Studies on Photosynthesis and Translocation of Photosynthate in Mulberry Tree

V. Utilization of reserve substance in the process of regrowth after shoot pruning in a growing season*

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INTRODUCTION

The present investigation was intended to make clear the role of reserve substance on the regrowth of mulberry plants following shoot pruning in the midst of a growing season. The importance of reserve substance on the early growth in spring or on the regrowth following shoot pruning has been pointed out by not a few researchers. For example, Ohyama* explained the poor regrowth of mulberry following shoot pruning in July owing to the deficiency of reserve substance in storage organs. Hatta and Homma* proved that the sprouted young mulberry plants after pruning grew depending on the reserve substance for about a month. Tazaki* also suggested that mulberry growth depended upon reserve substance in the early stage of regrowth after shoot pruning in June analyzing matter production and distribution consisting of the growth of shoot, and respiration of non-assimilatory organs.

There was, however, a large barrier to the study of reserve substance, i.e., the difficulty of discriminating reserve substance translocated from storage organs to newly developed organs from the substance assimilated by the newly developed leaves through photosynthetic activity. By dint of radio-isotopes, however, the discrimination became possible. This paper deals chiefly with the movement of labelled photosynthetic product in the process of regrowth after shoot pruning that was assimilated prior to shoot pruning and was stored in stump and root.

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MATERIALS AND METHODS

Materials used in the experiment were two-year-old mulberry plants of the variety Ichinose raised from saplings made by semi-soft wood cutting. The saplings were planted in 1/2000a Wagner pots on May 16, 1972 and the stem of the saplings was pruned remaining 5 cm of the basal part. Only one shoot per one sapling was left to develop removing other shoots.

On July 31, 1972, 40 μCi 14CO2 per one plant (specific activity 63 μCi/m-mole CO2) was administered to the 7th leaf numbered from the base. The number of leaves developed was 37 and the length of stem was 112 cm on an average at the time of administration. The leaf was enclosed with a vinyl bag whose volume was about 1.2 l and 14CO2 evolved by the addition of lactic acid to 14C-sodium carbonate was circulated in a closed system over the enclosed leaf outdoors for 40 minutes under the light intensity over 20 klx and air temperature of 31~32°C. Other details of 14CO2 administration were described in the previous paper*.

Shoots were cut down 8 days after the administration. Photosynthetic activity of leaves developed after shoot pruning was measured by means of an infrared CO2 gas-analyzer. An assimilatory chamber used for the measurement 10 days after the shoot pruning was a cylindrical one whose diameter and length were 3.3 and 20 cm respectively and a whole intact shoot was set in the chamber. The intact shoot set in the chamber was placed outdoors and the photosynthetic rate was measured under the light intensity over 44 klx.
and air temperature of about 34°C, with air flow through the chamber at the rate of 0.5 l/min. On the 17th and 35th day after pruning, another cubic assimilatory chamber was used whose size was 19×25×0.8 cm and a cut leaf with petiol was set in the chamber. The chamber was immersed in the water bath whose temperature was regulated at 25°C and was illuminated by a xenon lamp over 40 klx. The rate of aeration in the chamber was 2~3 l/min.
At the time of pruning, and 10, 16, 23 and 34 days after the pruning, 3 plants were harvested and dissected into each organ. Dry weight and the rate of $^{14}$C disintegration were measured after drying each organ. The details of counting $^{14}$C activity were mentioned in the previous paper\(^9\).

**RESULTS**

1. **Regrowth of lateral shoots after pruning.**

Following shoot pruning, 3 or 5 lateral shoots per one plant developed. Fig. 1 shows the growth curve of the longest one in a plant. The growth was somewhat sluggish in the early period and became vigorous in the later period of the experiment.

2. **Dry weight of newly developed organs and storage organs.**

Fig. 2 shows the time trend of dry weight of lateral shoots and dry weight increment of stump and root after pruning. Following pruning, dry weight of lateral shoots began to rise and continued to increase till the end of the experiment. On the other hand, dry weight of storage organs which was equivalent to the dry weight of stump and root in the case of this experiment decreased to reach the minimum 16 days after pruning. Thereafter the dry weight of storage organs began to increase and recovered the initial level before the end of the experiment.

