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An Estimate of Growth and Maintenance Respiration in Hinoki Cypress (*Chamaecyparis obtusa*) Seedlings

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Abstract: The quantitative relationship between respiration and growth was investigated for hinoki cypress (*Chamaecyparis obtusa* (Sieb. et Zucc) Endl.) seedlings (including roots). The relation of annual specific respiration rate to annual relative growth rate was fitted by a single straight line over all seedlings. From this relation, respiration was divided into two components, maintenance and growth respiration which were proportional to dry mass and its increment, respectively. Any seedlings consumed annually 391% of the dry mass by maintenance respiration and 24% of the dry mass increment by growth respiration. The ratio of growth respiration to total respiration, varying among seedlings, ranged from 3 to 13% with the average of 8%.

Key words: Annual relative growth rate, annual specific respiration rate, *Chamaecyparis obtusa*, growth respiration, maintenance respiration

Introduction

As reviewed by Amthor (1989) and Sprugel *et al.* (1995), several experiments have demonstrated that there exists the quantitative relationship between respiration and growth in plants; the respiration could be expressed as two components, one of which is related to the growth rate of living tissue or growth respiration and another to its dry mass or maintenance respiration.

In these experiments, the estimation of the two components, growth and maintenance respiration, is based on the plant size differences caused by the time-dependent growth process (Yokota and Hagihara, 1995; Adu-Bredu *et al.*, 1996, 1997). However, the plant size differs at the same growth stage by various environmental factors except for time (Ogawa and Kira, 1977). In this case of the time-independent growth process, it may be expected to exist the quantitative relationship between respiration and growth for different-sized plants, because growth and maintenance respiration were able to be estimated in the different-sized stems of several woody species (Sprugel, 1990; Ryan, 1990; Ryan *et al.*, 1995).

The present study for hinoki cypress (*Chamaecyparis obtusa* (Sieb. et Zucc) Endl.) seedlings, attempt to analyze the quantitative relationship between respiration and growth and to determine separately the growth and maintenance respiration in the time-independent growth process.

Materials and Methods

Study Site

This experiment was conducted from October 28, 1981 to October 18, 1982 on hinoki cypress (*Chamaecyparis obtusa* (Sieb. et Zucc) Endl.) seedlings grown at the Midorigaoka Nursery, Gifu District Forest Office, at Minokamo, Gifu Prefecture, Central Japan (Ogawa *et al.*, 1985, 1986). Seeds were sown in March 1980 and transplanted in March 1981.

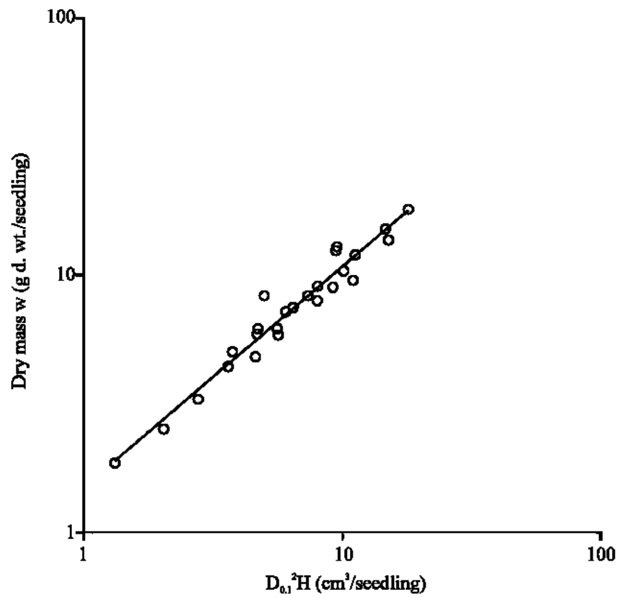

Fig. 1: An example of allometric relation of seedling dry mass w to the square of stem diameter at 10% of height times the height $D_{0.1}{}^2H$ on May 27, 1982. The line gives the allometric regression of $w = 1.50(D_{0.1}{}^2H)^{0.86}$ with the coefficient of determination of 0.93

