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Effects of Girdling and Shoot Apex Removal on Photosynthetic Rate and Stomatal Conductance of Detached *Cryptomeria japonica* Shoots*

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Abstract

Reduction of net photosynthetic rate (P_n) independent of the stomatal conductance (g_s) of detached *Cryptomeria japonica* shoots was recognized and compared with reduction of P_n due to water stress. An assimilation chamber method was used to measure of changes in P_n and g_s of detached *Cryptomeria japonica* shoots. *C. japonica* shoots were used and underwent the following treatments: (1) one shoot was not after being place in the chamber and exposed to water stress. (2) three shoots were girdled in order to inhibit photosynthate translocation. (3) three shoots were girdled, and apexes were removed in order to reduce consumption of photosynthate. The following observations were made; in (1) P_n declined with g_s due to the water stress treatment; in (2) the effects of the shoot girdling treatment were not remarkable; in (3) P_n and g_s were stable after the removal of the apexes. After girdling, P_n declined drastically, but g_s were not affected by the dirdling.

In this study, a relationship was suggested between sink demand and the control mechanism of photosynthesis.

Key words : *Cryptomeria japonica* D. Don, assimilation chamber method, photosynthetic rate, stomatal conductance, photosynthate translocation.

1. Introduction

In many studies which determine gas exchange potential and gas exchange responses to various environmental factors in an entire individual tree, an assimilation chamber method has been used on detached shoots (e. g., Hashimoto and Suzaki, 1979; Gyokusen and Suzaki, 1990). Two problems must be considered in these studies. One is that environmental conditions, such as light and humidity in the

* 田代直明・玉泉幸一郎・矢幡 久：環状剥皮および成長点除去処理がスギ切り枝の光合成速度と気孔コンダクタンスに及ぼす影響

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chamber are different from natural conditions (Ceulemans, 1989). The other is that endogenous factors of shoots can change as a result of detachment (e.g., Koike, 1986). It is, therefore, important to understand the effects of experimental conditions on responses of materials when the data is applied to explain phenomena under natural condition (Gyokusen and Suzaki, 1990). In particular, evaluation of the effects of endogenous factors in detached shoots is important, and has been discussed mainly in relation to changes in conductive resistance (Clark, 1954; Negishi, 1955; Koike, 1986; Gyokusen and Yahata, 1992). For example, Koike (1986) examined the effect of water stress induced by conductive inhibition on photosynthetic rates in detached shoots, and he suggested the most appropriate method of treating the detached shoots.

However, decline of net photosynthetic rate occurred independently of water stress when measurements are made for detached materials. Thorne and Koller (1974) shown that assimilate demand is related to photosynthetic activity in intact plants.

It is assumed that decline of net photosynthetic rate in detached shoots are caused by translocation inhibition of assimilation products due to the removal of sink.

In this study, experiments involving shoot girdling and shoot apex removal were carried out in order to test this assumption.

2. Materials and methods

2.1. Plant Materials

Plant materials were sampled from a 15-year-old *Cryptomeria japonica* D. Don (cv.Kumotoshi) tree (8 m in tree height, 17 cm in DBH) growing under field conditions in the Nursery of Kyushu University, Fukuoka, Japan. Primary shoots were collected from the south side of the crown of the sample tree.

2.2. Experimental Methods

All experiments were conducted from 8th to 11th October 1991. Detached shoots were harvested in the morning were placed in a bucket, and immediately cut in tap water to avoid cavitation. The shoots were placed in 200ml volumetric cylinders filled with distilled water, and cut under water again to a length of 25cm from shoot apex just before measurement. The top 10cm of the shoots were placed in an assimilation chamber. All measurements were carried out on the same day that the shoots were collected.

Treatments applied in this study were as follows (Fig. 1).

Treatment A: a shoot was cut at the stem below the chamber to subject the shoot to water stress. One shoot was examined this treatment.

Treatment B: the shoots were girdled to a length of 5mm outside the chamber.

