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Seasonal variations in water relations of roses (*Rosa hybrida* cv. Sonia)

L. URBAN*, R. BRUN and P. PYRRHA

Unité de Recherche Intégrée en Horticulture, Institut National de la Recherche Agronomique, Sophia-Antipolis, 06410 Biot, France

Abstract

Parameters of water relations were measured throughout the season in phenologically identical leaves of rose plants grown in a heated greenhouse. The increase in osmotic potential observed from spring to early autumn seems to result from the decrease in the non-osmotic water fraction, and, conversely, its decrease from early autumn to winter seems to be due to an increase in the non-osmotic water fraction. These observations support the hypothesis that the non-osmotic water fraction may be correlated to starch concentration in rose leaves.

Introduction

Rose quality is commercially defined mainly by stem length and size of the flower bud. Cell enlargement, which is the primary means by which plants increase in size, is sensitive to water deficit. Roses tend to be small during the summer period, even if the water supply is non-limiting in soilless conditions and the vapour pressure deficit is substantially reduced (Urban 1993). To understand why rose size decreases during the summer period, it is necessary to know more about seasonal changes in their water relations.

Seasonal changes in water relations have been observed in many species. Changes in osmotic potential and cell wall elasticity have been observed in response to summer drought (*e.g.* Roberts *et al.* 1980, Tyree and Jarvis 1982, Abrams 1988, 1990). Significant seasonal shifts in osmotic and elastic properties have been observed, even under well-watered conditions (Ritchie and Shula 1984, Kwon and Pallardy 1989, Kubiske and Abrams 1991). Large seasonal variations in the relative

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Abbreviations: A_p - non-osmotic water fraction; DM - dry mass; ε - average modulus of elasticity; EC - electrical conductivity; FM - fresh mass; ψ_π - osmotic potential; ψ_p - turgor potential; RWC - relative water content; SM - saturated mass.

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* To whom correspondence should be sent.

water content of apoplastic water have been found in conifers; they have been attributed to ontogeny (Tyree *et al.* 1978).

The aim of this work is to follow the seasonal changes in water relations of rose plants grown in soilless greenhouse conditions.

Materials and methods

The experiment was conducted from spring 1991 to winter 1992 on *Rosa hybrida* cv. Sonia plants grown in a greenhouse. Cuttings were rooted in rockwool cubes on 2 April 1990, then planted on rockwool slabs (Cultilène) on 10 May (7.5 plants per m^2).

Air temperature setpoints were maintained in the greenhouse with a standard climate-control computer. The prescribed daytime temperature for ventilation was set at 20 °C, with a minimum nighttime temperature of 13 °C throughout the season. Shading (*LS16* from *Ludwig Svenson, Hass Energieschirme*, Puderbach-Niederdreis, Germany) was started as soon as total solar radiation reached 800 W m^{-2} and air temperature rose above 30 °C. Average and maximal daytime values of vapour pressure deficit of the air are given in Fig. 1A.

Fertilization followed the recommendations of Brun and Tramier (1988), with pH set at 5.6. Irrigation was scheduled using a standard computer (*Systeem 9, INDAL-ERAL*, Mallemort, France) equipped with a *Kipp and Zonen* solar energy sensor. Irrigation was triggered for each 2.8×10^6 J m^{-2} increment of external horizontal solar energy. Irrigation delivered 100 % of the expected maximum evapotranspiration (De Villèle 1972). There were two additional irrigations during the night. Cumulative drainage over 24 h was at least 40 % of the supplied volume. The electrical conductivity (EC) of the drainage water was set at 1.8 dS m^{-1}. This EC was chosen following the recommendations of Brun and Tramier (1988) for rose cultivation in rockwool. The method devised to achieve the EC monitoring has been described in a previous article (Brun *et al.* 1994).

Parameters of leaf water relations were measured for five periods: 29 April to 17 May 1991, 12 to 27 June 1991, 15 to 30 July 1991, 16 September to 1 October 1991 and 13 to 28 January 1992. Pressure-volume analysis was performed on young mature leaves left unshaded by other foliage (12 leaves per considered period). Estimates of the osmotic potential of leaves at full turgor (ψ_π^{100}), the osmotic potential at zero turgor (ψ_π^0), the relative water content at zero turgor (RWC^0), the non-osmotic water fraction (A_p) and the average modulus of elasticity (ε) were obtained using a method for analysing pressure-volume curves based on a non-linear model, which was found to be more effective in reproducing values observed in the non-turgid region of pressure-volume curves of rose leaves than the usual linear model (Urban *et al.* 1993). Basically, our method consists in identifying the linear relationship between ψ_π^{-1} and RWC with the tangent to this non-linear curve at the point of turgor loss. The relative water content (RWC) is expressed as follows:
RWC = 100(FM-DM)/(SM-DM) where FM, DM and SM represent fresh mass, dry mass and saturated mass of the leaves, respectively.

ψ_π^{100} is given by the extrapolation of the tangent to 100% RWC. The intersection of the tangent with the horizontal axis at $\psi_\pi^{-1} = 0$ gives the value of A_p. ε was calculated as follows:

$\varepsilon = (\psi_\pi^{100} - \psi_\pi^{0})(100 - A_p^{100})/(100 - RWC^0)$ where ψ_π represents the turgor potential. Exponents 0 and 100 are relative to values at turgor-loss and full turgor, respectively.

Data were analyzed using an one way *ANOVA* (time-treatment, $P > 0.05$).

