

## Crop load effects on stem diameter variations in peach evaluated with an integrated plant and fruit model

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**Highlights:** Integrating a mechanistic carbon and water flow model with a model of peach fruit water and carbon accumulation enabled to quantify plant carbon relations with varying crop load. Physiological processes at the plant level could as such be related to effects on fruit growth.

**Keywords:** water relations, carbon relations, stem diameter, fruit growth

### INTRODUCTION

Peach fruit production and quality (*Prunus persica* (L.) Batsch.) are substantially affected by physiological processes related to whole-plant water and carbon relations (e.g. Fishman and Génard, 1998; Conejero et al., 2010). To enhance the understanding of water and dry matter accumulation in peach fruit, it is therefore essential to assess the link with plant water and carbon status. In recent years, some effort has already been done to unravel and interpret variations in stem diameter ( $D_{\text{stem}}$ ) with respect to the plant water and carbon status (e.g. Sevanto et al., 2003; Daudet et al., 2005; De Schepper and Steppe, 2011; De Swaef et al., 2012). Recorded variations in  $D_{\text{stem}}$  are an overall result of several distinct mechanisms which are (in)directly related to water and carbon status: irreversible radial growth, reversible shrinking and swelling (in relation to varying levels of hydration) of living cells and expansion or contraction of dead conducting xylem elements due to the increase or relaxation of internal tensions (Daudet et al., 2005).

The present study aims at unravelling the quantitative effects of crop load on  $D_{\text{stem}}$ , the plant carbon status and fruit growth. Therefore, the dynamic water and carbon flow and storage model of De Schepper and Steppe (2010) was coupled to the fruit water and carbon accumulation model of Fishman and Génard (1998) and was used to describe  $D_{\text{stem}}$  for three different crop loads.

### MATERIALS AND METHODS

The experiment was performed in 2008, in a seven-year-old early maturing peach orchard (*Prunus persica* (L.) Batsch, cv. Flordastar grafted on GF-677 peach rootstock) at the CEBAS-CSIC experimental station in Santomera (Murcia, Spain) (38°06'N, 1°02'W, elevation 110 m). Trees were irrigated daily above the estimated crop evapotranspiration (156%  $ET_c$ ) to assure non-limiting soil water availability. On 10 March (DOY 70) the peach trees were thinned to obtain three different crop load treatments. In a control treatment (*Commercial crop load*) fruits were hand-thinned to leave 25 cm between the fruits to obtain a commercial crop load. In a second treatment, fruits were not thinned, leaving all fruits on the tree (*High crop load*). In a third treatment, all fruits were removed by hand (*Zero crop load*). Three trees were monitored per treatment. On 30 April (DOY 121) fruits of the *Commercial* and *High crop load* treatments were harvested.

Solar radiation, air temperature, relative humidity and wind speed at 2 m above the soil surface were measured by an automatic weather station located near the experimental site and stored every 30 min.

In addition, stem diameter ( $D_{\text{stem}}$ ) variations were measured throughout the experimental period on three trees per treatment. Therefore, a set of linear variable displacement transducers (LVDT) (Model DF 2.5, accuracy 10  $\mu\text{m}$ , Solartron Metrology, Bognor Regis, UK) was used.

### MODEL DESCRIPTION

We extended the tree model of De Schepper and Steppe (2010) with a fruit model (Fishman and Génard, 1998) as demonstrated in Fig. 1. Climatic data were used as input variables to estimate transpiration rate

based on Penman-Monteith (Allen et al., 1998). In the model, vertical water transport within the conductive xylem (X) or phloem (Pc) is driven by pressure potential gradients, because such transport does not require membranes to be crossed. In the case of radial flow or flow to the fruits, membranes need to be crossed and, consequently, flows were described based on total water potential gradients. Within the phloem, dissolved sugars were assumed to be transported by the flowing water according to the principle of mass flow. Unloading at the root level (U) was defined to be dependent on the sucrose concentration. Loading in the crown (L) was simplified to a single parameter which was calibrated using  $D_{\text{stem}}$  data. Transport of carbon and water from the xylem and phloem compartment in the crown towards the fruits was calculated using the model of Fishman and Génard (1998). The number of fruits varied between the different treatments and this was included in the model by multiplying the fruit carbon and water accumulation by the number of fruits.

