation (SCAR, 1988).

Many moss communities existed at Magoke-Daira in patch form on dry sandy soil, on moist sandy soil, and in pools of melted snow. Seven moss blocks in quadrats of 10×10 cm and 3–5 cm in thickness, were taken from *Ceratodon purpureus* communities in different growing conditions.

No. 1: This community was developed on moist soil. It was covered thinly with sand and looked green.

No. 2: This community existed on moist soil near community No. 1. It was not covered with sand and looked greenish brown with epiphytic algae.

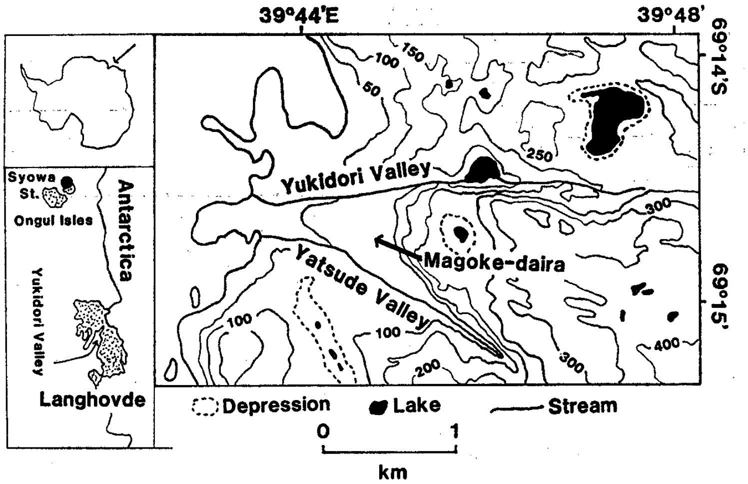


Fig. 1. The map of sampling site in Langhovde, East Antarctica.

No. 3: This community was found at the bottom of a pool of melted snow about 5 cm in depth, and the mosses were attached with epiphytic algae. It looked black.

No. 4: This community was at a dry site and was covered thickly with sand. When the sand was removed, it looked fresh and green.

Nos. 5 to 7: These communities were near each other at a dry site and were selected according to the gradient of epiphytic algae attached to them. Community No. 5 was the lowest in gradient, and community No. 7 was the highest.

Collected moss blocks were transported to the research ship by a helicopter on June 19. On the ship, they were placed in darkness at 5°C until the measurements of CO_2 uptake were taken.

The measurements were carried out while the ship was at anchor for the air transport of cargo because the throbbing of the engines disturbed the measurements. Sample No. 7 could not be measured on the ship because the ship had already started. Concerning sample No. 6 only the relationship between net photosynthesis and water content was measured.

The measurements were taken for 5 days during the period from January 30 to February 13.

The samples for the measurements were cut out from the upper part of collected moss blocks and they were green or black, 0.5–0.8 cm in thickness, and included a small amount of sand particles. The sample was put in a 9 cm Petri dish and was fully moistened. Then the sample was incubated under an illumination of about 900 μmol $m^{-2}s^{-1}$ of photosynthetically active photon flux density (*PPFD*) and at 10°C for 2 h.

The measurement system of CO_2 uptake is shown in Fig. 2. CO_2 was removed from the air by soda lime, and a small amount of N_2 gas containing 1% CO_2 gas was added to the air free from CO_2. The CO_2 concentration in the air was regulated from 340 to 350 ppm of volume. The Petri dish with the sample was put into an assimilation chamber (Koito Industries Ltd., MC-A3W). Two IRGAs (Horiba Ltd., VIA-300) were used to measure the CO_2 concentration at the entrance and the exit of the chamber. The illumination source was a 400W Metalhalide lamp (Mitsubishi Electric Corporation

