PEACH: A USER FRIENDLY PEACH TREE GROWTH AND YIELD SIMULATION MODEL FOR RESEARCH AND EDUCATION

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Abstract

PEACH, a computer simulation model of annual carbon supply and demand for reproductive and vegetative growth of peach trees is presented. The model simulates daily and seasonal photosynthetic carbon assimilation using seasonal canopy light interception, daily minimum and maximum temperature, and solar radiation as inputs. Carbon partitioning and organ growth are simulated using daily environmental parameters with organ-specific growth and respiration potentials to determine conditional growth capacities and maintenance respiration requirements (i.e. daily carbon demand) of each organ type. Whole tree maintenance respiration is subtracted from the pool of carbon available from photosynthesis. The carbon demand for growth and growth respiration of above-ground organs is then calculated, and adjusted in accordance with available carbon. Residual carbon after whole tree maintenance respiration and above-ground growth is partitioned to the roots. The model operates in the Microsoft® Windows™ environment, allowing easy adjustment of input parameters, rate variables, and state variables for conducting simulation experiments. Default variables for specific peach cultivars and orchard systems in central California are included so that theoretical simulations can be conducted without requiring a full set of site-specific data for each simulation experiment. Results from sample simulations experiments testing the effects of time of fruit thinning, location, and leaf photosynthetic rate on tree growth and fruit yield are discussed.

1. Introduction

PEACH is a computer simulation model of the annual carbon supply and demand in peach trees (DeJong and Grossman, 1994; Grossman and DeJong, 1994b). It is a state-variable model in which fruit, leaf, current-year stem, branch, trunk, and root weight are state variables, and minimum and maximum air and soil temperatures, degree-days, solar radiation and canopy light interception are the driving variables. Photosynthetic carbon assimilation and stored carbohydrates provide the supply of carbon that is demanded for maintenance respiration and growth.

Photosynthetic carbon assimilation is simulated from seasonal patterns of canopy light interception, daily minimum and maximum air temperatures, and solar radiation. The rate variables that characterize photosynthesis are derived from previous studies on peach (DeJong and Doyle, 1984, 1985; DeJong, et al., 1989; DeJong, et al., 1990).

Maintenance respiration is simulated from fruit, leaf, current-year stem, branch, trunk, and root weights, and minimum and maximum air and soil temperatures. The rate variables that characterize maintenance respiration are derived from previous studies on peach (DeJong and Goudriaan, 1989; Grossman and DeJong, 1994a).

Growth is simulated from experimentally-determined maximum organ growth potentials for fruits, leaves, current-year stems, branches, and trunk (Grossman and DeJong, 1995a,b), and degree days. First, the potential net sink strength, the potential growth rate (g dd^{-1}) for each organ type is calculated. Then, the daily conditional growth, the amount of growth that could occur given the number of degree days

Proc. 4th. Int. Sym.
Comp. Mod. on Fruit Research
Ed R. Habib and Ph. Blaise
Acta Hort. 416. ISHS 1996

accumulated on that day, is calculated. The carbohydrate cost of this growth is calculated as the sum of the carbohydrate equivalent weight of the dry weight added by growth and the respiratory cost of that growth.

PEACH simulates partitioning on a daily basis. Carbohydrate is first supplied for maintenance respiration. Then carbohydrate is supplied for the growth of fruits, leaves, current-year stems, and branches, the organs closest to the source. If sufficient carbohydrate is available, these organs grow at their conditional growth rate. If insufficient carbohydrate is available, the fraction of conditional growth that can be supported is calculated as the ratio of the carbohydrate requirement for conditional growth to the carbohydrate available after maintenance respiration. This fraction is multiplied by the conditional growth for each organ type to determine organ growth. Trunk growth is determined by calculating the ratio of carbohydrate requirement for conditional trunk growth to the carbohydrate available after fruit, leaf, stem and branch growth. The model is balanced by assigning carbohydrate remaining after trunk growth to the roots.

Fruits, stems, leaves, and branches are allowed to grow at their conditional rates for the first 500 degree-days after bloom. The carbohydrate cost of this growth is supplied by storage carbohydrates and is deducted from the trunk and roots.

PEACH is implemented under Microsoft® Windows™ Microsoft environment using Visual Basic™. PEACH provides a graphical user interface that allows selection of cultivar, orchard spacing, training system, weather data, location, and other parameters. Full season model runs take approximately 2 1/2 minutes on a 468/66 personal computer. Graphical output is possible and spreadsheet output is Excel-compatible. Help is available on-line and in manual format. Default variables for one cling peach cultivar in four training systems and one freestone peach cultivar in one training system are provided, so that theoretical simulations may be conducted without obtaining site-specific data for each simulation.

