林木の光合成と呼吸 (II)

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短 報

Study on Photosynthesis and Respiration of Tree (II)
Diurnal Change of Photosynthesis in Needles of *Cryptomeria japonica* and *Chamaecyparis obtusa*

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林木の光合成と呼吸 (II)
スギ，ヒノキ針葉の光合成日変化

萩原秋男*

Introduction

Recently, the harvest method[1] of primary production has made a remarkable progress in the theoretical and technical study. This method is based on the principle that the total primary production can be estimated by summing up various fractions of the assimilate which are utilized for different community processes such as biomass increment, losses due to death and respiration, and consumption due to grazing by animals. This approach is now available for the reasonable assessment of the primary production in the forest community.

On the other hand, the photosynthetic method[2,3] has been used to estimate the total canopy photosynthesis. Total photosynthesis in the canopy is calculated from the light-dependent photosynthesis of a single leaf by integrating the photosynthesis in a single leaf along the light profile through a canopy. MONSI and SAEKI have developed this method to estimate the total matter production of the herb community. This method was also applied to forest community by some workers[4~6].

The harvest method would be reasonable for the determination of the primary production of the forest community during a long period. On the other hand, the photosynthetic method would be an excellent approach to the estimation of the primary production of the forest community within a short term and to the study of the structure and function of forest canopy.

In this experiment, the author attempted to estimate the diurnal changes of photosynthesis in needles of *Chamaecyparis obtusa* and *Cryptomeria japonica*, using the photosynthetic method. Furthermore, the daily photosynthesis (per unit dry weight of needles) and the daily compensation point which reduced the daily surplus photosynthesis in needles to zero (i. e., the sum of photosynthesis in the daytime is equal to that of respiration in a day) were also suggested with the mathematical formula.

Materials and Methods

The materials used for this experiment were the current leaves of *Chamaecyparis obtusa* and *Cryptomeria japonica* of 14 years. Experimental materials used in this study were obtained from the field of Nagoya University. The soil of habitat was red and very shallow.

The rate of CO_2 exchange was determined by measuring the CO_2 concentration and aerating velocity of air through an assimilatory chamber, using an infra-red gas analyser of HARTMANN & BRAUN (URAS-1). The used assimilatory chamber was of polyethylene 12 cm in diameter and 0.6 cm in depth, with a removal lid to allow the introduction of the leaf. Detached leaves were placed with their bases inserted into a small vinyl tube filled with water. After the sufficient period of pre-illumination, photosynthesis was determined and 1.5 hr was the maximum time for one experiment.

The light source consisted of six 500 W incandescent lamps. The light was filtered through 10 cm of water to absorb heat. Light intensity was regulated by voltage supplied to the lamps. The temperature in the chamber was controlled by circulating air through coiled glass tubing placed in a constant temperature bath. Determinations of CO_2 exchange was carried out at 25℃ and air flow rate of 0.5 *l*/min.

The twigs were taken from planted trees at the same height and direction. The twigs taken from the field were immediately placed in the laboratory. Before the measurement of gas exchange, the leaves were detached from twigs and pre-illuminated. After the determination of photosynthesis and respiration, the leaves were kept for 24 hours at 105℃

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and the leaf dry weight was determined.

The light intensity at the horizontal plan was obtained by reading the photometer (TOSHIBA) in fine days. This measurement was carried out near the field of Nagoya University, and through daytime at 30 minutes intervals in August, 1972.