Treatment C: shoot apexes were removed, and the shoots were girdled in the same

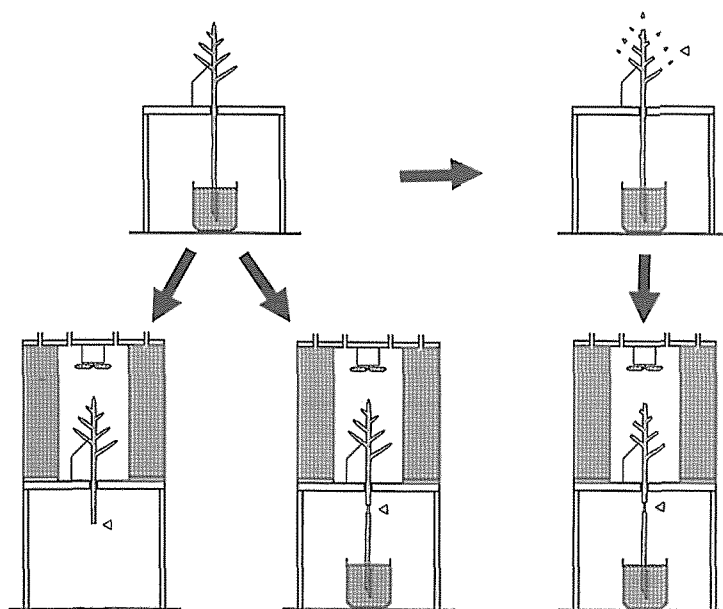


Fig. 1 Schematic illustrations of treatments.

Treatment A: a shoot at the stem below the chamber was cut in order to subject the shoot to a water stress condition. Treatment B: the shoots were girdled at the stem below the chamber to a length of 5 mm. Treatment C: shoot apices were removed and the shoots were girdled in the same way as in treatment B. Shoot removal and the girdling were done after P_n and T_r became stable. The shoot apices were removed before the shoots were placed into the chamber.

way as in treatment B.

Three shoots were examined in treatments B and C.

Shoot cutting and girdling were carried out after net photosynthetic rate (P_n) and transpiration rate (T_r) became stable. The shoot apices were removed before the shoots were placed in the chamber. Treated surfaces were covered with silicone in order to prevent loss of water from the treated surfaces except for treatment A.

Dark respiration rate (R_d) were measured just before the treatments and after the measurement of P_n and T_r in order to confirm that wound respiration resulting from the treatments did not occur (data not shown).

P_n , T_r and R_d were measured by an open air system using the assimilation chamber method. Figure 2 shows a schematic diagram of the chamber. An infrared gas analyzer (Shimadzu, IRA-102) was used for the measurement of CO_2 concentration of input and output air. Temperature and humidity of input and output air were measured with hygrometers (VISALA, HMP 133 Y). Environmental conditions in the chamber during measurements were regulated as follows: Photosynthetic photon flux

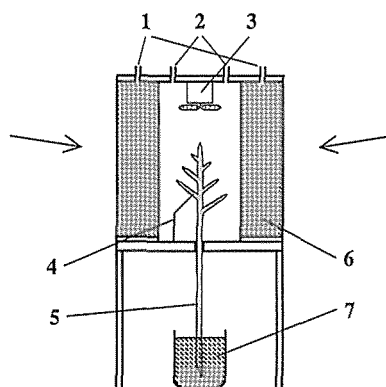


Fig. 2 Vertical section of a cylindrical assimilation chamber used for measurements of gas exchange rates.

1: Vents for circulating cooling water 2: inlet and outlet of air 3: fan 4: thermocouple 5: a shoot 6: cooling water 7: distilled water

density ($PPFD$) at the center of the chamber was $900 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, which exceeded the light saturation point of photosynthetic rate in *C. japonica* (Hashimoto and Suzuki, 1979). Leaf temperature was maintained at 26°C by controlling air temperature in the chamber with a water collar (COOLNICS, CTE-240). The vapor pressure difference (V_{pd}) was controlled in a range of 1.3 to 2.0 kPa by passing air through the water, which temperature was regulated. Data were recorded every 2 minutes.

