—研究ノート—
Scientific Note

Field Measurement of the Photosynthesis of Mosses with a Portable CO_2 Porometer at Langhovde, East Antarctica

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携帯用光合成測定装置を用いた南極，ラングホブデでの蘚類の光合成の測定

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要旨：南極に生育する植物の一次生産量を計算するためや，蘚類・地衣類の環境適応を調べるために，光合成の測定がなされてきたが，その例は少ない．この測定には多くの計器，機材が必要とされ，それが南極での測定が少ない原因と考えられる．近年，数種の携帯用の光合成・蒸散測定装置が発売された（例えば，The Analytical Development 社，LI-COR 社，Warz 社）が，これらはいずれも葉を挟んで，その二酸化炭素の取り込みを測定するものであり，蘚類・地衣類には用いることができなかった．9 cm シャーレが入る小型同化箱を開発し，測定装置（小糸製作所，KIP9000）をそれにあわせて改良し，東南極のラングホブデ雪鳥沢で，2 種の蘚類の光合成と暗呼吸速度を測定した．サンプル1（*Bryum pseudotriquetrum* と *Ceratodon purpureus* の混生したもの）で約9時間，サンプル2（*C. purpureus*）で約11時間の連続測定を行った．呼吸速度が大変大きく，そのため光補償点はかなり高かった．この装置で得られた結果は，同時期に同じ場所で使用した大型の測定装置（分析部：堀場製作所 VIA-300，同化箱：小糸製作所 MC-A3W）で得られた結果（Y. INO: Ecol. Res., **5**, 195, 1990）とほぼ同じであった．ただし，最大光合成速度は若干高かった．

Abstract: The photosynthesis of mosses was measured with a portable CO_2 porometer (modified Koito KIP9000) at Langhovde, East Antarctica in January 1988. An assimilation chamber, 10 cm × 10 cm × 6.5 cm, which was made for this measurement, was used in collecting data for 9 h in Sample 1 and 11 h in Sample 2. Samples were mixed communities of *Bryum pseudotriquetrum* and *Ceratodon purpureus* (Sample 1) and *C. purpureus* (Sample 2) collected in the Yukidori Valley, Langhovde. Both samples had high respiration rates. Net photosynthetic rates were negative at low irradiance and changed to positive rates at high irradiance. Maximum photosynthetic rates were higher than those of other mosses measured with other equipment (analyzer: Horiba VIA-300, assimilation chamber: Koito MC-A3W) in the Yukidori Valley in the same period (Y. INO: Ecol. Res., **5**, 195, 1990)

1. Introduction

Photosynthetic activity is the most important form of metabolism for green plants and is one of the indicators in the estimation of their growth rates and

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physiological activity. The amount of carbon fixed in photosynthesis can be used to calculate the growth of the plant and energy flow in the ecosystem. The rate of energy or organic matter which is supplied to the heterotrophic organisms from green plants in an ecosystem is indispensable to study the function of the ecosystem as a whole. Besides, photosynthetic characteristics are key to understanding the adaptation of plants to the environment.

Some measurements of photosynthesis of Antarctic bryophytes and lichens have been carried out by Lange at Kiel (LANGE and KAPPEN, 1972), COLLINS in the United Kingdom (COLLINS, 1977), INO at East Ongul Island (INO, 1983) and Langhovde (INO, 1990), and KAPPEN at Kiel (KAPPEN, 1983; KAPPEN and REDON, 1987), King George Island (KAPPEN *et al*., 1986, 1988), Casey station (KAPPEN, 1989a, b) and Livingston Island (KAPPEN *et al*., 1990). Photosynthesis of cryptoendolithic biomes was measured by FRIEDMANN at Würzburg (KAPPEN and FRIEDMANN, 1983) and by VESTAL at McMurdo Station (VESTAL *et al*., 1984).

