EFFECTS OF TEMPERATURE AND LIGHT ON THE TRANSLOCATION OF PHOTOSYNTHETIC PRODUCTS

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By

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Various investigations have been already published concerning the effects of the environmental conditions on the translocation of photosynthetic products (1). Detailed studies on the effects of temperature which is most important among the environmental conditions have been performed. Most of them were performed by placing the whole plants, or a part of the stems in a difinite temperature (2). When the photosynthetic products move from a certain organ to another, the temperature conditions of both supplying and receiving organs imply something important. However, we can hardly find reports on their relative temperature conditions. It can be easily surmised that the temperature of a supplying organ has an effect on the translocation mainly through photosynthesis. On the other hand, the fact that dry weight of a receiving organ is largely affected by its temperature circumstances can be often observed. Therfore, we have investigated the pattern of the translocation from the leaf blade to the roots when the temperature of both organs were changed. It is concidered that this study is necessary for getting a clue to an elucidation for migration mechanism.

For this purpose an experiment on the relation of temperature and photosynthesis was made first, and the optimum temperature for the photosynthesis was measured in barley plants. As it was supposed that the respiration would be the most effected metabolism when the temperature of the roots was varied, an optimum temperature for root respiration was sought. After this the rate of translocation was measured when a supplying organ is maintained in an optimum temperature for photosynthesis and receiving for respiration.

On the other hand, although the light is also an important environmental condition, reports on it are few. Temperature has an effect on entire plants, and light has its effect on the movement through the leaf blade, supplying organ. These are the reason for measuring the rate of translocation of photosynthetic products from a leaf blade to roots in different lighting periods.

In this paper the results of the experiments upon the effects of temperature and light on the translocation of photosynthetic products will be mentioned.

Experimental

1) Measurement of an optimum temperature for the photosynthesis:

Barley plants were cultivated by hydroponics for one month and $^{14}CO_2$ 100 μc was incorporated into the leaf blade under different temperature conditions. Intensity of the illumination was 30,000Lux.

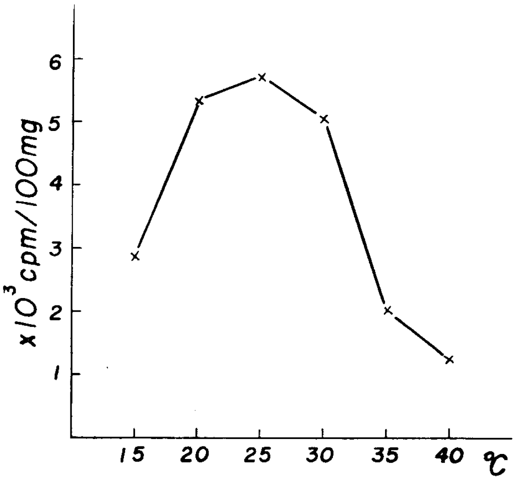

Fig. 1. Effect of temperature on the photosynthesis.

After the incorporated sample were wet digested with the mixture solution of conc. H_2SO_4 and 30% H_2O_2 (1:1), radioactivities were measured by the G.M. counter according to the usual way (3). The results are shown in Fig. 1. A radioautograph of a part of the sample was taken and the result is shown in Fig. 2. They were photosyntyesized at temperatures of 35°, 25° and 15°C in the given order.

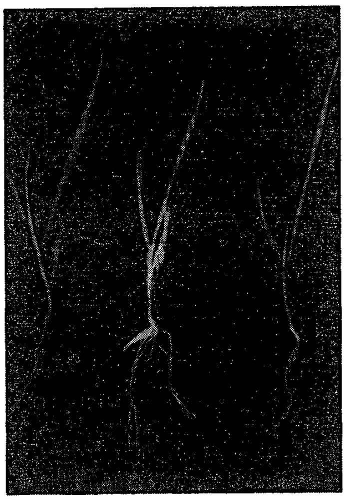

Fig. 2. Radioautograph of ^{14}C-photosynthate in barley plants.
From left to right at 35, 25, 15°C.

