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In situ measurement of leaf water use efficiency of lilac (*Syringa vulgaris*): comparison with crop plants

O. Bethenod, J. Pilarski* and P. Quetin

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Introduction

In order to understand the regulation between the net CO₂ assimilation rate (*A*) and the transpiration rate (*E*), leaf gas exchange was measured in the field; leaf water use efficiency (*WUE*) of lilac (*Syringa vulgaris*) was compared to those of maize (*Zea mays* L.) and potato (*Solanum tuberosum* L.).

Bierhuizen and Slatyer (1965) pointed out that, for a given water saturation deficit (*vpd*), *WUE* (*A/E*), at the leaf level depends upon the intercellular CO₂ concentration (*C_i*) and stomatal conductance (*g_c*): $A = g_c (C_a - C_i)$; $E = 1.6 g_c (vpd)$; $A/E = (C_a - C_i)/1.6 vdp$; with C_a = CO₂ concentration in air.

A direct estimate of *WUE* is therefore given by the slope of the relationship between *A* and *g_c*. All 3 species considered here are able to maintain their xylem water potential: regardless of the value

their predawn water potential reached between 0.2 and 0.6 MPa, the minimal xylem water potential did not fall below -1.3 MPa for potato and -1.6 MPa for maize and lilac at Grignon. In this case, *C_i* remains constant throughout the day (Bethenod *et al.*, 1988).

Jones (1973) proposed to represent this regulation by the curve of *A versus C_i* called the demand function (Farquahar and Sharkey, 1982). If *C_a* is placed on the *C_i* axis, the leaf CO₂ conductance (*g_c*) is the slope of the straight line joining *C_a* to the corresponding *C_i* on the demand function: this defines the supply function. Our first aim was to study the proportionality between *A* and *g_c*, in order to show how demand function and supply function adjust to each other. But beyond a limit on the demand function, *C_i* increases and *WUE* decreases because of large *g_c* values; *A* then remains at its maximal value (*A_{max}*). The second aim of this work was to compare the *A_{max}* values for the studied species.

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Materials and Methods

Lilac, potato and maize were grown in the field at Grignon, 40 km west of Paris.

Measurements were made with a Parkinson leaf chamber (A.D.C.). The gas circuit was modified: pressurized dry air from cylinders provided a CO₂ concentration in the chamber higher than that in natural air. Two gas-flow controllers (Tylan) ensured a constant flow rate at both reference and chamber levels.

CO₂ net assimilation (*A*) data were normalized at 338 μmol·mol⁻¹ for C_a, according to Bethenod *et al.* (1988) for C₃ leaves; for C₄ leaves, *A* is approximately the same above 320 μmol·mol⁻¹ CO₂. Fig. 1 shows 3 hypothetical adjustments between demand and supply functions. The data shown in following figures correspond to a typical day for each species. Each symbol represents a leaf on different plants in the field for maize and potato, and of 2 trees in a hedge for lilac.

Results

Normalized net assimilation (*A_c*) is plotted *versus* photosynthetic photon flux density (*PPFD*) in Fig. 2. Note that the lilac data show a low scatter. For potato, the high scatter could indicate water stress; but this is not apparent from leaf water potential data (Bethenod *et al.*, 1988). This scatter can be induced by: 1) individual variability and 2) changes in *A* between morning and evening at the same level of incident *PPFD*. The maximum values for potato are about the same as those for lilac.

C_i increases slightly when *PPFD* decreases below 500 μmol·m⁻²·s⁻¹ (Fig. 3).

