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Photosynthesis in Polygonum reynoutria L. ssp. asiatica Grown at Different Altitudes

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Summary

A relation between environmental conditions and photosynthetic ability was investigated with *Polygonum reynoutria L. ssp. asiatica* growing in various conditions.

The optimum and the maximum temperatures for photosynthesis in the plants under field conditions varied seasonally with the variation of air-temperature. Both temperatures were located on much lower level with the plants grown at high elevation. In their seedlings cultured under an artificial controlled condition, the optimum temperature differed to every seed-source which was different in environmental temperature.

The optimum temperature had a wide range in the plants grown natively at low elevation, and had a narrow range in those grown natively at high elevation. The width of the range was narrowed by transplantation into high elevation from low one, and was similar to that of the range in the native plants in the habitat into which the plants were transplanted. The width. however, was never changed by transplantation into low elevation from high one.

The optimum and the maximum temperatures for photosynthesis may be genotypically decided, although both temperatures showed a variance with the seasonal variation of air-temperature. Such plasticity on both temperatures for photosynthesis seems to be larger in the plants grown natively at low elevation than ones grown natively at high elevation.

Introduction

The environmental condition in which plants are growing is known to give a great effect on their physiological function. For example, the seasonal variation of air-temperature has been shown to change the levels of cold hardiness

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(3), respiratory activity (14), and some factors on photosynthesis (5, 8).

On the other hand, some workers (1, 10) have reported that the photosynthetic functions were genotypically limited in some plants grown under environments being diverse in light intensity or temperature.

This paper reports a genotypical action and a plastical one in the photosynthetic function of plants.

Materials and Methods

Polygonum reynoutria L. ssp. asiatica was used as experimental material for the measurement of photosynthetic ability. Experiments were carried out on the plants grown in fields under natural conditions and in a controlled artificial environment.

In field experiments, several experimental fields were prepared at diverse altitudes. These fields were variable on environmental factors that are elevation-dependent, but were similar on soil type, soil-water content, and light condition. *P. reynoutria* growing natively in these fields was used for experiments. Their habitats may be mainly characterized by the difference of air-temperature caused from different altitudes. These fields were found in the campus of Shinshu University, Matsumoto (about 600m above sea-level, a low-altitude habitat), Tateshina Highland in Nagano Prefecture (about 1500m above sea-level, a middle-altitude habitat), and west slope of Mt. Yatsugatake (about 1900m above sea-level, a high-altitude habitat). These fields were situated at practically the same latitude (34°14' N. at Matsumoto).

In October of 1968, plants growing natively in the low-altitude habitat were transplanted into the middle-altitude one, and plants growing natively in the middle-altitude habitat into the low-altitude one. In these cases, the former plants were designated as middle-altitude transplanted plants, and the latter plants as low-altitude transplanted plants.

For the experiments in an artificial condition, the seeds of *P. reynoutria* were collected from Matsumoto, Tateshina Highland, and Mt. Aso in Kyushu (about 1400m above sea-level, about 32°50' N.) in October of 1969. These seeds were germinated at 25° C in December of the same year. These seedlings were grown with 20,000 lux light at 25° C for 100 days, and then were used to determine photosynthetic ability. Although Mt. Aso had a great difference from the northern habitats in latitude and some soil-factors, the southern seedlings, that were grown from the seeds collected in Mt. Aso, were used for comparison with the present experiments.

The plants under various environments as described above were used to determine the optimum and the maximum temperatures for photosynesis. Photosynthetic ability was measured by using Product Meter (Nikko Science Co. Ltd.) or by using Bioxygraph (Kyusui Kagaku Kenkyusho Co. Ltd.) with light intensity of 10,000 lux at various temperatures. The leaves used for the measurement were the third one from the top-most among leaves completely expanding. The experiments on plants in field conditions were taken in 1969–1971.

