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## Objectives:

This project has two major objectives. The first is to review and develop research data on almond (and related species) tree growth; biomass production; dry matter partitioning; and carbon and nitrogen assimilation, utilization and distribution in order to estimate the amount of carbon that is sequestered in almond orchards.

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, seasonal and hourly temperature, pruning, crop load and water stress.

## Introduction:

To estimate the ability of almond orchards to sequester carbon we need to estimate the amount of carbon contained in the biomass of trees. We are taking two approaches to do this: developing a database on the amount of biomass contained in existing orchards and developing a model of almond tree growth and development that can estimate the annual carbon budget of almond trees from the time an orchard is planted until it reaches maturity (development of the L-Almond model).

## Developing a database on standing biomass in almond:

Since relatively little published data are available on whole tree biomass accumulation in almond trees we have been working with professional orchard removal companies to obtain data from them on the weight of chippings they obtain subsequent to the removal of an orchard. While this has been more difficult than anticipated we are making good progress on this objective. As anticipated data from 61 removed orchards representing 2034 acres indicated that orchard biomass varies greatly among orchards. In this set of removed orchards the amount of dry biomass removed varied from 4 to 63 dry tons per acre with the mean and median dry tons per acre removed being 27.7 and 26.3, respectively.

In light of this large variation in orchard standing biomass we have begun to develop methods to survey orchards to estimate standing biomass based on combining measured mean trunk circumference data, missing tree data from aerial photography and biomass data from orchard removal. This involves cooperative work between an orchard removal company (GF Ag Services LLC. Ripon), an enterprise specializing in remote sensing data (Newfields, Sacramento) and UC researchers (DeJong and Lampinen labs, UC Davis).

## Developing an L-Almond Model:

The first step in developing the L-Almond model was to develop statistical models to describe patterns of buds that occur along Nonpareil almond shoots of different lengths. During 2009 and 2010 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. Detailed statistical models of Almond shoot development of the Nonpareil cultivar were completed in 2011.

The second step was to begin converting the L-Peach model into an L-Almond model by inserting leaf photosynthetic characteristics, fruit growth patterns and the statistical models of shoot bud fates of Nonpareil almond into the L-Peach model. This work has been completed and a preliminary version of the L-Almond model has been developed (figure 1). We are now in the process of testing and validating the functioning and quantitative outputs of the model.

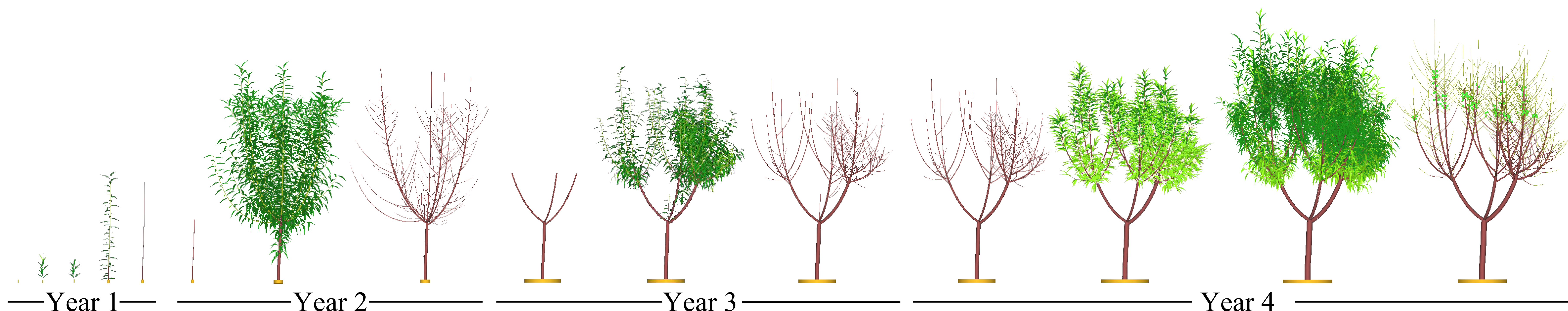


Figure 1. Simulated virtual almond trees produced by the L-Almond model. These renditions are preliminary images depicting four years of growth of young almond trees. Year 1 are trees growing in the nursery. The trees were pruned in the computer during the simulated dormant season between each year but minimal pruning was done between years 3 and 4. The architecture of the trees was developed according to bud fate models developed for Nonpareil almond. Additional research is now required to test the outputs of the model and improve the accuracy of the physiological functioning according to data available from field experiments.