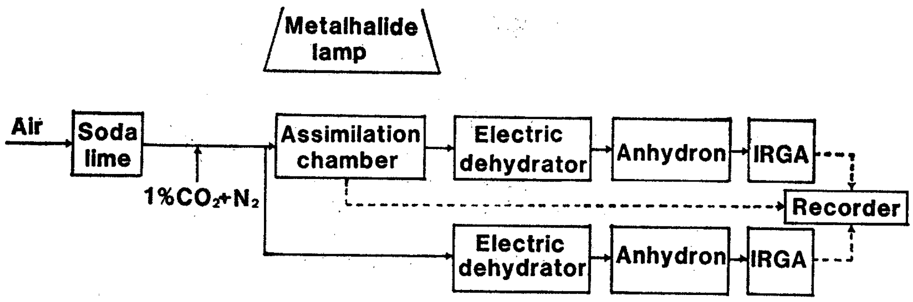


Fig. 2. The measurement system of net photosynthesis and dark respiration (CO_2 uptake) in the laboratory on the research ship SHIRASE *in the Antarctic and at Waseda University in Japan.*

Ltd., BOC 400C-U) and the *PPFD* intensity was regulated with the interposition of black nets between the lamp and the chamber.

The first experiment in each measurement was done to find out the optimum water content for net photoshynthesis. The Petri dish with the sample was taken out from the chamber every 30 or 40 min and, after being weighed, was returned to the chamber. This treatment was repeated until the CO_2 uptake began to drop. Thus, the relationship between the net photosynthetic rate (P_n) and the water content of the sample was obtained.

The water content shows not only the water amount in moss tissues, but also the water contained inter-shoots and on the surface of sand particles in the whole sample. The water content which produced the highest rate of CO_2 uptake was defined as the optimum water content for net photosynthesis.

The relationships between P_n and *PPFD* and P_n and the sample temperature (T) were taken at the optimum water content. After the measurement, the sample was frozen at $-20°C$ and transported to Japan in a dark condition.

The samples were kept in a freezer at $-20°C$ until the pretreatment for the measurements of the CO_2 uptake were made in Japan. The samples were removed from the freezer to a refrigerator at 3°C, and the next day they were transferred to a growth chamber at 10°C and incubated for 2 days under continuous illumination of 50–60 μmol $m^{-2}s^{-1}$. The measurements were carried out under the same treatment and with the same equipment used in the Antarctic.

3. Results

The relationship of net photoshynthesis to illumination intensity and temperature was measured under the optimum water content for net photosynthesis. The optimum water content suggests the lowest CO_2 diffusion resistance at the surface of moss shoots (DILKS and PROCTOR, 1979).

Table 1 shows the optimum water content of the samples measured in the Antarctic and in Japan. Sample No. 2 was cut again for a treatment in Japan, so its water content cannot be compared to that measured in the Antarctic. Sample No. 7 was not measured in the Antarctic.

There is little difference in the optimum water content measured in the Antarctic

Table 1. Optimum water content for net photosynthesis measured under laboratory condition in the Antarctic and in Japan. Water content is represented by percentage to dry weight of sample.

Sample	The Antarctic	Japan	Sample	The Antarctic	Japan
No. 1	73%	60%	No. 4	46%	32%
No. 2	90		No. 5	40	47
No. 3	160	148	No. 6	57	37

Sample No. 2 was cut again before the measurement in Japan.
Sample No. 7 was not measured in the Antarctic.

and in Japan. Sample No. 3 showed the highest optimum content. The reason may be that the habitat of this sample was in water.

Figure 3 shows the relationships between CO_2 uptake and *PPFD* at different temperatures measured in the Antarctic and in Japan. The maximum net photosynthetic rates were in a range of 100–200 $mgCO_2\,m^{-2}\,h^{-1}$ and the dark respiration rates were accelerated with the increases in temperature.

No. 1: Net photosynthetic rate at different temperatures registered at the maximum at 500–800 $\mu mol\,m^{-2}\,s^{-1}$ in the Antarctic. The illumination intensity measured in Japan, however, was slightly higher than that measured in the Antarctic. The dark respiration rate measured in the Antarctic was higher than that measured in Japan in each temperature.

No. 2: The response of the net photosynthetic rate to the sample temperature measured in Japan was sharper than that measured in the Antarctic. The rates at 20°C were markedly lower than the rates at 15°C measured in both laboratories. The positive uptake of CO_2 at 20°C measured in Japan was not recognized under strong illumination.