Fig. 4 displays *A_c* *versus* *g_c*. Up to *g_c* values between 0.20 and 0.23

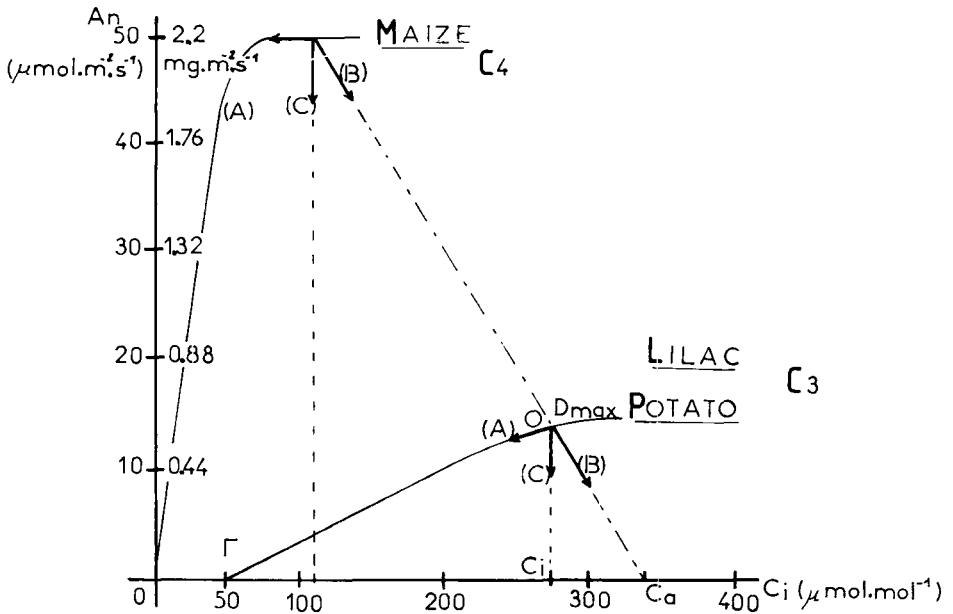


Fig. 1. Theoretical adjustment between demand and supply functions: 3 hypothetical patterns are displayed: A: supply function shifts without any change in demand function; B: demand function shifts without any change in supply function; C: regulation: *C_a* - *C_i* = constant.

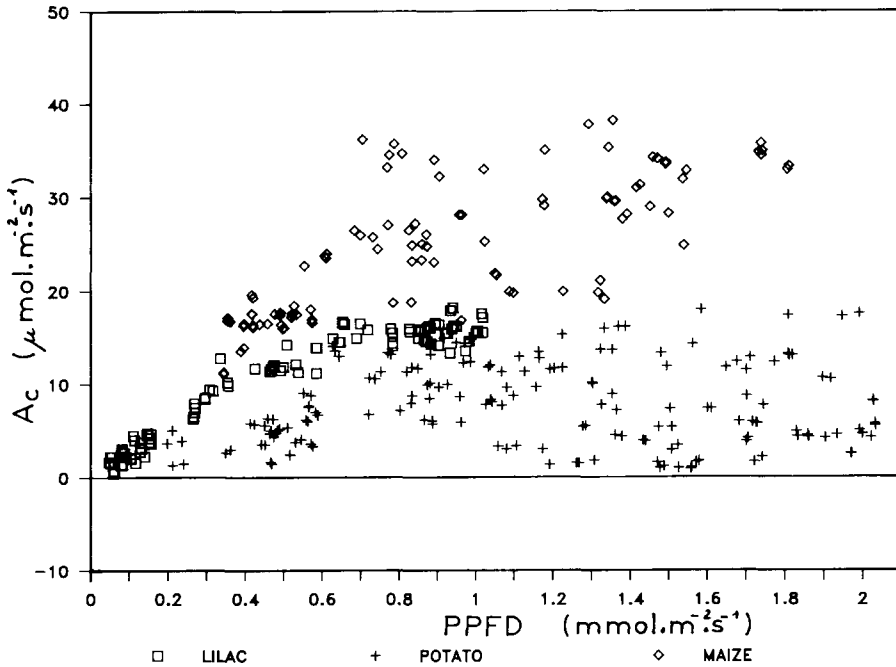


Fig. 2. Net CO_2 assimilation (A_c) versus incident photosynthetic photon flux density, (PPFD); each symbol corresponds to different leaves of a different plant (maize, potato) or a different leaf on 2 trees (lilac). Data are from Aug. 1, 1986 (potato); Aug. 17 (maize), and Sept. 7, 1987 (lilac).

$\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, the g_c dependence of A_c is almost linear and the slope of this line represents $C_a - C_i$. Beyond these values, A does not increase for both C_3 plants, although g_c can be large for lilac. Consequently, 2 phases exist in this $A - g_c$ relationship: a C_i regulated phase for g_c below $0.2 \text{ mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, and a maximum assimilation phase for g_c above $0.23 \text{ mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$.

Discussion and Conclusion

The relation between net assimilation (A_c) and leaf conductance to CO_2 (g_c) is de-

scribed by a hyperbolic curve (Schulze and Hall, 1982; Küppers, 1984), which may be reduced to both asymptotes (Pereira *et al.*, 1987). The regulated phase and the maximum assimilation phase could be summarized by these 2 asymptotes (Fig. 5). H is the point where the maximum of demand function crosses the C_i regulation line. We can observe that, if WUE of maize is higher than the WUE of lilac or potato, the junction occurs within the same range of values of g_c ($0.2 \leq g_c < 0.23 \text{ mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) for the 3 plants studied here, which are known to be very different from one another as far as CO_2 fixation is concerned. Above these values of g_c , water is wasted.