2. Model simulations

Simulations of various types were conducted to demonstrate the utility of the model for this meeting. These simulations were conducted for Ross cling peach trees trained in a perpendicular V system (DeJong, et al., 1994). Weather data were obtained from the California Irrigation Management System (CIMIS).

2.1. Time of thinning

In the first set of simulations, the model was parameterized for the Kearney Agricultural Center, Parlier, California, in 1993. In these simulations, bloom occurred on March 5. Three thinning dates were simulated: April 1 (day 91), May 1 (day 121) and May 31 (day 151).

Air and soil temperatures reached their highest values near calendar day 200 (June 19, Fig 1). The number of degree-days per day also peaked near this time. The maximum solar radiation was approximately 730 langleys day^{-1}, attained near calendar day 150 (May 30).

Throughout the season, individual fruit dry weight was higher on earlier thinned trees than on later thinned trees, although crop dry weight was higher on later thinned trees prior to thinning (Figure 2). At harvest, crop dry weight was highest on the earliest thinned trees. Vegetative growth was affected much less than individual fruit growth. These data are similar to the experimental and simulation results obtained for a freestone peach cultivar, Cal Red (Grossman and DeJong, 1994b).

2.2. Location

Simulations were run for two areas in the central valley of California that experience significantly different environmental parameters. The weather at Modesto is moderated by its proximity to the San Joaquin River delta. Shafter, located in the southern portion of the San Joaquin Valley, experiences warmer weather (Fig 3). Degree-day accumulation is more rapid at Shafter than at Modesto. Solar radiation at the two locations is not significantly different. Weather data for 1993 were used in the simulation.

Because Shafter is warmer than Modesto, bloom and vegetative bud break were set one week earlier for Shafter than for Modesto. Thinning was carried out at 865 degree-days after bloom. Harvest was carried out at 2005 degree-days after bloom. These dates were determined from commercial thinning and harvest dates at the Kearney Agricultural Center in 1993.

Early in the season, fruit dry weight was higher at Shafter than at Modesto due to the earlier bloom date and more rapid accumulation of degree-days (Figs 4). Fruit dry weight at the time of thinning was lower in Shafter than in Modesto due to greater source limitations on fruit growth at Shafter. Final individual fruit dry weight at harvest was lower at Shafter than at Modesto. Harvest occurred 34 days earlier at Shafter than at Modesto, although bloom was only 7 days earlier.

Leaf dry weight was greater in Shafter than in Modesto for the first 4.5 months, but Modesto had more leaf dry weight at the end of the season. Stem weights at Shafter were higher than at Modesto.

Daily assimilation at Shafter was lower than daily assimilation at Modesto during the late summer due to the high air temperatures at Shafter (Fig 6). Daily maintenance respiration at Shafter was higher than at Modesto for the majority of the season due to higher air and soil temperatures. Although total assimilation was lower at Modesto than at Shafter, total maintenance respiration was even lower. As a result, total growth was higher at Modesto than at Shafter.

2.3. Leaf photosynthetic rate

The sensitivity of PEACH to the maximum gross photosynthetic rate (AMAXG) was tested by comparing the simulations with the standard setting (22.5 μmol CO_2 m^{-2} sec^{-1}), to simulations with a 20% reduction and a 20% increase in AMAXG. Peak daily assimilation increased approximately 9.2% with the increased AMAXG and decreased approximately 10.9% with the decreased AMAXG (Fig 7). Total assimilation increased 8.6% and decreased 10.3% with the increased and decreased AMAXG, respectively (Figure 8). Total growth increased slightly less than total assimilation, due to increased maintenance respiration.

Due to source limitations on fruit growth, leaf and stem growth, increasing AMAXG increased fruit, leaf and stem dry weight (Figure 9). Fruit dry weight increased 11.6% and decreased 9.6% with increased and decreased AMAXG respectively. Leaf and stem growth were affected to a much lesser extent. Thus, although the PEACH model is sensitive to AMAXG, the response of the various tree components is not linear.

Although these simulation have not been validated with field data, they do serve to show the potential utility of the PEACH model as a tool for identifying key factors that influence peach fruit growth and tree yield potential. The model can also be used to identify areas of research where more information is needed. It provides a preliminary means of testing when changes in a particular factor would be expected to result in substantial changes in tree growth or yield. We are currently obtaining more data on the seasonal fruit growth potential of several additional peach cultivars. Further refinements in other aspects of the model are planned. The current model will be available for distribution to interested individuals in the near future.