Although there are various habitats for mosses and lichens in Antarctica, measurements of photosynthesis in those habitats are meagre. The problem lies in the difficulty in transporting the large amount of equipment needed to conduct the study. KAPPEN wrote that operation with controlled plant chambers requires considerable technical instrumentation, which can only be housed in a large trailer serving as a mobile field laboratory (KAPPEN *et al*., 1986). Because of the lack of transportation, it is advantageous to use portable equipment.

Some types of portable CO_2 and H_2O porometers have been developed for the measurement of photosynthesis and transpiration of vascular plants in the field. But the shape of the assimilation chamber of these porometers did not fit the mosses and lichens. A new chamber which can accomodate mosses was developed for measurement of the photosynthesis of Antarctic mosses in their habitat.

2. Materials

The Yukidori Valley (69°15′S, 39°46′E) is situated in the middle of the Langhovde ice-free area, on the east coast of Lützow-Holm Bay. KANDA *et al*. (1990) described this valley in detail.

Sample 1, about 10 cm × 10 cm in area, was sampled from a moist community on sand in the lower reaches (5 m a.s.l.) of the Yukidori Valley. It was composed of *Ceratodon purpureus* and *Bryum pseudotriquetrum.*

Sample 2, about 10 cm × 10 cm in area, was taken from a *Ceratodon purpureus* community on the sunny side of the stream in upper reaches (100 m a.s.l.). Cyanobacteria grew on the surface of those mosses.

3. Methods

Net photosynthesis and dark respiration (CO_2 exchange) of the upper green portion from each moss sample were measured with a CO_2 porometer (Koito, KIP9000) and a small assimilation chamber, 10 cm × 10 cm × 6.5 cm, which was made for this measurement. A fan was installed horizontally at the bottom to circulate the air. Sensors of air and moss temperature and photon flux density (PFD) were set in the chamber, and the data were recorded in the logger of porometer. Air temperature in the chamber was controlled with a heat exchanger attached below the chamber.

The sample was put in a plastic Petri dish, 9 cm in diameter and 0.6 cm in depth, in its natural growing density and was sprayed with water. To make the water content of the sample close to the optimum water content for photosynthesis, the damped moss was shaken and the excess water on the surface was removed. The dish with the moss was placed in the chamber and photosynthesis was measured under natural radiation. The sample was taken out from the chamber every 1 h and weighed. Water was sprayed to restore the initial weight and the sample was returned to the chamber. Dark respiration was measured by covering the chamber with a thick paper box.

The measurement of Sample 1 was carried out from 1146 to 2020, January 9, 1988. Temperature, PFD and CO_2 concentration data were sampled every 132 s. The measurement of Sample 2 was conducted from 0905 to 2010, January 10, the data sampling interval was 155 s.

4. Results

Figure 1 shows the diurnal changes of net photosynthetic rate (Pn), moss temperature (MT) and irradiance (PFD: photon flux density) in Sample 1. First, the dark respiration rate (nagative Pn) was measured by covering the chamber. At the start of photosynthesis measurement, PFD was higher than 1300 μmol m^{-2} s^{-1} and it decreased to 130 μmol m^{-2} s^{-1} at the end. The moss temperature fluctuated in the range of about 4°C from the start of the photosynthesis measurement to 1620. The

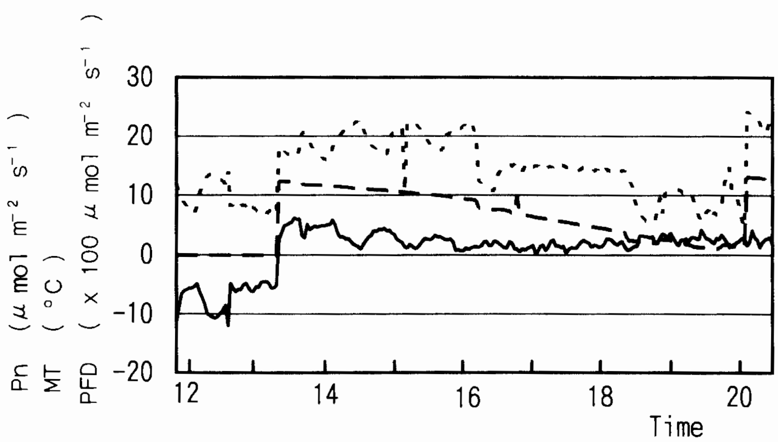

Fig. 1. Diel changes of net photosynthetic rate (Pn: CO_2 μmol m^{-2} s^{-1}), moss temperature (MT: °C) and photon flux density (PFD: 100 μmol m^{-2} s^{-1}) in the Sample 1 moss block with a CO_2 porometer in Langhovde.
——— : Photosynthetic rate, — — — : PFD, - - - - - -: Moss temperature.

