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Short communication

Photosynthetic response of Japanese rose species *Rosa bracteata* and *Rosa rugosa* to temperature and light

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Abstract

The photosynthetic leaf characteristics of two rose species native to Japan were measured. The optimum temperature range for photosynthesis of *Rosa bracteata* was higher than that of *Rosa rugosa*. The photosynthetic response to temperature of *R. bracteata* was slower than that of *R. rugosa*. Maximum photosynthetic rates were reached at an irradiance of higher than 750 μ mol m^{-2} s^{-1} in both species. At saturating irradiances, the net photosynthetic rate of *R. bracteata* was 18.7 μ mol m^{-2} s^{-1}, higher than that of *R. rugosa* (16.8 μ mol m^{-2} s^{-1}). At low irradiances, the net photosynthetic rate of *R. rugosa* was higher than that of *R. bracteata*. The light compensation point of *R. rugosa* was lower than that of *R. bracteata*. Thus, these rose species may be showing adaptations that allow them to photosynthesize efficiently under their native environmental conditions.

Keywords: Photosynthesis; *Rosa rugosa* Thunb. ex Murray; *Rosa bracteata* Wendl.

1. Introduction

The land area of Japan extends over nearly 21° of latitude from about 24°N to 45°N — from the subtropical zone of the southern area to the frozen zone of the

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alpine summits and northern parts of Hokkaido. Encompassed in these areas, there are about 15 taxa (species and varieties) of the genus *Rosa* showing wide morphological and ecological diversity.

Among these species, *Rosa rugosa* Thunb. ex Murray is distributed from the temperate and northern parts of East Asia to the Kuriles, Kamchatka and Sakhalin. In Japan, it grows on the sandy shores of Hokkaido, the Pacific side of Honshu as far south as the northern Kanto, and on the Japan sea side south to the San'in District (Ohwi, 1965). Thus, by distribution area, it is thought that *R. rugosa* is adaptive to lower temperature and lower light. So far *R. rugosa* has been used in breeding programmes to introduce cold hardiness and resistance to insects and disease.

Rosa bracteata Wendl. is distributed in South China, Taiwan and on Ishigaki Island, one of the Ryukyu Islands in the southern most part of Japan. The distribution area is in the subtropical zone and it is thought that *R. bracteata* is an important gene resource for breeding heat-resistant cultivars.

It is likely that these two species from contrasting habitats have adapted to the different environmental conditions, including temperature, irradiation level and rainfall and might show considerable differences in their photosynthetic responses to temperature and irradiation.

Many researchers have measured the photosynthetic rates of leaves and whole plants of roses at various irradiance levels (Aikin and Hanan, 1975; Hand and Cockshull, 1975; Rouhani and Khosh-Khui, 1979; Bozarth et al., 1982; Pasian and Lieth, 1989; Lieth and Pasian, 1990; Jiao et al., 1991; Baille et al., 1996) and temperatures (Bozarth et al., 1982; Jiao et al., 1988; Pasian and Lieth, 1989; Lieth and Pasian, 1990; Jiao et al., 1991). However, all of these researchers used cultivars as experimental materials except for Rouhani and Khosh-Khui (1979).

In this investigation, we have measured photosynthetic and leaf characteristics in contrasting species as gene resources native to Japan to get useful information for breeding heat-resistant or shade-tolerant roses.

2. Materials and methods

2.1. Plant materials

R. bracteata, native to Ishigaki Island (124° 09′E, 24° 20′N) and *R. rugosa*, native to Monbetsu, Hokkaido (143° 04′E, 44° 23′N), were used in this study. On Ishigaki Island, there are high temperatures from spring to autumn and it rains throughout the year. In Monbetsu, there are cool temperatures from spring to autumn and it rains mostly during the summer season. Plants of both species were grafted on *R. multiflora* rootstock in January, 1996 and grown outside in pots under the same environmental conditions at the Kanagawa Prefectural Agricultural Research Institute. From July to September 1996, temperatures fluctuated between 16.4 and 33.7°C (night/day maxima). CO_2 concentration was ambient (350–400 ppm) and light level was under ambient solar radiation. A single plant (i.e. one genotype) was used to provide the grafting materials for each species. In July, all plants were pinched to encourage uniformity of sprouting. It was suggested that 10 days old rose leaves have an almost completely developed photosynthetic mechanism while senescence dose not begin until rose leaves are older than 40 days (Pasian and Lieth, 1989). Therefore, the leaves used for the photosynthetic experiments were approximately 35 days old.

In this experiment, we assume that the differences of photosynthetic characteristics are heritable and the rootstock has not any effect on the photosynthesis of the scion.