No. 3: The net photosynthetic rates at 15°C and 20°C measured in Japan did not saturate at 1000 $\mu mol\,m^{-2}\,s^{-1}$. The dark respiration rates measured in the Antarctic at 5°C and 10°C were markedly higher than those measured in Japan.

No. 4: The changes of net photosynthetic rates to the temperature gradients measured in the Antarctic were very small.

No. 5: The net photosynthetic rates at the saturated *PPFD* and the dark respiration rates measured in both laboratories were almost equal and they were lower than those of other samples.

4. Discussion

The fact that the optimum water content is almost equal suggests that the structure of the moss surface did not change by the storage because CO_2 diffusion resistance is decided by the water amount attached to the moss surface (DILKS and PROCTOR, 1979).

The *PPFD* at the maximum net photosynthetic rates measured in Japan was generally lower than that in the Antarctic. It seems that the response pattern of the net photosynthesis to the *PPFD* changed to that of shade plants. The suppression of net photosynthesis at a higher temperature and the change to the shade type may relate to the reaction system, membrane permeability, chlorophyll content, etc.

The response pattern of net photosynthesis to temperature seems to be a basic im-

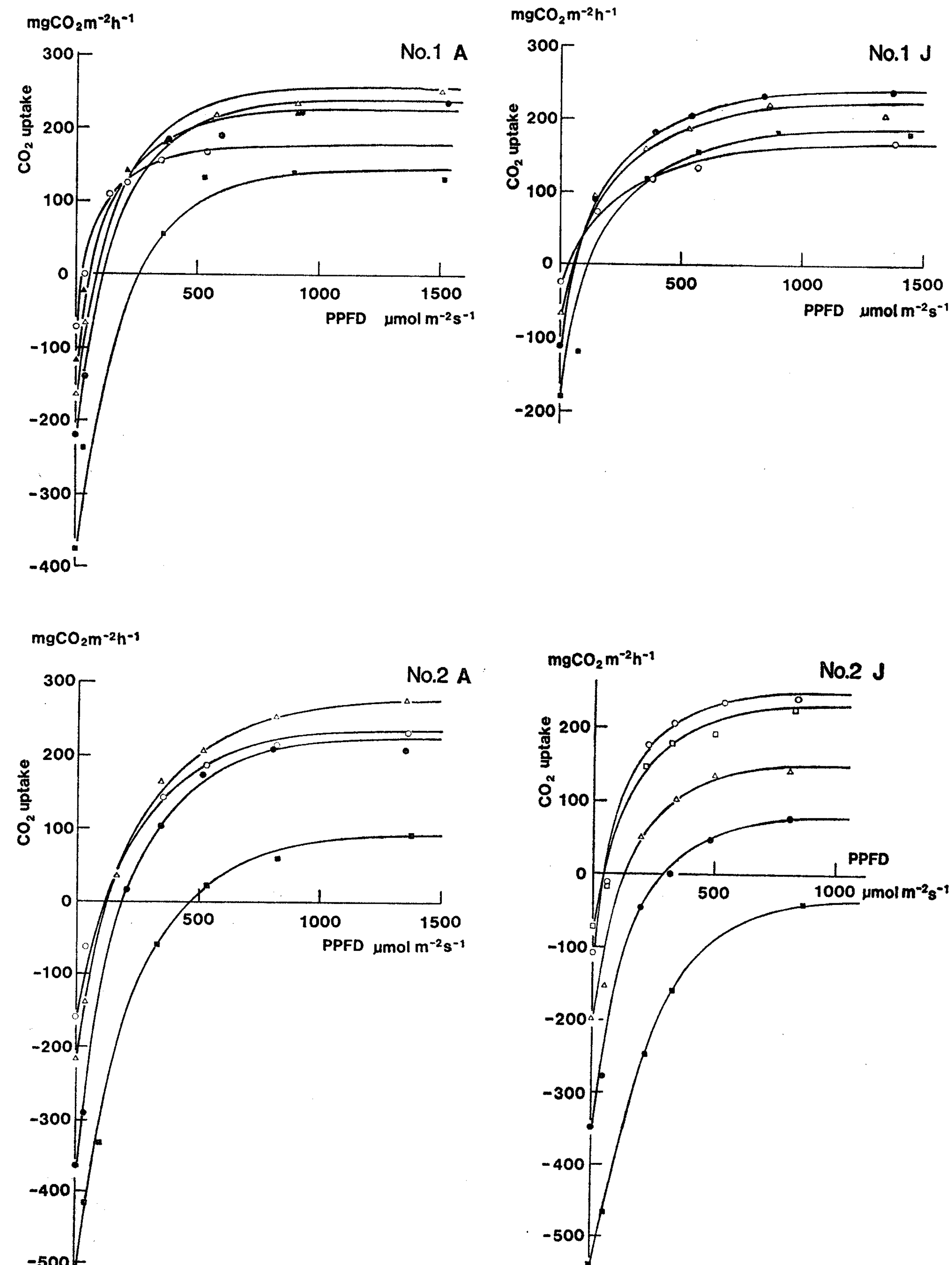


Fig. 3. *The relationships between net photosynthetic rate (CO_2 uptake) and photosynthetically active photon flux density (PPFD) at different temperatures measured on the research ship* SHIRASE *in the Antarctic (A) and at Waseda University in Japan (J). No. refers to sample number.* □, *2°C;* ○, *5°C;* ▲, *8°C;* △, *10°C;* ●, *15°C;* ■, *20°C.*

