Characteristics of Photosynthesis in Mulberry Leaves

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Cultivation of mulberry trees in Japan generally adopts the method by which mulberry trees are grown to stamps 30–40 cm in height above ground, enabling them to develop a number of shoots every year for harvesting. In March, before the sprouting, or in June, after the first harvesting, shoots elongated in the previous year are cut off at their basal portion to form mushroomshaped stamps.

Sprouting of mulberry trees occurs in April, and leaf-fall from late November to early December. During that period, harvesting is made 2 to 3 times usually.

As photosynthetic organs are harvested in mulberry trees, like pasture plants, the harvesting implies directly the damage or destruction of productive structure. In the past with plenty of labor available in rural areas, harvesting of lower leaves, leaving upper leaves with high photosynthetic activity unharvested, or harvesting by thinning 1/3 or 1/2 of a stamp was practiced with the consideration to alleviate adverse effects on roots as well as to reduce overgrowth conditions. However, at present, the method to harvest entire shoots including growing points that cause marked damage to productive structure is popularized. In a short term, the extent of the damage is in parallel to the yields. In view of that relationship, it is important to make clear photosynthetic characteristics of mulberry trees in order to establish a rational system of harvesting with regards to time, method and extent of harvesting.

Effects of environmental factors

Soil moisture, nitrogen supply, temperature, light intensity, CO_2 concentration, etc. are well known as environmental factors effecting photosynthetic rate. Of them, artificial supply of water and nitrogen is relatively easy under field conditions, but temperature, light intensity, and CO_2 concentration are difficult to be controlled. In the present paper, relationships between photosynthetic rate and the latter three factors will be presented.

1) Temperature and photosynthetic rate

Apparent photosynthetic rate of mulberry leaves varies with different leaf-age and date of leaf-unfolding. Therefore, it was measured, using leaf groups different in leaf age and date of unfolding, at different leaf temperatures centering 30°C. Fig. 1 shows relationship between temperature and apparent photosynthetic rate expressed by relative values by taking the rate of each leaf at 30°C as 100. This result shows that the relationship between relative photosynthetic rate (rP) and leaf temperature (T) can be indicated by the following equation, irrespective of magnitude of the rate of each leaf:

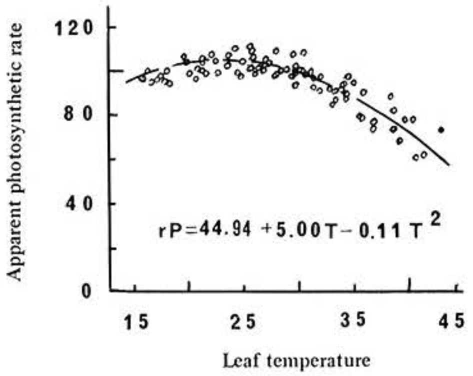

Fig. 1. Relation of apparent photosynthetic rate expressed by relative value* (rP) to leaf temperature (T)

Note: * calculated by taking the apparent photosynthetic rate at 30°C as 100. for each leaf differing in date of leaf unfolding and leaf age

$$rP = 44.94 + 5.00T - 0.11T^2$$

Thus, it can be said that the maximum value of apparent photosynthetic rate is observed at leaf temperature near 23°C. The similar relationship obtained by adding respiratory rates showed the maximum value at around 30°C, with the maximum and minimum values, 100 and 80 respectively, within the same range of temperature.[1] This result suggests that the decrease of apparent photosynthetic rate at higher temperature regime might have been caused by increased respiratory rates at higher temperatures.

2) Light intensity and photosynthetic rate

Light intensity is a factor greatly determining photosynthetic rate. Similar to the above study on temperature effect, apparent photosynthetic rates measured under different light intensities were converted to relative rates (rP′) by taking the photosynthetic rate of each leaf group at 50 klux as 100. Their relationship to light intensity (L) is shown in Fig. 2, where three curves related to different maturity of leaves are identified.

The first curve is expressed by young leaves, area of which is still continuing to increase, and is represented by the equation:

$$rP_1' = \frac{L}{0.0507+0.0055L} - 52.85$$

The second curve is expressed by completed leaves with the termination of leaf area expansion, but still having relatively high respiratory rate, and is represented by the equation:

$$rP_2' = \frac{L}{0.0522+0.0062L} - 36.68$$

The third curve is shown by matured leaves with a respiratory rate already lowered to a stable level, and is represented by

$$rP_3' = \frac{L}{0.0446+0.0069L} - 26.96$$

These three experimental equations represent saturation curve. The compensation point is higher with younger leaves, and the light saturation point, ranging 35–40 klux, also shows a tendency that the younger the leaves the higher is the light saturation point.[2]

3) CO_2 concentration and photosynthetic rate

It is known that the relationship between CO_2 concentration and photosynthetic rate is expressed by a CO_2-saturating curve. However, the result obtained within a narrow range of relatively low CO_2 concentration, 100–500 ppm, will be presented here.

