Virtual Kiwifruit: Modelling Annual Growth Cycle and Light Distribution

Mikolaj Cieslak[1], Alla N. Seleznyova[2], and Jim Hanan[1]
[1]ARC Centre for Complex Systems & Advanced Computational Modelling Centre
Department of Mathematics, University of Queensland, Brisbane, QLD 4072, Australia
[2]HortResearch, Private Bag 11 030, Palmerston North, New Zealand
{cieslak|jim}@maths.uq.edu.au or aseleznyova@hortresearch.co.nz

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Introduction. The aims of our research are to develop hypotheses related to the processes underlying branching pattern of the kiwifruit vine, and to study the effects of horticultural manipulation (winter pruning and rootstock) on the light distribution within the vine's canopy.

Kiwifruit (*Actinidia deliciosa*) is a perennial vine of horticultural importance. The pattern of growth cessation of annual shoots creates three distinct shoot types (short, medium, and long), and is influenced by genotype, environmental conditions, and rootstock (Foster *et al*., 2007). These shoot types are not evenly distributed along the parent shoot, but form branching zones (Seleznyova *et al*., 2002).

We base our modelling approach on the assumption that branching pattern emerges from the overall vigour of shoots and the likelihood of shoot tip abortion at the preformed and neoformed stages of primordia outgrowth. This approach differs from that of Seleznyova *et al*. (2002) for kiwifruit because we do not represent branching patterns as a succession of branching zones, but instead model axillary shoot development as a stochastic process. Similarly, it differs from the approach of Louran *et al*. (2007) for modelling shoot architecture of grapevine cultivars, because we do not represent final metamer (phytomer) number as sequences in segmented zones, but instead model shoot growth cessation. This allows us to compute distributions of final node number and of different axillary shoots types along the parent shoot.

Hypotheses.

H_1. Axillary shoot vigour depends on its position along the parent cane. Kiwifruit conforms to Champagnat's architectural model (Hallé *et al*., 1978), so that relay axes (vigorous shoots) develop in the region of the maximum curvature of the parent axis.

H_2. There is intrinsic variation in shoot vigour emerging during budbreak (Foster *et al*., 2007).

H_3. Growth cessation occurs with different probabilities during any of three developmental stages: opening of the initial cluster of leaves, expansion of the preformed metamers, and production and expansion of the neoformed metamers (Seleznyova *et al*., 2002; Foster *et al*., 2007).

Model. We use L-systems (Karwowski and Prusinkiewicz, 2003) to create a 3-D virtual plant representation (Room *et al*., 1996) of the annual growth cycle of a managed mature kiwifruit vine. In the beginning of each cycle, the structure consists of the main trunk, two leaders, and a specified number of canes trained on a T-bar structure. We focus on the development of axillary bud outgrowth from these canes. Axillary shoot growth is modelled as a discrete-time non-stationary Markov chain (Taylor and Karlin, 1998), with three states: dormant, growing and aborted. The transition probabilities are defined over one phyllochron, and are modulated by a function of position (H_1), initial shoot vigour (H_2) and stage of shoot development (H_3). The distribution of the initial cluster size is based on data from Seleznyova *et al*. (2002).

This approach differs from that of Godin *et al*. (1997), which may be used to model branching patterns with Markov processes, because we represent the temporal structure of the data rather than the spatial structure. That is, the states in our model correspond to the physical states of the shoot apical meristem instead of the branching zones as would be the case in Godin *et al*.'s approach.

Our architectural model simulates distributions of different shoot types along the parent canes and node number distributions for axillary shoots (Fig. 1). These are compared with the existing experimental data from Seleznyova *et al*. (2002) (not shown).

To study the effects of canopy structure on light distribution, we interface our virtual kiwifruit vine with a light environment model using the open L-system formalism. The light environment model estimates the irradiance reaching the canopy leaves using a quasi-Monte Carlo path tracing algorithm (Cieslak *et al*., 2007). We manipulate the canopy structure by changing parameters related to the position and number of canes along the leaders, and quantify the effect of canopy structure on light interception.

Conclusion. The presented architectural model forms a basis for further modelling of the vine's growth and of the interactions between plant architecture, resource allocation and environment. The model will be used to explore the complexity of the vine's architecture, and to predict its behaviour under the influence of various management practices and environmental parameters (e.g., temperature and light).

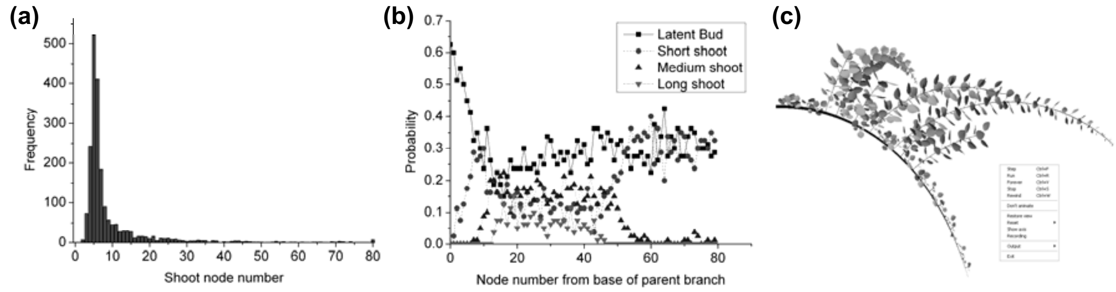

Figure 1: Output from the virtual kiwifruit model: (a) final node number distribution, (b) probability distributions of different axillary shoot types for long parent shoots, and (c) 3-D representation of an individual cane.

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