2.2. Gas exchange measurements

The plants were moved to Yokohama National University and were grown in experimental field of the university for 1 week, where measurements were to take place in September, 1996. After transferring the plants to the laboratory for 2 h from the field, leaves, still attached to the mother plant, were inserted into a plastic chamber. Air from a storage bag containing 360 ppm CO_2 was pumped continuously through the chamber at a rate of 5 l min^{-1}. The relative humidity of the air was maintained at 40–45% by passing it through a potassium hydroxide solution. Irradiation of 0–1750 μ mol m^{-2} s^{-1} at the leaf surface was provided by a metal halide lamp. The irradiation level was controlled by varying the distance between the leaf and the lamp. The temperature was maintained at 24 ± 1°C on the lower surface of leaf by using a water bath circulation system between the lamp and the leaf chamber. In the studies on leaf temperature response, the temperature was adjusted from 10 to 35°C by cooling the pipe between the air storage bag and the leaf chamber with ice. Gas exchanges were determined using an IR gas analyzer (LI-1632, LI-COR). Three replications (three leaves) were made for each measurement; standard errors were calculated and have been included in the figures.

2.3. Measurement of chlorophyll content

The chlorophyll content of the leaves was determined after extraction in 80% acetone at −20°C (Arnon, 1949). Absorption was measured, using a spectrophotometer (UV-265FW, Shimadzu), at 645 and 663 nm and chlorophyll content was calculated using the equation: $\text{chlorophyll}_{a+b} = 8.02(A_{663}) + 20.21(A_{645})$. Three replicates were made of each measurement.

3. Results and discussion

Plants which are native to and grown in cool environments generally exhibit higher photosynthetic rates at low temperatures, and optimum photosynthetic rates occur at lower temperatures in comparison with plants which are native to and grown in warm environments (Berry and Björkman, 1980). Conversely, the latter plants exhibit a superior photosynthetic performance at high temperatures (Berry and Björkman, 1980). The net photosynthetic rates of contrasting species native to Japan measured at an irradiance of 360 μ mol m^{-2} s^{-1} and 360 ppm CO_2 increased to a maximum and then decreased over the range 10–35°C (Fig. 1). The optimum temperature range, the rates within 5% of the maximum, of *R. bracteata* was higher than that of *R. rugosa* (Fig. 1). The photosynthetic response to temperature of *R. bracteata* was slower than that of *R. rugosa* (Fig. 1). *R. bracteata*, native to a warm environment, is an evergreen species and has a long growing season, whereas *R. rugosa*, native to a cool environment, is deciduous like many other rose species and its growing season is restricted to summer. Such

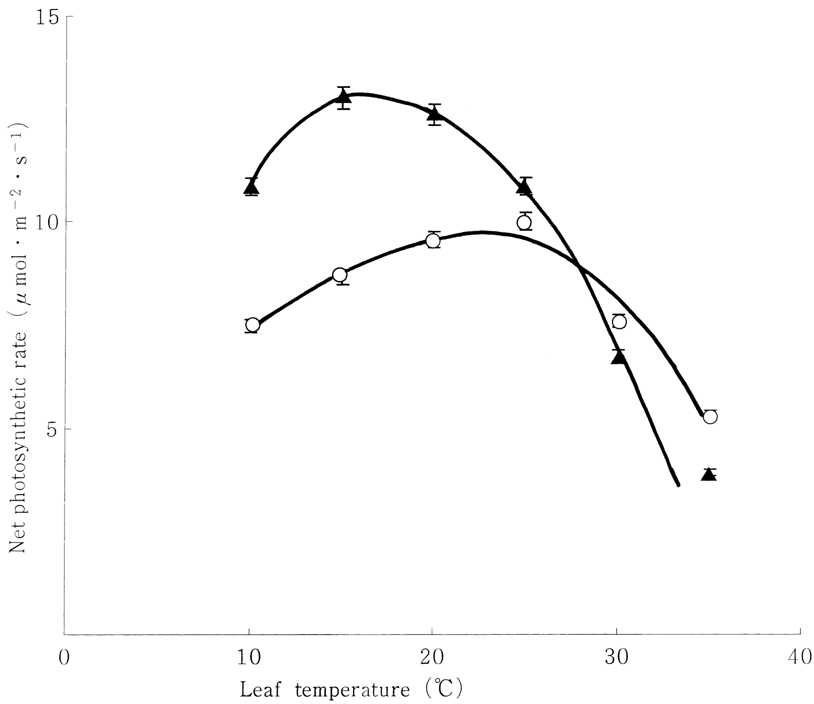

Fig. 1. Effect of leaf temperature on photosynthesis in mature leaves of two rose species at 360 ppm CO_2 concentration and an irradiance of 360 μ mol m^{-2} s^{-1}. *R. bracteata* (○), *R. rugosa* (▲). Lines were fitted by eye drawn. Vertical bars represent the standard errors.