Results and Discussion

1) Light-photosynthesis curves in detached needles

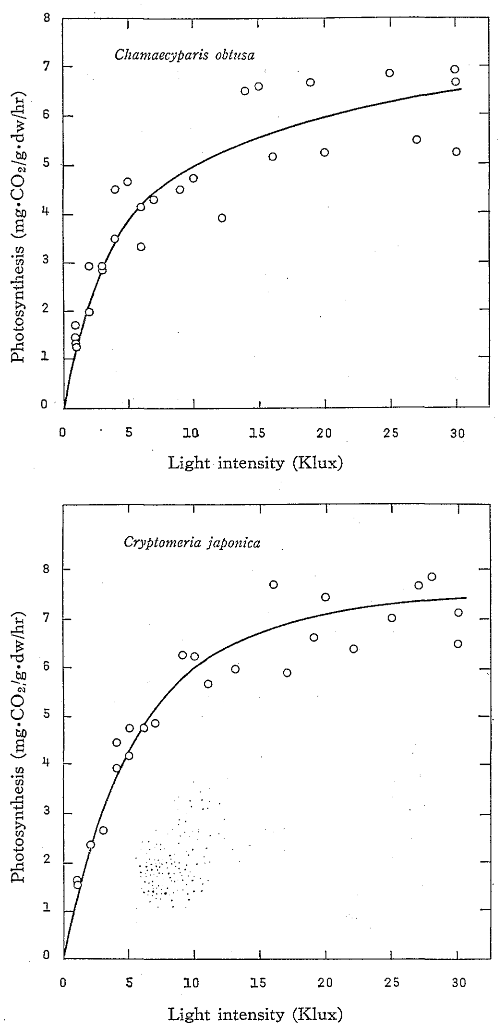

Fig. 1. Light-photosynthesis curves in the detached leaves of *Cryptomeria japonica* and *Chamaecyparis obtusa*. The constants a and b in Eq. (1) are as follows: *Chamaecyparis obtusa*; $a=0.292$ and $b=2.012$. *Cryptomeria japonica*; $a=0.235$ and $b=1.927$. Mean respiration is 1.026 mg·CO_2/g·dw/hr in *Cryptomeria japonica* and 0.865 mg·CO_2/g·dw/hr in *Chamaecyparis obtusa*

The relations of photosynthesis to light intensity in needles of two species are shown in Fig. 1.

As already pointed out by many workers, a rectangular hyperbola given by the formula (1) can well describe the relation between photosynthesis (p, mg CO_2/g·dw/hr) and light intensity (I, Klux).

$$p=\frac{bI}{1+aI} \qquad (1)$$

The constants a and b are asymptote or the light-saturated rate of photosynthesis and the initial gradient of the curve at the origin. Transforming Eq. (1) into the following formula,

$$\frac{1}{p}=\frac{1}{bI}+\frac{a}{b}, \qquad (2)$$

the two parameters a and b can be determined by the least squares method. According to the results obtained in the previous paper,[7] the calculated maximum values of photosynthesis were 8.20 mg CO_2/g·dw/hr in *Chamaecyparis obtusa* and 6.89 mg CO_2/g·dw/hr in *Cryptomeria japonica*. The calculated compensation point was 0.49 Klux in *Chamaecyparis obtusa* and 0.61 Klux in *Cryptomeria japonica*. The mean respiration was 0.87 mg CO_2/g·dw/hr in *Chamaecyparis obtusa* and 1.03 mg CO_2/g·dw/hr in *Cryptomeria japonica*.

2) Diurnal changes of light intensity

The light intensity was measured through daytime at 30-minute intervals. The observation was carried out in fine days in August, 1972, in Nagoya. The relative light intensity is defined as the ratio of

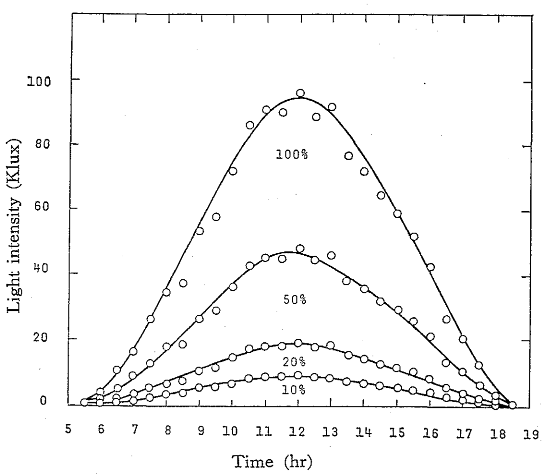

Fig. 2. Mean diurnal change of light intensity in 100%, 50%, 20% and 10% of incident light intensity on the forest canopy. The curves were calculated by Eq. (3). The curve for 100% corresponds to the mean diurnal change of light intensity in August measured at Nagoya

the light intensity above the canopy. In Fig. 2, the estimated relative light intensity (100, 50, 20 and 10%) is shown. As illustrated in Fig. 2, the light intensity at the given time t hours from sunrise on a fine day could fairly well be described by the following equation:[5,8)]

$$I = I_{\max} \sin^2 wt$$

$$w = \frac{\pi}{E} \qquad (3)$$

In this equation, 'I' attains its maximum value $I_{\max}$ (Klux) at the heighest altitude of the sun, w is angular velocity, and E denotes day length in hours. The constant $I_{\max}$ and E on a fine day in August at Nagoya were 96 Klux and 13 hours, respectively.