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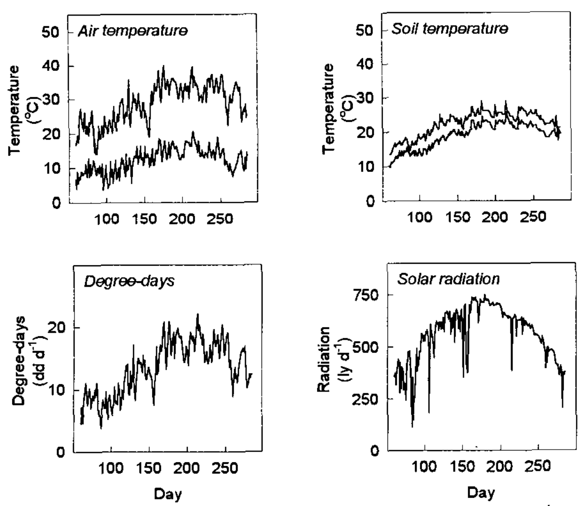

Figure 1. Seasonal patterns of air temperature, soil temperature, degree-day accumulation and solar radiation at the Kearney Agricultural Center, during 1993.

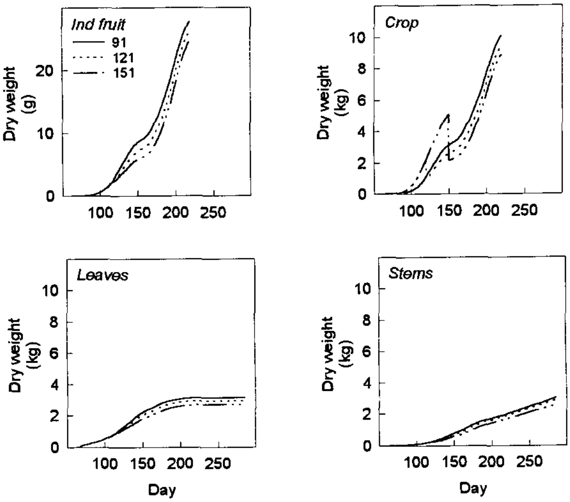

Figure 2. Simulated seasonal patterns of individual fruit, crop, leaf and stem dry weight per tree for peach trees at the Kearney Agricultural Center thinned on calendar days 91, 121 and 151.

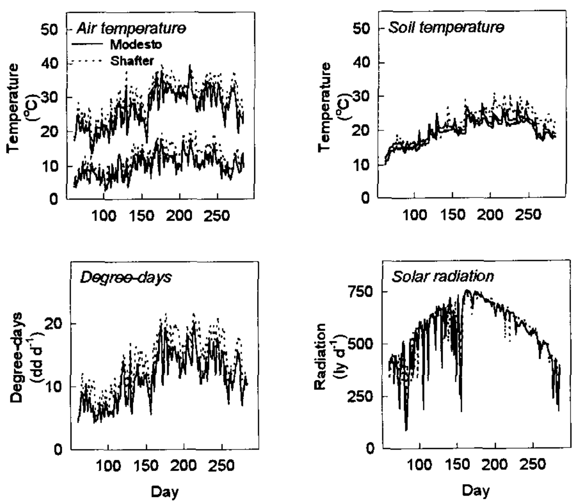

Figure 3. Seasonal patterns of air temperature, soil temperature, degree-day accumulation and solar radiation at Modesto and Shafter during 1993.

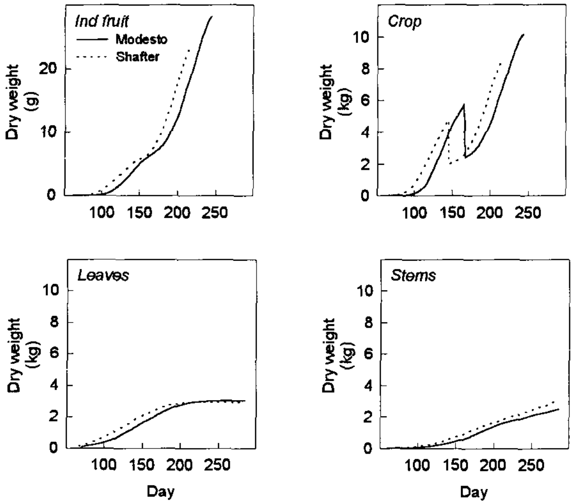

Figure 4. Simulated seasonal patterns of individual fruit, crop, leaf and stem dry weight per tree for peach trees at Modesto and Shafter.

