Assessing the Carbon Budget of Almond Trees and Developing a 3-D Computer Simulation Model of Almond Tree Architectural Growth and Dry Matter Partitioning

Project No.: **09-PREC1-DeJong**

Project Leaders:

Ted M. DeJong
Department of Plant Sciences
UC Davis
One Shields Ave.
Davis, CA 95616
(530) 572-1843
tmdejong@ucdavis.edu

Project Cooperators/Personnel:

J. Six, B. Lampinen, Plant Science Department Faculty
Claudia Negron, Katherine Jarvis-Shean, Graduate Students
Sam Metcalf, Staff Research Associate
Sergio Tombesi, Visiting Graduate Student
David Da Silva, Post-Doctoral Researcher

Objectives:

This project has two major objectives. The first is to review the available research data that has been collected in California on almond (and related species) tree growth; biomass productivity; dry matter partitioning; and carbon and nitrogen assimilation, utilization and distribution.

The second and longer term objective is to develop a comprehensive, functional-structural tree model of almond tree architectural development, growth, and carbon partitioning/source-sink interactions within the tree. This model will simulate growth and physiological responses to light distribution within the canopy and daily temperature changes as well as responses to user imposed pruning practices.

Eventually, pertinent data from both of these objectives will be compiled and provided to Johan Six's laboratory for greenhouse gas modeling purposes.

Interpretive Summary:

Objective 1:
A review of available literature on tree growth; dry matter partitioning and biomass productivity of almond trees over multiple years indicated that there is not enough published data to make reliable estimates of the amount of carbon contained in the standing biomass of mature almond orchards at this time. However, in the past several years it has become standard practice to engage professional tree removal companies to remove almond orchards at the end of their productive life. Since these companies haul and weigh the chippings subsequent to the removal of an orchard, reasonable estimates of orchard standing biomass should be available from these operations. This year we have contacted several of these companies and requested their cooperation in sharing data resulting from orchard removal. We are receiving some cooperation and are beginning to compile data. The data we are attempting to compile includes location of the orchard (so that we can get an aerial view of it from Google earth images), age of the orchard, spacing of the trees and cultivars. In addition, Bruce Lampinen's laboratory has measured the total canopy light interception of some orchards just prior to removal to be able to calibrate the biomass estimates with ground cover estimates from Google images and make adjustments for missing trees. We are in the process of collecting and analyzing those data but it is too early to report results. We believe that this approach will provide good estimates of standing biomass of mature almond orchards and will be useful for estimating beneficial environmental aspects of orchards.

Objective 2:
Almond tree growth and yield is dependent on a complex set of interactions involving the plant genotype, the physiological and developmental processes that occur within the tree, the interaction of these processes with the environment that the tree grows in, and responses to horticultural manipulation of the tree by the grower. Understanding carbon budget, growth and yield responses of perennial crops like almond are even more complex than most crops because the effects of all these factors are carried out over multiple years.

Recent advances in computer technology have made it possible to develop functional-structural plant models that simultaneously simulate whole plant photosynthesis, tree architectural growth and carbon partitioning within the structure of the tree, and display tree structural development in three dimensions on a computer screen. The most advanced of these types of models is the L-Peach model that is being developed to simulate peach tree growth and development. The long-term objective of this project is to continue the development of the L-Peach model and convert it to an L-Almond model.

The first step was to develop statistical models to describe patterns of buds that occur along Nonpareil almond shoots of different lengths. Preliminary statistical models were developed last year based on data collected in 2008. During 2009, three field studies were initiated to develop more detailed statistical shoot models to describe shoots of cultivars with contrasting growth habits (Nonpareil, Aldrich and Winters) and to study shoot architectural responses to water stress and pruning. The data collection phase of these studies will continue through next year.

The second step was to begin converting the L-Peach model into an L-Almond model by inserting leaf photosynthetic characteristics of almond trees and the statistical models of almond shoots into the L-Peach model. Preliminary work on this was done last year and this exercise documented that it could be done. However, we must now wait until the more robust statistical models are developed based on the field work described above.

In the meantime we have completed research to incorporate water transport within the tree structures generated by the L-Peach model so that daily courses of water potential can be calculated for every node within the structure of the simulated trees. Work on calculating carbohydrate flows in the phloem of the simulated trees is underway and is expected to be functional by the end of the year. When this is complete it will be the first time any model has ever been developed that achieved this level of physiological functionality. Because of the efforts to accomplish this ground-breaking phloem transport research, work on the incorporation of nitrogen uptake and distribution within the simulated trees has been delayed until next year. Development of this integrated dynamic simulation model of almond tree growth and productivity is a challenging project but will result in the most sophisticated environmental physiology-based model of a fruit or nut tree ever developed.

