Changes in Photosynthetic Capacities of the Overwintered Tea Leaves Induced by Shoot Plucking

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HAKAMATA and SAKAI\(^{5}\) showed that the growth of the first flush of tea was dependent on photosynthetic capacity of the overwintered leaves. However, the present author\(^{6}\) found that the photosynthetic rates of overwintered leaves decreased during the development of new shoots. This decrease could not be prevented by a removal of new shoots. In contrast, the photosynthetic rates of matured but not overwintered leaves were enhanced by the removal of new shoots\(^{6}\). Thus the photosynthetic rates of overwintered leaves seemed to decrease irreversibly and the irreversible process might be induced by the growth of new shoots. To ascertain this influence, the new shoots were removed before and after their sprouting and the photosynthetic rates of overwintered leaves were measured.

The decrease of the photosynthetic rates in overwintered leaves was not correlated with the changes in total nitrogen, soluble protein and the specific activities of ribulose-1,5 bisphosphate carboxylase\(^{5}\). In rice leaves, the highest correlation was found between the content of fraction-1 protein and the photosynthetic rates\(^{3}\). On the other hand, in chilling injured leaves of Pinus sylvestris, Öquist et al\(^{8}\) showed that the suppression of the photosynthetic rates was resulted from the decreased activity of photosynthetic electron transport rather than the activity of ribulose-1,5 bisphosphate carboxylase. Also, in the senescent leaves of Phaseolus vulgaris, Jenkins and Woolhouse\(^{7}\) showed that the decrease in rate of non-cyclic electron transport might be important in limiting the rate of photosynthesis. Therefore in the overwintered leaves, it is also possible that the photosynthetic rates are influenced by the activity of electron transport rather than by fraction-1 protein. In this study, not only the changes in fraction-1 protein but also the photosynthesis vs light intensity curves were measured. As a result, it was concluded that the photosynthetic rates of overwintered leaves were mainly influenced by the content of fraction-1 protein.

Materials and Methods

One year-old clonal tea plants (Camellia sinensis (L.) O. Kuntze cv. Yabukita) grown on a nursery bed were used.

Plants were divided in three blocks. In the first block, all new shoots were removed before the unfolding in their first leaves on March 23, 1981 (early-plucking). In the second block, new shoots were removed on April 21, during the developmental stage of three leaves and a bud (late-plucking). In the last block, new shoots were not removed (control). About 80% of apical shoots expanded their first leaves on April 5. But any axillary shoots did not grow during the experiment.

Leaves which matured in the previous autumn (1980) and overwintered were used. The overwintered leaves born on the top and the second of leaf position at the start of experiment were sampled every 12 to 14 days, to determine the photosynthetic rates, the contents of total nitrogen, soluble protein and fraction-1 protein.

The leaf photosynthesis was determined by the incorporation rate of \(^{14}\)C with leaf discs\(^{2}\). Total nitrogen was determined according to Kjeldahl\(^{10}\). Soluble protein was extracted with 50 mM of phosphate buffer (pH 7.0)\(^{3}\) and determined according to Itzhaki and Gill\(^{8}\).

A part of extract of soluble protein was
boiled with 2% SDS, and fraction-I protein was separated from the extract by the electrophoresis with 0.2% SDS polyacrylamide gel. After the gel was stained with 1% of amidoblack and destained with 7% of acetic acid, a band of large subunit of fraction-I protein was extracted with formamide. The content of fraction-I protein was determined by the absorbance at $A_{625}$ as shown by Blenkinsop and Dale. 

**Results**

The photosynthetic rate in the overwintered leaves of control plants decreased after the sprouting of new shoots (Fig. 1). The photosynthetic rate in the late-plucked plants steadily decreased as in control plants, while that in early-plucked plants gradually increased, hence the level on May 6 was higher than that in the control plants. Then the photosynthetic rate in early-plucked plants decreased to attain the same level as in control plants.

The total nitrogen in the control plants slightly increased until May 6, then it decreased as shown in Fig. 2a. The new shoot removal enhanced the total nitrogen irrespective of the time of removal. However, the magnitude of its increment was greater in the early-plucked plants than in the late-plucked plants.

