FERTILIZER RESEARCH AND EDUCATION PROGRAM CONFERENCE

PROCEEDINGS

NOVEMBER 14, 2001
TULARE, CA

CDFA™
California Department of Food and Agriculture

Seasonal Patterns of Nutrient Uptake and Partitioning as a Function of Crop Load of the 'Hass' Avocado

Project Leaders:
Richard Rosecrance
California State University
School of Agriculture
Chico, CA
(530) 898-5699
rrosecrance@csuchico.edu

Carol J. Lovatt
Dept. of Botany and Plant Sciences
University of California
Riverside, CA
(909) 787-4663
carol.lovatt@ucr.edu

Ben Faber
Cooperative Extension Ventura County
(805) 645-1451
bafaber@ucdavis.edu

Cooperators:
Sam McIntyre and Scott Savard
Somis Pacific Ag Management

INTRODUCTION

For the 'Hass' avocado industry of California, optimal rates and times for soil fertilization of nitrogen, phosphorus, and potassium have not been adequately determined. Fertilization rates, and optimal leaf nutrient ranges have been borrowed from citrus. Competition from Mexico and Chile requires the California avocado industry to increase production per acre to remain profitable. Optimizing fertilization is essential to achieve this goal.

The seasonal pattern of nutrient uptake is a key component of fertilizer management. Matching fertilizer application times and rates with periods of high nutrient demand not only maximizes yield, but also increases nutrient-use efficiency and, thus, reduces the potential for groundwater pollution. Experiments on nutrient uptake and allocation are routinely done to develop best management practices for commercial annual crops. However, determining nutrient uptake in mature trees is considerably more difficult, requiring repeated tree excavations at important phenological periods over the season. Thus, few best management practices have been developed for perennial tree crops.

The goal of this project is to determine the seasonal pattern of nutrient uptake and partitioning in alternate-bearing 'Hass' avocado trees. The research will quantify the amount of each nutrient partitioned into vegetative or reproductive growth, and storage pools. The research will identify the periods of high nutrient use from bloom to harvest as a function of crop load, and thus identify the amount of each nutrient required, and when it is required to produce an on-crop and good return crop the following year. The results will enable us to provide guidelines for fertilization based on maximum nutrient-use efficiency, and eliminate applications made during ineffective periods for uptake to thus protect the groundwater, and increase profitability for California's 6,000 avocado growers.

PROJECT OBJECTIVES

The objectives of the study include:

1. Quantify the seasonal pattern of N, P, K, B, Ca, and Zn uptake and partitioning in 'Hass' avocado trees bearing.
2. Quantify the effects of different crop loads on these seasonal patterns of nutrient uptake, partitioning into vegetative and reproductive growth, and storage.
3. Determine the seasonal patterns of nutrient uptake in alternate bear avocado trees and develop best management fertilizer practices for the 'Hass' avocado tree

PROJECT DESCRIPTION

The research is being conducted in a commercially bearing avocado orchard in Somis, CA. In June, 2001, 60 trees were selected for inclusion in the project based on their trunk diameter, height, canopy size, and fruiting potential. Thirty of these trees were subsequently defruited to establish both lightly fruiting and heavy fruiting trees. The experiment is a

Table 1. Effect of tree size on total fresh weight, and distribution of mature avocado trees.

	Large Tree		*Small Tree*	
Tree Component	*Fresh Weight (kg)*	*Proportion of total*	*Fresh Weight (kg)*	*Proportion of total*
Leaves	64	8	38	10
Immature Fruit	39	5	24	6
Mature Fruit	48	6	0	0
Fine Roots	37	5	23	6
Roots > 5 mm	105	13	41	10
Rootstock	85	11	39	10
Trunk	80	10	25	6
Scaffold Branches	310	38	177	45
Current Yr. Wood	40	5	23	6
Total	808	100	389	100