P_n , T_r and R_d were calculated according to the method of von Caemmerer and Farquhar (1981). Leaf area for calculation of P_n and stomatal conductance (g_s) were estimated by the equation of Katsuno (1988).

Xylem pressure potential (X_{pp}) was measured with a pressure chamber (Daiki, DIK-7000) before and after measurements of P_n , T_r , and R_d to confirm that water stress is not induced by cavitation during measurements of treatments B and C.

3. Results and Discussion

The X_{pp} values obtained before and after measurements are shown in Table 1. In treatment A, X_{pp} after the measurement decreased to -2.30 MPa. The result indicated that significant water stress occurred in this treatment. In treatments B and C, X_{pp} were maintained at high values (> -0.175) and only small decline of X_{pp} were observed throughout the measurement. Gyokusen and Suzaki (1990) shown that X_{pp} in high value (> -0.4 MPa) was ineffective photosynthetic rate in *Chamaecyparis obtusa*. Further, Sasaki *et al.*(1987) shown that the threshold value of X_{pp} which

Table 1 Xylem pressure potential (X_{pp}) of before and after the measurement of net photosynthetic rate and stomatal conductance.

Samples	Xylem pressure potential (MPa)	
	before	after
A	-0.10	-2.30
B1	-0.15	-0.15
B2	-0.05	-0.10
B3	-0.05	-0.15
C1	-0.15	-0.15
C2	-0.10	-0.17
C3	-0.10	-0.12

affects P_n , is -0.74 MPa in *C. japonica* seedlings. Therefore, we concluded water stress did not occur though the measurements in treatments B and C.

Figure 3, 4 and 5 show changes in P_n and g_s before and after treatments.

In treatment A (Fig. 3), g_s began to decline 30 minutes after treatment. Subsequently, P_n also began to decline. The g_s declined drastically 70 minutes after treatment. This decline thought to be a result of decline in cell turgor. The decline of P_n also occurred a few minutes after the decline of g_s . Subsequently, P_n was synchronized with the decline of g_s . Therefore, in treatment A, both of P_n and g_s were affected by water stress due to the decline of X_{pp} .

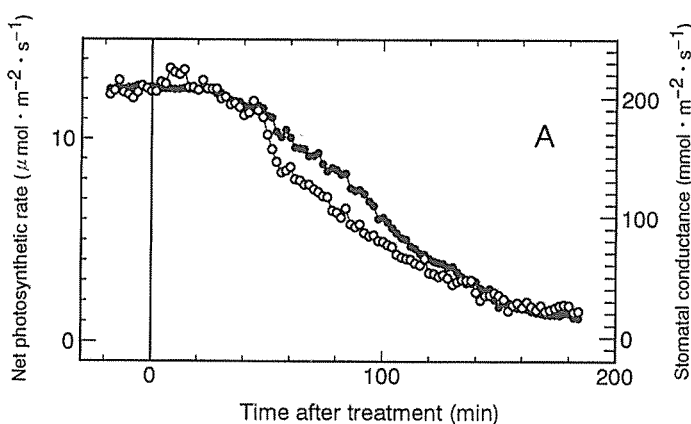


Fig. 3 Time course of net photosynthetic rate (P_n) (closed circles) and stomatal conductance (g_s) (open circles) of detached shoot of *C. japonica* D. Don before and after shoot removal (treatment A). The vertical line at zero on the x-axis indicates time of treatment.

