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

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Introduction

In order to understand the regulation between the net CO_2 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 CO_2 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 $C_a = CO_2$ 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 CO_2 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 CO_2 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.

CO_2 net assimilation *(A)* data were normalized at 338 μmol·mol^{-1} for C_a, according to Bethenod *et al.* (1988) for C_3 leaves; for C_4 leaves, *A* is approximately the same above 320 μmol·mol^{-1} CO_2. 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

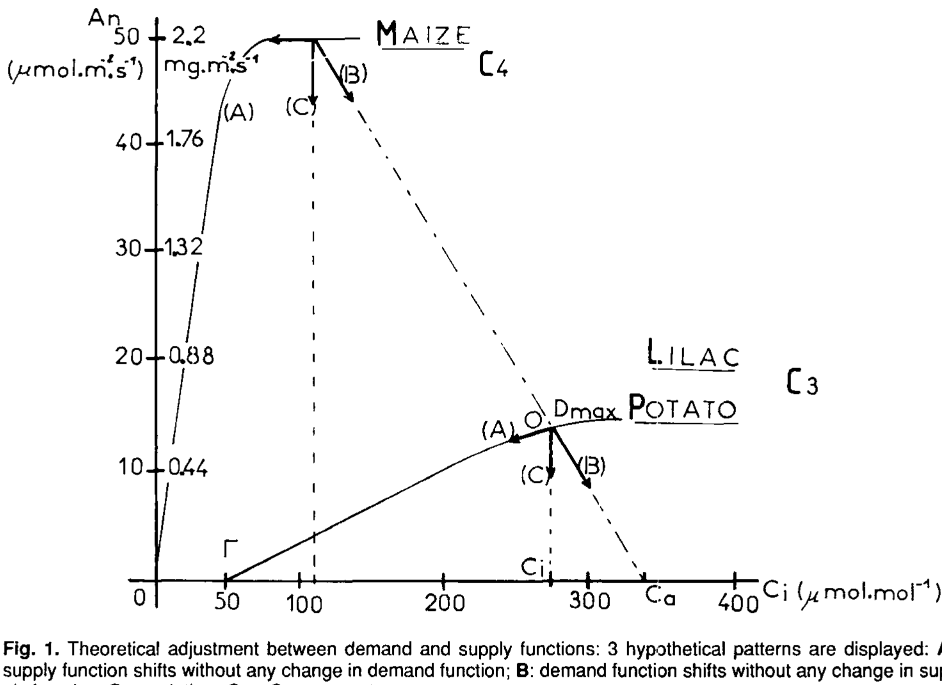

Fig. 1. Theoretical adjustment between demand and supply functions: 3 hypothetical patterns are displayed: **A**: supply function shifts without any change in demand function; **B**: demand function shifts without any change in supply function; **C**: regulation: $C_a - C_i$ = constant.

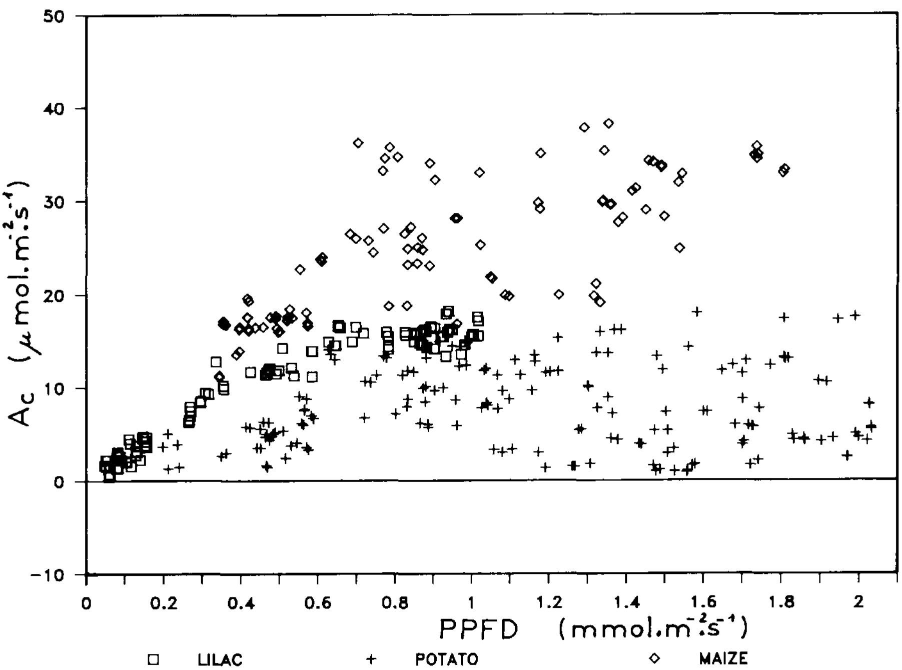

Fig. 2. Net CO_2 assimilation (A_c) *versus* incident photosynthetic photon flux density, *(PPFD);* each symbol corresponds to different leaves of a different plant (maize, potato) or a different leaf on 2 trees (lilac). Data are from Aug. 1, 1986 (potato); Aug. 17 (maize), and Sept. 7, 1987 (lilac).

mol·m^{-2}·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 mol·m^{-2}·s^{-1}, and a maximum assimilation phase for g_c above 0.23 mol·m^{-2}·s^{-1}.

Discussion and Conclusion

The relation between net assimilation (A_c) and leaf conductance to CO_2 (g_c) is described 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 ($0.2 \leq g_c < 0.23$ mol·m^{-2}·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.