randomized complete block design, with the following factors: 1) cropping status (heavily cropping—On and lightly cropping—Off trees), and 2) time of excavation. Four trees (two on- and two-off year trees) will be excavated at each harvest date. There is a total of 13 excavation dates. For each date, two on- and two off-year trees will be excavated, the entire tree will be dissected into the following components, and the total weight of each component determined: leaves, new shoots, inflorescences or fruit (separated into seed and flesh), small branches (≤ 2.5 cm), mid-size branches (2.5-5.0 cm), scaffolding branches, scion trunk (dissected into bark and wood), rootstock trunk (dissected into bark and wood), scaffolding roots, small roots, and new roots. Sub-samples will be dried, ground, and analyzed for carbon, nitrogen, nitrate-nitrogen, phosphorus, potassium, calcium, iron, magnesium, manganese, zinc, boron, sulfur, copper, sodium, chloride, and aluminum. These analyses will allow us to meet objective (1) to determine the period(s) of high nutrient demand in the phenology of the 'Hass' avocado tree. Having trees with varying crop loads will enable us to meet objective (2) to quantify the effect of crop load on nutrient uptake and partitioning into new vegetative and reproductive growth, and storage.

Data analysis. The results obtained above will be used to calculate g nutrient per tree by the following equation using nitrogen as the example:

g N/g dry wt tissue X g dry wt tissue/g fr wt tissue X total fr wt tissue/tree = total g N/tree

Nutrient uptake will be determined as the difference in total tree nutrient contents from sequential tree excavations. The total amount of each nutrient required by developing flowers and fruit will be plotted monthly over the course of fruit development along with the increase in individual fruit biomass. The total increase in vegetative biomass (both roots and shoots) and total nutrient content of each component will be calculated and plotted monthly.

RESULTS AND CONCLUSIONS

As part of the first season of a two and half-year study, a large and small tree was excavated to see if tree size influenced the distribution of the various tree components (Table 1). Although the large tree weighed twice as much as the small tree, the tree components comprised similar percentages of the total tree weight in both trees. This is important because tree size can be used as a covariant in determining total tree nutrient uptake. The roots, leaves, and trunk and canopy branches, for example, comprised approximately 30%, 10%, and 50% of total tree fresh weight in both large and small trees. At the time of submitting this report, the nutrient and data analyses from the summer tree excavations were incomplete.

Precision Horticulture: Technology Development and Research and Management Applications

Project Leaders:
Patrick H. Brown
Department of Pomology
University of California, Davis
530-752-0929
phbrown@ucdavis.edu.

Nacer Bellaloui
College of Agriculture
California State University, Chico
Chico, CA

Cooperators:
Hening Hu
Department of Pomology
University of California, Davis

Shrini K. Upadhyaya
Department of Biological and Agricultural Engineering
University of California, Davis

William Reinert
Precision Farm Enterprises
Davis, CA
Uriel Rosa
Department of Biological and Agricultural Engineering
University of California, Davis

Paramount Farming Company
Bakersfield, CA

Richard Plant
Department of Agronomy and Range Science
University of California, Davis

Bob Beede
University of California Cooperative Extension
Kings County

INTRODUCTION

Recent studies have determined that yield is the primary determinant of nutrient demand and uptake efficiency and therefore, fertilizer needs. In tree crops, however, yields vary dramatically from tree to tree within an orchard and between orchards, making accurate fertilizer recommendations impossible. Given this fundamental limitation, it has been impossible to develop truly efficient orchard fertilizer management systems, or to conduct nutritional research experiments properly.

The ability to map yield in an orchard and to use that information to optimize inputs would revolutionize tree crop industries and directly contribute to improved resource use efficiency. The benefits to in-field experimentation would be equally significant. The most direct benefit of this information would be the ability to optimize fertilization strategies on a site-specific basis. This is the key to improving nutrient use efficiency.

