Soil Respiration in the Vicinity of Syowa Station, Antarctica

1. Relationships between Soil Respiration Rate and Water Content or Nitrogen Content

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南極，昭和基地周辺の土壌呼吸

1. 土壌呼吸速度と土壌の含水率，チッソ含有率との関係

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要旨：1978年1月と2月に南極の昭和基地周辺各地で表層土壌を採取し，凍結状態で日本に持ち帰った．その一部72点を用いて，10°C，暗所で放出されるCO_2量を赤外線ガス分析機で測定した．土壌の湿重と乾重とから水分含有率を求めた．また，ケールダール法によってチッソを定量した．

CO_2放出速度は平均13.3 mg C/(kg 乾燥土壌・日)で，最低値は0.0，最高値は84.9であった．東京近郊数カ所の土壌で得られた値より大きなものがいくつもあった．砂質土壌のため，水分含有率は一般に小さかった．チッソ含有率は0.001–0.45%で，きわめて小さかった．土壌呼吸速度と水分含有率，あるいはチッソ含有率との間に高い相関関係が認められた．

Abstract: With 72 samples of soil which were taken in the vicinity of Syowa Station, Antarctica, carbon dioxide evolution rate, *i.e.* soil respiration, water content and nitrogen content were measured. The range of soil respiration rates at 10°C was 0.0 to 84.9 mg C/(kg dry soil·day). Some of soil respiration rates measured at 10°C were higher than those taken under the same condition with a few types of floral zone in Japan.

Nitrogen contents in sample soil were very low with the range of 0.011 to 4.51 mg N/g dry soil.

There were good correlations between soil respiration rates and nitrogen contents or water contents.

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1. Introduction

In the vicinity of Syowa Station, the ice-free area expands during the summer season and moss communities develop on sandy soil in the area. As none of higher plants are found in this floral zone, the biotic activity of this region must be lower than that of other climatic regions. Microorganisms such as rotifer, tardigrade, protozoan, etc. live in the moss communities, and concerning these organisms some reports were taxonomically and ecologically presented (*cf.* MATSUDA, 1968). Microorganisms such as bacteria and algae probably live not only within the moss communities but also on the surface of ice, rock, gravel and sandy particle in this region. As for the analysis of an antarctic biome, it is significant to undertake the measurement of biotic activities of microorganisms in sandy soil as well as of visible organisms.

There are two methods to study the function of ecosystem. One method is the attempt of clarify the structure and the function of each population lived in the ecosystem. The other is the measurement of matter flow or energy flow in the ecosystem and is suitable to study the function of ecosystem in case it is difficult to separate the community into components.

There are some methods to estimate the biotic activity of microorganisms. One of them is the measurement of respiration. Carbon dioxide evolution from soil, *i.e.* soil respiration, has been used as an indicator of the decomposition of soil organic matter, but it can be regarded as the total image of metabolic activity including plant root, microfauna and microflora.

The study in relation to the soil respiration in the Antarctic has not been reported yet. In the Arctic Circle, some measurements of soil respiration were done at different floral zones near Barrow in Alaska and its rates were summarized by COYNE and KELLEY (1979).

2. Materials and Methods

One of the present authors, H. KANDA sampled surface soil in the vicinity of Syowa Station in January and February, 1978. Most of the samples that were taken at Cape Ryûgû, East Ongul Island, West Ongul Island, Skarvsnes and Skallen (Fig. 1 and Table 1) were composed of the efflorescence of gneiss and the rests were of diatomite. The soil samples looked inorganic but sometimes they were somewhat greened with blue green algae adhered to sand particles and gravels. Put in the plastic petri dish of 9 cm in diameter under the aseptic condition, these samples were sent

Table 1. Localities of soil samples and its ecological note.