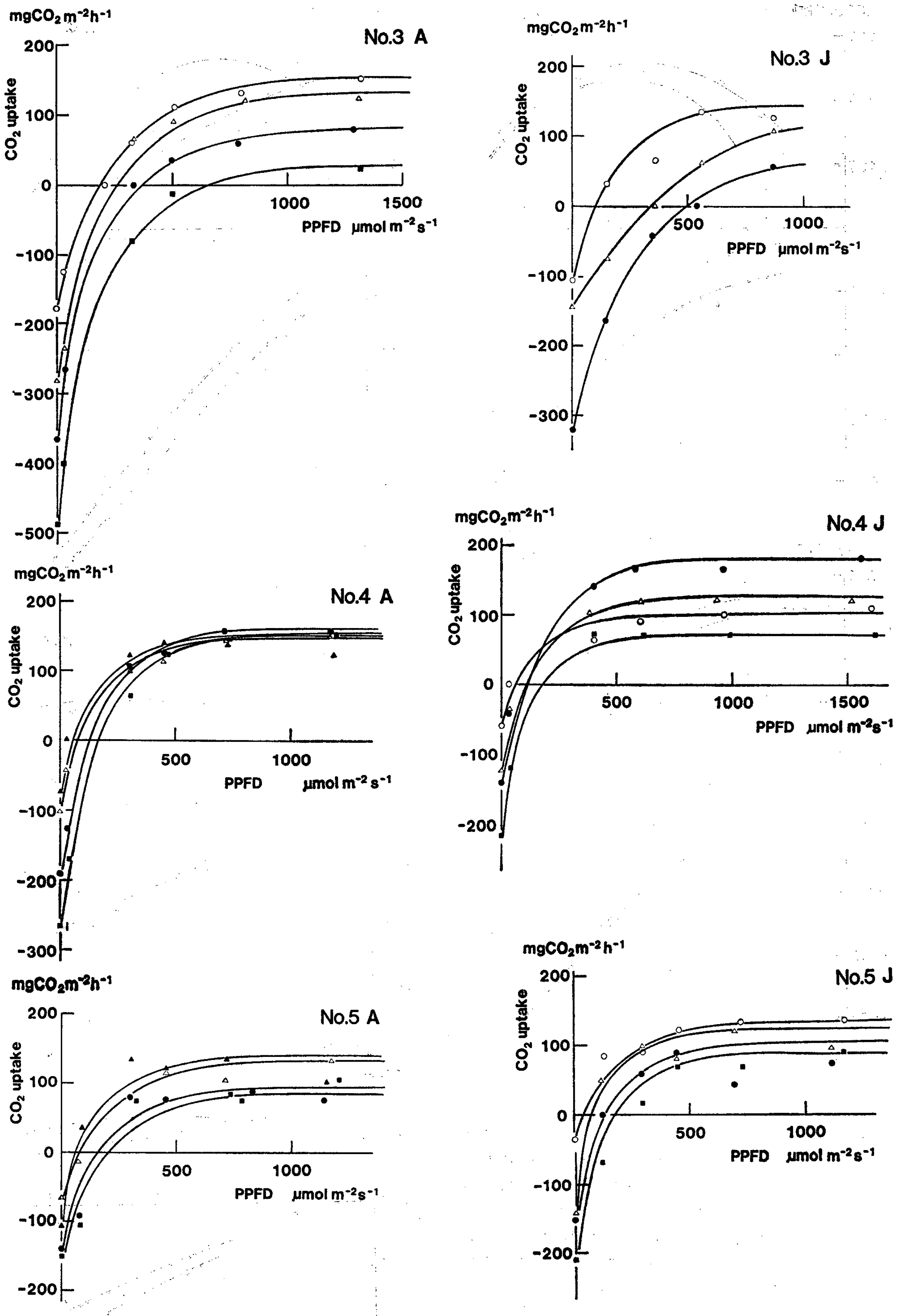
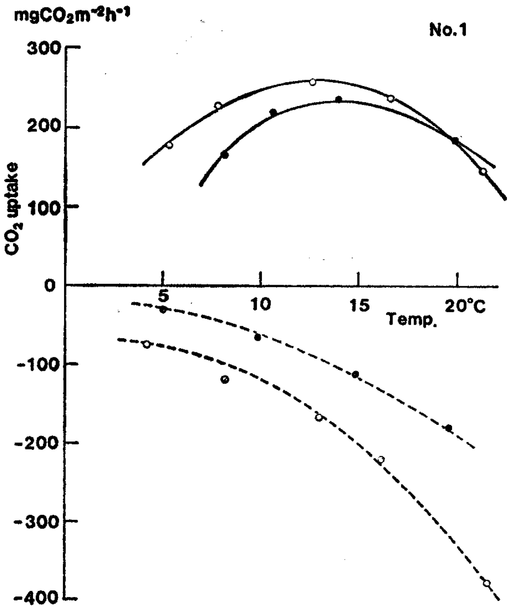
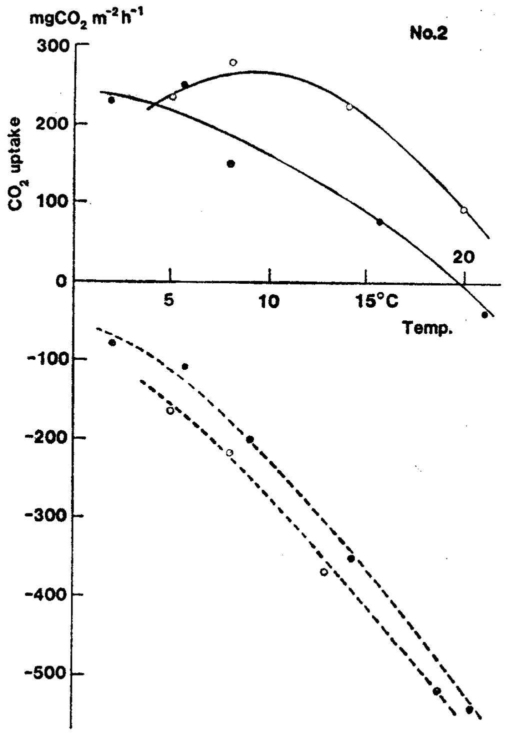