Measurement of Dry Mass and Respiration

Twenty-five seedlings were monthly harvested. At each harvest, seven of them were used for respiration measurement with an infra-red gas analyzer (URAS-1; Hartmann and Braun). Air was stored in an air bag and was fed into a respiration chamber at a rate of 0.2 L min^{-1} during winter season and 0.5 L min^{-1} during summer season. The air temperature in the respiration chamber in a water bath was adjusted to the mean air temperature in the nursery by circulating air through the coiled glass tube in the water bath.

After measuring the respiration, seedling height H, stem diameter at 10% of the height $D_{0.1}$ and dry mass w were assessed for all of the sampled seedlings.

Estimation of Dry Mass and Annual Respiration

A 2×1 m subplot was set up to follow the time course of seedling mass and respiration rate. The density in the subplot was 62 m^{-2} throughout the experimental period. The census of H and $D_{0.1}$ were made monthly in the subplot for 80 individuals excluding 44 ones on the border rows on a seedbed.

The dry mass w of the 80 seedlings in the subplot were estimated from the w-$D_{0.1}{}^2H$ allometry obtained from the monthly data of the 25 sampled seedlings (Fig. 1). On the other hand, the respiration rate r of the seedlings in the subplot was estimated from a power function of w to r (Fig. 2), which were determined from the monthly data of the sampled seedlings.

On the basis of the growth curve of the seedling mass w (Fig. 3), the average dry mass W over the year was calculated as follows:

$$W = \frac{BMD}{\Delta t} \quad (1)$$

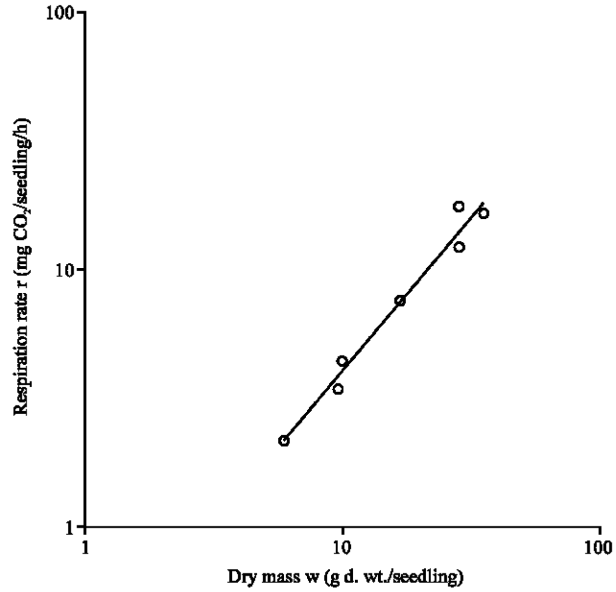

Fig. 2: An example of relationship between respiration rate of a seedling r and its dry mass w on October 18, 1982. The data are fitted to the power function expressed by $r = 0.262w^{1.19}$ with the coefficient of determination of 0.92

