FAST BREAKING PAPERS - 2009

October 2009

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Jaume Flexas talks with *ScienceWatch.com* and answers a few questions about this month's Fast Breaking Paper in the field of Plant & Animal Science. The author has also sent along images of his work.

Article Title: Mesophyll conductance to CO2: current knowledge and future prospects
Authors: **Flexas, J**;Ribas-Carbo, M;Diaz-Espej, A;Galmes, J;Medrano, H
Journal: PLANT CELL ENVIRON
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SW: Why do you think your paper is highly cited?

Recently, mesophyll conductance has become one of the most important aspects of photosynthetic regulation. During photosynthesis, CO_2 has to move from the atmosphere surrounding the leaf to the sub-stomatal internal cavities through the stomata, and from there to the site of carboxylation inside the chloroplast stroma through the mesophyll—passing leaf internal gas, cell wall, liquid, and lipid phases (Figure 1). The resistances inside the leaf mesophyll, or its inverse mesophyll conductance to CO_2 (g_m)—i.e., the facility for CO_2 diffusion inside leaves—have often been overlooked in photosynthesis studies.

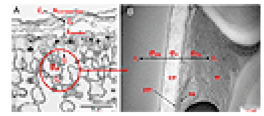
However, this field of research has exponentially increased in activity over the past 23 years, as judged by the evolution of the number of publications on this subject (Figure 2). Very renowned research groups in photosynthesis—including those of Graham Farquhar, John Evans, and Suzanne von Caemmerer (ANU, Australia), Ichiro Terashima (University of Tokyo, Japan), Steve Long (Urbana, IL, USA), Tom Sharkey (Michigan State University, USA), Ülo Niinemets (Estonian University of Life Sciences, Estonia), Francesco Loreto (CNR Rome, Italy) and Bernard Genty (CEA Cadarache, France), among others, are involved in this research and leading the field.

As an increasing number of researchers have become involved in the same area, our paper, along with another by Charles Warren of the University of Sydney's School of Biological Sciences, entitled: "Stand aside stomata, another actor deserves centre stage: the forgotten role of the internal conductance to CO_2 transfer," (*Journal of Experimental Botany* 59:[7]: 1475-87, 2008) were the first and only complete reviews about g_m published in nearly a decade. This may be one of the main reasons why it is highly cited.

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

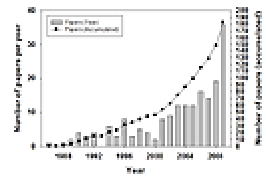
It synthesizes all the aspects on current knowledge about mesophyll conductance, including an historical review of the term and concept, a brief description of available methodology for its estimation, an evaluation of its variability among plant groups, a synthesis of g_m responses to environmental variables, both in the short term and in acclimation, a summary of current knowledge on its physiological and molecular basis, its implications for plant ecology, ecophysiology, and modelling, and a proposal of future prospects for research.

Figure 1 [+] details



Micrograph of the abaxial surface of an olive leaf...

Figure 2 [+] details



Evolution of publications on mesophyll conductance to...

SW: Would you summarize the significance of your paper in layman's terms?

Classically, photosynthesis in higher plants has been considered limited by two factors: stomatal conductance, which regulates the CO_2 supply, and leaf biochemistry—understood as the basic photochemistry, carboxylation, and Calvin cycle reactions—which regulate the CO_2 demand.

In contrast, g_m has been implicitly assumed to be infinite and therefore non-limiting for photosynthesis. The evidences accumulated along the past 20 years clearly show that g_m is sufficiently small so as to significantly limit photosynthesis, especially in species with thick leaves, such as most evergreens.

Moreover, it can be regulated, it has a structural as well as metabolic basis, and it responds rapidly to changes in environmental conditions. In other words, it is now clear that there is a third player in the photosynthesis game, of quantitative importance similar to that of stomata and Rubisco in terms of photosynthesis regulation and/or restriction. This leads to the need of reconsidering the current understanding of the regulation of photosynthesis *in vivo*, as well as reformulating current models of prediction of photosynthesis.

SW: How did you become involved in this research, and were there any problems along the way?

As I had already mentioned in a previous Fast Moving Front commentary, I began to be involved in research on g_m during my Ph.D. thesis, particularly in relation to the fact that drought-induced decreases of g_m could explain drought-induced depressions of photosynthesis, and help solve a long-standing controversy regarding stomatal versus metabolic limitations to photosynthesis under drought conditions.

Later on, I became interested in many aspects of the regulation of g_m, such as its response to environmental variables other than drought, along with CO_2 concentration or vapor pressure deficit, its variations with leaf ageing, and the involvement of some aquaporins in its regulation.

The main problems when doing research on g_m concern the accuracy and validity of the methods for its estimation. All methods rely on quite a few assumptions and are very sensitive to variations in key input parameters.

For this reason, it is necessary to perform accurate tests on the validity of several assumptions and parameters, and use at least two independent methods for the estimation of g_m, which makes these studies very dependent on experimental rigor and also time-consuming.

Concerning the review itself, I became involved on it when I was invited to write a review on g_m by *Plant, Cell and Environment* editors Keith Mott and Tom Sharkey, in recognition for the contribution of our research group to the present knowledge on g_m. Considering the excellence of the above mentioned researchers and others in this field, I was really honored at being selected to write this review, and I'm grateful to the editors for this opportunity.

SW: Where do you see your research leading in the future?

There are needs to explore interspecific differences in g_m and its responses to the environment, as well as to study the structural, physiological, and molecular mechanisms underlying the regulation of g_m. I believe that this is a field which shall develop rapidly in the near future, and that is where my research will mostly focus.

SW: Do you foresee any social or political implications for your research?

Stomatal diffusion conductance and the enzymatic capacity of foliage photosynthetic apparatus have been recognized as important regulatory and limiting factors for photosynthesis and these are the two sole physiological components of most commonly used photosynthesis models—which are the basis for predictions of crop yields, plant responses to climate change, etc.

The accuracy of these prediction models is to some extent limited by the fact that they ignore variations of g_m. Therefore, incorporating algorithms for the estimation of g_m and its variability will improve our prediction capacity.

On the other hand, improved knowledge on the mechanisms regulating g_m and its genetic basis may, in the near future, open new opportunities for the biotechnological improvement of plant photosynthesis, water use efficiency, and yield.

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