Results

I. *General observations.*

Air-temperature in the middle altitude was 4–5° C lower than that in the low altitude throughout the year (13). *Polygonum* plants grown in the low- and the middle-altitude haditats during long years were morphologically similar to each other, but the season of flowering for the middle-altitude plants (late July) was about 2 weeks earlier than that for the low-altitude ones (early August). With the transplanted plants, the aboveground part of the middle-altitude transplanted plants had a tendency of yearly debility, but the low-altitude transplanted ones grew more vigorously than the low-altitude plants.

II. *The optimum and the maximum temperatures for photosynthesis.*

(1) *P. reynoutria* in several habitats being diverse in altitude.

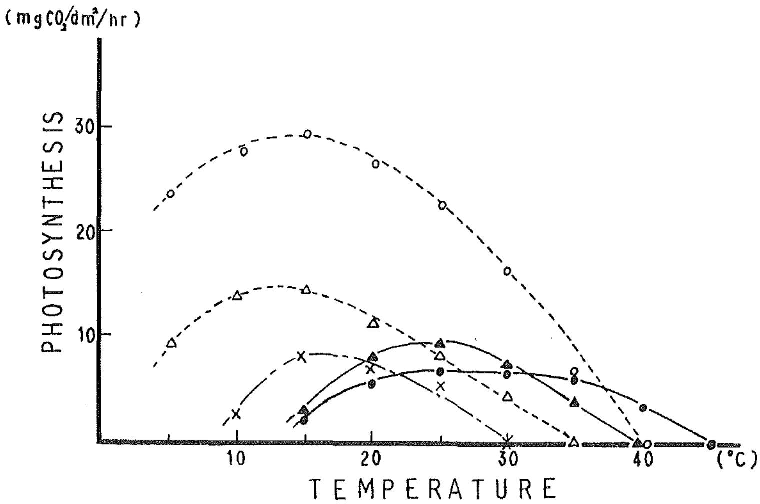

Fig. 1. Seasonal variation of temperature-photosynthesis curve in the native plants grown in a few habitats being different in altitude. The low-altitude plants: measurement in May, ···○···, in August, —●—; the middle-altitude plants: measurement in May, ···△···, in August, —▲—; the high-altitude plants: measurement in August, —×—.

A temperature-photosynthesis curve was determined in late May and early August on the low-, the middle-, and the high-altitude plants, and these results were obtained as in Fig. 1.

A difference between both plants of the low- and the middle-altitudes was found on the optimum temeperature for photosynthesis, that is, the range of the optimum temperature in August was wider in the low-altitude plants (20–35° C) than in the middle-altitude ones (about 25° C). It's value was higher in the former plants than in the latter. In the same season, the maximum temperature for photosynthesis also was higher in the low-altitude plants than in the middle-altitude ones. Both temperatures of the optimum and the maximum were seasonally varied with the plants in both fields.

The photosynthetic ability at the optimum temperature in the low-altitude plants in May was higher than in the middle-altitude ones; but in August, it was lower than in the middle-altitude plants. A gross production through a summer's daytime, however, may be larger in the low-altitude plants than in the middle, because the former plants had the wide range of the optimum temperature for photosynthesis. The photosynthetic ability of the plants in the same habitat was greatly higher in May than in August.