A corollary effort associated with this project has been the analysis of data from the Regional Variety trials sponsored by the Almond Board (1993-2005) and from the spur dynamics study carried out by Dr. Lampinen's laboratory from 2001 to 2007, in order to develop an understanding of factors controlling bearing and long-term spur behaviour needed for developing and validating the L-Almond model. **Three significant publications have resulted from this research.**

### 1. The first provides an understanding of the relationship between Spring temperatures and the timing of hull-split.

#### Fruit development in almond is influenced by early Spring temperatures in California

S. Tombesi, R. Scalia, J. Connell, B. Lampinen and T.M. DeJong

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The period from full bloom (FB) to fruit maturity for individual cultivars of peach, nectarine, plum, and prune is influenced by daily temperatures between the start of FB and 30 d after FB (DAFB). Typically, warm Springs accelerate fruit development. Almond is closely-related to peach, but the date of fruit maturity is not always closely related to the date of harvest. Normally the date of "hull-split" (HS) signals the beginning of fruit maturity. The aim of this study was to determine if the length of the period between FB and HS in several important Californian almond cultivars was related to temperatures shortly after the start of FB. Data on the dates of FB and HS from three locations in the Central Valleys of California (North, Central, and South) were analysed over 8 years to determine the effect of Spring temperatures on the duration of fruit development. Data on 28 cultivars were evaluated, but only the results for 12 of the most important cultivars are reported here. The length of the period of fruit development from FB to HS was negatively correlated with the accumulation of degree-days between FB and 90 DAFB (mean  $R^2 = 0.51 \pm 0.3$ ), with generally poorer correlations with degree-days to 30 or 50 DAFB (mean  $R^2 = 0.31 \pm 0.02$  and  $0.36 \pm 0.3$ , respectively). These results suggest that temperatures in the first 90 DAFB are the primary factor influencing the time of nut maturity in almond cultivars in California.

Data from this paper have been used to develop a web-based model to help growers predict hull-split in their orchards by late May of each year.

See: Hull-split Prediction Model at <http://fruitsandnuts.ucdavis.edu/Weather Services/>

### 2. The second publication provides insight into the factors that influence individual spur productivity and mortality in almond tree canopies.

#### Spur behaviour in almond trees: relationships between previous year spur leaf area, fruit bearing and mortality

Bruce D. Lampinen, Sergio Tombesi, Samuel Metcalf and Theodore M. DeJong

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In mature almond (*Prunus dulcis*) orchards the majority of crop is borne on spurs (short, proleptic shoots) that can live for several years and can produce from one to five fruit. Previous research has led to the hypothesis that spur longevity is related to spur light exposure, cropping and age. However, limited quantitative data are available to substantiate these hypotheses. The objective of this study was to determine spur characteristics that were most highly correlated with spur productivity and longevity in mature, bearing almond trees. We particularly focused on characteristics related to the spur light environment and spur crop load. Previous year spur leaf area was strongly related to spur viability and flowering; the greater the leaf area in the previous year, the higher the probability of spur survival into the next year and the higher the probability for the spur to bear one or more flowers. Previous year bearing also appeared to influence viability and return bloom, especially in spurs with low leaf area. These results suggest that spur source-sink balance is basic to the life cycle of almond spurs. Furthermore, the results are consistent with the hypothesis that spurs are semi-autonomous organs with respect to carbohydrate balance for much of the growing season. The models developed from this work will provide the basis for developing a functional-structural almond crop model that simulates cropping at the spur level. Finally, this information provides general thresholds for maintaining spur viability and productivity that will be useful for developing and evaluating tree training systems and orchard management practices.

### 3. The third publication increases understanding of the potential for almond orchards to yield large crops in two successive years.

#### Relationships between spur- and orchard-level fruit bearing in almond (*Prunus dulcis*)

Sergio Tombesi, Bruce D. Lampinen, Samuel Metcalf and Theodore M. DeJong

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Almond is often considered to be a moderately alternate-bearing species but historical yield data typically do not exhibit clear patterns of alternate bearing at the orchard level, while research has indicated that spurs (the main fruit bearing unit in almond trees) rarely produce fruit in two subsequent years. The objective of the present work was to analyze the bearing behavior of almond trees at both the orchard level and the individual spur level over multiple years to explain this apparent paradox. The 10-year yield patterns of three almond cultivars grown at three different sites within California were analyzed for tendencies of alternate bearing at the orchard level. At the individual spur level, data on spur viability, and number of flowers and fruits per spur were collected on 2400 individually tagged spurs that were observed over 6 years to characterize bearing at that level. At the orchard level one cultivar (Nonpareil) did exhibit a tendency for alternate bearing at one site (Kern) but other cultivars and sites did not. The orchard and the individual trees in which the spur population study was conducted showed tendencies for alternate bearing but the spur population did not. Only a relatively small percentage of the total tagged spur population bore fruit in any given year and therefore while individual fruiting spurs exhibited a high level of non-bearing after fruiting the previous year the spurs that did produce fruit in any year generally did not constitute enough of the total spur population to exhibit alternate bearing at the whole population level. Our results suggest that annual bearing fluctuations in almond are probably mainly due to year-to-year variations of parameters affecting fruit set and that high rates of fruit set in a given year may involve a larger-than-normal percentage of a spur population in fruit bearing. This would limit the size of the spur population available for flowering in the subsequent year and could cause alternate year-bearing. However, from historical records, this would appear to be the exception rather than a normal circumstance. Therefore, almond should not be considered to be a strictly alternate-bearing species.



