Estimation of Primary Production in Moss Community on East Ongul Island, Antarctica

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南極東オングル島コケ群落の過去17年間の一次生産量の推定

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要旨: 南極生態系の機構解明のため，コケ群落の一次生産量の推定を試みた．1982 年 1 月に昭和基地で東オングル島産のコケ群落の光合成，呼吸速度を赤外線ガス分析計を使って同化箱法で測定した．

ヤノウエノアカゴケ (*Ceratodon purpureus*), キョクチセンボンゴケ (*Pottia heimii*), オオハリガネゴケ (*Bryum pseudotriquetrum*) の混生群落で，それらの表面はらん藻と地衣におおわれていた．

総光合成速度と呼吸速度は，それぞれ日射量と気温との積 (R-T index) に二次式で近似できた．1959 年 11 月から 1981 年 1 月まで，基地閉鎖期間を除く 17 回の夏 (11 月から 3 月) の昭和基地の気象資料を用いて，コケ群落の総生産量と呼吸消費量を計算した．両者の差を純生産量とすると，平均純生産量は 3.7 g dw/m^2・yr，最大値，最小値は 12.8，-16.2 g dw/m^2・yr であった．

Abstract: This investigation is a part of the works to make clear the function of an Antarctic ecosystem. The photosynthetic activity and the respiration of moss community sampled on East Ongul Island, East Antarctica, were measured in January 1982 at Syowa Station with an infrared gas analyzer. Three species of mosses, *Ceratodon purpureus*, *Pottia heimii* and *Bryum pseudotriquetrum* were included in the community. The surface of all moss communities was covered with blue-green algae and lichens, and the growth condition of moss communities looked very poor.

Positive correlations were observed between the gross photosynthetic rate or respiration rate and the R-T index, which is the product of daily radiation amount and daily mean air temperature. The net production rates in summer, from November to March, were estimated by the use of meteorological data for 17 years. Mean net production rate of moss community was 3.7 g dw/m^2·yr, and the maximum and the minimum rates were 12.8 and -16.2 g dw/m^2·yr, respectively.

1. Introdution

The primary productions of different ecosystems were mainly measured from the 1960's to the 1970's and some of them were listed in some textbooks (WHITTAKER, 1975; CANNELL, 1982). The primary production in an arctic region was mainly investigated in Point Barrow, the Scandinavian Peninsula, and the arctic region of USSR (WIELGOLASKI and ROSSWALL, 1972; ROSSWALL and HEAL, 1975; TIESZEN, 1978).

On the other hand, concerning an Antarctic ecosystem, there are few data of phytomass and primary production. Some reports were published about a maritime Antarc-

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tic ecosystem (COLLINS *et al.*, 1975; COLLINS, 1977; DAVIS, 1981). The climate of continental Antarctica is more rigorous than that of maritime Antarctica. Therefore, it is estimated that the phytomass or the primary production in ice-free area of continental Antarctica is much smaller than that of maritime Antarctic ecosystem.

The producers in the Antarctic ecosystem are mosses, liverworts, lichens and algae. Two species of flowering plants also live in the Antarctic Peninsula. Many moss communities are found in places where the supply of water is abundant. Generally, mosses exist in turf-form, carpet-form or cushion-form community and lichens are attached to the surfaces of rock and moss community. Algae live in water and just under ground surface. Moss community exists in patch condition and has high density of biomass. The biomass density of the naked land is very low. Therefore, the production of moss community is important to the function of the Antarctic ecosystem, that is, energy flow, matter transport, cooperation of organisms, etc.

In the 1960's RASTORFER (1970) measured photosynthetic activities of two species of mosses which were sampled in Victoria Land, East Antarctica. But his data could not be referred to, because his technique with a manometer was not suitable for the measurement of photosynthesis (INO, 1983).

The present author stayed at Syowa Station on East Ongul Island (69°00'S, 39°35'E) in January 1982, and measured the photosynthetic activity of moss community living on this island. The measurement was a part of the investigation to make clear the function of an Antarctic ecosystem in the vicinity of Syowa Station. In the previous paper (INO, 1983), the author concluded that the gross photosynthetic rates or respiration rates were correlated with the product of the air temperature and illumination intensity (I-T index). In this paper, the primary production of moss community is estimated by the use of the above relationships.