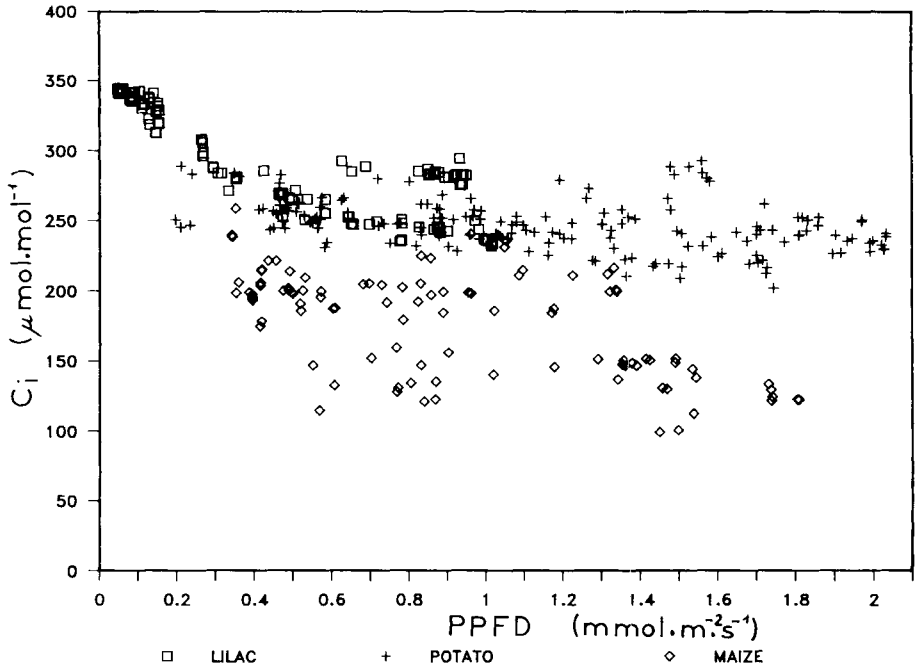


Fig. 3. C_i versus PPFD, with the same symbols as those in Fig. 2.

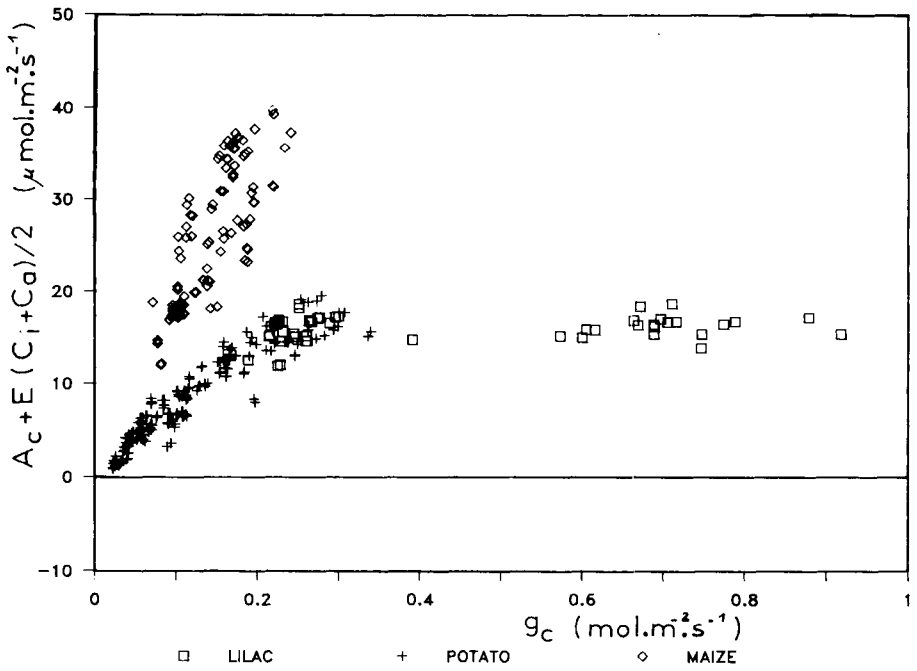


Fig. 4. A_c , corrected for transpiration efflux, versus g_c ; same symbols as those in Fig. 2 with PPFD > 400 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$.

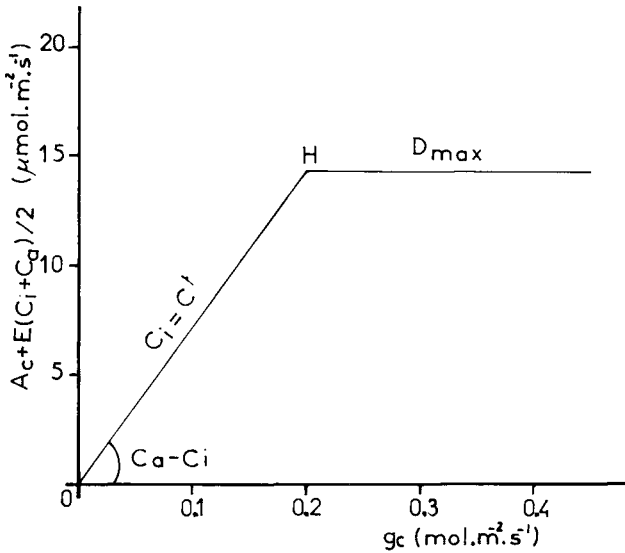


Fig. 5. Ideotype of the relationship between A_c and g_c . H would be the function of the maximum demand function ($D_{max} = A_{max}$) and the C_i regulation line.

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