fluctuation disappeared from 1640 to 1810. After that the fluctuation began again. The cause of the fluctuation was the delayed response of the temperature controller. The photosynthetic rate dropped with the increase of moss temperature and rose with the decrease of temperature.

Figure 2 shows the diel changes of net photosynthetic rate, PFD and moss temperature in Sample 2. The change of PFD was smooth because the weather was clear. The first 6 points show the dark respiration rates. When PFD was high, moss temperature fluctuated in a higher range and the photosynthetic rate showed minimal fluctuation. The photosynthetic rate decreased with the decrease of PFD and moss temperature from 1730. Just before the end of the experiment, the moss temperature rose suddenly but the photosynthetic rate did not increase.

The relationships between moss temperature and respiration rate are shown in Fig. 3. The moss temperature of Sample 2 changed from 6.6℃ to 13.6℃, and the

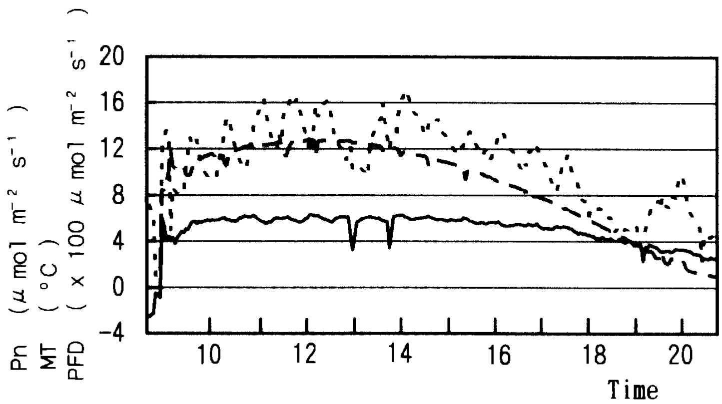

Fig. 2. Diel changes of net photosynthetic rate (Pn: CO_2 $\mu mol\ m^{-2}\ s^{-1}$), moss temperature (MT: ℃) and photon flux density (PFD: 100 $\mu mol\ m^{-2}\ s^{-1}$) in the Sample 2 moss block with a CO_2 porometer in Langhovde.
———: Photosynthetic rate, — — —: PFD, - - - - - - -: Moss temperature.

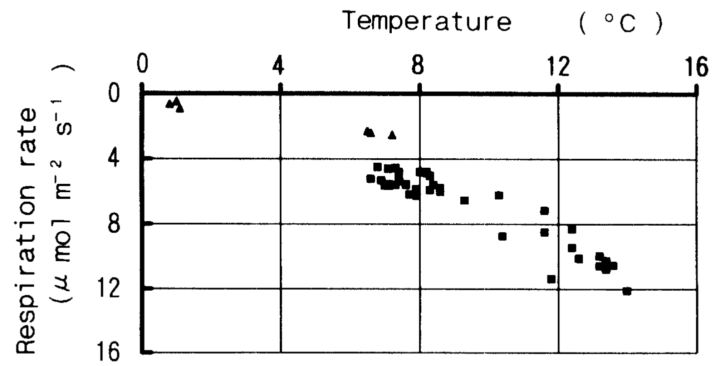

Fig. 3. The relationship between respiration rate and moss temperature of Samples 1 (■) and 2 (▲) moss blocks with a CO_2 porometer in Langhovde.

respiration rate changed from 4.5 μmol m^{-2} s^{-1} to 12.1 μmol m^{-2} s^{-1} with this temperature increase. The moss temperature and respiration rate in Sample 1 were lower than those of Sample 2. The correlation coefficients of the moss temperature and respiration rate in Samples 1 and 2 was 0.95 and 0.99, respectively.