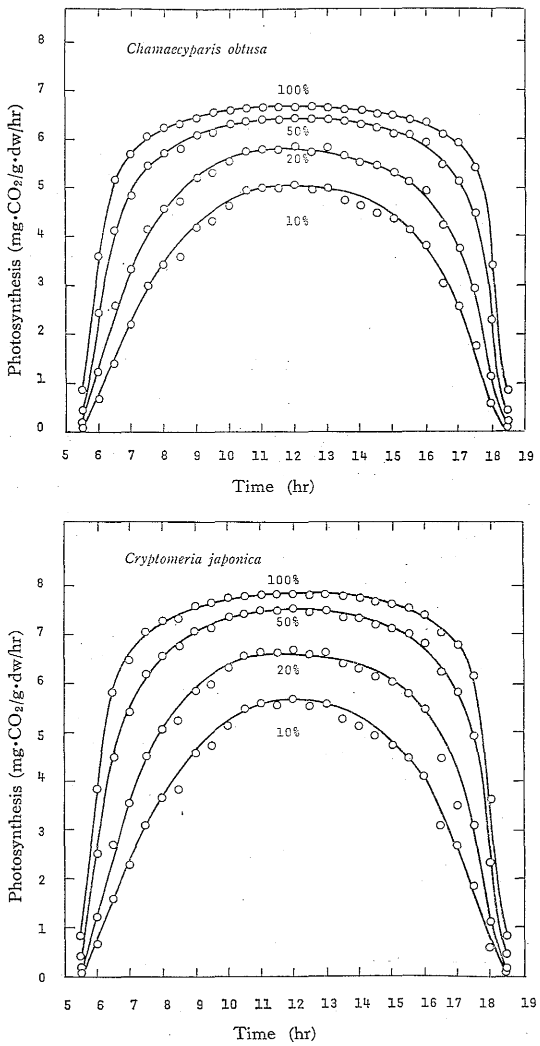

Fig. 3. Mean diurnal change of photosynthesis corresponding to 100%, 50%, 20% and 10% light intensity. The values were calculated by Eq. (4)

3) **Diurnal change of photosynthesis in needles**

The functional relationship between photosynthesis and light intensity given by Eq. (1) is known to be influenced by experimental conditions, such as design and microenvironment in the assimilation chamber, amount or velocity of air through the chamber[9,10)], physiological characteristics of photosynthetic tissues[7,11,12)], physical properities of light source[13)], etc. Despite of tecnical progress, it is not yet certain that the photosynthetic method can give truly accurate estimation of normal photosynthesis under natural conditions. However, when we study the structure and the function of forest canopy, the photosynthetic method is an efficient method.

Putting the estimated values of I into Eq. (1), the diurnal changes of photosynthesis (per unit dry weight of needles) for each species were calculated as shown in Fig. 3, together with the diurnal change of photosynthesis corresponding to the relative light intensity in 50, 20 and 10% of incident light intensity above the forest canopy.

The diurnal changes of photosynthesis curves represented broad-top curve at 100 and 50% of light intensity, and approximated to one-top curve according to decreasing relative light intensity. Therefore, it is assumed that the photosynthesis of leaves approximating the top of the forest canopy is almost constant in broad daylight on fine day,

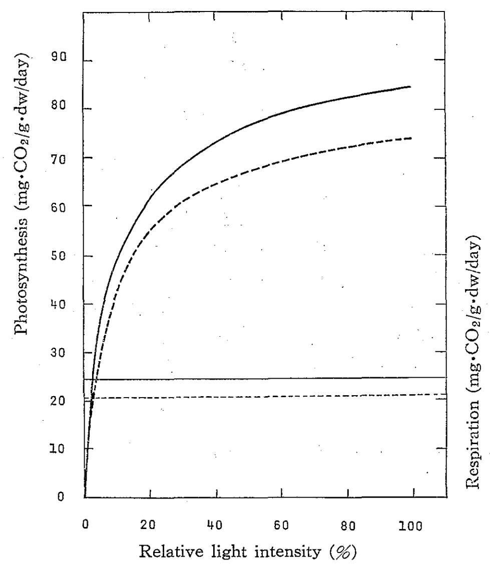

Fig. 4. Daily photosynthesis corresponding to the relative light intensity and mean daily respiration at 25°C. Broken lines; *Chamaecyparis obtusa*. Solid lines; *Cryptomeria japonica*. The curves were calculated by Eq. (5)

and has considerable activity on rainy and cloudy days.

