当年生ヒノキ苗の地上部および地下部の周期的成長

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短　　報

Periodic Shoot and Root Growth in First-Year Seedlings of Hinoki (*Chamaecyparis obtusa*)*

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I. Introduction

As reviewed by CANNELL (1985), periodic shoot and root growth is documented for several woody species. That is, intermittent shoot growth is often paralleled by opposite fluctuations in root growth. The mass balance between the shoot and root systems is maintained by the compensating allocation of photosynthates between the two systems.

Allometric analysis is one of effective ways of clarifying the interrelationship between shoot and root growth. CANNELL and WILLETT (1976), DREW and LEDIG (1980), and DREW (1982) attempted to analyze allometrically the dry-weight growth of coniferous seedlings. Their studies showed that periodic growth of roots and shoots tended to keep a constant ratio between their relative growth rates.

However, little is known about the characteristics of growth periodicity for hinoki, *Chamaecyparis obtusa* (S. and Z.) ENDL., seedlings. In this paper, for first-year hinoki seedlings we investigate seasonal changes in the top-root (T/R) ratios, and analyze the periodicity of shoot and root growth on the basis of the allometric relationship between the two systems. This paper is a part of a series of studies on the growth and dry-matter production of hinoki seedlings (OGAWA and others, 1985, 1986, 1988).

II. Materials and Methods

1. Study site

This study was made from April 1984 to March 1985 on hinoki seedlings growing in the Midorigaoka Nursery, Gifu District Forest Office, at Minokamo, Gifu Prefecture.

Seeds were sown on March 29, 1984. Germination was almost completed by mid-June. The seedling density, which was determined for a subplot with a size of 1 m×1 m established in the seedbed of 1 m×78 m, was kept at a constant value of about 1,360 seedlings m^{-2} after mid-June.

2. Assessment of dry weight

The first sampling was made on April 27, 1984, and the final, or 18th, sampling was made on March 14, 1985. The samplings were made at semimonthly intervals during May through October, whereas they were made at monthly intervals during November through March. One hundred seedlings were harvested at each sampling from the seedbed.

At each harvest, the seedlings were divided into leaves, roots, and stems. These parts were oven-dried at 85°C for 24 h, transferred to desicators, and weighed after cooling.

III. Results

1. Leaf stages

The seedlings progressed through several distinct leaf stages; two or rarely three cotyledons were followed by primary leaves and eventually by secondary, or foliage leaves. The primary and foliage leaves were first visible in early May and mid-June, respectively. The foliage leaves started to grow in area after the dry-weight growth of the cotyledons and primary leaves terminated. Most of the cotyledons and primary leaves died in autumn.

2. Distribution of dry matter among organs

Figure 1 shows the seasonal changes in percentage distributions of the total dry-matter among leaves,

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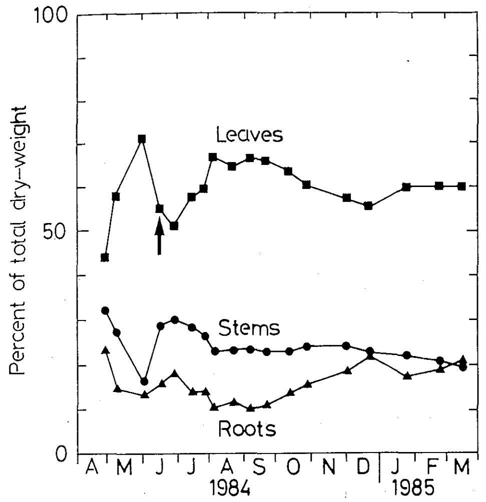

Fig. 1. Seasonal changes in dry-matter distributions among leaves, roots, and stems, expressed as percentages of the mean total dry-weights

The arrow shows the time when the foliage leaves were first visible.

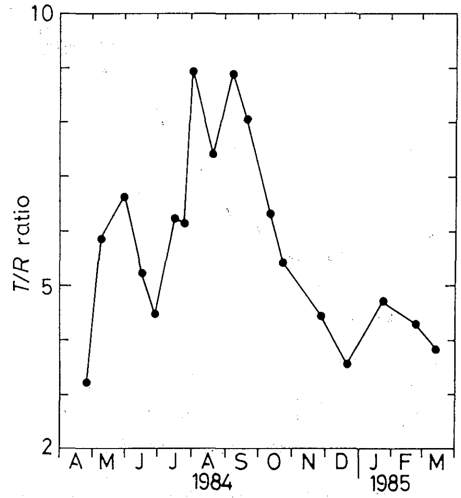

Fig. 2. Seasonal changes in T/R ratios, which were calculated by dividing the mean dry-weights of roots into the mean dry-weights of shoots

roots, and stems. The percentage distribution in leaves increased conspicuously with the development of the cotyledons and primary leaves during the period between late April and late June, and with the development of the foliage leaves during the period between late June and early September.

Fluctuations of the percentage distributions in leaves and roots tended to be inversely related to each other over the entire growth period. When the percentage distribution in leaves increased, that in roots decreased, and vice versa. On the other hand, the percentage distribution in stems changed inversely with that in leaves until early August. In other words, the percentage distribution in stems changed in a way similar to that in roots. However, after early August the percentage distribution in stems stayed approximately at a constant level, although it decreased slightly from late November to mid-March.

