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.: **08-STEWCROP4-DeJong/Six**

Project Leaders:

T.M. DeJong
Plant Sciences Department
University of California, Davis
One Shields Ave., Mail Stop II
Davis, CA 95616
(530) 572-1843
tmdejong@ucdavis.edu

Johan Six
Plant Sciences Department
University of California, Davis
One Shields Ave., Mail Stop II
Davis, CA 95616
(530) 752-1212
jwsix@ucdavis.edu

Project Cooperator: B. Lampinen

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 and growth, and carbon partitioning/source sink interactions within the plant. This model will simulate growth and physiological responses to light distribution within the canopy and daily temperature changes as well as respond to user imposed pruning practices.

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

Interpretive Summary:

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 budgets and 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. Most experimental research concerning factors that influence these complex processes and the interactions between them has been limited to dealing with one, two or at most three, environmental and/or management factors at a time and then monitoring a limited set of plant responses at the tissue, organ, or whole plant level. While these experimental approaches have yielded substantial information about crop responses to specific factors, many times experiments have led to conflicting results and it has been very difficult to develop an integrated understanding of crop growth and yield responses over multiple years in complex environments. Because of this lack of integrated understanding, research tends to be repeated in various forms over the years and true progress in some areas tends to stagnate until new experimental approaches are developed. Furthermore research tends to get concentrated on specific topics that are measurable with newly available equipment (like Pn, stomatal conductance, water potential, etc.) while information on other important topics (like canopy development processes, canopy architecture, bud fates, carbohydrate storage, etc.) tends to be neglected.

Ecologists and systems biologists are interested in understanding the dynamic interactions of plants with their environment in order to assess the positive and negative influences of tree crop production on the environment. Because perennial crop growth is so complex and dynamic over long periods of time there have been very few quantitative studies of tree growth dynamics and carbon or nutrient budgets over time.

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 simultaneously display tree structural development in three dimensions on a computer screen. The most advanced of these types of models is being developed to simulate peach tree growth and development, and recent advances have successfully simulated responses to pruning and fruit thinning as well as environmental factors such as light and temperature.

In simple terms, this project can be thought of as an attempt to build a working almond tree in silico by assembling all the pertinent physiological and developmental concepts, information and data required to make an almond tree functional, into a unified, integrated computer graphics simulation model. It can be likened to trying to build a working car by studying a car and how it functions and then trying to build a working car by having a third of its parts, no instruction manual, creating missing parts by understanding the general behavior of how the car is supposed to work, and then

assembling the car. This exercise forces one to pay attention to all parts (not just the ones that appear most important or interesting at first glance, or those that are easy to measure) and develop an integrated understanding of tree function. This process points out the most important things that we don't understand about trees but also provides a context for the evaluation of new information or data within the context of the whole plant.

Since we only formally received funding for this project last month work has only recently begun on converting the current L-Peach model into and a 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 and insert them into the larger L-Almond model. This was done based on data collected last spring. Leaf photosynthetic characteristics of Nonpareil almond trees have been also inserted into the new model. Evaluation of this preliminary almond model has begun (Figure 1). Simultaneously, research is being done to incorporate water transport within the tree structure and calculate daily courses of water potential at every node within the structure of the simulated trees and incorporation of nitrogen uptake and distribution within the simulated trees tree is anticipated to begin in January. Development of this integrated dynamic simulation model of almond tree growth and productivity is a challenging project and is already forcing us to consider new aspects of how almond trees actually function.

Figure 1. On the left is a picture of a Nonpareil almond tree after one year of growth in the field. The tree on the right is a picture of a simulated Nonpareil almond tree after one year of simulated growth in the field.