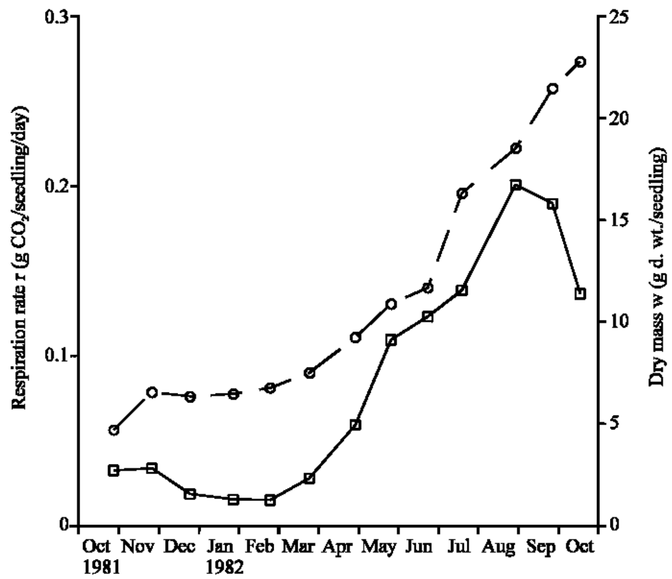

Fig. 3: An example of the time trends in dry mass w (circle) and respiration rate r (square) of a seedling (No. 41) in the subplot. The dry masses and respiration rates of 80 seedlings in the subplot were estimated by the allometric relation in Fig. 1 and by the power relation in Fig. 2, respectively. The respiration rate r is expressed on a dry matter basis assuming a conversion factor of 0.614 g dry wt (g CO_2)$^{-1}$ (Yoda, 1983)

where BMD is the biomass duration (Kvet and Ondok, 1971) computed by graphical integration of the growth curve and Δt is the experimental period, 355 days. On the other hand, the annual respiration rate R of a seedling was determined by graphical integration of the seasonal change in the respiration r in Fig. 3.

In the discussion to follow, I analyze the maintenance and growth respiration with the data on the average dry mass W and the annual respiration rate R for the seedlings (including roots) in the subplot.

Results and Discussion

Figure 4 shows that the ratio of annual respiration rate to seedling dry mass or the specific respiration rate R/W was plotted against the relative growth rate $\Delta W/W$ for the 80 seedlings in the subplot. It appears from the diagram that the specific respiration rate R/W increases with the relative growth rate $\Delta W/W$. The relation could be linearly fitted as follows:

$$R / W = m + g \frac{\Delta W}{W} \tag{2}$$

where m and g are constants for maintenance and growth respiration, respectively. The values of m and g were estimated to be 3.9090.035 (SE) year^{-1} and 0.2370.022, respectively.

Equation (2) can be transformed as:

$$R = mW + g\Delta W$$

$$= R_m + R_g$$

This equation indicates that respiration can be divided into the two terms; the first is the maintenance respiration R_m which is proportional to the seedling dry mass W and the second is the growth respiration R_g which is proportional to the increment of the seedling dry mass ΔW (Thornley, 1970; Hesketh *et al*., 1971; Thornley and Hesketh, 1972; Kimura *et al*., 1978).

From values of the constants m and g, we can see that the hinoki cypress seedlings consume 391% of the seedling dry mass by maintenance respiration and 24% of the seedling dry mass growth by growth respiration.

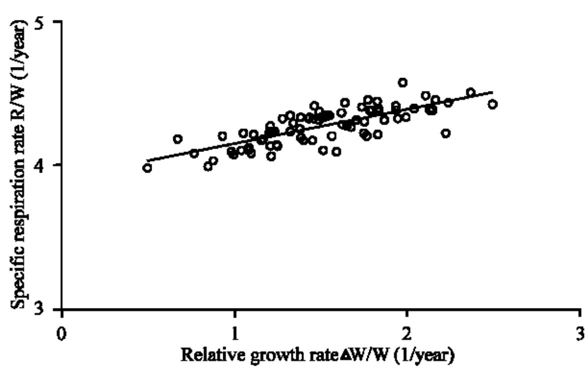

Fig. 4: Linear relation of specific respiration rate R/W to relative growth rate $\Delta W/W$ for 80 seedlings in the subplot. The specific respiration rate was defined as the ratio of annual respiration rate R to seedling dry mass W averaged over one year by Eq. 1. The line stands for the relationship given in Eq. 2 with the coefficient of determination of 0.58

