University of California
Division of Agricultural Sciences

PROJECT PLAN/RESEARCH GRANT PROPOSAL

Project Year: **2008-09** Anticipated Duration of Project: **4 years**

Project Leaders: **T.M.DeJong and B.D. Lampinen** Location: **Plant Sciences Department, UC Davis**

Cooperating Personnel: **Sam Metcalf, Claudia Negron, Romeo Favreau**

Project Title: **Developing a 3-D Computer Simulation Model of Walnut Tree Architectural Growth and Dry Matter Partitioning**

Keywords
Commodity(s): **carbon partitioning, tree architecture, pruning, crop modeling, walnut**

Relevant AES/CE Project No. **CA-D-4142-H**

Problem and its Significance:

Crop growth and yield is dependent on a complex set of interactions involving the plant genotype, the physiological and developmental processes that occur within the crop plant, the interaction of these processes with the environment that the plant grows in and responses to horticultural manipulation of the plant by the crop manager. Understanding crop growth and yield responses on perennial crops like walnut 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 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.) tend to be neglected.

At the same time, molecular level plant biologists and geneticists are eager to apply their new-found tools of genomics, proteomics and metabolomics to solve crop production problems but they have even less understanding of the complex factors and processes controlling or influencing crop growth and yield than the field biologists/pomologists. If these so-called modern techniques of plant biology are ever to be successfully applied to solving complex crop production problems a more complete understanding of the factors influencing plant growth processes and complex interactions between them and the environment will be necessary. It will also be important to be able to predict outcomes of specific metabolic or developmental changes over several 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 simultaneously display tree structural development in three dimensions on a computer screen (Allen et al. 2005, 2007). 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 (Figure 1 and Smith et al. 2008) as well as environmental factors such as light and temperature (Lopez et al, 2008). Current 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 tree. The overall objective of this proposal is to develop a walnut tree model that would adapt all of the features of the L-Peach model to simulating walnut tree growth and crop productivity. This is a complex job but this project will capitalize on nearly 20 years of modeling experience with peach trees and apply it to walnut.

This project can be thought of as an attempt to build a working walnut tree *in silico* by assembling all the pertinent physiological and developmental concepts, information and data required to make a walnut tree functional into a unified, integrated 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 manual and creating the 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 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 whole plant functioning as it becomes available.

Objectives:

The overall objective of this project will be to develop a comprehensive functional-structural tree model of walnut 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.

Plans and Procedures:

The basic approach will be to convert the current L-PEACH model into a walnut model by adjusting model parameters to fit walnut data rather than data for peach. This process will utilize physiological and growth data that has been collected over the past two decades on previous walnuts projects by other researchers. The project will proceed along two parallel tracks. One track will involve substituting available physiological data on walnut into the appropriate places in the model and identifying walnut-specific data that are not available and would have to be gathered. The second track will be to develop research on sub-projects to gather the essential data for walnut that are unavailable.

One of the main areas where we already know walnut-specific data needs to be collected is related to shoot architecture and growth. There will need to be intensive studies of shoot growth patterns and fates of buds that occur in one year and grow out in subsequent years. Colleagues in France have developed efficient means to characterize these patterns (Guedon et al. 2001) and collaborations have already been established to use their techniques and statistical procedures to carry out this aspect of the project. One of the primary objectives of the first two years of study will be to conduct field experiments to characterize the natural growth of shoots of several size classes over two years and also to study the response of the same shoot types to pruning. The goal of these studies will be to develop general concepts of shoot behavior and also specific data on the behavior of individual shoot types.

A second substantial challenge will be to convert the peach model from a plant that has a lateral bearing habit (with lateral flower buds, ie.peach) to a plant with a terminal bearing habit and the influence of the different bearing habit on subsequent canopy development. (Note: Although the walnut industry refers to all of the modern new cultivars as "lateral bearing", botanically this is not the case. Cultivars like Chandler have terminal and lateral mixed (vegetative and reproductive) buds that produce short fruitful shoots that all bear fruit terminally. This has interesting ramifications on tree architecture that make continuation of length growth in walnut substantially different than peach.) Adapting the model to this different bearing habit initially will be done by adopting shoot growth behaviors that have been modeled in apples (also terminal bearing) by French colleagues and then adapting them to fit walnut.

The field research will be primarily conducted by a graduate student with some help from Sam Metcalf, Bruce Lampinen's SRA. The graduate student will also work directly

on the modeling with support from the computer scientist working in the DeJong lab (Romeo Favreau). Travel funds are being requested to support in state travel to conduct field research and for the graduate student to make one study visit to Montpellier, France, to analyze data on shoot growth behaviors and learn the statistical techniques involved in this rather complicated analysis (Guedon et al 2001).

