Are ecophysiological model essential for European plant science

Michel Génard

Postprint
Version définitive du manuscrit publié dans / Final version of the manuscript published in : Journal of Experimental Botany – E-Letters, 2005, August, 18

Are ecophysiological model essential for European plant science?

- Michel Génard, Plant Scientist

INRA, Plantes et Systèmes de culture Horticoles Dom. St Paul, Agroparc, 84914 Avignon Cedex 9 France

Re: "European plant science: a field of opportunities" *56(417): 1699-1709 doi:10.1093/jxb/eri212*

In their paper on European plant science, the European Plant Science Organization (EPSO) propose that the integration of the information generated by new technology (genotyping and phenotyping) is needed to provide a global view of how plants operate and how they interact with environment. I would like to develop some aspects of this particular point because of its crucial importance for plant science. Some attempts at integration from the gene to the cell have been successfully undertaken (Tomita et al., 1999), but the integration to the organ or the plant has not yet been done. The organ and plant levels are the domain of ecophysiologists and the future in European plant science is to couple approaches of cell physiologists with those of ecophysiologists. A similar situation existed in the past decade in the field of heart research with coexisting independent research providing bottom-up models of cell physiology and top-down models of heart 3D geometry. Following what they called a middle-out modelling, the scientists successfully coupled both approaches (Noble, 2002). However, to follow this route, ecophysiological models have to enlarge their ability to simulate the complexity of plant functioning. Indeed, the plants have the characteristics of complex systems as defined by Wu and Marceau (2002) i.e. exchanging energy and/or mass with their environment and composed of a large number of diverse components that interact with each other nonlinearly. Most of the current models are restricted to the description of phenology, growth and carbon-nitrogen-water balance at the plant level. We need a new generation of models able to simulate important aspects of the metabolism and biophysical behaviours at the plant and organ level (Lescourret and Génard, 2005). To be useful, these models have to be mechanistic enough to account for complex interactions between processes. As illustrated hereafter, such ecophysiological models should be the main link between basic plant science and ecology or agronomy.

The EPSO propose that great improvement in the efficiency of plant breeding could be reached following three complementary routes based either on transgenic technologies, on tools from genomics (used to increase the effectiveness of conventional plant breeding), and on the increase of the diversity of crop available to farmers. Recent works showed that coupling these technologies with mechanistic ecophysiological models could increase their effectiveness (Tardieu, 2003; Yin et al., 2004). The possible interest of a new generation of ecophysiological models can be exemplified through the analysis of the effect of change in sugar unloading in fruit tissues. Assuming for instance that one gene could be manipulated to increase the intensity of unloaded sucrose, the consequence would be an increase of sugar concentration in the tissues and a decrease of tissues water potential which would in turn increase the flux of water supply. Finally, the increase of sucrose supply would increase the carbon and water stored in the fruit and thus the fruit size. Several models built by our team based on peach tree showed that it would also increase the fruit sugar concentration and ethylene emission, and that it would have consequences on leaf photosynthesis and on leaf and stem carbohydrates reserve pool. Indeed, the change in assimilate supply to the fruit overrides the fruit functioning and also the source-sink relationship within the plant. In the usual breeding context, several genes are manipulated and it is clear that the consequences of such changes would be impossible to analyse without a model, especially if the genes are interacting with each other.

According to the EPSO, new agricultures that are economically-viable and respectful of environment have to be proposed. It can be based on improved crops as above-mentioned, but the management of these improved crops in response to environmental factors and production objectives is an essential task to achieve. I think that ecophysiological models can be powerful tools to analyze the effect of new management strategies on plant functioning. Coupling ecophysiological models with optimization procedures, would allow us in the near future to look for optimum plant management systems for a given set of production and environmental objectives. To go further, the interactions between plant and soil and plant and pests, will have to be considered. These interactions are the object of much basic researches but the coupling of ecophysiological plant models with soil and pest models have to be developed intensively to answer important questions such as how to manage irrigation in the context of low water availability or how to limit the use of pesticides without loosing too much yield or quality? Another important point in terms of new agriculture is the ability of ecophysiological models to interfere with sensor technology. These technologies are considered to be promising for field management but the signals measured by the sensors have to be transformed in meaningful variables to define their best use. Moreover, it is important to predict the effect on yield, quality,..., of using management rules based on sensor technologies. An interesting example concerns the water management using micromorphometric sensors. The micromorphometric signal issued from sensor positioned on the plant stem has been linked to a model of fruit growth which allows evaluation of the consequence of different intensities of the sensor signal (and water management strategies) on fruit growth (Génard and Huguet, 1996).

From these short considerations, I have tried to show why new ecophysiological models, the "ecological niche" of which is at the parting of the ways between physiology and agronomy, have to be proposed. They should be an important cornerstone for the development of plant science in the future.

References

Genard M, Huguet JG. 1996. Modeling the response of peach fruit growth to water stress. Tree Physiology 16, 407-415.

Lescourret F, Génard M. 2005. A virtual peach fruit model simulating changes in fruit quality during the final stage of fruit growth. Tree Physiology 25, in press.

Noble D. 2002. Modeling the heart: from genes to cells to the whole organ. Science 295: 1678-1682.

Tardieu F. 2003. Virtual plants: modelling as a too for the genomics of tolerance to water deficit. Trends in Plant Science 8, 9-14.

Tomita M, Hashimoto K, Takahashi K, Shimizy TS, Matsuzaki Y, Miyoshi F, Saito K, Tanida S, Yugi K, Venter JC, Hutchison CA. 1999 E-CELL: software environment for whole-cell simulation. Bioinformatics 15, 72-84.

Wu J, Marceau D. 2002. Modeling complex ecological systems: an introduction. Ecological Modelling 153, 1-6.

Yin X, Struik PC, Kropff MJ. 2004. Role of crop physiology in predicting gene-to-phenotype relationships. Trends in Plant Science 9, 426 -432.

Published August 18, 2005