Locality	Number of sample	Distance from waterside	Topographical and ecological notes
Cape Ryûgû			
Ryûgû-nisi Point	5	1,2 m	At watersides on outcrops exposed to southwest, algal community is dominated with *Nostoc commune* and there is a trace of penguin rookery near by.
Zyôdo Terrace	23	1,2,3,4,5, 10,15 m	The most largest pond, from which a stream is running to sea, of the Cape Ryûgû. Fresh water algal community and skua rookery at the pond and stream banks.
Pond I	6	2,5,10,20 m	All ponds are located in the U-shaped valley running in the west-east direction, and there are moraine belts formed of boulders and sandy or silty soil. Non visible vegetation.
Pond II	1	1 m	
Pond III	5	2,5,10,20 m	
Pond IV	7	2,5,10 m	
Pond V	1	10 m	
Skarvsnes			
Lake Hunazoko	5	1,5,10 m	−25 m sea level. The salinity value of the pond water is very high and rich fresh water algae (diatomite).
Lake Suribati	8	2,5,10,15, 25,45 m	−33 m sea level. Silty sand or diatomite.
Skallen			
Magoke Point	3	1,2 m	Rich moss community formed along streams.
Southern part of Skallen	3	2 m	Poor moss and lichen community.
East Ongul Island			
Lake Minami	1	2 m	Non visible vegetation.
Syowa Station	1	1 m	〃
West Ongul Island			
Lake Ô-ike	1	2 m	Non visible vegetation.

to Japan in a frozen state at −20°C and were kept in freezer at −20°C until the respiration was measured.

The amount of evolved carbon dioxide was measured with the differential infrared gas analyzer (Beckman, 315A).

Before the measurement of soil respiration, it was ascertained that the respiratory vessel was airtight.

Each sample was put in a dark container at 10°C one day before the measurement and settled in a plastic vessel for a respiratory measurement (Fig. 2). Carbon dioxide evolution rates were measured in open system, *i.e.* the air did not circulate in the system, under the conditions of 10°C in dark. The water content of the sample

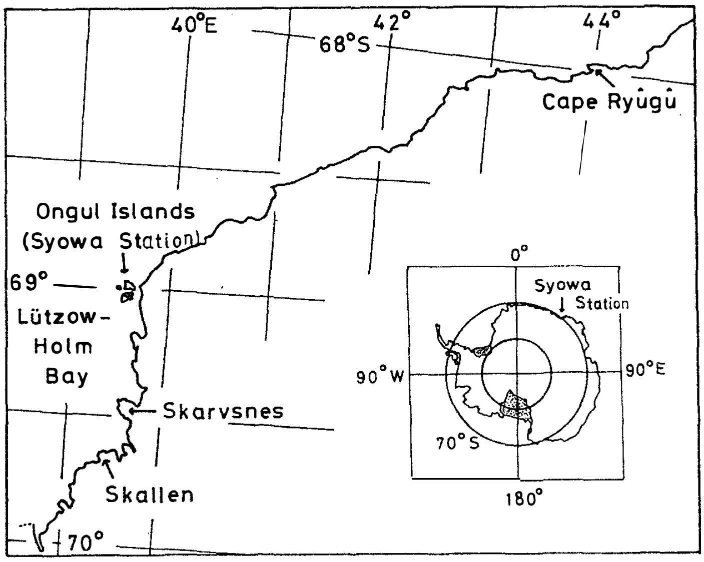

Fig. 1. Localities of soil sampling.

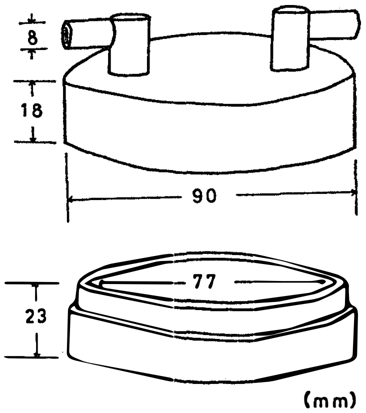

Fig. 2. Plastic chamber for measurement of carbon dioxide evolution rate.

was not controlled. Air flow rates were in the range of 2.5 to 5.0 m*l*/s and the rate was controlled according to the difference of carbon dioxide concentration.

After the measurement of respiration, wet and dry weights were taken, and 1 to 4 g of dry soil was used for nitrogen analysis with the Technicon Auto Analyzer by the industrial method 30–69A. By this method, nitrogen which was able to change into ammonium sulphate by heat decomposition in sulphuric acid is measured.