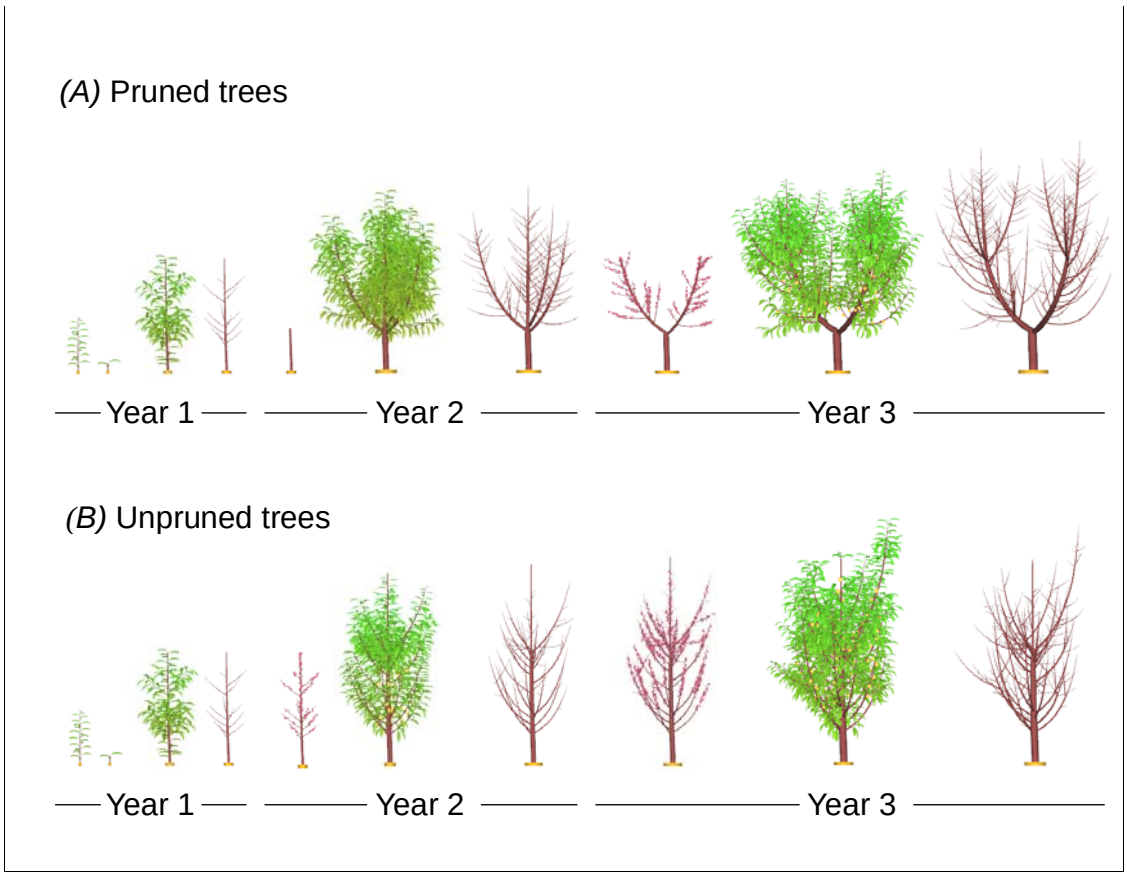

Fig 1. Model output showing three-dimensional depiction of a pruned peach tree (A) and an unpruned peach tree (B) over three years of growth. The pruned tree was trained to a perpendicular V system by means of pruning cuts in winter. The final tree height was about 3.0 m.

References:

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. 139-150. (Springer: The Netherlands).

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BUDGET REQUEST Budget Year

Funding Source

Salaries and Benefits

Postdocs/RA's	GSR 50% during school, 100% in summer		$ 20265
SRA's	20%		$ 10113
Lab/Field Assistance			$
Subtotal		Sub2	$ 30378
Employee benefits	Sub6		$ 10779
		SUBTOTAL	$ 41157
Supplies and Expenses		Sub 3	$
Equipment		Sub 4	$
Travel		Sub 5	$ 3000
		TOTAL	$ 44157

Department account number _____

_____ Date _____

Originator's Signature

COOPERATIVE EXTENSION County Director _____ Date _____

Program Director _____ Date _____

AGRICULTURAL EXPERIMENT STATION Department Chair _____ Date _____

LIAISON OFFICER _____ Date _____

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