5. Discussion

The relationship between net photosynthetic rate and PFD and moss temperature was correlated with KAPPEN's model (KAPPEN *et al.*, 1988). Multiple correlation coefficients of Samples 1 and 2 were 0.78 and 0.87, respectively. Respiration rate was correlated with moss temperature by linear regression.

Photosynthetic rates calculated under several conditions of PFD and moss temperature are shown in Figs. 4 and 5. Moss temperature during most of the

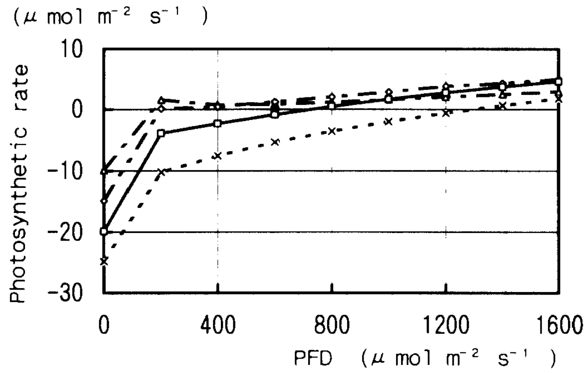

Fig. 4. Calculated net photosynthetic rate at different temperatures and PFD of Sample 1. Net photosynthetic rate was calculated by KAPPEN's model (KAPPEN et al., 1988), and respiration rate was calculated by linear regression.
-----×----- : 25°C, ——□—— : 20°C, —··◇··— : 15°C, —•—△—•— : 10°C

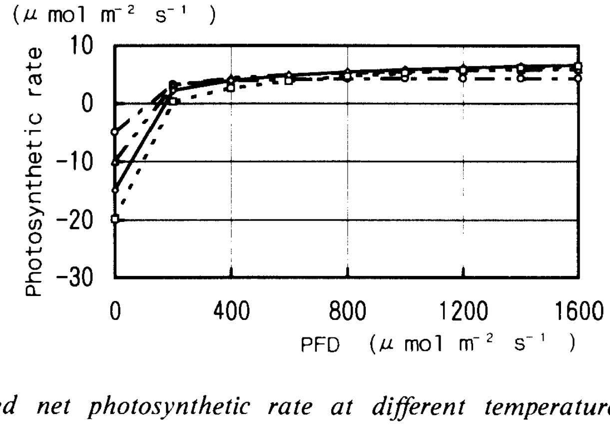

Fig. 5. Calculated net photosynthetic rate at different temperatures and PFD of Sample 2. Net photosynthetic rate was calculated by KAPPEN's model (KAPPEN et al., 1988) and respiration rate was calculated by linear regression.
——□—— : 20°C, —··◇··— : 15°C, —•—△—•— : 10°C, -----○----- : 5°C

measurements of Sample 1 was higher than 10°C. Figure 4 shows the relationships between photosynthetic rate and PFD at 10, 15, 20 and 25°C, respectively. Respiration rate at every temperature was high and the net photosynthetic rate changed to a positive rate at high PFD. The maximum photosynthetic rate amounted to 5 μmol m^{-2} s^{-1} at 1600 μmol m^{-2} s^{-1} and 15°C or 20°C, this rate was higher than some rates in other mosses measured in the Yukidori Valley (INO, 1990).

The relationship for Sample 2 is shown in Fig. 5. The respiration rate at 20°C was equal to that at 20°C for Sample 1, but the photosynthesis at 20°C became a positive rate at lower PFD than that at 20°C of Sample 1. The photosynthetic rates at higher than 10°C were almost the same at high PFD.

The respiration rates of both samples were very high at the higher temperature. This characteristic is not important in the Antarctic environment, because moss temperature decreases with decreasing PFD and the respiration rate decreases with the decrease of temperature.

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