3. Results

The air flowing on the soil in the respiratory vessel drew out the air, which was rich in carbon dioxide, from the space among particles. Therefore, at the beginnig of aeration, high concentration of carbon dioxide was recorded. It decreased slowly and attained to a constant concentration within 1 to 3 hours. The period to attain the constancy could be shortened by the rapid aeration in the beginning. It is known as "Birch effect" that the explosive evolution of carbon dioxide occurs after thawing (ROVIRA, 1953) or rewetting (SOULIDES and ALLISON, 1960). But this phenomenon was not seen in our measurement. Soil respiration rates were calculated with the constant concentration.

From 72 samples used for measurement, soil respiration rates were estimated in the range of 0.0 mg C/(kg dry soil·day) to 84.9 mg C/(kg·day). The frequency distribution of these rates is shown in Fig. 3, with the mean rate calculated as 13.3 mg C/(kg·day). The soil samples from Magoke Point and from the southern part of Skallen had higher mean rate of 40.6 and 69.5 mg C/(kg·day), respectively. The places whose biotic activities were extremely high exist in the Antarctic.

Water content was represented by the percentage of the water amount to the dry weight of soil. Many samples had low water content. The soil samples near waterside of a pond showed higher water content, and further remarkable content, 496%, was recorded in diatomite which was sampled at the waterside in Skarvsnes.

A few samples had the nitrogen content more than 0.1% of dry weight of soil, but the mean content was very low, 0.032%. The frequency distribution of nitrogen contents is shown in Fig. 4.

Most of samples were taken at some distances from the waterside (Table 1). The soil respiration rates and the water contents at each distance are plotted in Fig. 5 with 8 examples. The maximum rate and content were recorded within 5 m from waterside. Although the water contents of soils became less than 1% at the places 20 or

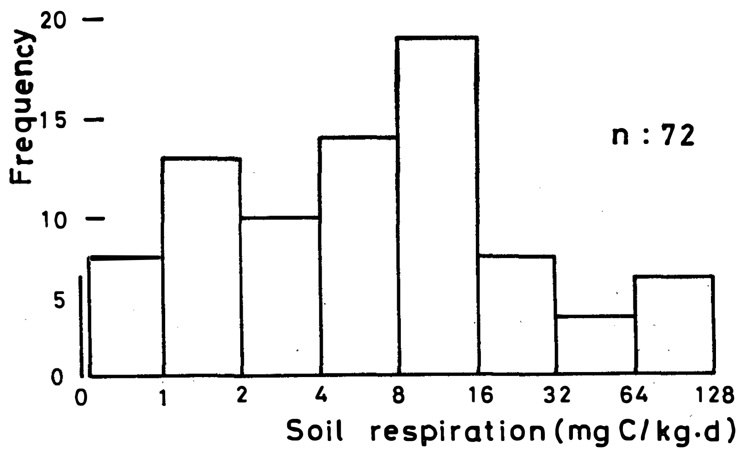

Fig. 3. Frequency distribution of soil respiration rate. The mean rate of 72 samples was 13.3 mg C/(kg dry soil·day).

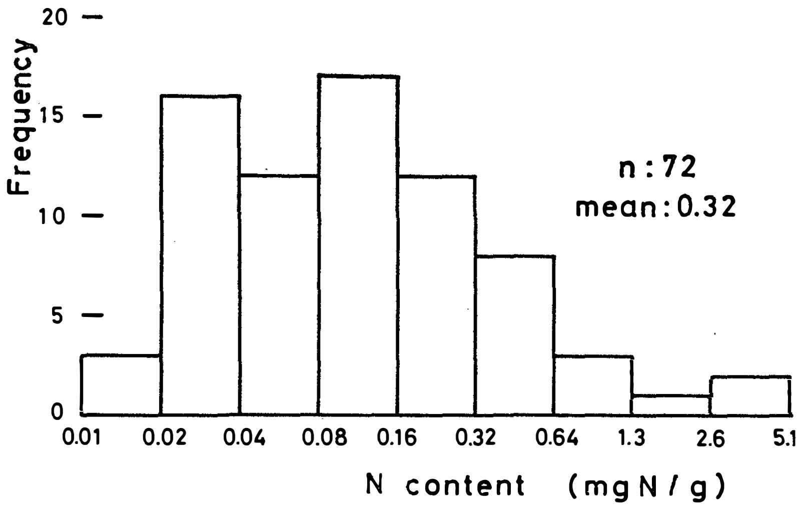

Fig. 4. Frequency distribution of nitrogen content of soil samples. The mean content of 72 samples was 0.32 mg N/g dry soil.