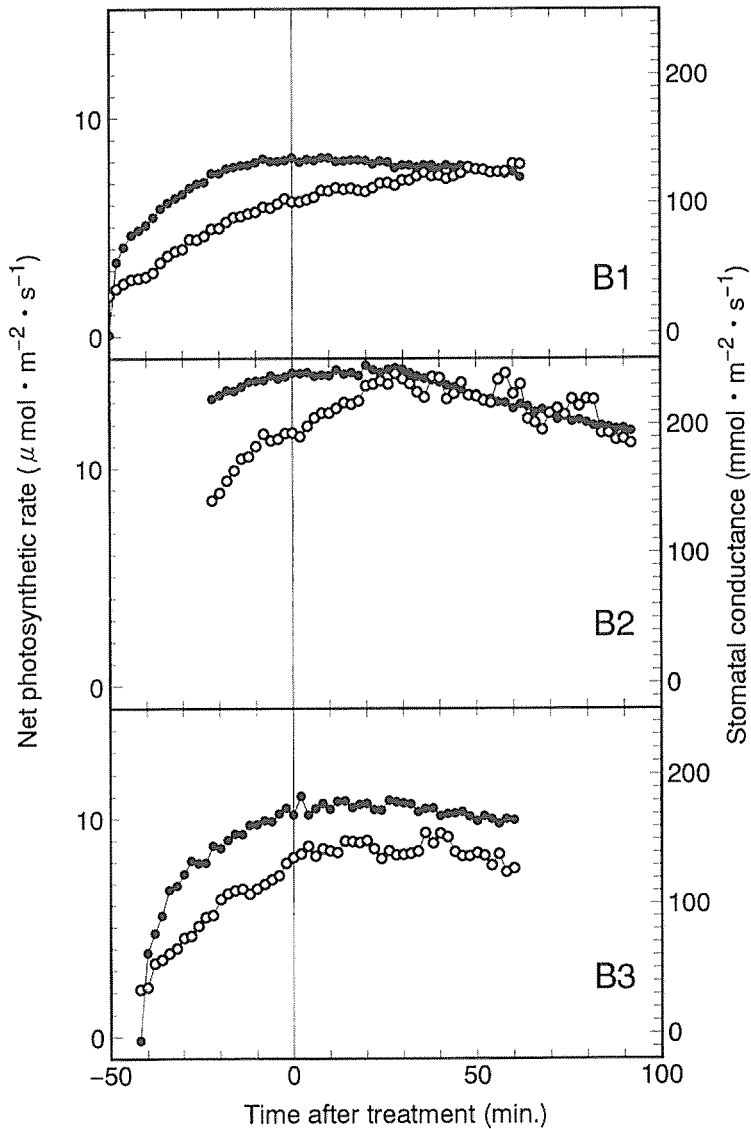


Fig. 4 Time course of net photosynthetic rate (P_n) (closed circles) and stomatal conductance (g_s) (open circles) of detached shoots of *C. japonica* D. Don, before and after shoot girdling (treatment B). The vertical line at zero on the x-axis indicates the time of treatment.

Figure 4 shows changes of P_n and g_s in treatment B. No significant decline of P_n independent from g_s was observed in the B1 shoot. In the B2 shoot, P_n was synchronized with g_s . In the B3 shoot, both P_n and g_s did not decline after treatment. The results show that the treatment did not affect P_n and g_s in all shoots.