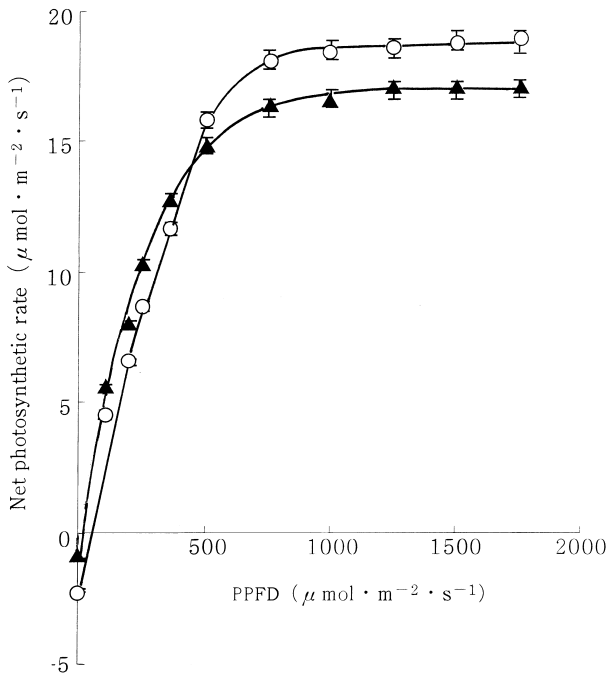

Fig. 2. Effect of PPFD levels on photosynthesis in mature leaves of two rose species at 360 ppm CO_2 concentration and 24 ± 1°C. *R. bracteata* (○), *R. rugosa* (▲). Lines were fitted by eye drawn. Vertical bars represent the standard errors.

characteristics may be connected with the specific photosynthetic responses to temperature of the two species.

The responses of the net photosynthetic rates of the two species to increasing photosynthetic photon flux densities (PPFD) were similar with maxima at higher than 750 μ mol m^{-2} s^{-1} and then the net photosynthetic rates were saturated (Fig. 2). At the whole plant level (the plant and canopy level), it is reported that the light saturation is about 1000 μ mol m^{-2} s^{-1} in rose plants (Hand and Cockshull, 1975; Jiao et al., 1991; Baille et al., 1996). However, at the leaf level (a single leaf level), the PPFD is lower than that observed at the whole plant level (about 500 μ mol m^{-2} s^{-1}) (Aikin and Hanan, 1975; Bozarth et al., 1982; Pasian and Lieth, 1989). The saturating PPFDs measured in our experiment were determined at the leaf level and were higher than PPFDs in the literature. At saturation irradiances, net photosynthetic rates were 18.7 μ mol m^{-2} s^{-1} in *R. bracteata* and 16.8 μ mol m^{-2} s^{-1} in *R. rugosa* (Fig. 2). These rates are the higher rates measured at the leaf level (Lieth and Pasian, 1990). The previous literature therefore suggests that we measured photosynthesis at the maximal stage and that *R. bracteata* has a higher photosynthetic ability than *R. rugosa*.

Table 1
Leaf thickness and chlorophyll content of two rose species[a]

Species	Leaf thickness (μm)	Chlorophyll content ($a + b$)	
		mg/g fresh wt	mg/cm^2 leaf area
R. bracteata	158.3 ± 11.0 b	1.04 ± 0.018 a	0.043 ± 0.0006 a
R. rugosa	186.7 ± 13.1 a	0.80 ± 0.016 b	0.032 ± 0.0006 b

[a] Different letters within a column indicate significant differences by *t*-test at 5% level.

At lower light intensities, the net photosynthetic rate of *R. rugosa* was higher than that of *R. bracteata* (Fig. 2). And under 360 μ mol m^{-2} s^{-1} the maximum rate of net photosynthesis of *R. rugosa* was greater than that of *R. bracteata* (Fig. 1). It is known that plants growing under high light intensities in their native habitats have a high capacity for photosynthesis at a saturating light intensity and they show lower rates of net photosynthesis than shade plants at low light intensities (Boardman, 1977). *R. bracteata* is native to the southern most part of Japan and grows in high light intensity habitats. On the contrary, *R. rugosa* grows in lower light conditions (shorter duration of sunshine and cloudy weather in growing season). The light compensation points of *R. bracteata* and *R. rugosa* were 60 and 40 μ mol m^{-2} s^{-1}, respectively. Therefore, *R. rugosa* seems to show adaptations to the environment to utilize light more efficiently and it can be speculated that this species may be an important gene resource for breeding cultivars adapted to lower light. Such cultivars adapted to lower light might be the best source of genes for breeding indoor plants.

It is generally known that the leaves of shade plants are thinner and richer in chlorophyll than the leaves of sun plants (Boardman, 1977). In this experiment, the leaves of *R. bracteata* were thinner than those of *R. rugosa* and had a greater chlorophyll content per unit fresh weight and leaf area (Table 1).

Thus *R. bracteata* and *R. rugosa* might be adapted to perform photosynthesis efficiently under their native environmental conditions.

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