2. Materials and Methods

The samples for the measurement of photosynthesis were mixed communities of *Ceratodon purpureus*, *Pottia heimii* and *Bryum pseudotriquetrum*. The surface of all moss communities on East Ongul Island is covered with imperfect lichen; *Lapraria* sp. (KASHIWADANI, 1973) and blue-green algae; *Gloeocapsa* sp. (FUKUSHIMA, 1959), *Nostoc* sp. and *Stigonema* sp. (AKIYAMA, 1974). NAKANISHI (1977) evaluated such moss community as Vitality 1 and its grade means that mosses are largely moribund. However, his definition is problematical, because when a number of 3 cm^2 blocks separated from some communities were cultured with nutrient solution at 10°C and 6 klx, many green shoots began to grow actively in all blocks. It was estimated that most of moss communities covered with blue-green algae were in the rest condition for growth.

The lower parts of moss communities held sand particles in their rhizoids and stems. In order to remove sand, those parts were cut away, and board-like samples of about 5 mm thickness were prepared. Some board-like samples were put on the plate in the assimilation chamber of 16.5 cm square and 10 cm height. Air was admitted into the chamber and the carbon dioxide concentrations at the entrance and the exit of the chamber were measured with an infrared gas analyzer (Horiba, 315A). Illumination intensity was measured with a selenium illuminometer and temperatures of air and moss were measured with thermister thermometers. The details of the method were described in the previous paper (Ino, 1983).

Photosynthetic activity was measured under daylight condition and respiration activity was measured by covering the chamber with aluminum foil. The change of carbon dioxide concentration is caused by the photosynthesis and respiration of photosynthetic plants and the respiration of non-photosynthetic organisms. Gross photosynthetic rate is obtained by the addition of the change of carbon dioxide concentration in a dark period and the change in a light period.

Photorespiration was neglected for the reasons of measurement technique. Therefore, the photosynthetic rate seems to be underestimated to some extent.

The gross photosynthetic rate and the respiration rate (mg CO_2/g·h) were converted into dry matter base (mg dw/g·h) with the transformation factor 0.61. This factor is calculated under the assumption that the mean carbon component of dry matter is equivalent to the content of polyssacharide of $C_6H_{10}O_5$. Then, the moss weight (g) was converted into the area (m^2) of community.

The gross production rate and the respiration rate (g dw/m^2·d) were respectively correlated with the product of daily sum of hourly mean illumination intensity and daily sum of hourly mean air temperature in the assimilation chamber (I-T index). These correlations could be approximated with the second-degree polynomial regression equations in the previous paper (Ino, 1983) as shown in Fig. 1. Both regression curves crossed together at two points and in the section of lower I-T index than the left crossing point, the gross production rate was higher than the respiration rate. Higher I-T index than the right crossing point did not occur in natural condition. By the use of these relationships and the meteorological data at Syowa Station, the primary production of moss community on East Ongul Island was estimated.

In the previous paper (Ino, 1983), the author concluded that if the illumination intensity and air temperature are taken, the primary production of moss community

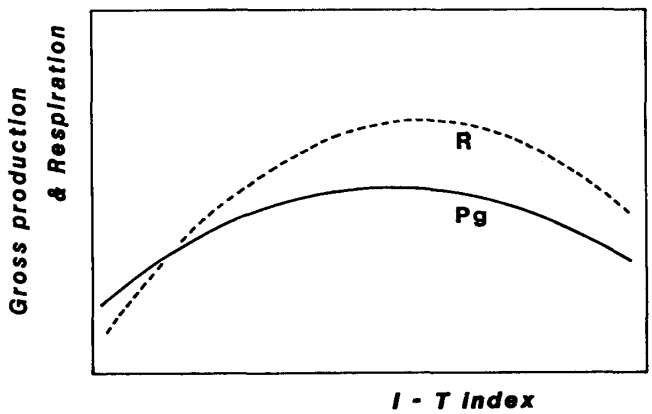

Fig. 1. Relative relationships between the gross production or the respiration loss of dry matter and the I-T index, which is the product of daily sum of hourly mean illumination intensity and daily sum of hourly mean air temperature in the assimilation chamber. 'R' is the respiration loss rate and 'Pg' is the gross production rate. When air temperature is low, the gross production rate is higher than the respiration loss rate.