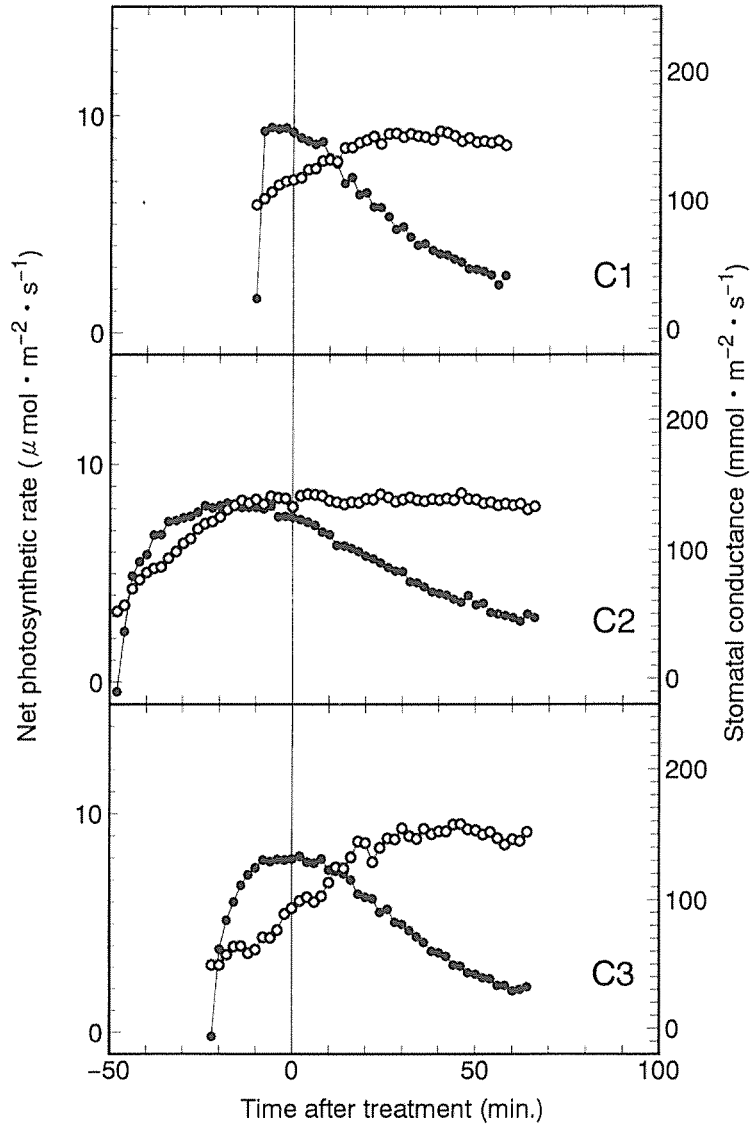


Fig. 5 Time course of net photosynthetic rate (P_n) (closed circles) and stomatal conductance (g_s) (open circles) of detached shoots of *C. japonica* D. Don, before and after shoot girdling, after removal of shoot apices (treatment C). The vertical line at zero on the x-axis indicates the time of treatment.

Figure 5 shows changes of P_n and g_s in treatment C. In every shoot in this treatment, P_n and g_s were not affected by shoot apex removal. P_n declined drastically after girdling. However, g_s were still stable (C2), and the value increased (C1, C3) after girdling.