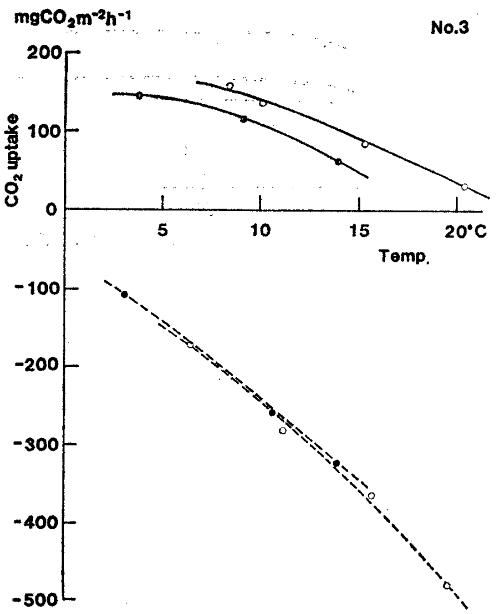
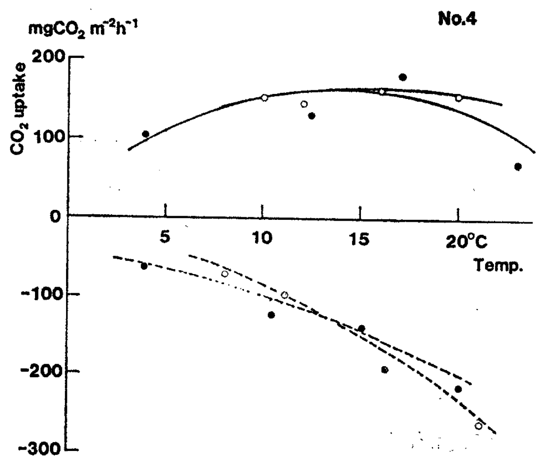