can be calculated. The meteorological observation at Syowa Station has not measured illumination intensity but radiation. Therefore, the primary production was calculated in the following processes.

1) Conversion of the inside air temperature of the assimilation chamber into the outside air temperature.

2) Conversion of hourly mean illumination intensities into hourly radiation amounts.

3) Estimation of the relationships between the gross production rates or respiration rates and the products of the sum of hourly mean air temperatures and daily radiation amount.

4) Calculation of the daily amounts of gross production and respiration from February 1980 to January 1982, when the data of hourly air temperature are utilizable.

5) Calculation of the regression equations of the relationships between the gross production rates or the respiration rates which were obtained at the above item, and the products of daily mean air temperatures and daily radiation amounts from February 1980 to January 1982.

6) Calculation of daily gross production rates and respiration rates using the above equations in the summer seasons of 1959 to 1980.

3. Results and Discussion

The air temperature in the assimilation chamber was largely affected by radiation intensity. It could not be directly related with radiation intensity, because the radiation was made to increase temperature with time lag. But a positive correlation was recognized between the inside and the outside temperatures without the consideration for the effect of radiation. Figure 2 shows the relationship between hourly mean air temperatures of the inside and outside of the assimilation chamber. The air temperature in the assimilation chamber which is used in the I-T index can be exchanged into the outside air temperature of the chamber by the use of the above relation.

The meteorological observation at Syowa Station has measured not illumination intensity but radiation amount, and so the illumination intensity in the I-T index must be exchanged into the radiation amount. The relationship between the hourly mean illumination intensities (klx) measured beside the assimilation chamber and the hourly radiation amount ($J/cm^2 \cdot h$) measured by the meteorological observation from the 9th to 16th of January 1982, was formulated by a linear regression (Fig. 3). This line did not pass the origin. The reason was that the zero point of illuminometer shifted to the minus range. By this equation, illumination intensity can be converted into radiation amount.

Then the product of daily radiation amount and daily sum of hourly mean air temperatures (R*-T index) was related with gross production or daily respiration loss. The respiration rate became 0 mg CO_2 at -2°C in this relation. Therefore, the value with 2°C added to hourly mean air temperature was used instead of the hourly mean air temperature. Each relationship could be approximated with the second-degree polynomial regression equation (Fig. 4). Two points of seven calculated values exist out of the figure.

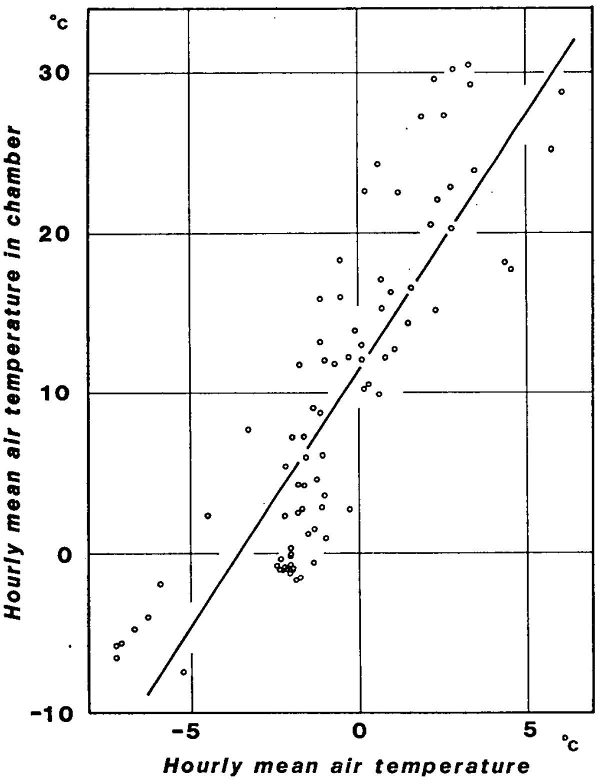

Fig. 2. Relationship between hourly mean air temperatures inside and outside of the assimilation chamber. This correlation is expressed by a line, $Y=3.19\,X+11.45$; $r=0.85$.