The soluble protein in the control plants increased until the sprouting of new shoots, thereafter it sharply decreased (Fig. 2b). The decrease of soluble protein in the late-plucked plants was partially reduced. In the early-plucked plants, the soluble protein continued to increase until May 6, when it started to decrease.

Fraction-I protein in the control plants changed following the similar manner to soluble protein (Fig. 2b). The content of fraction-I protein in the late-plucked plants decreased with the less rate than that in control plants. In early-plucked plants, its content increased until May 6. Then it sharply decreased to attain the same level as that in the late-plucked plants.

Table 1 shows the correlation between the photosynthetic rates and the above mentioned three cellular components. The correlation between the photosynthetic rates and the content of total nitrogen was low. There was some correlation between the photosynthetic rates and the content of soluble protein in control and late-plucked plants. The photosynthetic rates were highly correlated with the content of fraction-I protein.

Fig. 3 shows the relationship between
Table 1. Correlation coefficients between the photosynthetic rate and the content of the three cellular components in overwintered leaves.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total nitrogen</th>
<th>Soluble protein</th>
<th>Fraction-1 protein</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.254</td>
<td>0.725</td>
<td>0.909**</td>
<td>6</td>
</tr>
<tr>
<td>Early-plucking</td>
<td>-0.616</td>
<td>0.010</td>
<td>0.804</td>
<td>6</td>
</tr>
<tr>
<td>Late-plucking</td>
<td>-0.892</td>
<td>0.929</td>
<td>0.963*</td>
<td>4</td>
</tr>
</tbody>
</table>

*: Significant at 5% level.
**: Significant at 2.5% level.

n: Numbers of samples.

Fig. 3. Photosynthetic rates of the overwintered leaves as a function of the light intensity. The photosynthetic rates were measured on March 23 (a), April 22 (b) and May 19 (c), respectively. Symbols are the same as in Fig. 1.

the light intensity and photosynthesis determined at the different developmental stages of shoots. The maximum rates of the photosynthesis determined on March 23 and April 22 were almost the same, while the lower value was obtained on May 19. Neither the developmental stage nor the presence or absence of new shoots affected the initial slope of photosynthesis against the light intensity.

Discussion

The photosynthetic rate of overwintered leaves was highly correlated with fraction-1
protein, but not with either soluble protein or total nitrogen. The initial slopes in photosynthetic rate vs light intensity curves did not change, when the maximum rate of photosynthesis decreased. These results suggest that the photosynthetic rates of overwintered leaves were influenced by the content of fraction-1 protein, rather than by the light reactions of photosynthesis.

The photosynthetic rates of overwintered leaves decreased with the development of new shoots. The photosynthetic rates also continued to decrease by the removal of new shoots at the developmental stage of three leaves and a bud. Small but appreciable increase in photosynthesis was obtained when the new shoots had been removed before their sprouting. These results indicate that an irreversible decrease of the photosynthesis of overwintered leaves occurred with the development of new shoots. Moreover, the onset of the irreversible decrease was partly suppressed by the removal of new shoots before their sprouting but not at the developmental stage of three leaves and a bud.

The enhancement of the photosynthetic rates by the new shoot removal was lower in overwintered leaves than in mature leaves in which the photosynthetic rates sharply increased. Moreover, even after the new shoot removal, the photosynthetic rates of overwintered leaves decreased on May 6 and attained the same level as in control plants. These facts must be involved in the consideration of the yield of a first flush and the following flush of tea.

In tea culture, almost all new leaves that developed in spring are harvested, so that tea plants are dependent on the photosynthesis of overwintered leaves until the new shoots develop again. If we improve the photosynthetic rates of overwintered leaves for some period, the yield of tea will be increased. For example, cytokinin plays a role in delaying leaf senescence and COBERT and BEEVER showed that senescence-delaying effects of disbudding could be attributed to the increased export of root cytokinin. Also, SATOH et al showed that cytokinin levels increased in the remaining leaves after a shoot removal. In overwintered tea leaves, the export of root cytokinins or the cytokinins levels in leaves might not increase after the new shoot removal. Thus, with any treatment that increases the cytokinin levels in overwintered leaves, the decrease of the photosynthetic rates may be delayed and the yield of tea will be increased.