This project aims to develop the means to rapidly harvest and map pistachio tree yields in commercial orchards on a tree-by-tree basis by integrating the Global Positioning System (GPS) and yield monitors into the harvesting machinery. This will be followed by development of statistical and visual computational methodology to analyze and map results. Soil and plant testing will be used to determine the cause of yield variability and experimental manipulations will be conducted to optimize yield and management efficiency. The lessons learned in this project will then be extended to all tree crops in California.

The ability to optimize production systems benefits everyone from producer to consumer. It will allow researchers to conduct better research programs and improve our ability to protect the environment.

PROJECT OBJECTIVES

Short-term aim: In the first years of this current project we will develop the harvesting machinery, initiate statistical and mapping methodologies to allow growers to view and interpret the annual productivity of each tree in their orchards. This will then be used to optimize fertilization strategies, and to improve on-farm research capability.

The specific objectives are:

1. To develop technology to allow large-scale, tree-to-tree yield analysis.
2. To utilize this technology to determine the factors that contribute to yield variability including statistical, mapping, and biological interpretations.
3. To conduct a demonstration research project utilizing these technologies.
4. To conduct workshops to demonstrate the technology.

PROJECT DESCRIPTION

We selected 80 acres containing roughly 12,000 trees of a pistachio ranch located at the Paramount Farming Company in southern California. Different tasks of the project are underway, including designing, developing, and building a modified pistachio harvest machine to allow for the collection of real-time, tree-by-tree harvest data. In collaboration with Paramount Farming and Precision Farming Enterprise, we are adapting a commercial pistachio harvester to include a yield monitor, profiler, and a modified GPS system. Building a yield monitoring system will allow us to monitor the yield on tree-by-tree basis. In addition, we are conducting crop diagnostics using high-resolution aerial maps that include growth, stress, and multi-spectral infrared map which combines thermal infrared, near infrared and visible light into a single image for maximum crop diagnostics. These images assist in the determination of tree growth and environmental variation. GPS-sensor- based systems of Electrical Conductivity (EC), and Texture and Compaction Index (TCI) were used to identify the variability in soil properties across the field.

RESULTS

In year 2001, we mapped 80 acres for soil Texture and Compaction Index (TCI), moisture content (MC) (Figure 1 and 2), and Electrical Conductivity (EC) (Figure 3 and 4) using GPS-based technology. Soil and leaf samples were taken to analyze the soil fertility and leaf nutrition status. The harvesting equipment for pistachio is being modified, and a weighing system has been designed and built.

Aerial images were taken using remote sensing technology (images are currently being analyzed). By comparing patterns and trends between the three images, a greater understanding of the crop conditions and potential causes of variability can be gained. The presence of a change in one or more of the images can yield important information on the possible causes, trends and implications of a crop production problem. The soil texture and compaction index showed differences across the field. This is indicated by the light and dark colors on the TCI map. TCI ranges from about 900 to 1300 (draft, lb). Also, the EC across the field showed differences at 1-foot deep (ranges from 16 to 153 mS/m) and at 3-foot deep (ranges from 18 to 164 mS/m). However, moisture content (MC) of the soil did not show a significant difference across the field (18-22%). Differences in TCI and EC across the field will be used for further investigation to understand the source of variations. Therefore, soil and leaf samples were taken from sites where differences in TCI and EC occurred. The samples will be analyzed for chemical and physical characteristics of the soil and nutrient status in leaf tissues. This approach would allow us to identify the source of variation across the field, and enable us to relate those variation sources to the location of each tree as mapped by the GPS. Our aim here is to link the measured parameters to the yield of each tree. The yield of each tree will be harvested using modified harvesting equipment, which is currently under testing using tomatoes. The non-significant differences in soil moisture content across the field may be due to the continuous irrigation of the field. Therefore, further TCI and MC measurements will be carried out under water stress conditions.

The preliminary results clearly indicate that this is a feasible project, and that it is possible to develop a practical, and valuable harvester to provide tree-by-tree yield data. Once this data is available, growers will be able to optimize tree performance, identify problem areas, locate superior trees, design and easily test new field practices, and spot pending orchard problems before they become serious.