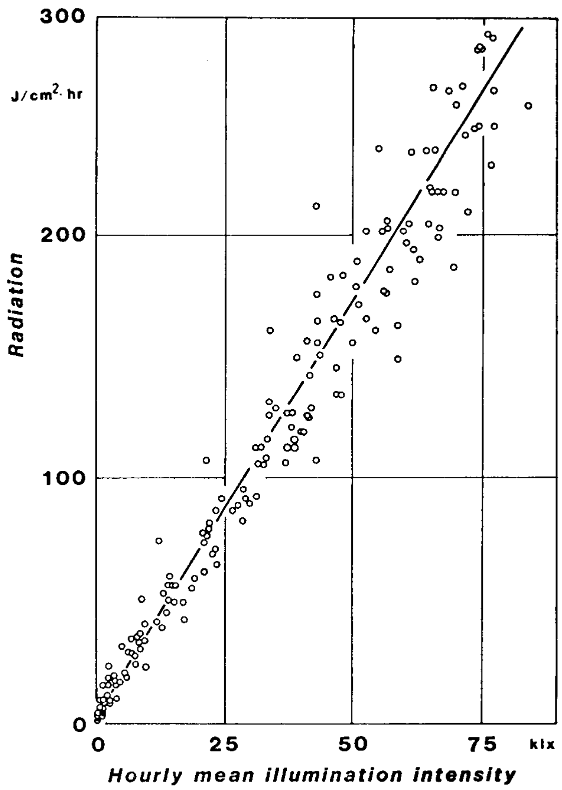

Fig. 3. Relationship between hourly radiation amount and hourly mean illumination intensity. This correlation is expressed by a line, $Y=3.29\,X+3.95$; $r=0.98$.

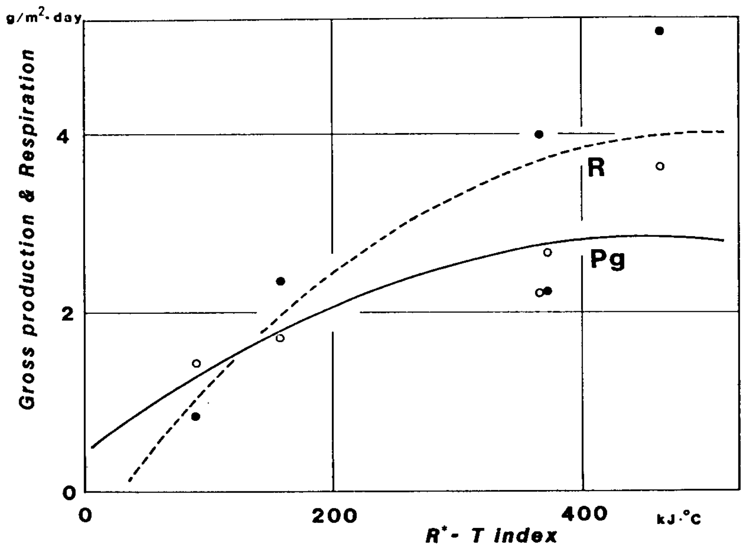

Fig. 4. Relationships between the gross production (○) or respiration loss (●) amounts and the R-T index, which is the product of daily radiation amount and the daily sum of hourly mean air temperature. Each relationship is expressed by a curve of the second-degree polynomial regression equation. Two of seven calculated points exist outside of the figure.*

