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Understanding Leaf Area Expansion in Sunflower and Wheat Grown under Low-Phosphorus Conditions

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Reductions in plant leaf area and growth as a consequence of P limitations have been attributed both to direct effects of P shortage on the expansion of individual leaves and to a reduced production of assimilates required for growth. In this work we used experimental and simulation techniques to study their importance in determining total plant leaf area on sunflower and wheat plants grown under P-deficient conditions. In both species we studied experimentally the effects of P deficiency on leaf initiation, leaf emergence, leaf expansion, and leaf photosynthesis; in wheat we also studied tillering. Simulation techniques were used to independently calculate source- and sink-limited growth. In our models, sink-limited growth is determined by the effects of temperature on leaf emergence and leaf expansion. In the model, P deficiency can affect the strength of the sink by changing the rate of leaf unfolding and tiller emergence. Carbohydrate demand is supplied from canopy photosynthesis calculated using the subroutines of the model SUCROS (Goudriaan and van Laar, 1994).

Experimental results showed that after 42 d of emergence, total dry weight and total leaf area were reduced to 82% and 83% in low-P sunflower plants, and to 61% and 67% in low-P wheat plants. Total leaf area of P-deficient plants was reduced as the plants had fewer and smaller leaves. In sunflower the fewer number of leaves per plant was due to an increased phyllochron, and in wheat both to an increased phyllochron and to a reduced number of tillers per plant. In low-P plants the higher phyllochron was associated with a reduced rate of leaf primordia initiation and a reduced rate of leaf elongation. In low-P plants the size of individual leaves was determined by a reduced rate of leaf expansion (LER, cm^2 day^{-1}). In sunflower P deficiency also reduced the duration of expansion of individual leaves. The values of LER of individual leaves were not associated with

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their concentration of P, supporting the conclusion that in low-P plants LER is not regulated at leaf level. Low P affected photosynthesis much less at low than at high radiation. Consequently, the apparent quantum yield and dark respiration were not affected by P. The values of maximum CO_2 assimilation (AMAX) in wheat and sunflower were asymptotically related to the concentration of P (%) in their leaves (Fig. 1). Coefficients in the equations of Figure 1 showed a differential sensitivity of AMAX to leaf P percent between wheat and sunflower. Simulated and experimental results (Table I) indicated that in sunflower grown under mild P-stress conditions, the availability of assimilates limited leaf expansion. In wheat, the effects of P deficiency on leaf emergence and tillering explained most of the observed reduction in plant leaf area; the lack of assimilates due to the effects of P deficiency on AMAX did not limit leaf area expansion, and direct effects of P deficiency on the individual expansion of leaves explained up to one-third of the observed reduction in plant leaf area. In general terms, wheat responded to a low P supply mainly by reducing the size of the sink. In sunflower, both sink size and assimilate supply (source) were important in determining the response of this species to low-P conditions. We believe that the effects of P on sink size and activity, i.e., cell division and cell elongation, are still interesting areas of research.

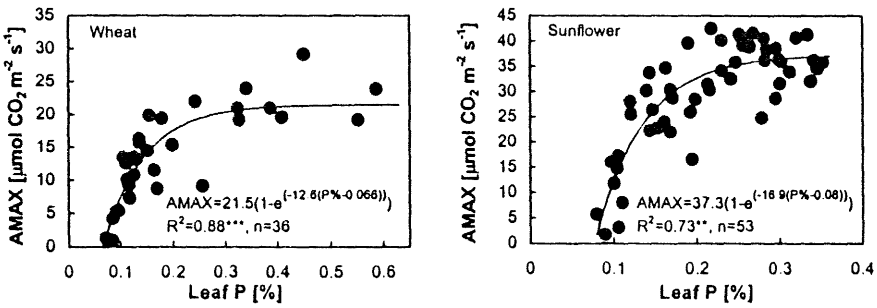

Figure 1. Photosynthesis at high radiation (AMAX) as a function of the concentration of P in the leaves of wheat and sunflower plants grown under different levels of P supply. Adapted from Rodríguez et al., 1998a and Rodríguez et al., 1998b.

Table I. *Estimated Percentage of the Observed Reduction in Total Leaf Area in Sunflower and Wheat Grown under a Mild P Deficiency*

This deficiency was explained by a lack of assimilates, direct effects on the individual leaf expansion, and by other factors, e.g., phyllochron, duration of individual leaf expansion, and number of tillers. Adapted from Rodríguez et al., 1998a and Rodríguez et al., 1998b.

	Assimilates	Direct	Other
Sunflower	42%	17%	41%
Wheat	0%	32%	68%

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