Apparent photosynthetic rates determined under various CO_2 concentrations were converted to relative values by taking the photosynthetic

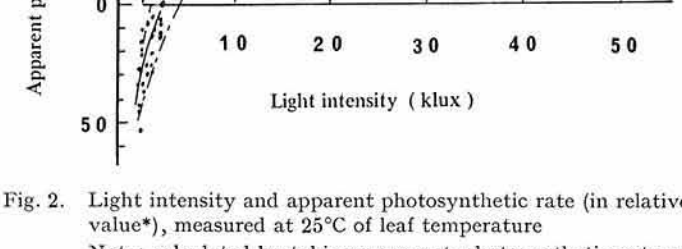

Fig. 2. Light intensity and apparent photosynthetic rate (in relative value*), measured at 25°C of leaf temperature

Note: calculated by taking apparent photosynthetic rate at 52 klux as 100.

rP'_1: leaves of the 5th to 7th leaf position

rP'_2: leaves of the 8th to 14th leaf position

rP'_3: leaves of the 18th to 43th leaf position

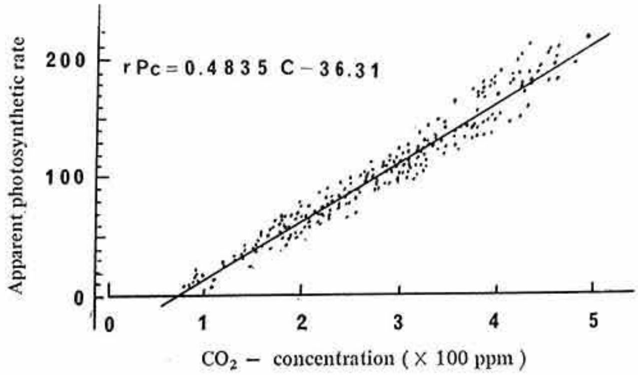

Fig. 3. CO_2 concentration (C) and apparent photosynthetic rate (in relative value*, rPc) measured at 25°C of leaf temperature and 40 klux of light intensity
Note: * shown in percent to the apparent photosynthetic rate at 300±10 ppm of CO_2

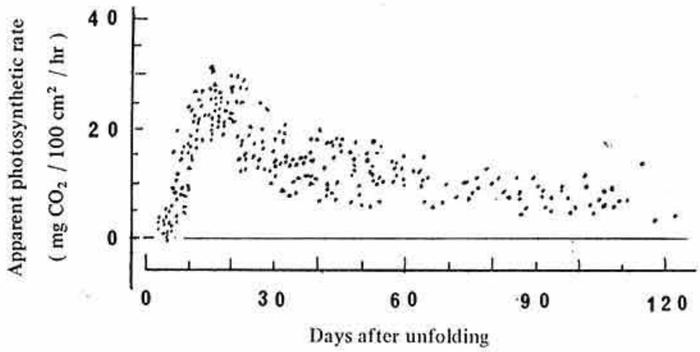

Fig. 4. Relationship between apparent photosynthetic rate* of leaves unfolded in early June-early July and days after unfolding of leaves.
Note: * at leaf temperature 25°C, saturating light intensity, and 300 ppm of CO_2.

rate at 300±10 ppm of CO_2 as 100, and expressed as a function of CO_2 concentration. As shown in Fig. 3, the relationship between relative photosynthetic rate (rPc) and CO_2 concentration (C) is represented quite well by the following experimental equation:

$$rPc = 0.4835C - 36.31$$

Namely, the photosynthetic rate is proportional to CO_2 concentration within a relatively narrow range of CO_2 concentration.[3)]

Changes in photosynthetic rate with progress of leaf age

Apparent photosynthetic rate of leaves successively unfolded on the mulberry saplings which had planted to pots in early May was measured continuously during the progress of leaf age, and shown as a function of number of days after unfolding of each leaf. As given in Fig. 4, the leaves unfolded in a period from early June to early July showed the highest photosynthetic rate of about 30 mg CO_2/100 cm^2/hr at 17–18 days after unfolding, followed by the gradual decrease after that. On the contrary, the leaves unfolded in mid-July∼early August showed the highest photosynthetic rate reaching about 40 mg CO_2/100 cm^2/hr with less number of days after unfolding (Fig. 5). Number of days after unfolding required for reaching compensation point is also less with this group of leaves. The leaves unfolded in mid∼late August showed the highest rate of 20 mg CO_2/100 cm^2/hr, and those unfolded in September gave the highest rate only less than 10 mg CO_2/100 cm^2/hr (Fig. 6).