Hourly mean air temperature from February 1980 to January 1982 was provided by the Office of Antarctic Observations, Japan Meteorological Agency. Daily gross production amounts and daily respiration amounts were calculated for that the period with two regression equations. The difference between the two amounts was regarded as the net production amount. Figure 5 shows daily net production amounts from November 1980 to January 1982. When air temperature is high, daily net production became a minus amount. When the R*-T index is lower than 25 or when the daily sum of hourly

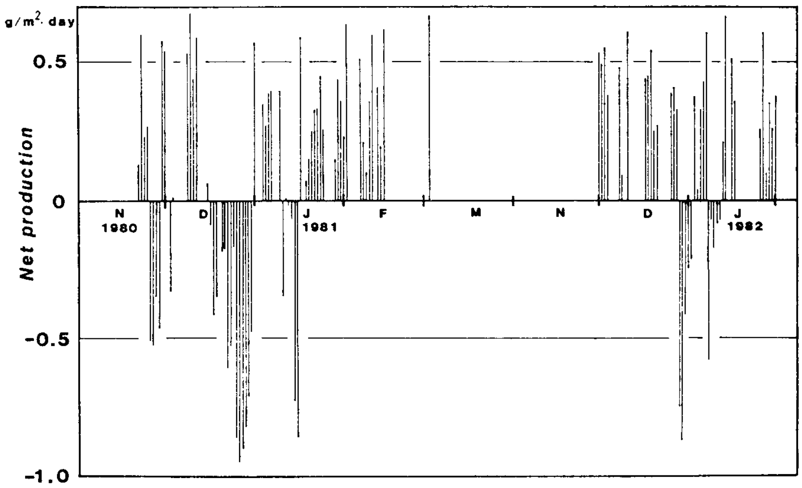

Fig. 5. Daily net production amounts of moss communities in the summer season estimated by the relations in Fig. 4. Net production is the difference of gross production and respiration loss amounts and the summer season is from November to March. The sections where vertical lines are not shown are days when the net production cannot be estimated, because gross production or respiration loss is calculated at 0 g/m²·d or minus. Minus net production amount means that respiration loss amount is larger than gross production amount.

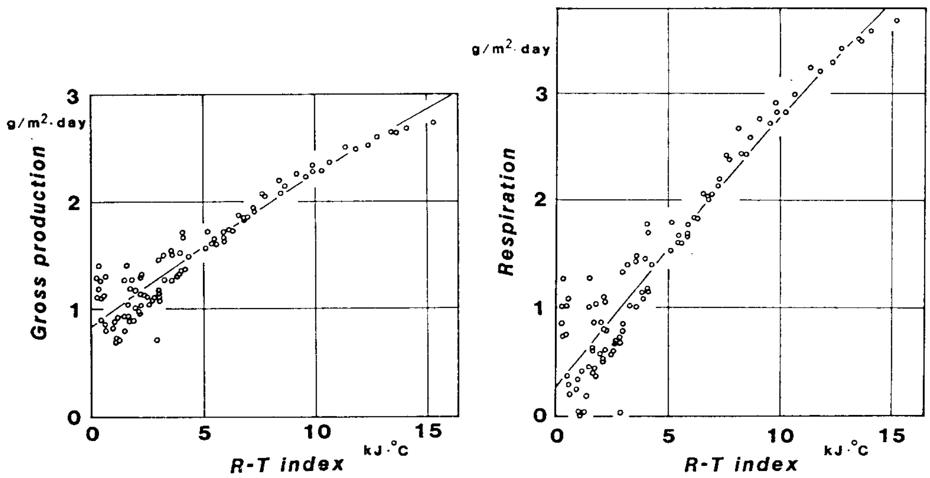

Fig. 6. Relationships between the gross production and the R-T index (left) and the respiration loss and the R-T index (right). R-T index is the product of daily radiation amount and the value with 2°C added to daily mean air temperature. These relationships are approximated by curves of the second-degree polynomial regression equations.

mean air temperature is lower than 0°C, the respiration rates become minus; therefore, in such cases the calculation was not done. There were many days which were not calculated even in summer.