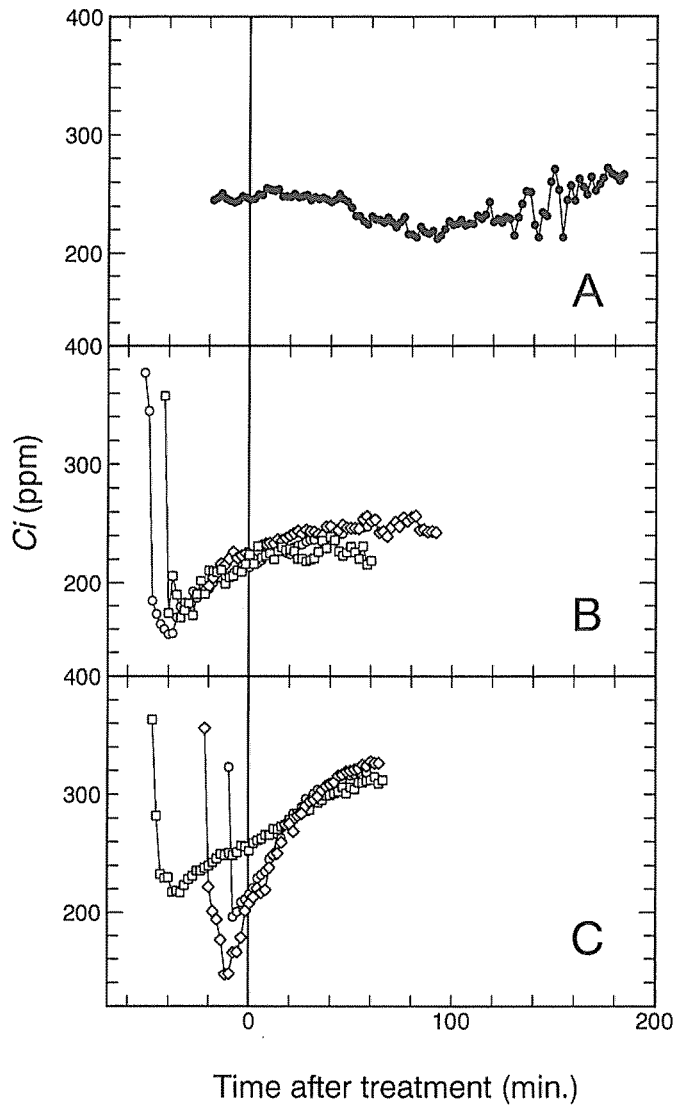


Fig. 6 Time course of intercellular CO_2 concentration in treatment A(upper), B(middle), C(lower),. ○:1, □:2, ◇:3 in treatment B and C. The vertical line at zero on the x-axis indicates the time of treatment.

Fig. 6 shows time courses of intercellular CO₂ concentration (C_i) estimated using $C_i = C_a - 1.6 * P_n / g_s$. In treatment A, C_i was kept constant for 20 minutes after treatment, then reduced slightly until the 100 minutes mark, and increased to some extent at the end of the measurement. In treatment B, C_i increased before and after girdling, but stabilized around 240 ppm at 20 minutes after treatment. We conclude that the effects of girdling were not significant in this treatment. In treatment C, however, C_i increased rapidly and reached around 320 ppm in the end of the measurements. The result in treatment C was due to the decline of P_n independent from g_s (Fig. 5). Wong *et al.* (1979) proposed the hypothesis that P_n and g_s were regulated thereby stabilizing C_i . The results of treatments A and B support the hypothesis. However, the result in treatment C cannot be explained by this hypothesis. Consequently, the existence of a different control mechanism in P_n and g_s was hypothesized to explain the phenomena.

Thorne and Koller (1974) shown that the reduction of sink caused an increase in starch concentration in leaves. Chatterton *et al.* (1972) observed an inverse relationship between starch concentration and photosynthetic rate. Accordingly, the reduction of P_n in treatment C was caused by inhibition of photosynthate translocation and accumulation of photosynthate.

In this study, effects of shoot apex removal could not be separated from shoot girdling in treatment C. Therefore, it will be necessary to conduct a shoot apex removal treatment without girdling.

We suggested that P_n was controlled by some factors other than water stress. It is necessary to consider carefully the results obtained using detached shoots.

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環状剥皮および成長点除去処理がスギ切り枝の 光合成速度と気孔コンダクタンスに及ぼす影響

田代直明・玉泉幸一郎・矢幡久

要 約

樹木の切枝を用いてガス交換の計測をおこなう際、測定値に及ぼす切断の影響を知ることとは、その測定値を個体の成長モデルなどに活用する上で重要である。従来、切枝に関する問題としては、水ストレスによる光合成速度の低下がおもに議論されてきたが、水分条件が十分な状態においても光合成速度が低下する現象をみとめた。そこで本研究では、その原因として同化産物の転流阻害を仮定し、この現象の再現を試みた。同時に水ストレスによって生じる光合成速度と気孔コンダクタンスの低下と比較した。

断水による水ストレス、環状剥皮、環状剥皮および成長点除去の各処理を施したスギの光合成と気孔コンダクタンスの動きを同化箱法で計測した。その結果、(1) 水ストレス処理では、気孔コンダクタンスと光合成速度は同調して低下した。(2) 環状剥皮処理では気孔コンダクタンスと光合成速度に低下は認められなかった。(3) 環状剥皮および成長点除去処理では気孔コンダクタンスは変化せず、光合成速度のみが急激に低下した。

以上のように同化産物の転流阻害を目的とした処理において、水ストレスで生じた光合成速度と気孔コンダクタンスの変化とは異なる光合成速度のみの低下が生じた。このことは光合成速度と気孔コンダクタンスの制御に水ストレスとは異なる機構が存在することを示唆している。

キーワード：スギ，同化箱法，光合成速度，気孔コンダクタンス，光合成産物の転流。