ADVANCES AND BOTTLENECKS IN MODELLING PLANT WATER AND NUTRIENT RELATIONSHIPS: SUMMARY OF A GROUP DISCUSSION

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This report is a summary of a group discussion at the symposium 'Models in protected cultivation' held in Wageningen, August 1997. Water and nutrients share similar transport paths in the root medium and in the plants. Water acts not only as a transport medium for nutrients but also as a solvent of nutrients. Concentration gradients of solute and solvent regulate diffusive transport in the binary mixtures. Dissolved nutrients convected in the water stream in turn become part of the water flow driving potential by osmosis. At the macroscopic scale, the theoretical foundations of these processes are well understood. This is not true for the microscopic mechanisms in cell membranes from the root to the leaf. Although we have limited knowledge on what transpiration rate is optimal for plant growth and product quality, current theoretical knowledge of crop transpiration is sufficiently advanced to permit accurate modelling and use model output to manage water application for greenhouse crops. Climate control operations, like ventilation or shading, modify the transpiration flux. Including these effects is the next refinement step to introduce in the models. There is a difference between crop water use, i.e., the amount of water that plants take up and crop water requirement, i.e., the amount of water providing the highest yield and quality. Application of the existing knowledge to irrigation management in greenhouses remains rudimentary. This is an area where simple modelling would improve considerably the control that growers can exert on the plant water status and the concentration of solutes in the root medium. Another constraint associated with protected cultivation is the small root volume that limits water storage. Consequently, the rapid changes in the root medium water potential during the period between irrigations may limit water availability, increase the lag of water uptake behind transpiration and generate water stress. The effects on productivity may be minor, but we don't know the consequences for quality of changes in turgor pressure, and periodic shrinkage and expansion of fruits, leaves and stems.

A number of models have been developed for transport of water and nutrients in the soil. Despite better control opportunities in artificial substrates the control of moisture content of these substrates is far less understood than that of soils. This is a consequence of the small root volume in artificial substrates in greenhouses, the desire to use high frequency watering, and the lack of knowledge of the hydraulic properties of artificial substrates. Low mobility of water and solutes in the micro pores of substrates distort the information derived by classical soil sensors and chemical analysis. As a result, management of the leaching fraction remains inefficient. Rules for dilution of recycled drainage water are empirical, based mainly on observations of salinity effects on yield reduction. Reports of product quality improvements and positive interactions with enriched CO_2 atmosphere have appeared. The experimental and conceptual deficiencies in these areas preclude a useful contribution of modelling to improve management and control.

Problems associated with nutrient uptake are linked with the water movement into plants. Still, semi-permeability of cell membranes operates a separation. Another consideration is the distinction between uptake and assimilation that involves energy consumption. It is known that these processes are dependent on the physiological developmental stage of the plants. Crop models for simulating uptake and nutritional effects on growth and development are still in an early phase of development. Some crop

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models already integrate the nitrogen balance in their structure. Submodels for other elements of the mineral nutrition are still lacking. As light intensity, spectral composition and photoperiodicity influence the morphology of plants, these factors must also have an effect on nutrient needs and uptake. The same is true about temperature, absolute and day-to-night fluctuations. Furthermore, soil physicists and plant physiologists rarely work together on modelling nutrient and water relations in the soil/substrate - plant system. Whereas practical recommendations, based on experiments conducted in solutions and hydroponics, seem well established, growth and management models have not yet included them.

Biochemical reactions intervene in the transport of water and nutrients through the plant living tissues. Chemical and mechanical signals causing stomatal closure and cavitation modify the conduction path of the flow. Short and long term responses of the plant may be quite different. An integrated view on mechanistic understanding of the interrelationship between short and long term processes is lacking. To model these physiological processes, a better communication between cell or plant physiologists and crop modellers must be established.

The management of the root medium can benefit from crop models that would include functions for the water and nutrients uptake. They would then improve the efficacy of control through algorithms that "understand" the changing requirements of plants. In parallel with the developments of suitable sensors of water and nutrient status for feedback, they would minimize leaching requirements and loss of fertilizer.