No.3 A
No.3 J
No.4 A
No.4 J
No.5 A
No.5 J
mgCO2m-2h-1
CO2 uptake
PPFD μmol m-2s-1
200
100
0
-100
-200
-300
-400
-500
500
1000
1500

Fig. 3.









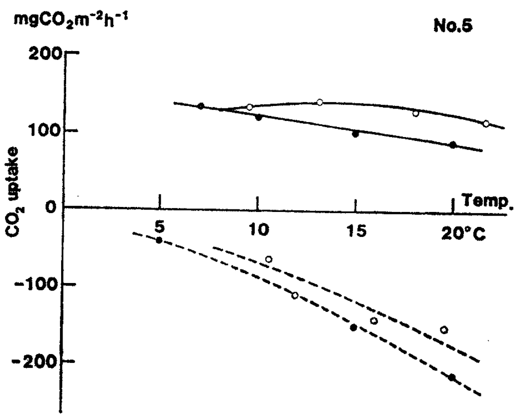


Fig. 4. The relationships between net photosynthetic rate at saturated illumination intensity or dark respiration rate (CO_2 uptake) and sample temperature (T). The open circles show the rates measured on the research ship SHIRASE in the Antarctic and the closed circles show the rates measured at Waseda University in Japan.

portant feature of Antarctic mosses. The relationship between moss temperature and the maximum rates of net photosynthesis at that temperature is shown in Fig. 4.

It is clear that Antarctic mosses do not always have a low optimum temperature for net photosynthesis. The temperature of mosses growing on an otherwise bare land is higher than the air temperature (MATSUDA, 1968). This is because the mosses are exposed to direct radiation. This may be the reason that Antarctic mosses used in this experiment have a high optimum temperature for net photosynthesis. Only the mosses living in cold water had a low optimum temperature.

These results show that the storage at −20°C for a period longer than three months gave undesirable effects on net photosynthesis and dark respiration activities of some of the mosses used in this experiment. It is very important to find a better way of transportation of the samples for the development of the ecophysiological studies of Antarctic mosses.

Acknowledgments

I wish to thank Prof. O. WATANABE, the leader of the 29th Japanese Antarctic Research Expedition (JARE-29), and all members of JARE-29 for their friendly cooperation. I am deeply indebted to Dr. H. KANDA and Dr. S. OHTANI (JARE-29), and Mr. Y. MOCHIDA and Mr. H. SUGAWARA (JARE-28) for their kind support at Langhovde.

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(Received May 9, 1989; Revised manuscript received August 21, 1989)