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NOTE

COMPARISON OF PHOTOSYNTHETIC EFFICIENCY AND STOMATAL DISTRIBUTION IN DETACHED LEAVES OF FOUR ROSE SPECIES[1]

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Abstract — The photosynthetic rates of detached, young, and actively growing leaves from four rose species were determined. It was concluded that roses were non-efficient plants since they reached light saturation between 8 and 22 klx and had maximum photosynthetic rates of only 10–18 mg CO_2/dm^2 per hr.

The stomata of different species were shown to be different in frequency and size and were also anomocytic. Specific leaf weights, chlorophyll contents, chlorophyll a/b ratios and ash contents also differed among the species and cultivars studied.

INTRODUCTION

There is increased interest in the use of laboratory tests to assess or explain the field or garden performance of species, varieties and clones of plants [5].

Although plant growth is affected by many environmental and physiological factors, a primary determinant is the capacity to fix CO_2. Black *et al.* [2] reviewed the work of many investigators on different crops and divided the plants into two groups: (a) those with high photosynthetic capacity, in which there is continued increase in uptake of CO_2 as light intensity increases to nearly full sunlight (100 klx). Maximum CO_2 uptake at atmospheric concentrations ranges from 50–80 mg/dm^2 of leaf area/hr in these efficient plants; (b) plants with low photosynthetic capacity in which the rates of photosynthetic assimilation range from 15–35 mg/dm^2 per hr and are saturated at light intensities in the range of 10–35 klx.

The rate of movement of CO_2 from the atmosphere to the chloroplasts may limit photosynthesis. The rate of CO_2 fixation is affected by factors present outside the leaf, at the leaf surface, and inside the leaf. The diffusion of CO_2 through the leaf surface is governed by stomatal resistance and cuticule permeability. Stomatal resistance to diffusion is reduced by increases in the number and aperture of the stomata [7].

The number of stomata present in the epidermis of plant leaves may range from a few thousand to over a hundred thousand per cm^2, the exact number depending on the species and on the environmental conditions under which the leaf has developed [4].

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Variation in stomatal number is reported among species [9], and stomata may occur on both surfaces of leaves or on the lower side only [4, 11].

Apart from the work of Howland [6], who showed that greenhouse roses are efficient in net photosynthesis over a wide range of light intensities, there are no reports of the photosynthetic efficiency of species within the genus *Rosa* in regard to either CO_2 fixation or stomatal behavior. In the present investigation we determined photosynthetic rates, light saturation levels, stomatal sizes and numbers and certain leaf characteristics of four rose species.

MATERIALS AND METHODS

Four species of outdoor grown roses (*R. damascena* Mill., *R. chinensis* Jacq. Var. *minima* Rehd., *R. canina* L. and *R. hybrida* L.) were used in this study. Within *R. hybrida*, the three cultivars "Baccara", "Nabati" (a local variety with yellow flowers) and "Safid" (a local variety with white flowers), were selected. All samples were collected in the morning, and four replicates were used for each determination.

Photosynthetic rates were measured on detached young actively growing leaves taken from plants at full bloom. The young leaves were cut under water and then inserted in plexiglass chambers. Compressed air in a storage tank was pumped continuously through the chamber at a rate of 350 ml/min, the air flow being regulated by valves and measured by ball-float flow meters. The relative humidity of the air entering the chamber varied between 66 and 76%. Illumination at 7, 12, 20, 32 and 42 klx at the leaf level was provided by two 300-W incandescent flood lamps. Temperature was maintained at $22 \pm 4^\circ C$ in the chamber by using a water bath circulation system after the infrared radiation had been removed with a 5-cm layer of 2% aqueous solution of $CuSO_4$.

Leaves in the chamber were kept in the dark for 5 min and then the light was turned on until an equilibrium rate of photosynthesis was obtained (20–35 min). The light was then turned off and dark respiration was measured on the same leaf sample for 10–15 min.

Measurements of CO_2 exchange were made with a Beckman IR nondispersion CO_2 analyser model 215B. Photosynthetic rates were calculated according to the method of Brown and Rosenberg [3].

After measuring the rates of photosynthesis of the leaves their areas were determined by the method of Spark [12]. Chlorophyll content of leaves were determined as described by Arnon [1]. Dry weight and ash content were determined at 90°C and 450°C, respectively.

The number of stomata per cm^2 of the lower and upper surfaces of the leaves were determined from cellulose acetate peels examined under microscope, according to the methods of Knech and Orton [8].