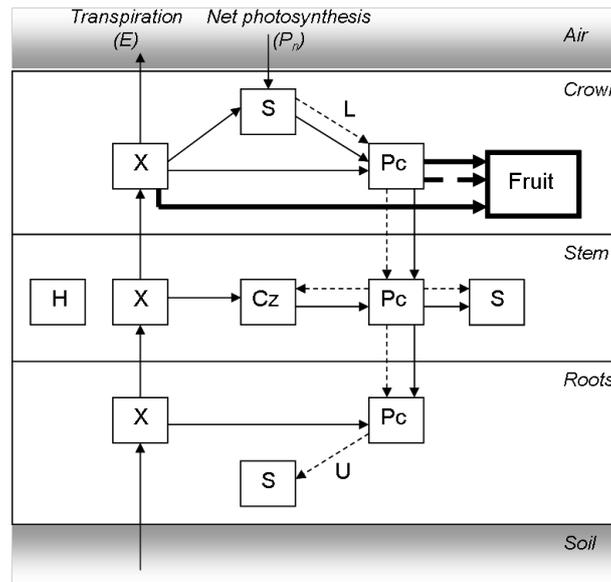


Fig. 1. Diagram with model compartments (H, heartwood; X, conductive xylem; Pc, conductive phloem; S, storage cells; Cz, cambial zone; Fruit) and water (full line) and sugar (dashed line) transport. This transport can occur in both directions: the flow is positive when it is in the direction of the arrow and negative when it is in the opposite direction. L represents loading of sugar in the phloem, U represents unloading of sugar in the storage cells. Thick lines represent flows calculated with the Fishman and Génard model (1998).

The concurrent water and carbon transport causes changes in water content in the different tissues. In the stem and fruit compartment these were converted to volume and corresponding stem and fruit diameter changes (Steppe et al., 2006). Finally, respiration and starch conversion are taken into account in order to close the carbon balance. More details on the model description and equations can be found in De Schepper and Steppe (2010).

The model, consisting of a set of algebraic and differential equations, was implemented and solved numerically using the modelling and simulation software package PhytoSim (Phyto-IT BVBA, Mariakerke, Belgium). This environment allows model implementation, simulation, calibration, sensitivity analysis, identifiability analysis and data acquisition.

## RESULTS AND DISCUSSION

The three treatments (*zero*, *commercial* and *maximum crop load*), varied in the number of fruits at the start of the simulation (DOY 70): on average 0, 547, 3114 fruits per tree, respectively. From harvest on (DOY 121), the number of fruits was zero for all treatments. Apart from the number of fruits, model parameters for all treatments were equal. A set of parameters was optimised using measured data on three treatments, with three trees per treatment. Model simulations and measurements of stem diameter are presented in Fig. 2. Simulations of diurnal variations and overall growth rate of  $D_{\text{stem}}$  corresponded very well with measurements on all three treatments.

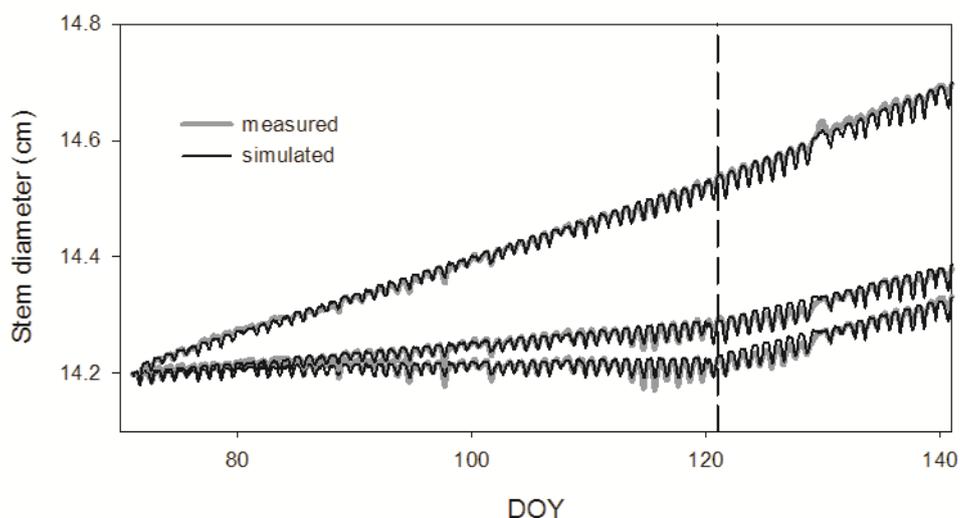


Fig. 2. Measured and simulated stem diameter for the three treatments: *zero crop load* (top), *commercial crop load* (middle) and *maximum crop load* (low). Measured and simulated data are the mean of three trees per treatment. The vertical dashed line indicates harvest of the fruits.

Before harvest,  $D_{\text{stem}}$  growth rate of the *zero crop load* treatment exceeded the growth rate in other treatments because of a relatively higher availability of sugars in the phloem tissue, which were laterally used for growth in the cambial zone of the stem (Fig. 2).  $D_{\text{stem}}$  growth rate increased after harvest for the *commercial* and *maximum crop load* treatments, as a result of an increased amount of sugars available in the phloem tissue after fruit removal.

During the fruit growth period, the enhanced fruit number in the *maximum crop load* treatment increased the competition for sugars between different individual fruits. Consequently, the amount of sugars in the phloem decreased, causing a reduced growth of individual fruits. As such, the average fruit weight in the *commercial crop load* was 123.5 g, whereas for the *maximum crop load* the average was 30.23 g (Conejero et al., 2010).

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