This pattern of changes in photosynthetic rate associated with leaf age was not appreciably effected by changing the plant growth by delayed planting dates. Therefore, this pattern can be regarded to be determined by the date of leaf unfolding. This fact has an important bearing in considering the time and method of harvesting, and subsequent plant growth after harvest.

Photosynthetic rate by growth stage and leaf position

Mulberry trees continue to unfold new leaves during the most of their growing period, from April to early September. Consequently, leaves of various ages are being arranged in layers at any growth stage.

Fig. 7 shows photosynthetic rates by leaf position in mid∼late June (A), early July∼early

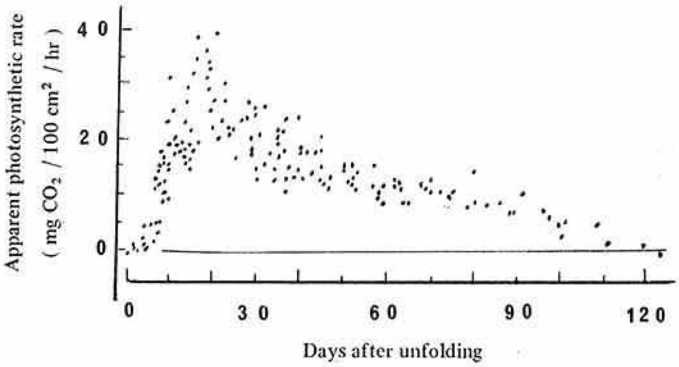

Fig. 5. Relationship between apparent photosynthetic rate* of leaves unfolded in mid-July∼early August and days after unfolding.

Note: * same as in Fig. 4.

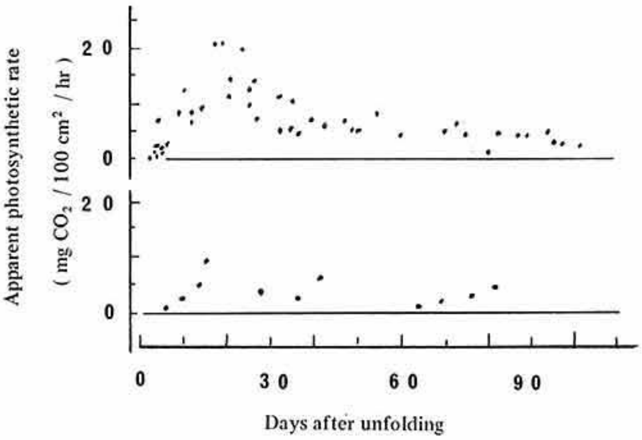

Fig. 6. Relationship between apparent photosynthetic rate* of leaves unfolded in mid∼late August (upper) and in September (lower) and days after unfolding.

Note: * same as in Fig. 4.

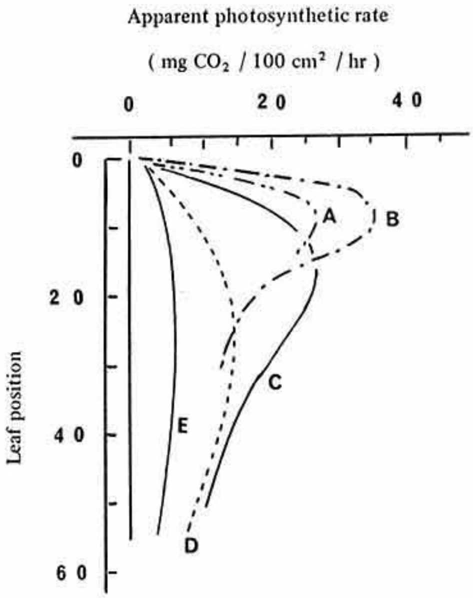

Fig. 7. Apparent photosynthetic rate* in relation to leaf position.

Note: Leaf position counted from the top of plants.

* same as in Fig. 4.

A: In mid~late June, B: earlyJuly~early August, C: mid-August~early September, D: mid-September~mid-October, and E: late October~mid-November.

August (B), mid-August~early September (C), mid-September~mid October (D), and late October~mid-November (E). In all cases, apparent photosynthetic rates were measured under a saturating light.[4] In actual field conditions, however, leaves at lower position are under the shade of upper leaves, and hence they are exposed to reduced light intensity. The actual photosynthetic rates at the lower layer must considerably be lower than the level shown in Fig. 7.

On the basis of the photosynthetic characteristics shown above, it has to be said that the currently prevalent harvesting method in Japan, i.e., cutting whole shoots, is not reasonable. From the standpoint of increasing yields, it may be rational to harvest lower leaves, leaving upper leaves which have high photosynthetic rate unharvested. However, in relation to this problem, the finding by Satoh et al.[5] must be added. They observed that when shoots were harvested, leaving lower leaves unharvested, the photosynthetic rate, which had already decreased, of the remaining lower leaves was increased to a considerable extent.

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