RESULTS AND DISCUSSION

Considerable variation was observed among the four rose species for some of the characteristics studied (Table 1). Specific leaf dry weight varied from 271 mg/dm^2 in *R.*

Table 1. The measurement of some characteristics of leaves in different species of roses

Species	Specific dry wt (mg/dm²)	Ash (%)*	mg chl/g fresh wt	chl a/b ratio
Rosa canina L.	484	8.50	1.79	2.48
Rosa damascena Mill.	271	4.15	1.76	3.14
Rosa chinensis Jacq. Var. *minima* Rehd.	485	6.33	1.84	2.12
Rosa hybrida L. 'Safid'	774	8.85	1.19	2.18
Rosa hybrida L. 'Baccara'	689	10.58	1.42	2.85
Rosa hybrida L. 'Nabati'	661	8.27	2.63	2.20

*On the basis of dry weights of samples.

damascena to 774 mg/dm^2 in *R. hybrida* "Safid". *R. hybrida* "Baccara" had the maximum percentage of ash (10.58), while *R. damascena* had the minimum percentage (4.15). Chlorophyll content and chlorophyll a/b ratio of different rose species are also tabulated in Table 1. The chlorophyll (chl) content ranged from 1.19 to 2.63 mg chl/g fresh weight for cultivars "Safid" and "Nabati" of *R. hybrida*, respectively. The highest chlorophyll a/b ratio was observed in *R. damascena* with the value of 3.14 and *R. chinensis* Var. *minima* with the ratio of 2.12 had the lowest value. These data are similar to those of the other plants of low photosynthetic capacity reported by Black *et al.* [2].

Table 2 shows the variations in stomatal frequency and sizes of the rose species. *R. damascena* with 11,459 stomata/cm^2 had the maximum and *R. hybrida* "Safid" with 9330 stomata/cm^2 had the minimum frequency. This is in agreement with the findings of Meidner and Mansfield [9] who reported such variation for other plant species.

Table 2. Size and distribution of stomata on lower epidermis of different species of roses

Species	Mean no. of stomata/cm²	Size, µm	
		Length	Width
Rosa canina L.	9831	2.7	2.1
Rosa damascena Mill.	11,495	2.1	0.9
Rosa chinensis Jacq. Var. *minima* Rehd.	7525	5.0	3.0
Rosa hybrida L. 'Safid'	9330	5.3	3.2
Rosa hybrida L. 'Baccara'	9600	3.0	1.0
Rosa hybrida L. 'Nabati'	10,930	4.0	3.3

Stomatal length ranged from 2.1 µm in *R. damascena* to 5.3 µm in *R. hybrida* "Safid". Stomatal width varied from 0.9 µm in *R. damascena* to 3.3 µm in *R. hybrida* "Nabati" (Table 2). It was evident that rose stomata had no subsidiary cells and several ordinary epidermal cells irregularly surrounded the guard cells. This is the anomocytic or irregular-celled stomatal type, one of four principal stomatal types described by Metcalfe and Chalk [10] for dicotyledons.

The photosynthetic rates of different rose species and cultivars are shown in Fig. 1. The photosynthetic rates of roses increased with light intensity up to about 20 klx and then became stable. The maximum photosynthetic rates ranged from about 10-18 mg CO_2/dm^2 per hr. Because of their light saturation characteristics and low photosynthetic rates, the roses studied here should be classified as non-efficient plants according to Black *et al.* [2].

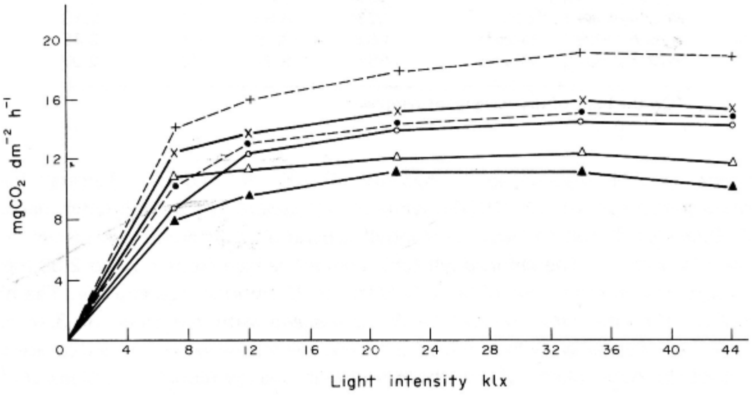

Fig. 1. CO_2 fixation of *Rosa canina*, (+ - - - - - - - - - - +); *R. damascena*, (x————x); *R. chinensis* Var. *minima*, (Δ————Δ); *R. hybrida* 'Baccara', (▲————▲); *R. hybrida* 'Nabati', (0————0); and *R. hybrida* 'Safid', (●————●) at different light intensities.

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