From the results an optimum temperature for the photosynthesis of the barley plants is around 25°C.

2) The effect of temperature on roots respiration:

In order to measure the root respiration it is very difficult to use intact plants, therefore, the method of measuring the excised roots was adopted.

Under the existence of pH 6 phosphate buffer O_2 uptake from the excised roots of barley plants were measureed by a Warburg's manometer. The measured temperature was ranged from 15° to 40°C. The measured results are indicated in Fig. 3 and the optimum temperature was, as seen in it, around 30°C.

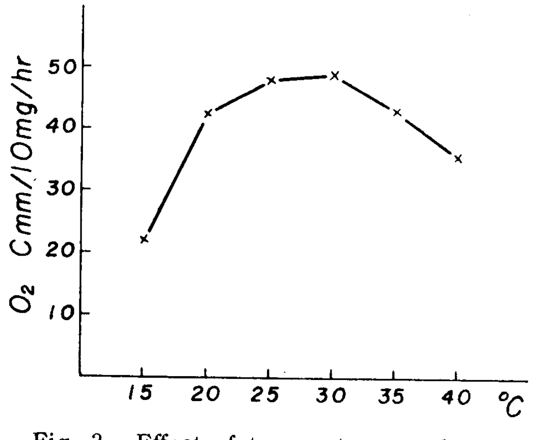

Fig. 3. Effect of temperature on the respiration of the excised roots.

3) The effect of temperature on translocation rates:

For getting the rate of translocation of the photosynthetic products with radioactive carbon it is quite common to measure the accumulation of radioactivity in a receiving organ. Some of ^{14}C coming in to the roots from the top are used as substrates of respiration at once, or it is quite possible to be exudated to the outside as organic substances[4] and the other part of it is considered to be sent back to the top again. Accordingly, the quantity of transport to the roots should be summed up into four categories: 1) radioactivity in roots, 2) $^{14}CO_2$ released from roots, 3) ^{14}C-organic compounds released from roots and 4) ^{14}C which ascends again. Concerning the last reascension part, there is no suitable method for the experiments, so the apparent rate of transport was measured. The apparent rate is the increased quantities of accumulated and released ^{14}C in a unit time.

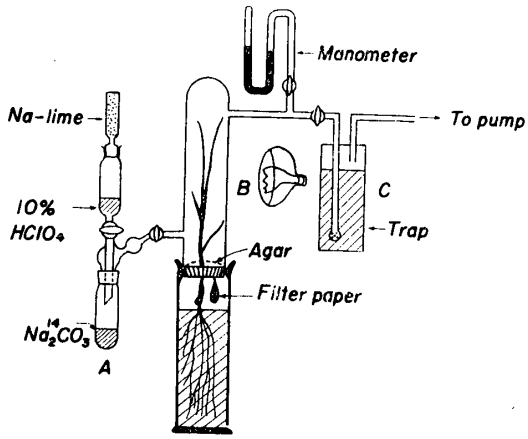

Fig. 4. Diagram of the apparatus for the measurement of the translocation rate.
(A) $^{14}CO_2$ generator
(B) Assimilation chamber
(C) Trap

The apparatus in Fig. 4 was used for the measurement. A) is $^{14}CO_2$ generator, B) assimilation chamber and C) is a trap. The cultural solution was maintained in weak alkaline and a filter paper containing 20%KOH was suspended in the upper part of the lower chamber.

After the sample was taken out, the cultural solution was centrifuged and it precipitated $Ba^{14}CO_3$ by adding $BaNO_3$ solution to the supernatant. Radioactivity was measured after it was filtered. The filter paper was dried and measured. We regarded both as ^{14}C exudated from the roots.