A relation of temperature-photosynthesis with the plants in the high-altitude

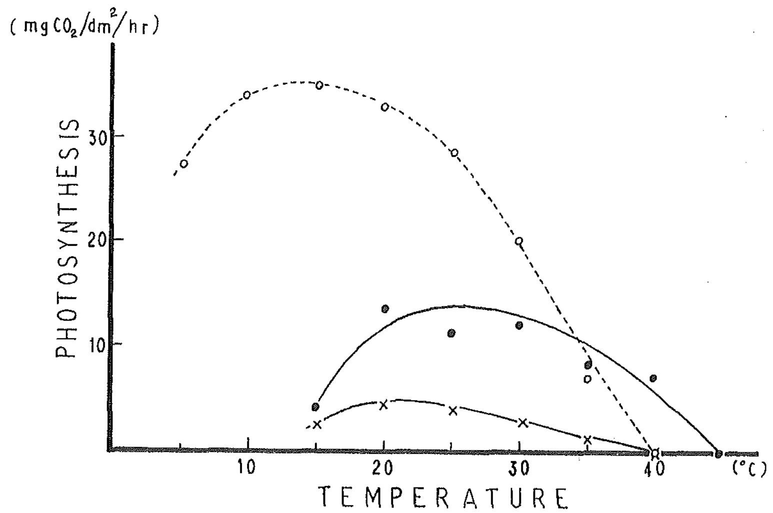

Fig. 2. A relation of temperature-photosynthesis changed by transplantation. Measurements were taken in the 2nd year after transplantation. The plants transplanted into the low-altitude habitat from the middle: measurement in May, ···○···, in August, —●—; the plants transplanted into the middle-altitude habitat from the low: measurement in August, —×—.

habitat was determined in early August (Fig. 1). The temperature-photosynthesis curve was similar to that with the middle-altitude plants, but the optimum and the maximum temperatures were lower than those with the middle-altitude ones measured in early August.

(2) *P. reynoutria* transplanted into diflerent altitude from native habitat.

The measurements of photosynthetic ability were taken in early August of 1970 (the 2nd year after transplantation). The results obtained are shown in Fig. 2.

Upon transplanting into the middle altitude from the low one, the plants were shifted on the optimum and the maximum temperatures for photosynthesis to a lower level than in the low altitude. The low-altitude transplanted plants, however, were shifted on the maximum temperature alone to a higher level than in the middle-altitude plants. The range of the optimum temperature was narrowed by transplanting into the middle altitude from the low one, and was a little enlarged by transplanting into the low altitude from the middle. The low-altitude transplanted plants, however, never produced a wide range of the optimum temperature such as the low-altiude plants.

The photosynthetic ability was greatly higher in the low-altitude transplanted plants than in the middle-altitude transplanted ones. The ability of the former plants was the highest among all measurements in the same season, whereas the ability of the latter plants was the lowest among all measurements containing the native plants.

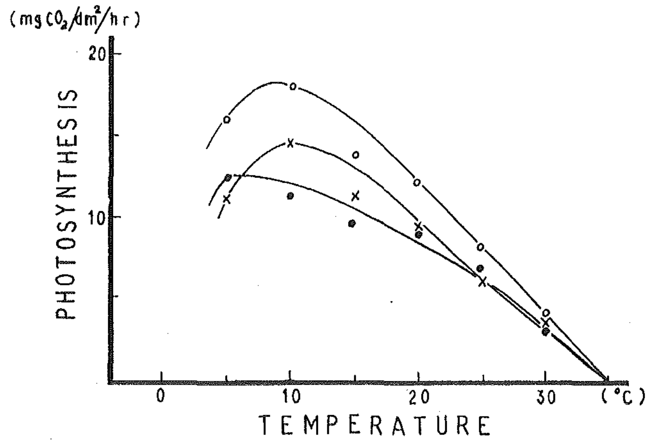

Fig. 3. Photosynthesis in *Polygonum* seedlings grown under a controlled condition. The seeds were collected from various seed-sources being different in altitude. The seedlings from the low-altitude plant's seeds, —○—; the seedlings from the middle-altitude plant's seeds, —●—; the seedlings from the southern plant's seeds, —×—.

(3) *P. reynoutria* grown under an artificial condition (20,000 lux light at 25°C).

The optimum temperature for photosynthesis was lower in plants under the artificial condition than under field conditions, and the range of the optimum temperature was narrowed in all the seedlings from seeds in different sources (Fig. 3). Therefore, the plants from the middle- and the low-altitude plant's seeds, and from the southern plant's seeds showed approximately 5, 8.5, and 10° C to the optimum temperature. Photosynthetic ability was the highest in the plants from the low-altitude plant's seeds, and had a similar level in the plants from the middle-altitude plant's seeds and the southern plant's seeds. These ability levels were lower than those in plants under field conditions.

