Comments of Examples of Practical Physiologically-Based Models.

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Physiologically-based fruit crop models have been found to be helpful to support practical crop management. Recent examples in apple production include: (1) a carbon balance model that provides predictions of likely weather effects on natural and chemically-induced fruit abscission, and (2) an apple-specific Penman-Monteith model of tree transpiration.

Simulations of carbon supply-demand balances from the simplified apple carbon balance model, “MaluSim” (Lakso et al. 2001), using real-time weather, has been found to correlate with observed natural fruit drop. Excess demand for carbon in relation to supply in the first weeks after bloom leads to reduced fruit growth rates and fruit abscission if critically-low growth rates are reached. Carbon balance simulations that integrate the effects of temperature and radiation also estimate the sensitivity of the apple tree with weather and also to applied growth regulators for thinning down the crop (Robinson and Lakso, 2011). Extension (grower advisor) specialists in several countries are testing and using the model initially to explain unusual responses, and now to predict likely responses so growers can adjust concentrations of thinners. In New York State in the US in one year alone it was estimated that the model saved the apple industry of US$ 5-10 million as the simulations warned growers of a severe carbon deficit that would have led to excessive drop of fruit without adjustments of the normal chemical thinner treatments.

In the case of irrigation scheduling for apple orchards in humid climates such as New York State, it was found that the use of the Reference ETo * Crop Coefficient often led to over-irrigation. An analysis of this method by Annandale and Stockle (1994) suggested that crop coefficients may be variable for tall crops in climates that had different humidity from the climate where the crop coefficient was determined. This is due to greatly differences in the heavy boundary layer in the grass reference and the small boundary layer in a well-mixed apple canopy (Jarvis, 1985). The very small boundary layer in an apple canopy means that stomatal conductances are much more important in apples than in grass, and that the variable ambient vapor pressure deficits (VPD) in humid climates are more important as well.

This situation led to the development an apple-specific Penman-Monteith equation for water use by apple trees (Dragoni and Lakso, 2011) validated against direct measurements (Dragoni et al., 2005). A key to the model was elucidating via physiological studies an unusual response of apple leaf stomata to VPD that is quite unique and plays a significant role in determining apple tree water use.

The success of these practical models demonstrates the value of fundamental research on plant growth and development, physiology and environmental responses focused on practical issues. Such understanding provides a sound basis for robust models.

Annandale, J.G. and Stockle, C.O., 1994. Fluctuation of crop evapotranspiration coefficients with weather: a sensitivity analysis. Irrigation Sci. 15: 1-7.

Dragoni, D., A.N. Lakso and R.M. Piccioni. 2005. Measuring transpiration in apple trees using heat pulse sap flow gauges calibrated with whole-canopy gas exchange chambers. Ag. Forest Meteorol. 130:85-94.

Dragoni, D. and A. N. Lakso, 2011. An apple-specific ET model. Acta Hort. 903:1175-1180.

Jarvis, P.G. 1985. Coupling of transpiration to the atmosphere in horticultural crops: the Omega factor. Acta Hort. 171:187-205.

Lakso, A.N., T.L. Robinson, M.C. Goffinet and M.D. White. 2001a. Apple fruit growth responses to varying thinning methods and timing. Acta Hort 557:407-412.

Lakso, A. N., M. D. White, and D. S. Tustin, 2001b. Simulation modeling of the effects of short and long-term climatic variations on carbon balance of apple trees. Acta Hort. 557:473-480.

Robinson, T. L. and A. N. Lakso. 2011. Predicting chemical thinning response with a carbohydrate model. Acta Hort. 903:743-750.