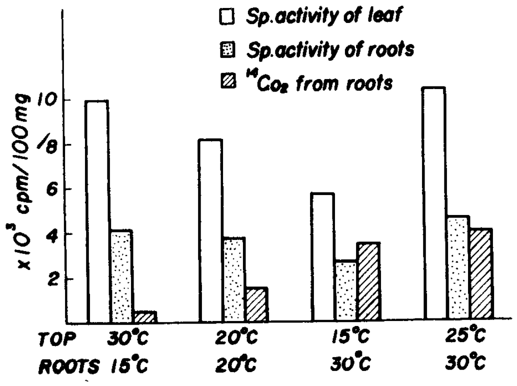

Fig. 5. Effect of temperature on the translocation of ^{14}C.

Each temperature of the top and roots was varied and translocated under the lighting of 30,000Lux for three hours. The measured results are shown in Fig. 5.

The rate of translocation reaches the maximum under the temperature conditions when the photosynthesis of the top and the respiration of the roots are most active.

4) The effect of light on the rate of translocation:

$^{14}CO_2$ 200 μc was supplied to a leaf blade of barley plants for five minutes under the lighting of 30,000 Lux. The inside of the chamber was washed with fresh air for five minutes, and the sample was then taken out and treated as seen as in Fig. 6. That is to say, a part of it was allowed to remain under the

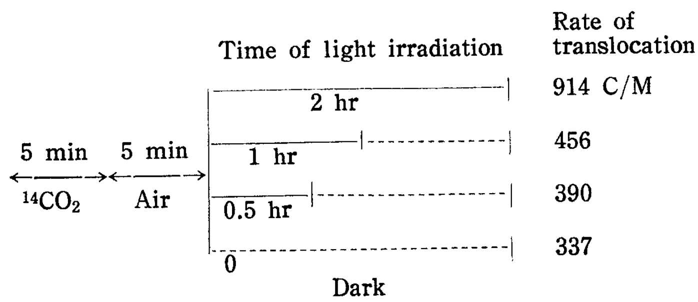

Fig. 6. Effect of light on the translocation of ^{14}C.

same light for two hours. After lighting of one hour another part was left for one hour in the dark place. The other was after thirty minutes lighting treated in the dark for the remaining hours. After the fixation of $^{14}CO_2$ the other plant was set in the dark. All of them treated at 25°C. The result was: the longer the lighting period became, the greater the rate of translocation became.

Discussion

According to "Münch's Pressure Flow Hypothesis", the translocation of photosynthetic products are moved with the difference of osmotic pressure of supplying and receiving organs. The osmotic pressure is shown by Van't Hoff's formula;

$$P=f(C)RT$$

Therfore, the larger the difference of temperature in both organs, the higher the rate of translocation became. In other words, photosynthetic products are easily transported when the temperature of the supplying organ is higher than the receiving one. The temperature in this formula is indicated by an absolute temperature, therefore, the difference between 35° to 15°C. only shows the change of 10 per cent. Accordingly, the change of this slight degree may be denied with the difference of concentration and the effect may not come to the surface. If we pay attention to the temperature condition only, however, the best condition should be the high temperature in the top and low parts of the roots. In this experiment these results could not be obtained. Rate of translocation was great when the root was maintained at a high temperature.

In either experiment on temperature and light the rate of movement is great in the top when the environmental conditions in which the photosynthesis could be active, and this accords with the previous papers. It would be a new opinion, however, that the rate of translocation is increased in the temperature condition such as the roots respiration activity. This implies that the data by the former measuring methods referred only to the quantity of accumulation in the receiving organ, and the amount of exudation from roots was ignored. When the root was maintained in a low temperature, the rate of accumulated in it is increased, but the issue from the root is restrained. Therefore, the amount of them is rather small by comparison with the one in a temperature plot. When the root was maintained in a high temperature, the rate of accumulation in the root was decreased and the loss by respiration increased.

Summary

Observations were made on the effect of temperature and light on the translocation from the leaf blade to the roots in water cultured barley plants.

When the top was maintained in an optimum temperature for photosynthesis and the root for respiration, the rate of translocation reached the maximum, but it was decreased in any other temperature conditions. The light irradiation time became longer, the larger the rate of translocation became.

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