3. **Photosynthetic rate of newly developed leaves.**

About 5 leaves had unfolded per one shoot 10 days after the pruning. These leaves were small in size and the leaf area attained scarcely to 100 cm\(^2\) putting together the area of these five leaves. Photosynthetic rate of the whole shoot was very low, but not negative as is seen in fig. 3. As the leaves grew in size after unfolding, photosynthetic rate increased, for example, rate for 5 leaves from the shoot base was 1.3, 9.0 12.7 mg CO\(_2\)/dm\(^2\)/hr for 10, 17 and 35 days after pruning, respectively. And the maximum rate recorded was 10.3 for the 4th leaf 17 days after pruning and 17.0 mg CO\(_2\)/dm\(^2\)/hr for the 10th leaf 35 days after pruning.
4. **¹⁴C activity in newly developed organs and storage organs.**

Fig. 4 shows ¹⁴C-specific activity (radioactivity in unit dry weight) in successive leaves, stem, stump and root of a plant harvested 34 days after shoot pruning. ¹⁴C-specific activity was the highest in the lowermost leaf developed earliest after pruning and became lower in the upper leaves. The variation of ¹⁴C-specific activity by stem position showed a similar trend with that in successive leaves attached to each stem position.

Change with time in total activity contained in newly developed and storage organs calculated by multiplying ¹⁴C-specific activity by the dry weight of the organ is shown in fig. 5.

It is clearly seen that the total activity in the storage organs decreased steadily as long as the experiment continued and that the total activity in the newly developed organs increased for about 20 days after shoot pruning. Total activity recovered from the whole plant decreased with the lapse of time.

The ratio of total activity recovered from the newly developed organs to that from the whole plant is presented in fig. 6. It may be possible that this ratio shows the degree of translocation of labelled photosynthetic product from storage organs to newly developed organs. The ratio was low in first 10 days after pruning, became quickly high in the next 10 days, and thereafter the increase became sluggish.

Economic ratio proposed by Midorikawa, the ratio of the increase of dry weight in the newly developed organs to the decrease in the storage organs was calculated for radioactivity of ¹⁴C. The values of 0.44 and 0.25 were obtained for 10 and 16 days after shoot pruning, respectively.

5. **Alcohol soluble ¹⁴C in storage organs.**

Time trends of total and 80% ethyl alcohol soluble activities of stump and root are presented in fig. 7. The ratio of alcohol soluble activity to total activity in root is in the range of 0.42~0.49 and fairly constant with the lapse of time. The ratio in stump was 0.26 at the time of shoot pruning. It is interesting that the ratio in stump increased temporarily to 0.40 after shoot pruning and settled down to the initial level afterwards.

**DISCUSSION**

As mulberry leaves are harvested for the purpose of silkworm raising in the midst of a growing season, it is favourable to extend assimilatory organs as soon as possible after shoot pruning or defoliation. In the regrowth after shoot pruning the dependence on the photosynthetic product assimilated prior to shoot pruning is clearly observed in fig. 4. That is, lower leaves that developed earlier after pruning contained more ¹⁴C than upper leaves which developed later. Until 10 days after shoot pruning, almost all of the increment of lateral shoot weight was regarded as derived from the storage substance supposing the economic ratio as
0.44. On the contrary, it appeared through the computation using the economic ratio 0.25 that about half of the increment of a 16-day-old lateral shoot weight had an origin in the reserve substance. This abrupt decrease of the dependence of newly developed organs on the reserve substance seems somewhat strange. But if we take into consideration the sharply increased photosynthetic rate of newly developed leaves, we may take the results for granted. That is to say, the rate of gross assimilation scarcely exceeded that of respiration 10 days after pruning, but the rate of net assimilation became fairly high 17 days after pruning. Relating to this Tazaki\(^{9}\) described that the net assimilation of mulberry leaf of the unfolding day was negative in spring and turned positive from the middle of June when the net assimilation increased after unfolding far more rapidly than in spring, the maximum assimilation appearing only 10 days after unfolding.