4) **Estimation of daily photosynthesis in needles**

From Eqs. (1) and (2), the mean hourly rate of photosynthesis at time 't' is expressed by the following equation:

$$p(t)=\frac{bI_{max}\sin^2 wt}{1+aI_{max}\sin^2 wt} \qquad (4)$$

The daily photosynthesis (mg CO_2/g·dw/day) can then be obtained by integrating $p(t)$ over the entire daylength as follows:

$$p_d=\int_0^E p(t)dt=\frac{Eb}{a}\{1-(1+aI_{max})^{-1/2}\} \qquad (5)$$

Fig. 4 shows the estimated daily photosynthesis, calculated by Eq. (5), corresponding to relative light intensity.

5) **Estimation of daily light compensation point**

The daily surplus photosynthesis in needles is expressed by the following formula:

$$p_s=p_d-R$$

$$R=\int_0^D \bar{r}dt \qquad (6)$$

In this formula, $\bar{r}$ is the mean respiration (mg CO_2/g·dw/hr) in needles, and D is 24 hours. The daily maximum light intensity which imputes the daily surplus photosynthesis to zero is given by putting $p_s=0$ in Eq. (5) and assuming Eq. (4) as follows:

$$I'_{max}=\frac{1}{a}\left\{\frac{Eb}{(Eb-Da\bar{r})^2}-1\right\} \qquad (7)$$

The daily light compensation point (C_d % light intensity) is then calculated by Eq. (7) as follows:

$$C_d=\frac{I'_{max}}{I_{max}}\times 100 \qquad (8)$$

The daily compensation point calculated by Eq. (8) was 3.06 and 2.48% light intensity, respectively, in *Cryptomeria japonica* and *Chamaecyparis obtusa*. Therefore, when the relative light intensity is 3.06 and 2.48%, respectively, in *Cryptomeria japonica* and *Chamaecyparis obtusa*, the daily production is zero. This shows that *Chamaecyparis obtusa* has stronger shade tolerance than *Cryptomeria japonica*.

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References

1) KIRA, T. and T. SHIDEI: Primary production and turnover of organic matter in different forest ecosystems of the Western Pacific. Jap. J. Ecol. **17**: 70～87, 1967
2) SAEKI, T.: Interrelationships between leaf amount, light distribution and total photosynthesis in a community. Bot. Mag. Tokyo. **73**: 55～63, 1960
3) MONSI, and T. SAEKI: Über den Lichtfakton in den Planzengesellschaften und seine Bedeutung für die Stoffproduktion. Jap. J. Bot. **14**: 22～52, 1953
4) KIRA, T., K. SHINOZAKI and K. HOZUMI: Structure of forest canopies as related to their primart productivity. Plant and Cell Physiol. **10**: 129～142, 1969
5) HOZUMI, K., K. YODA and T. KIRA: Production ecology of tropical forests in southwestern Cambodia, II. photosynthetic production in an evergreen seasonal forest. Nature and life in SE Asia **6**: 57～81, 1969
6) HOZUMI, K. and H. KIRITA: Estimation of the rate of total photosynthesis in forest canopies. Bot. Mag. Tokyo. **83**: 144～151, 1970
7) HAGIHARA, A.: Study on photosynthesis and respiration of tree, (I). Relation between photosynthesis and leaf age (in Japanese). J. Jap. For. Soc. **55**: 71～74, 1973
8) IKUSHIMA, I.: Ecological studies on the productivity of aquatic plant communities, III. Effect of depth on daily photosynthesis in submerged macrophytes. Bot. Mag. Tokyo. **80**: 57～67, 1967
9) TOTUKA, T.: Relationships between CO_2 concentration of air and dry matter production of higher plants (in Japanease). Bot. Mag. Tokyo. **79**: 51～60, 1966
10) FURUKAWA, A.: Carbon dioxide compensation points in popular plant. J. Jap. For. Soc. (accepted for publication)
11) SAEKI, T.: Variation of photosynthetic activity with aging of leaves and total photosynthesis in a plant community. Bot. Mag. Tokyo. **72**: 404～408, 1959
12) FURUKAWA, A.: Photosynthesis and respiration in poplar plant in relation to leaf. J. Jap. For. Soc. **55**: 119～123, 1973
13) BULLEY, N. R., C. D. NELSON and E. B. TREGUNNA: Photosynthesis: Action spectra for leaves in normal and low oxygen. Plant Physiol. **44**: 678～684, 1969

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