III. *Photosynthetic ability and respiratory activity at 25°C*

Photosynthetic ability was measured in August of 1971 (the 3rd year after transplantation) with 10,000 lux light at 25° C on the native plants and transplanted ones growing in the fields described above. The results obtained are shown in Table 1.

Table. 1. Photosynthetic abilities affected by the different altitudes of plant habitats and by their transplantation.

Altitude of experimental fields (m)	1900	1500		600	
		native	transplanted1)	native	transplanted2)
Respiration (O_2mg/dm²/hr)	0.58	1.73	2.31	2.31	2.31
Net production (CO_2mg/dm²/hr)	4.86	8.97	4.51	9.89	11.60

Measurements were taken in August of the 3rd year after transplantation.
1) transplanted from 600m.
2) transplanted from 1500m.

Their net productivities and their respiratory activities were decreased with increase in the altitude of their habitats. In the plants transplanted, the low-altitude transplanted plants made a greater net production than the native plants in the low habitat. The middle-altitude transplanted plants, however, photosynthesized on lower level than in the middle-altitude plants. These levels of the net productivity appeared to result a different growth-evidence of their above-ground parts observed between both kinds of the transplanted plants.

Discussion

It is known that some plants, growing in different environments, have morphological (4) or physiological (1, 6) differences though they belonged to the same species. In general, air-temperature varies seasonally in almost zones on the earth throughout the year. With such variation of the temperature, plants also in the zones are known to vary adaptively their physiological activities (7). In *P. reynoutria* under field conditions, the variable physiological activities were shown that the optimum and the maximum temperatures for photosynthesis were higher in summer than in spring in both fields of the low and the middle altitudes. This fact suggests that the physiological activities of the plants have a plasticity relative to the variation of environmental conditions, especially to a seasonal variation of air-temperature.

The seasonal variation of the optimum and the maximum temperatures for photosynthesis seems to be adaptation to the variance of environmental conditions. On the other hand, in the plants grown at higher altitude than in those grown at lower one, the range of the optimum temperature was narrower, and it's value was located on lower level. These characters were never changed under the artificial condition nor by transplantation, especially by transplantation into the low altitude from the middle. Therefore, it may be concluded that the characters were quite genotypic in the middle-altitude plant, and it seems to be differentiated through long years in an intense environment but not in a mild one. McNAUGHTON (10) also has obtained a similar conclusion with *Typha latifolia*. Although both temperatures for photosynthesis vary with a seasonal variation of air-temperature, a variable level of both temperatures may be defined by the environment of the habitats in which the plants have natively grown.

Some workers (11, 12) have reported on a few plants which never varied the optimum temperature when they were transplanted into diverse environments. By enzymological meanings, McNAUGHTON (10) has concluded that *Typha latifolia* has a genotypical relation of photosynthetic ability to environmental temperature. MARSDEN-JONES and TURRILL (9), and GROOT and BOSEHHUIZEN (4) have concluded that 2 forms of *Plantago major* found in diverse environments had different genotypes. In the *Plantago* plants, they have found also some morphological differences. At present, however, the differences were never found in *P. reynoutria*. This fact may suggest that *P. reynoutria* in the middle- and the high-altitude habitats was differentiated as a physiological genotype in a relatively new period. *P. reynoutria* at lower elevations had a larger plasticity for the optimum temperature than the plants at higher ones. The fact that the plasticity was narrowed by transplanting into higher elevations may suggest that the plants at lower elevations as yet retain the potential for differentiating their genotypes. COOH and JOHNSON (2) have reported that a heterophylly index for plasticity on the leaves of *Ranunculus flammula* was much higher in lower elevations, and that the plants having the high index were better able to survive in aquatic conditions.

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