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Studies on the Productivity of Korean White Pine Forest (I)*1
Effects of Temperature, Light and Water Stress on Photosynthesis and Dark Respiration Rates of Leaves

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잣나무林의 物質生産力에 関한 研究(I)*1
葉의 光合成速度와 呼吸速度에 미치는 光·温度·水分의 影響

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ABSTRACT

This study is to investigate the effects of temperature, light and water deficit on apparent phytosynthesis rate (Pn) and dark respiration rate (Rd) of leaves in the series of studies dealing with primary productivity of korean white pine forest. The results obtained are as follows: 1. The light saturation for Pn occured at about 40 Klux, and light compensation at 1.0 to 1.3 Klux. 2. The Pn of current leaves was highest, and Pn was decreased with increasing leaf age. 3. The Rd on the response of temperature in February was about two times value in all of the temperature ranges as compared with the ones in August. 4. The incipient water stress, above which Pn and Rd declined from 100%, was different for Pn (-10bar) and Rd (-bar). The high water stress required to reduce Pn to nearly 0% at -24 bar, but Rd was only 43% at -24 bar. 5. The optimum temperature range for Pn showed about 15 to 18°C in February and 23 to 26°C in August.

Key words; productivity of Korean white pine forest.

要 約

본 硏究는 잣나무林의 一次 生産力을 알기위한 것으로, 葉의 温度·光度·水分缺乏 등이 光合成速度 및 呼吸速度에 미치는 影響을 測定 報告한다. 1) 光飽和는 40Klwx 전후에서 일어나며 光補償点은 1.0~1.3Klwx 임을 알았다. 2) 當年葉의 光合成 速度가 가장 높고 葉令이 증가함에 따라 減少했다. 3) 温度反應에 따른 呼吸速度는 2月葉이 8月葉 보다 2倍 정도 높았고, 両者 모두 17℃ 이하에서 심한 減少를 보였다. 4) 光合成 速度는 약 -10bar에서 減少가 시작되며 약-24bar에서 0으로 되었다. 呼吸速度는 약 -5bar에서 減少가 시작 -24bar에서 43%정도 감소했다. 5) 光合成에 관한 最適温度는 8월 葉에서 23~26℃, 2月葉에서15~18℃를 나타냈다.

INTRODUCTION

The korean white pine, relatively has a wide natural range of geographic distribution in temperate zone, is dealt with a valuable planting tree from highland to lowland forest in Korea. From ecological standpoint, ontogenetically the korean white pine has a tendency to be well grown at highland, but it has a low growth rate or will be die when it is

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transplanted at warm temperate zone. Most studies in which growth rate of korean white pine has been discussed were based on the survey of stem volume or mineral content in soil.[3,7,14] Although the primary production in tree is defined as a CO_2 balance i.e., the difference of photosynthesis and respiration,[5,8,10,12] little is known about the ecophysiological behavior to environmental factors in korean white pine forest.

The purpose of this research was to investigate the effects of light intensity, temperature, and water deficit on korean white pine leaf photosynthesis and dark respiration. However, the measurements were made only using a slightly unfavorable growth tree in warm temperate zone, and during a limited season of the year, mainly in February and August. Thus the discussion in this study is restricted to this period and location.

MATERIALS AND METHODS

The measurements of photosynthesis and dark respiration rates were made from August 1979 to February 1980 on attached leaves from 7-year-old korean white pine (*Pinus koraiensis* S. et Z.) trees grown in the nursery of the Faculty of Agriculture, Kyushu University in Fukuoka in southern Japan. The CO_2 concentration of the air before and after passing an acrylic assimilation chamber (8cm x 13cm x15cm)in which the top o the branch were enclosed, were measured by an infrared CO_2 gas analyzer (Horiba LIA-2A, Differential System). The leaf temperature in chamber was maintained at a constant level (±0.5°C) of desired temperature between 8 and 40°C by a Komatsu Yamato Water Circulator. The leaf temperature of the sample in chamber was measured by a thermocouple attached to the leaf under surface. The rate of air supply to the chamber was 1 to 4 l/min. The air in chamber was mixed well by a fan with a velocity of 1 m/sec.

The water potential was measured by a pressure chamber. Illuminance was supplied with four astral lamps composed of nine incandescent lamps (24V, 40W). The rates in the figures are mean values of two or three times measurements.

RESULTS AND DISCUSSION

The relationship between the apparent photosynthesis rates of current, 1-; 2-year-old leaves and the light intensities are shown in Fig. 1. The light saturation occured at about 40 Klux in all of the current to

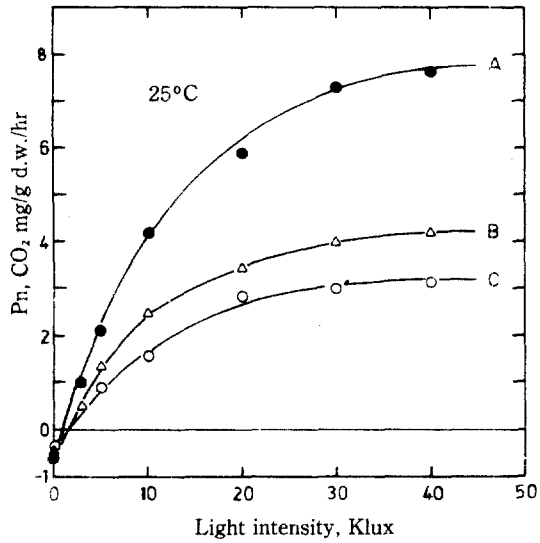

Fig. 1. Relationship between the *apparaent* photosynthesis rate (Pn) in *Pinus koraiensis* leaves and the light intensity in August. A. current; B, 1-; C, 2-year-old

2-year-old leaves, and the light compensation occured at 1.0 to 1.3 Klux. These results are similar to that found in experiments with sun leaves of woody plants (Larcher, 1975; Hashimoto, 1979). The rates of apparent photosynthesis decreased with a leaf age. The pattern may be suggested to cause the leafy superannuation in according to the increasing age. On a dry weight basis, the current leaves have 7.7 mg CO_2/g d.w./hr that is twice as compared with 1-; and 2-year-old leaves. The patterns were similar to those reported by Hashimoto & Suzaki (1979).