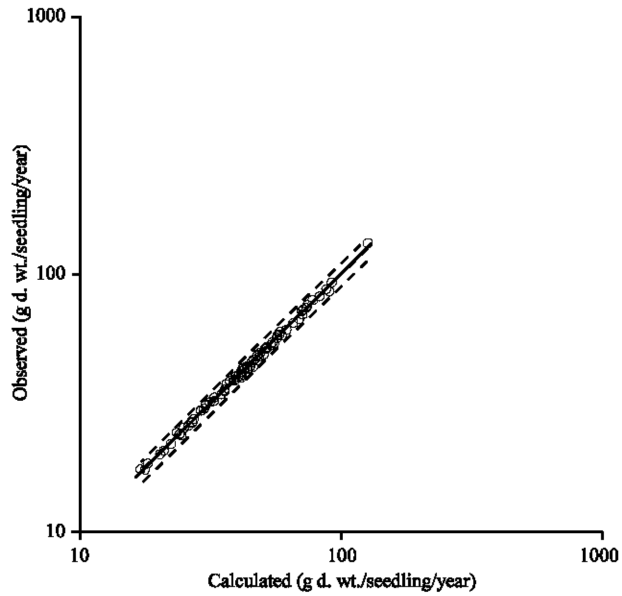

Fig. 5: Comparison between observed and calculated values of annual respiration rate for 80 seedlings in the subplot. The solid and dashed lines show 0 and 10% of the relative errors, respectively

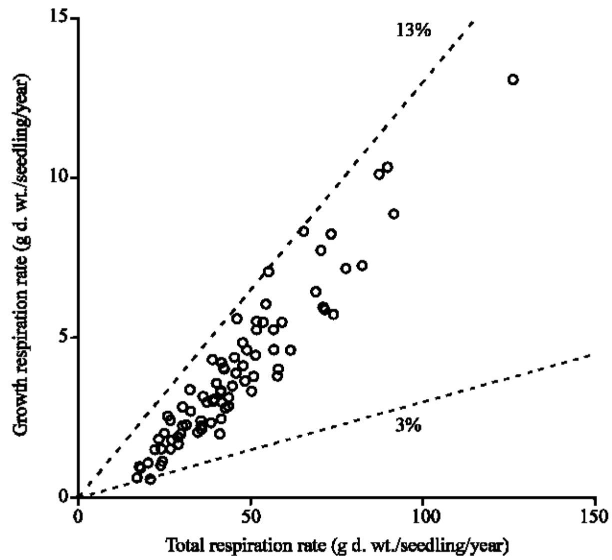

Fig. 6: Annual growth respiration rate plotted against annual total respiration rate for 80 seedlings in the subplot. The lines show that the ratio of annual growth respiration rate to annual total respiration rate ranges from 3 to 13%

On the basis of Eq. 3, numerical calculation of annual maintenance and growth respiration rates were made for 80 seedlings in the subplot. As shown in Fig. 5, the calculated value of the sum of maintenance and growth respiration coincided with the observed value within 10% of the relative error on the log-log coordinates.

To clarify the proportion of the total respiration in growth respiration or maintenance respiration, growth respiration is plotted against the total respiration (Fig. 6). The proportion of growth respiration, varying among individuals, ranged from 3 to 13% with the average of 8%. That is, dry matter loss by maintenance respiration is much higher than that by growth respiration. Most of respiration loss, more than 80% of the total respiration, is due to maintenance respiration in the present seedlings.

Conclusions

The present results indicate that the respiration of hinoki cypress seedlings can be separated into maintenance and growth respiration for the same growth stage or the time-independent growth process. The relation of specific respiration rate to relative growth rate was approximated by a single straight line over all seedlings. This means that the respired proportion of dry mass and its increment are regarded as constant for any seedlings at a given growth stage.

In general, woody species have a characteristic of accumulation of woody parts which is little respired. Thus it is suspected that the coefficient of maintenance respiration decreases every year. In other words, the regression line shifts downward year by year.

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