Economic ratio gives serious influence on the development of assimilatory organs in the use of the reserve substance and on the regrowth after pruning. Midorikawa\(^{14}\) made clear that the value of economic ratio was approximately 0.5 and showed no great fluctuation with the difference of species reserving the carbon as starch. Moreover, Hayashi et al.\(^{13}\) clarified that the ratio in rice plants remained approximately constant in a wide range of temperature (15~30°C) and that the ratio of potato was fairly constant irrespective of the tuber size or amount of reserve substance. The authors obtained the economic ratio of the same order calculated on \(^{14}\)C activity for the early growth of mulberry in spring (unpublished). It is interesting that the value obtained in mulberry plants was not so different from those for seeds of annuals.

An increase of the carbon resources which are easy to translocate will be advantageous for the regrowth after pruning. Coombe et al.\(^{12}\) reported that the application of gibberellin to barley seeds resulted in the appearance of amylase activity, which in turn caused the hydrolysis of the starch contained in the endosperm of the barley grain. Hatta and Homma\(^{15}\) reported that the activity of amylase in barks of hard-wood cutting was high when the growth of sprouted young plants depended on reserve substance from the cutting. These reports make us suppose that the amylase activity will be activated in the stump of mulberry plant after shoot pruning. Mechanisms operative in storage organs after shoot pruning will be put to more elaborate examination.

**Summary**

To evaluate the role of reserve substance on the regrowth after shoot pruning in a growing season, labelled photosynthetic product that was assimilated prior to shoot pruning and stored in the stump and root was traced in the process of regrowth. Results obtained will be summarized as follows.

1. Following shoot pruning, dry weight of lateral shoots increased, whereas that of storage organs (stump and root) decreased to reach the minimum 16 days after shoot pruning.

2. Photosynthetic rate of newly developed leaves was very low, but not negative 10 days after shoot pruning. Relatively high rates, such as 10 and 17 mgCO\(_2\)/dm\(^2\)/hr for 17 and 35 days after pruning respectively, were obtained.

3. Total activity recovered from the storage organs decreased steadily after shoot pruning, while that recovered from the newly developed organs increased for about 20 days. The ratio of total activity recovered from the newly developed organs to that from the whole plant was low for the first 10 days after shoot pruning, became quickly high for the next 10 days, and thereafter the increase became sluggish.

4. Economic ratios of \(^{14}\)C obtained 10 and 16 days after shoot pruning were 0.44 and 0.25, respectively.

5. The ratio of 80% alcohol soluble activity to total activity in stump increased temporarily after shoot pruning and afterwards settled down to the initial level.

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LITERATURE CITED


[和文摘要]

桑の光合成および光合成産物の転流・消費に関する研究

第5報 生育期間中における枝条切除後の再生長と貯蔵物質の利用

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生育期間中における桑枝条切除後の再生長におよぼす貯蔵物質の役割を明らかにするため、枝条切除前
に同化され、株に蓄積された 14C-光合成産物の再生長にともなう動態を追跡した。
得られた結果の概要は次の通りである。

1. 枝条を切除した後に、再生器官である側枝の乾物重量は増加した。いっぱい、貯蔵器官（株および根）
の重量は減少し、枝条切除後 16 日目に最小値に達した。

2. 枝条切除後10日目の新梢の光合成速度は低かったが、マイナスの値は示されなかった。枝条切
除後17日目には基部から4枚目の葉で 10 mg, 35日目には10枚目の葉で 17 mgCO2/dm²/hr とかなり高
い光合成速度が観測された。

3. 貯蔵器官中の全放射能は枝条切除後12日目に減少したが、再生器官中の全放射能は切除後20日間は
増加した。全植物体中の放射能に対する再生器官中の放射能の比率は枝条切除後11日から10日間は低く
次20日間は高くなり、その後の増加はみられなかった。

4. 枝条切除後10日間および15日間の14Cについての転形率はそれぞれ 0.44 および 0.25 であった。

5. 株中の全放射能に対する 80% アルコール可溶性の放射能の比率は枝条切除後20日間に増加し、その
後初期の水準に復帰した。