As shown in Fig. 2, the Arrhenius plots for the dark respiration rates of current leaves represented a convex curve inflecting at about 17°C, and the rates in August were higher than in February in all of the temperature range. The leaves in low growth temperature regime as February had more high respiration rates than the leaves in high growth

temperature regime as August, and that was similar to other reports.[11,13] In Arrhenius plots, the activation energy coefficient which were estimated to be 129 and 45 in low temperature ranges, were higher than 24 and 29 in high temperature ranges (Fig. 2).

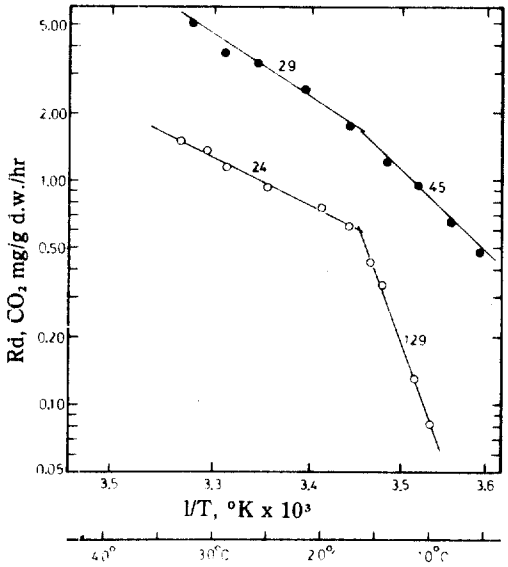

Fig. 2. Arrhenius plots for the dark respiration rate (Rd) in current leaves. ○, August, ●, February

However, the thermal coefficients (Q_{10}) of the dark respiration rates were calculated to be 1.8 in August and 1.9 in February in the high temperature range and 8.8 in August and 2.8 in February in the low temperature range, respectively. The high temperature range may be corresponded to the months with mean monthly air temperatures higher than 17°C, namely, those from May to September, and the low temperature range may be corresponded to the months from October to April in Korea.

The apparent photosynthesis and dark respiration rates decreased with increasing (i.e., lower) leaf water potential in Fig. 3. The threshold water stress, above which apparent photosynthesis and dark respiration rates declined from 100%, was differ for apparent photosynthesis (-10 bar) and dark respiration (-5 bar). Though a high water stress was required to reduce apparent photosynthesis rate to nearly 0% at -24 bar, dark respiration rate was only 43% at -24 bar (Fig. 3). The apparent photosynthesis

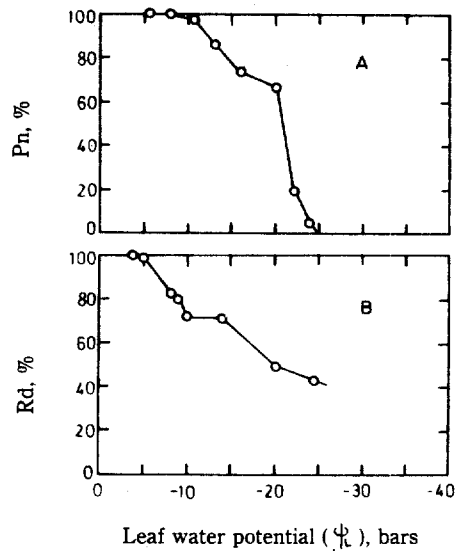

Fig. 3. Rates of the apparent photosynthesis (Pn, A) and dark respiration (Rd, B) at 20°C, expressed as a percentage of the initial well-watered rate, in relation to the leaf water potential.

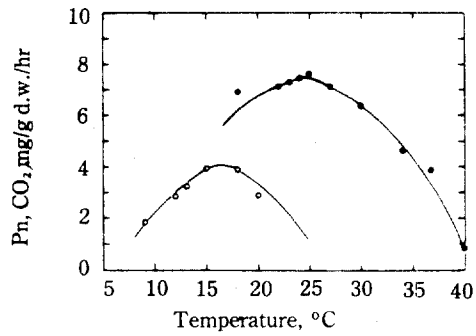

Fig. 4. The effects of temperature on the apparent photosynthesis rate (Pn) in current leaves. ○, February; ●, August.

rate became about 0% at -24 bar was similar to other experiments in white spruce and lodgepole pine (Brix, 1979). The critical leaf water potential for stomatal closure in Sitka spruce was -24.9 bar in upper level leaves of crown (Beadle et al., 1978).

Occasionally the acclimation of plant for environmental changes had been interpretated by the photosynthetic response of leaf to temperature in growing season.[11,13] The maximum apparent photosynthesis rate in August had more high rate than in February, optimum temperature ranges for

apparent photosynthesis rate occured at about 25°C in August and 15°C in February, respectively (Fig. 4). The difference of the maximum apparent photosynthesis rate might be thought to due to the difference of the monthly mean air temperature between August (about 28°C) and February (about 6°C) in Fukuoka Pref. in southern Japan. In Korea, the optimum growth temperature of korean white pine for apparent photosynthesis and dark respiration rates, from above mentioned results, might be considered as about 18 to 22°C because the monthly mean air temperature in growing season was about 10 to 25°C.

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