Results and discussion

The volume for water retention in artificial substrates is low compared to that of natural soils. Thus, water availability in the root medium can vary dramatically during the day if watering is insufficient. Moreover, when the concentration of the supplied nutrient solution is higher compared to that taken up by the plants and when transpiration is high, plants may contribute to an increase in salinity. However, water supply was abundant in our growing conditions. Moreover, EC of nutrient solutions were measured repeatedly and did not show any significant shift (data not shown).

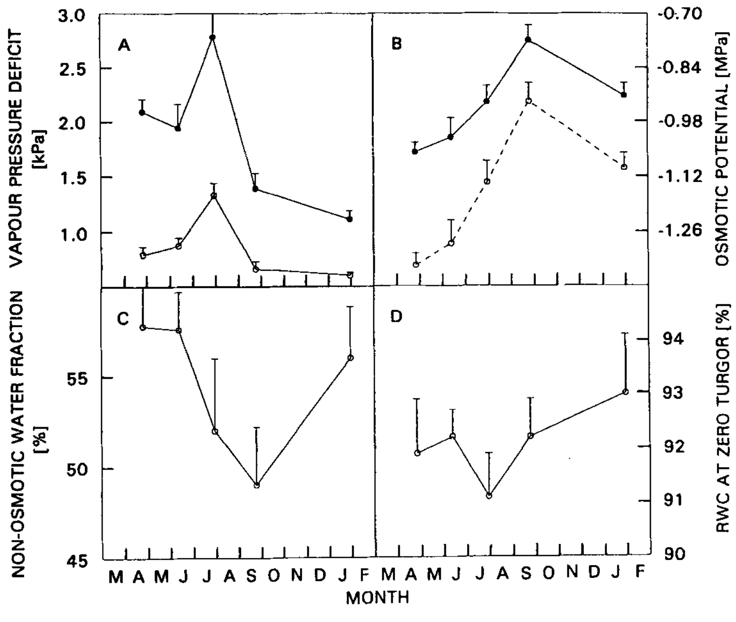

Fig. 1. Seasonal changes in (*A*) vapour pressure deficit of the air [average daytime values (*open circles*) and maximal values measured at noon (*closed circles*)], (*B*) osmotic potential of rose leaves at zero turgor (*open circles*) and at full turgor (*closed circles*), (*C*) non-osmotic water fraction, and (*D*) relative water content at zero turgor. Vertical bars on data points are standard deviations.

In the literature, there is often no clear distinction between ontogenetic and seasonal changes in water relations. In the case of greenhouse rose plants, there is continuous production of new stems and leaves throughout the year, so it was possible to follow purely seasonal effects, as we compared phenologically identical leaves. Moreover, in the literature, the effects of seasonal climatic changes are often confounded with variations in soil water availability induced by climatic changes. As stated previously, water availability was kept almost constant and unlimited throughout our trial.

These two reasons may explain why we did not observe any significant seasonal effect on ε (data not shown) unlike other authors (Ritchie and Shula 1984, Kwon and Pallardy 1989, Kubiske and Abrams 1991). These two reasons may also explain why we observed a 0.3 to 0.4 MPa increase in ψ_π^{100} and ψ_π^0, respectively, from April to September 1991, followed by a 0.1 to 0.2 MPa decrease (Fig. 1B), while other observations on ψ_π made, for instance, by Parker *et al.* (1982) on *Quercus alba*, *Q. rubra* and *Carya tomentosa* differed during a similar period. Indeed, the decrease in ψ_π^0 and ψ_π^{100}, observed by these authors, was attributed to normal ontogenetic accumulation of osmotically active solutes during leaf maturation. In our case, the observed increase in ψ_π^0 and ψ_π^{100} observed from April to September seems to result mainly from the decrease in A_p (Fig. 1C). Conversely, the decrease in ψ_π^0 and ψ_π^{100} observed from early autumn to winter seems to result from the increase in A_p.

Indeed, a decrease in A_p would lead to an increase in the osmotic water fraction and to an increase in ψ_π showing a diluting effect, and conversely (Radin 1983). We indicated in a previous paper that the surprisingly high non-osmotic water fraction in rose leaves (compared to other species) is probably not only due to apoplastic water but also to water bound to macromolecules in the symplasm (Urban *et al.* 1993). Zieslin *et al.* (1975) had observed that starch reserves in rose plants were highest in May and lowest from September to December. Such variations in starch reserves are very similar to the variations we observed in A_p. We feel that this could be an argument in favour of the hypothesis that A_p, determined from pressure-volume curves analysis, is correlated with starch concentration in rose leaves. In addition, Ackerson and Hebert (1981) observed that the osmotic volume tended to decrease as a result of accumulated starch in cotton leaves. Thus, they proposed the hypothesis that solute concentration could result from starch-induced decrease in cellular osmotic volume.

Although the summer drop in A_p and increase in ψ_π did not affect RWC^0 (Fig. 1D), it may reduce turgor and growth. This could explain the reduction in flower bud size, leaf area and stem length observed at this time of the year, especially in hot regions, even in soilless culture conditions with relative humidity control (Urban 1993). Clearly, the summer drop in A_p cannot be seen as a positive adaptive response to water deficit. Moreover, the variations in A_p do not correspond to the variations in vapour pressure deficit. The daytime average vapour pressure deficit and the maximal vapour pressure deficit showed a 450 Pa and a 840 Pa increase, respectively, in the third period (Fig. 1A) while A_p started to drop during the second period (Fig. 1C).

The seasonal variation observed in the non-osmotic water fraction rises new questions. It would now be interesting to investigate precisely how these variations

may be correlated to variations of reserves and involved in the summer decrease in the stem length of cut roses. The hypothesis that part of the non-osmotic water is associated with starch in rose leaves is under current investigation.

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