Before January 1980, hourly mean air temperature was not published and daily mean air temperature was usable. Therefore, to calculate the gross production and respiration rates before 1980, the temperature in R*-T index had to be changed from the sum of hourly mean air temperatures to daily mean air temperature, and the R*-T index was changed to the R-T index (kJ·°C).

Calculated amounts of the gross production and respiration rates from February 1980 to January 1982 were related with the product of daily mean air temperature and daily radiation amount in the same period (R-T index). These relationships were expressed as the second-degree polynomial regression equation (Fig. 6).

The gross production amount and the respiration loss amount of every day in summer before January 1980 were calculated with both equations. These amounts were summed up in every summer. In Fig. 7, the amounts of net production which were calculated in such process are shown. These amounts are the differences of gross production and respiration amounts. From 1962 to 1965, Syowa Station was closed, and so the net production was not calculated in this period. In seventeen summers there were four summers whose net productions became minus and the minus amount from 1976 to 1977 was especially large. The maximum, minimum and mean amounts of net production were 12.8, −16.2 and 3.7 g dw/m²·yr, respectively. Davis (1981) reported mean net primary production rates of 409 and 392 g dw/m²·yr at Signy Island but our predicted rates were much lower than those rates. The difference is attributed to poor growth condition in moss community on East Ongul Island. When the R-T index was about 5.4, the net production rate became 0 g and if R-T index was larger than 5.4, the net production rate became minus. The maximum daily mean air temperature was 5.6°C for seventeen years and under the condition of such air temperature, the radiation amount when daily net production becomes 0 g, is 0.7 kJ/cm²·d. This

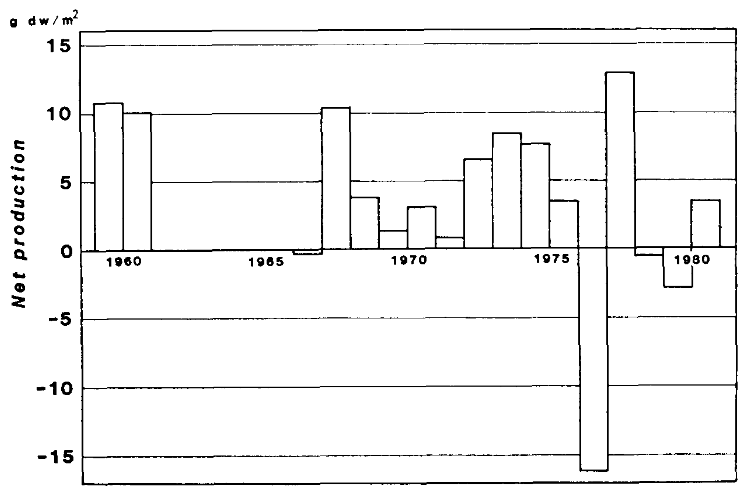

Fig. 7. Net productions of the moss communities in the summer season from November to March. Minus values are caused when respiration loss was larger than gross production. From 1962 to 1965, Syowa Station was closed.

amount roughly corresponds to the radiation in March. On such a warm day, the respiration loss amount was way above the gross production amount. The maximum daily radiation amount was 4.3 kJ/cm^2, and if daily mean air temperature of the day was −0.7°C, the net production was 0 g.

On East Ongul Island, moss community is very meager and there is no moss community larger than about 1 m^2 area. It is estimated that the primary production of moss communities on this island is very low. In the naked area, mean gross production which was estimated from soil respiration was 1.7 g dw/m^2 in the period from December to February (INO *et al.*, 1981). Probably, the primary production of algae which live around sand particles and gravels is higher than that of mosses on this island, because the naked area is larger beyond comparison with the area of moss communities. But moss growth is rapid in a land of abundant water and there are no blue-green algae and lichens on the surface of such moss community. Such community looks green and has high primary production. The primary production by moss community has an important value to the function of an Antarctic ecosystem only in an ice-free area which abounds in water.

If the primary production of lichens is measured, the primary production of the Antarctic ecosystem in the vicinity of Syowa Station will be approximately estimated and it will become the starting point to make clear the dynamics of the ecosystem.

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