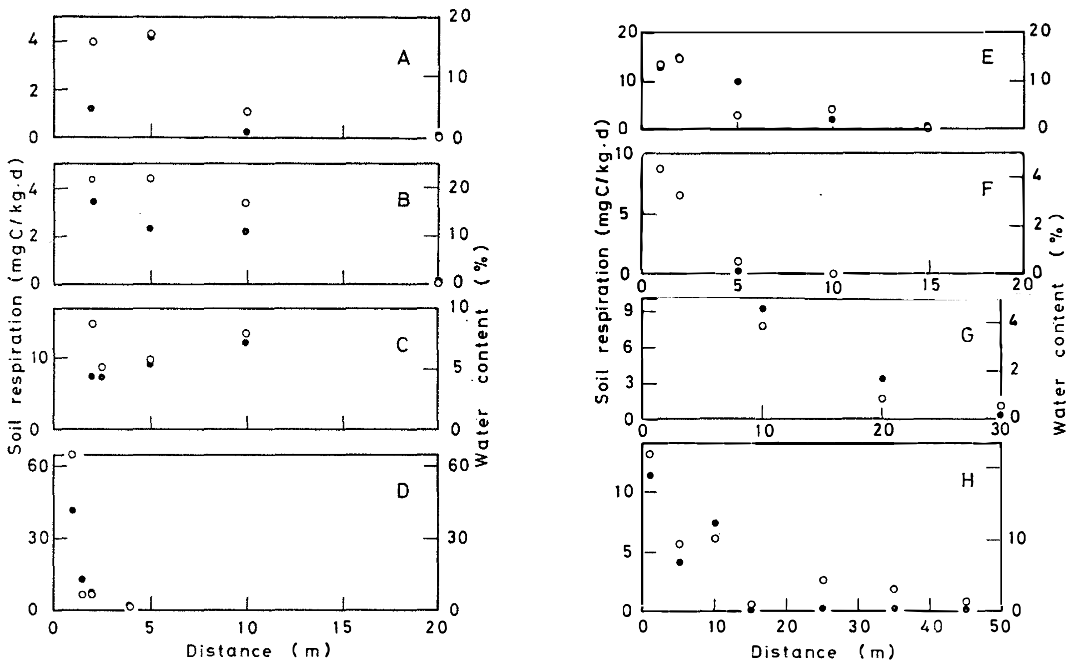

Fig. 5. Soil respiration rate and water content against the distance from waterside. Soil respiration rate is indicated by open circle and water content is indicated by solid circle. A: Pond I in Cape Ryûgû, B: Pond III in Cape Ryûgû, C: Pond IV in Cape Ryûgû, D: a river at Cape Ryûgû, E, F and G: three different directions from a pond of Zyôdo Terrace in Cape Ryûgû, and H: Lake Suribati in Skarvsnes.

30 m from waterside, the evolution of carbon dioxide was recognizable in those samples.

It is assumed that the gradient of biotic activity exists with pond as a center.

4. Discussion

The highest rate of carbon dioxide evolution was 84.9 mg C/(kg·day) and this rate is remarkably large. DOUGLAS and TEDROW (1959) reported 3 to 44 mg C/(kg·day) at Barrow with the alkaline absorption method. In Japan, INO and MONSI (1969) measured seasonal changes of soil respiration rates at 10, 20 and 30°C in some types of floral zone. They reported that at 10°C, most of rates were 10 to 20 mg C/(kg·day) and the highest rate was 26 mg C/(kg·day). It is possible to assume that at 10°C, soil respiration rates of the antarctic soil are not too low. There were reports that the soil surface temperature rose to 27°C in January near Syowa Station (MATSUDA, 1968) and that some lichens in a cold region can carry on photosynthesis at -25°C (LARCHER, 1975). Nevertheless, the quantity of the biotic metabolisms in antarctic soil will be little because snow and ice cover the soil surface during the greater part of a year and because the growing season is of short duration.