IV. Discussion

Figure 2 shows the seasonal changes in T/R ratio, which is defined as the ratio of the mean dry-weight of shoots to that of roots. The ratio ranged from 3.2 to 8.9 in the present study. On the other hand, the ratio was approximately in the range of 2 to 5 in second-year *C. obtusa* seedlings (NEGISI, 1977).

The seasonal changes in the ratio produced peaks during the following three periods; late April to late June, late June to late December, and late December to mid-March. Taking account of the seasonal changes in the percentage distributions among seedling parts (Fig. 1), the oscillations of the T/R ratio can be considered to result from the alternating variations of percentage distributions in leaves and roots, and from the larger percentage distribution in leaves than in stems.

To examine the relationship between shoot and root growths, we show the allometric relationship of mean shoot dry-weight w_S to mean root dry-weight w_R on logarithmic coordinates in Fig. 3. The allometric relationship is approximated by several segments with different slopes. This time-dependent process can be interpreted as the variation in the ratio between the relative growth rate (RGR) of shoots and roots, or as

$$\frac{1}{w_S}\frac{dw_S}{dt}=h\frac{1}{w_R}\frac{dw_R}{dt}, \qquad (1)$$

where h is an allometric coefficient.

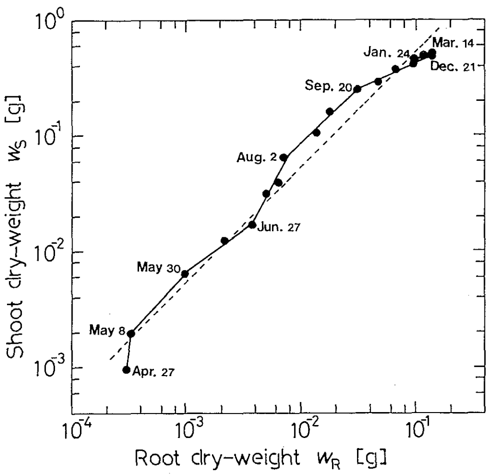

Fig. 3. Allometric relationships of the mean dry-weights of shoots w_S to the mean dry-weights of roots w_R

Each slope of the segments, the allometric exponent h in Eq. (1), is shown in Table 1. The dashed line gives the allometric regression of $w_S=5.06\ w_R^{0.98}$ over the year.

Table 1. Seasonal values of allometric coefficient h in Eq.(1)

	Period	h
(1)	Apr.27-May 8, 1984	6.84
(2)	May 8-May30	1.12
(3)	May30-Jun. 27	0.71
(4)	Jun. 27-Aug. 2	1.89
(5)	Aug. 2-Sep. 20	0.95
(6)	Sep. 20-Dec. 21	0.46
(7)	Dec. 21-Jan. 24, 1985	0.26*
(8)	Jan. 24-Mar.14	0.45

* The relative growth rates of shoots and roots were negative during the period.

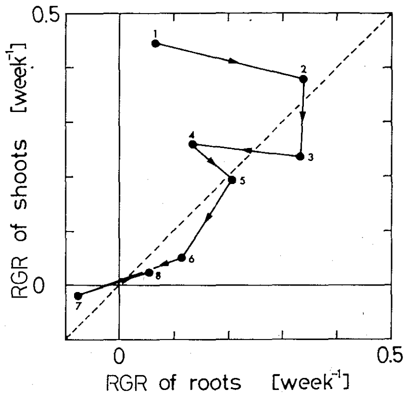

Fig. 4. Phase diagram between the RGRs of shoots and roots

Numerals correspond to the periods shown in Table 1. Progression through time is indicated by the arrows. The dashed line indicates that the shoot RGR is equal to the root RGR.

Table 1 gives the seasonal values of h which were computed for the data corresponding to the periods shown in the table. During the two periods of late April to late June and of late June to late December when the dry weight of shoots and roots increased monotonously, the values of h were larger than 1.0 in the early parts of the periods, nearly equal to 1.0 in the middle parts, and then smaller than 1.0 in the late parts. The seasonal trend of h suggests that the larger RGR of shoots than that of roots during some periods was followed by reversals during successive periods.

The greater RGR of shoots during early spring (h=6.84) was observed in the developmental period of cotyledons and primary leaves, and that during early summer (h=1.89) was seen in the developmental period of foliage leaves (Fig. 1). This shows that the fluctuation of h is closely related to the progress of leaf stages.

If a single straight line was fitted over the entire period, as represented by the dashed line in Fig. 3, the h-value of the regression line was 0.98 ± 0.08 at a 95%-confidence level. The value of h did not differ significantly from 1.0 at the level of 1%. CANNELL and WILLETT (1976) reported that for *Picea sitchensis* (BONG.) CARR. and *Pinus contorta* DOUGL. seedlings grown in pots under nursery conditions, the h-value between shoots and roots varied little from 1.0 over a period of several years.

Figure 4 exhibits a phase diagramatic relationship (NISHIWAKI and SHINOZAKI, 1952; SHINOZAKI, 1976) between the RGRs of shoots and roots during the periods given in Table 1. The locus of the data moved toward the origin, fluctuating around the straight line indicating that the shoot RGR is equal to the root RGR or h=1.0 in Eq. (1). Thus we can see in the diagram that the shoot and root systems grew alternately so as to equalize the RGRs of the two systems.

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