A corollary to this project was undertaken to determine the effect of spring temperatures subsequent to bloom on the length of the fruit development period between full bloom and the initiation of hull-split. Previous research with peach, nectarine, plum and prune indicate that temperatures (growing degree-hour accumulation) during the first 30 days after bloom are critical for determining the length of time between full bloom and harvest maturity (Ben Mimoun and DeJong, 1999, Day et al. 2008, DeBuse et al. 2010). In an attempt to determine if similar relationships apply to almond, we initiated a study based on data from the Regional Almond Variety Trials to determine if the period from full bloom to1% hull-split could be predicted from growing degree hours accumulated 30 days after bloom. Initial attempts at establishing similar relationships for 26 almond cultivars were only partially successful but further analysis indicated that there was a strong relationship between the length of the period between full bloom and 1% hull-split and accumulated degree-days between full bloom and 90 days after full bloom for many cultivars. Examples of these relationships for six Californian almond cultivars are shown in **Figure 1**.

These relationships will allow us to make seasonal adjustments in the length of the fruit development period in the L-Almond model (that we are in the process of developing) according to the weather patterns of a specific year. Perhaps more importantly these relationships can be used to help growers predict the date of 1% hull-split in May of any year. Based on the predicted date of 1% hull-split harvest maturity can be predicted by using data from Connell et al. (2008) that provides the average time required for major cultivars to go from 1% to 100% hull-split. This information should be useful to growers and processors for planning their harvest and marketing season as early as late May in any given year.

During the next year we plan to update the Harvest Prediction Models page in the UC Fruit and Nut Research and Information Center website to include an almond harvest prediction model. (http://fruitsandnuts.ucdavis.edu/Weather_Services/)

Bibliography:

Allen, MT., Prusinkiewicz, P., DeJong, TM. (2005) Using L-systems for modeling source-sink interactions, architecture and physiology of growing trees: the L-PEACH model. *New Phytologist* 166, 869-880.

Allen, MT., Prusinkiewicz, P., Favreau, RR., DeJong, TM. (2007) L-Peach, an L-system-based model for simulating architecture, carbohydrate source-sink interactions and physiological responses of growing trees. In ‘Functional-structural plant modeling in crop production’ (Eds. J Vos, LFM. de Visser, PC. Struick, JB Evers) pp. 1

Ben Mimoun M, and DeJong TM. 1999. Using the relation between growing degree hours and harvest date to estimate run-times for peach: a tree growth and yield simulation model. *Acta Horticulturae* 499: 107-114.

Day K., Lopez, G. and DeJong, T.. (2008). Using growing degree hours accumulated thirty days after bloom to predict peach and nectarine harvest date. Acta Hort. 803:163-166.

DeBuse, C., Lopez, G. and DeJong, T. (2010). Using spring weather data to predict harvest date for “Improved French” prune. Acta Hort. (in press)

Connell, J. H. Gradziel, T. M., Lampinen, B. D., Micke, W. C and Floyd J. (2008) Harvest maturity of almond cultivars in California’s Sacramento Valley. In: Proceedings of XIV GREMPA Meeting on Pistachios and Almond, Athens, Greece. (in press)

Esparza, G., DeJong, TM., and Grossman, Y.L. (1999) Modifying PEACH to model the vegetative and reproductive growth of almonds. Acta Hort. 499, 91-98.

Guédon, Y., Barthélémy, D., Caraglio, Y., Costes, E. (2001) Pattern analysis in branching and axillary flowering sequences. *Journal of Theoretical Biolog.* 212, 481-520.

Grossman, YL., and DeJong, TM. (1994) PEACH: A simulation model of reproductive and vegetative growth of peach trees. Tree Physiology 14, 329-345.

Lopez, G., Favreau, R.R., Smith, C., Costes, E., Prusinkiewicz, P. and DeJong, T.M. (2008) Integrating simulation of architectural development and source-sink behaviour of peach trees by incorporating Markov chain and physiological organ function sub-models into L-PEACH. *Functional Plant Biology* 35, 761-771.

Smith, C., Costes, E., Favreau, R., Lopez, G. and DeJong T. (2008) Improving the architecture of simulated trees in L-PEACH by integrating Markov chains and responses to pruning. Acta Horticulturae (in press).

Figure 1. The relationship between the number of days between full bloom and 1% hull-split and accumulated degree-days 90 days after full bloom for six almond cultivars. Regressions were based on data from Regional Variety Trials at Chico, Delta and Kern from 1997-2004.