There were many reports about the relation between the soil respiration rate and the environmental factor or biomass (*cf.* SINGH and GUPTA, 1977). The soil condition that is suitable for biotic activity works to increase the soil respiration rate. INO and MONSI (1969) find a good correlation between soil respiration rate and soil temperature, water content, organic carbon content or nitrogen content, respectively. In the present experiment, there a good correlation was found between the soil respiration rate and the water or nitrogen content (Figs. 6 and 7). Water is an indicator of activity and nitrogen is an indicator of biomass or resource. The correlation coefficients were 0.64 and 0.79, respectively. There was a better correlation between the soil respiration rate and the product of water content and nitrogen content, and the correlation coefficient was 0.82 (Fig. 8).

Generally, the rise of temperature causes the increase of respiration rate. With two samples, temperature-soil respiration rate curves were made. Soil respiration rates at temperatures higher than 20°C were less than expected. In a cold region, organisms which can give a high activity at low temperatures such as 5 to 10°C will be abundant.

A part of biotic activities in the environment where resources are meager was measured. The increases of water content and/or nitrogen content caused a rise in the respiration rate of microcosmos, a lump of earth. But temperature was not

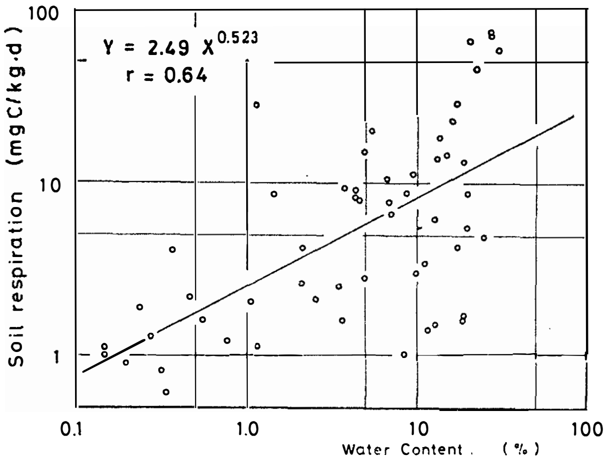

Fig. 6. Correlation between the soil respiration rate and the water content.

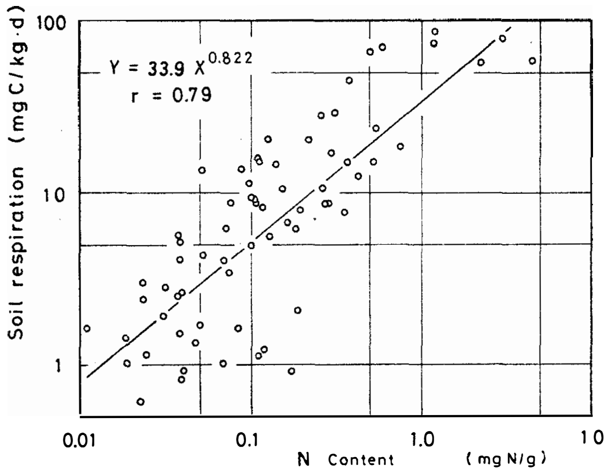

Fig. 7. Correlation between the soil respiration rate and the nitrogen content.

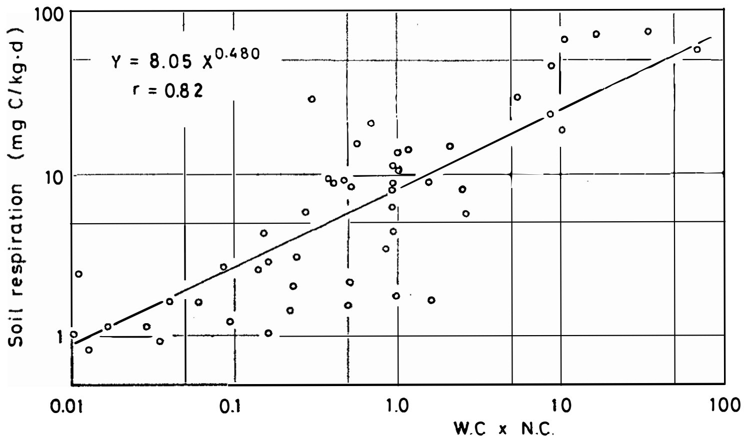

Fig. 8. Correlation between the soil respiration rate and the product of water content and nitrogen content.

a strong stimulus to biotic activities. To make clear the function of antarctic ecosystem, it is necessary to study the relation between the respiration rate and the natural resource or environmental factors from ecological and physiological points of view.

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