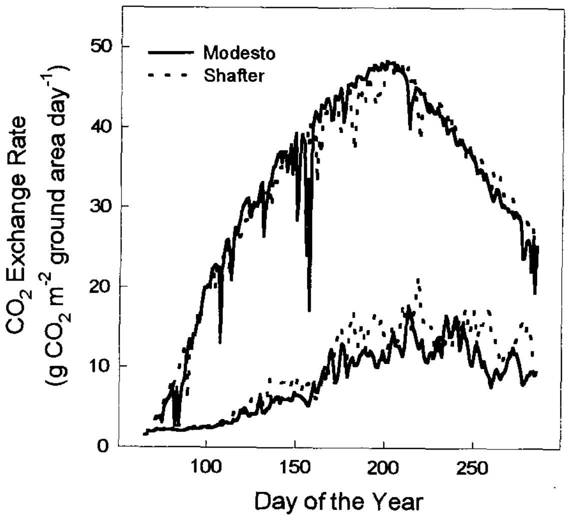

Figure 5. Simulated seasonal patterns of daily carbon assimilation, and maintenance respiration per ground area for peach trees at Modesto and Shafter.

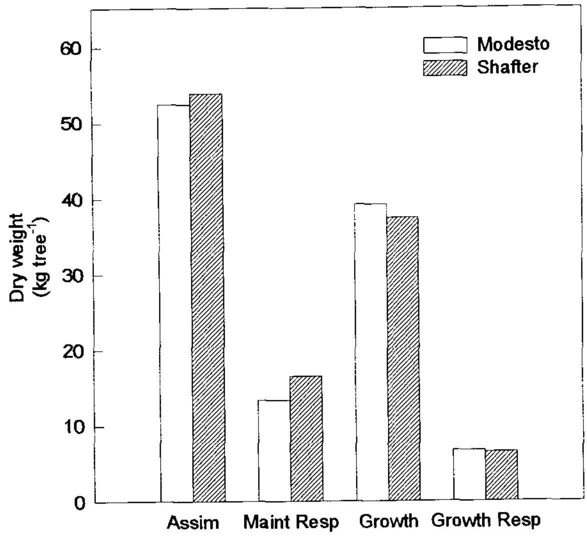

Figure 6. Simulated total assimilation, maintenance respiration, growth and growth respiration per tree for peach trees at Modesto and Shafter.

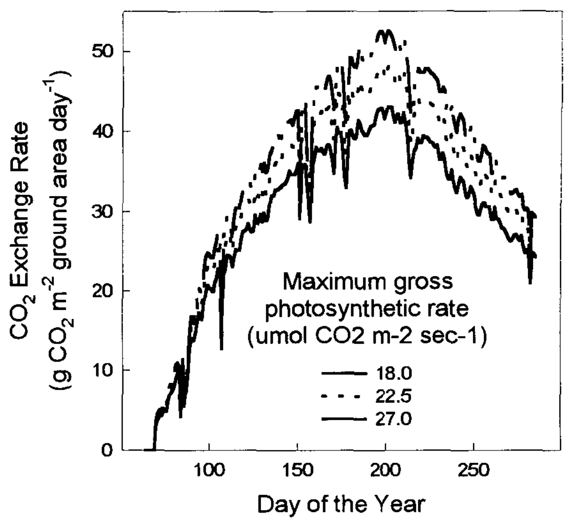

Figure 7. Effect of different maximum gross photosynthetic rates on simulated seasonal patterns of daily carbon assimilation per ground area for peach trees at the Kearney Agricultural Center.

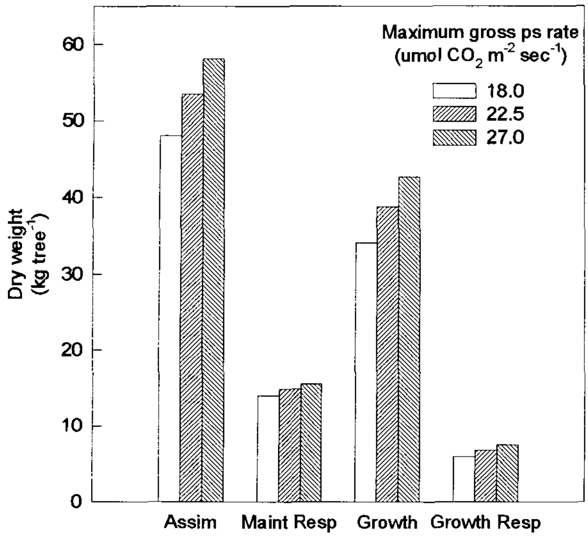

Figure 8. Effect of different maximum gross photosynthetic rates on simulated total assimilation, maintenance respiration, growth and growth respiration per tree for peach trees at the Kearney Agricultural Center.