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Integrating water transport into L-kiwi using an aspect-oriented approach

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Highlights: A simple as well as transparent soil-vine water transport model was created and integrated into the functional model L-kiwi using L-Systems and the aspect-oriented approach. The model will play an important part in modelling variability of the fruit quality within the vine canopy.

Keywords: Water transport, *Actinidia deliciosa*, kiwifruit, plant model, aspect-oriented approach

Water transport from the soil into the plant canopy plays an essential role in plant growth and development; it brings nutrients from the soil and root-produced hormones from the roots and influences many physiological processes. In kiwifruit, effects of manipulations such as use of rootstocks and root pruning on water potential and water transport are of considerable interest. Hence, our aim was to integrate the water transport into an existing model of a kiwifruit vine, L-kiwi (Cieslak et al. 2011a). We chose a version of L-kiwi (Cieslak et al. 2011b) which uses an aspect-oriented approach based on multi-modules. Namely, each element of the plant structure is represented by a sequence of L-system modules with each module representing an aspect of the element's function. Separate sets of productions are used for modelling each aspect, with context-sensitive rules facilitated by local lists of modules to consider/ignore.

The biological system comprised a kiwifruit vine grafted on a rootstock. The initial model (Cieslak et al. 2011b) included sub-models for architecture, carbon transport, auxin transport and biomechanics. In the water transport sub-model, we used transpiration fluxes from the leaves as boundary conditions for the water transport system. We used an empirical model of daily variation of leaf transpiration rate and included a feedback of leaf water potential on transpiration as suggested by Jarvis (1976). Another boundary condition for the vine transport system was set by the soil water potential based on the soil relative water content (Thornley et al. 1990). The root/soil space was represented by a two dimensional finite element system (Blendinger 1996). Effect of soil water content on the soil conductivity was implemented as suggested by Thornley & Jonson (Thornley et al. 1990). At each derivation step of the model, the computation of water transport included three phases: calculating the water flux in the plant structure based on the transpiration fluxes from the leaves, calculating water potentials of the plant modules, and adjusting the values of the water fluxes to take into account feedback impacting water content in the soil and evaluating errors.

The resulting model is simple and transparent. The aspect-oriented approach allowed the addition of the water transport sub-model without changes to other aspects of the system. Compared to L-peach (Allen et al. 2005), which uses an electric circuit analogy for implementation of water transport, the current model is more straightforward and each of its variables has a direct physiological interpretation. In particular, we do not use a notion of electromotive force to represent transpiration of leaves, but rather use the transpiration directly as boundary conditions. Further, the soil component of the model is more comprehensive as it allows adding variation of the soil water potential on the root soil boundary. The model is able to represent the patterns of water potential distribution within the plant and responses to irrigation and soil drying. In the future, the model will include a sub-model of fruit fresh weight and dry weight which requires carbon concentration and water potential as boundary conditions at the point of fruit attachment. This will allow to model variability of the fruit quality within the vine canopy.

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