Summary

Changes in the photosynthetic capacities of overwintered leaves with the development of new shoots and the effects of the removal of new shoots on the photosynthetic capacities were investigated. In one block, new shoots were removed before their sprouting (March 23). In the second block, new shoots were removed at the developmental stage of three leaves and a bud (April 21). The third block was kept as control without removal.

The photosynthetic rates in control plants decreased after the sprouting of the new shoots. The contents of soluble protein and fraction-1 protein changed with the similar manner with the photosynthetic rates, but fraction-1 protein \(r=0.909\) was more correlated with the photosynthetic rates than soluble protein \(r=0.725\). There was not any relationship between the photosynthetic rates and the content of total nitrogen.

By the removal of new shoots at the developmental stage of three leaves and a bud, the photosynthetic rates steadily decreased as those in control plants. The contents of total nitrogen and soluble protein were enhanced by the removal of new shoots. But the content of fraction-1 protein decreased with less rate than that in control plants. Fraction-1 protein was significantly correlated with the photosynthetic rates \(r=0.963\).

By the removal of new shoots before their sprouting, the photosynthetic rates gradually increased. On May 6, it decreased. The photosynthetic rates were correlated with the content of fraction-1 protein \(r=0.804\).

The initial slopes of the photosynthesis
vs light intensity curves did not change throughout the developmental stages, irrespective of the presence or absence of the new shoots.

These results seem to indicate that the onset of irreversible decrease in the photosynthesis was induced by the development of the new shoots and that the changes in the photosynthetic rates were mainly due to the changes of fraction-1 protein. Possible mechanisms which induce these changes were discussed.

References


* In Japanese with English summary.
新芽摘除による茶越冬葉の光合成機能の変化

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茶越冬葉の光合成速度は新芽生育に伴い減少する。そこで新芽を萌芽前と萌芽後に摘除して、越冬葉の光合成機能の変化を調べた。

一年生苗を用いて新芽萌芽前（3月23日）と一心三葉期（4月21日）にそれぞれ新芽と一心三葉を摘除する区および無処理区を設けた。前年の秋に展開し越冬した古葉の光合成速度、全窒素量、可溶性蛋白質量、フラクション1蛋白質量を臨時に測定した。

無処理区の光合成速度は新芽の萌芽後に減少した。可溶性蛋白質量とフラクション1蛋白質量は光合成速度と同様に変化し、後者（r = 0.909, 2.5％水準で有意）は前者（r = 0.725）に比べて光合成速度と一致して変化した。全窒素量と光合成速度には関係はみられなかった（r = 0.254）。

一心三葉期に新芽の全てを摘除しても越冬葉の光合成速度は無処理区とはほとんど同様に減少した。全窒素量と可溶性蛋白質量は新芽摘除により上昇およびやや減少した（光合成速度との相関はそれぞれ、r = -0.892, r = 0.929）。しかし、フラクション1蛋白質量は無処理区と同様に処理後も減少して、光合成速度とは高い相関（r = 0.963, 5％水準で有意）を示した。

新芽萌芽前に新芽を摘除すると、光合成速度は徐々に上昇し、その上昇は5月6日まで続いたが、その後減少した。光合成速度はフラクション1蛋白質量と高い相関（r = 0.804）を示した。光合成速度は全窒素量（r = -0.616）と可溶性蛋白質量（r = 0.010）とは相関を示さなかった。

越冬葉の光強度に対する光合成速度曲線の初期勾配は新芽の生育程度、また新芽の有無にかかわらず、ほとんど変わらなかった。

以上の結果より、越冬葉の光合成速度は新芽生育に伴い不可逆的に減少し、この減少は新芽萌芽前後に始まると推定された。また越冬葉の光合成速度の変化は主にフラクション1蛋白質量の変化で説明できた。