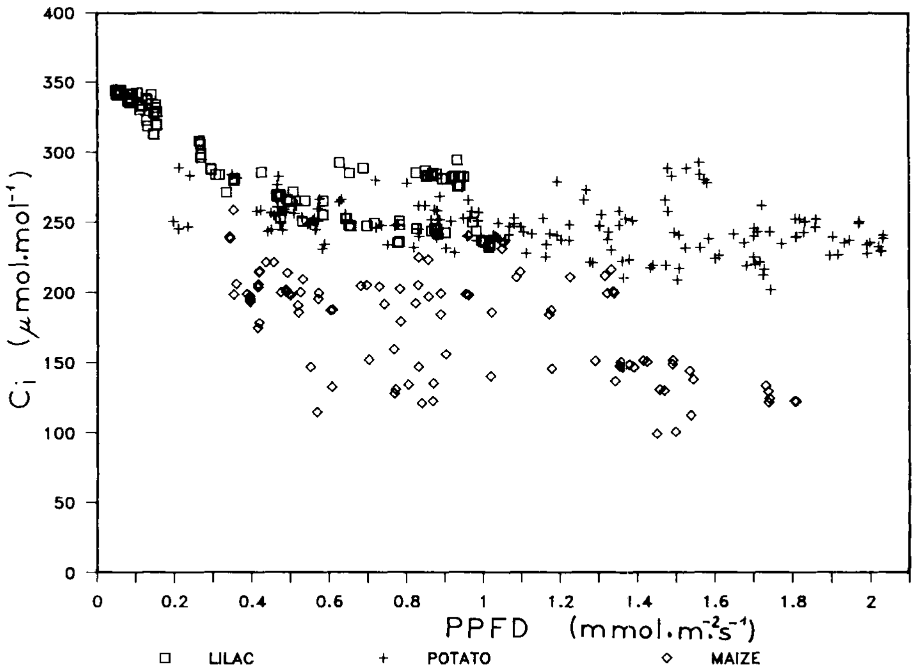

Fig. 3. C_i *versus PPFD*, with the same symbols as those in Fig. 2.

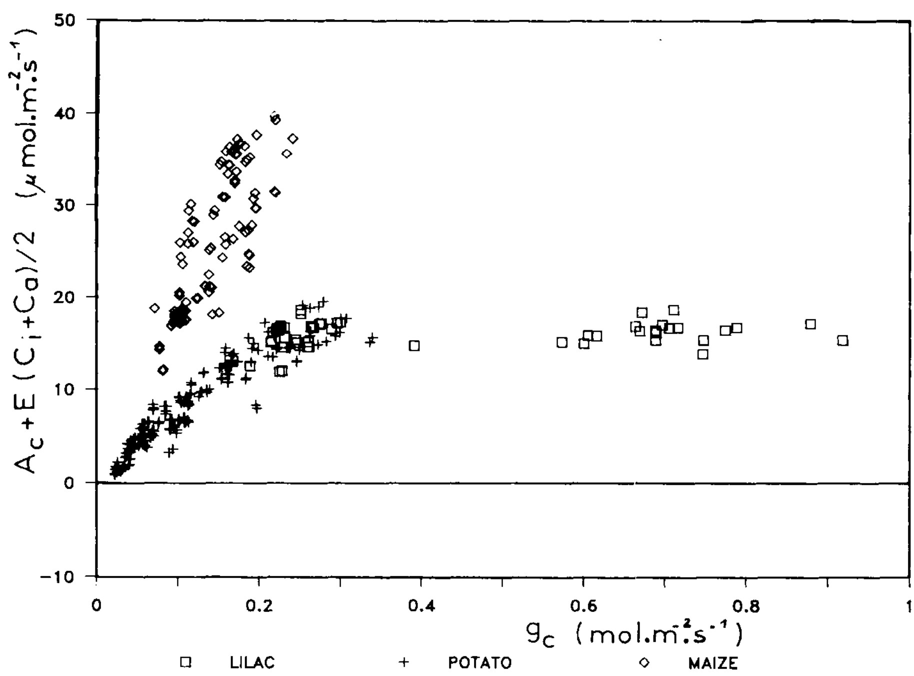

Fig. 4. A_c, corrected for transpiration efflux, *versus* g_c; same symbols as those in Fig. 2 with *PPFD* >400 $\mu mol^{-2} \cdot s^{-1}$.

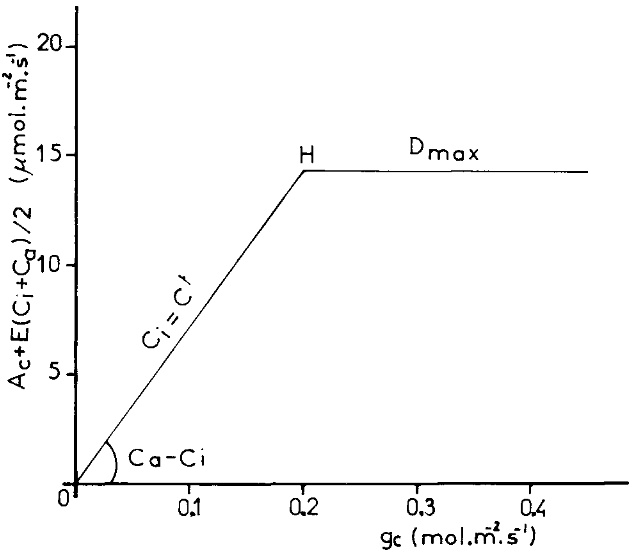

Fig. 5. Ideotype of the relationship between A_c and g_c. *H* would be the function of the maximum demand function ($D_{max} = A_{max}$) and the C_i regulation line.

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