We strongly believe this technology has important implications for all tree crops. Certain tree crops (prune, olive) can immediately adopt this technology, while others may need to see the advantages of precision management before considering adoption. As an example, almonds are currently shaken to the ground, raked, and picked in three operations, which makes individual tree harvesting and analysis difficult. These three operations also require a clean orchard floor (which in-

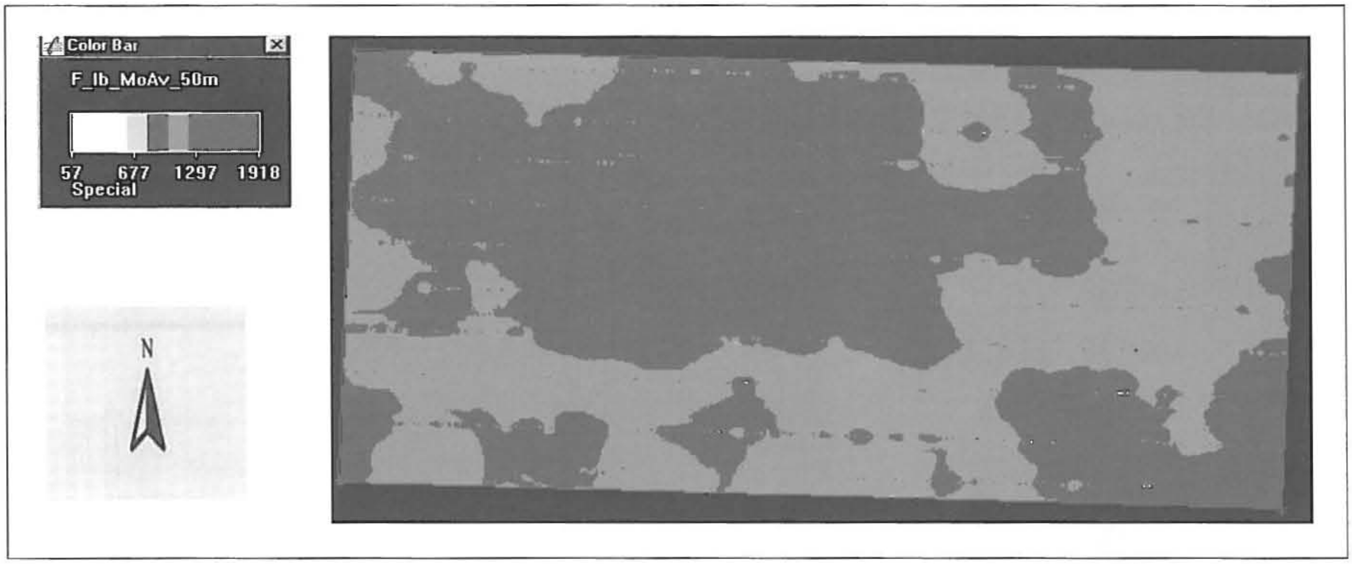

Figure 1. Distribution of soil compaction across the field. Soil compaction was measured using TCI-GPS-based technology sensors. Eighty acres of a pistachio orchard at Paramount Farming company was used for the study. TCI ranges from 900 to 1300 (draft, lb). Data are being analyzed. TCI will be measured under field stress conditions.

troduces herbicides and can prevent the use of cover crops), generates substantial dust (a major problem), limits management options, requires early irrigation cut-off (reducing efficiency of late season N-use), introduces ant problems and aflatoxin problems, and prevents individual tree analysis. Demonstration that tree-by-tree harvesting and mapping offers important management advantages might encourage the use of catch frames with all the contingent advantages in product quality, orchard management, and environmental health. (Of course there are many other factors to consider before a change of this magnitude could be considered—nut drying, nut drop, uneven maturity).

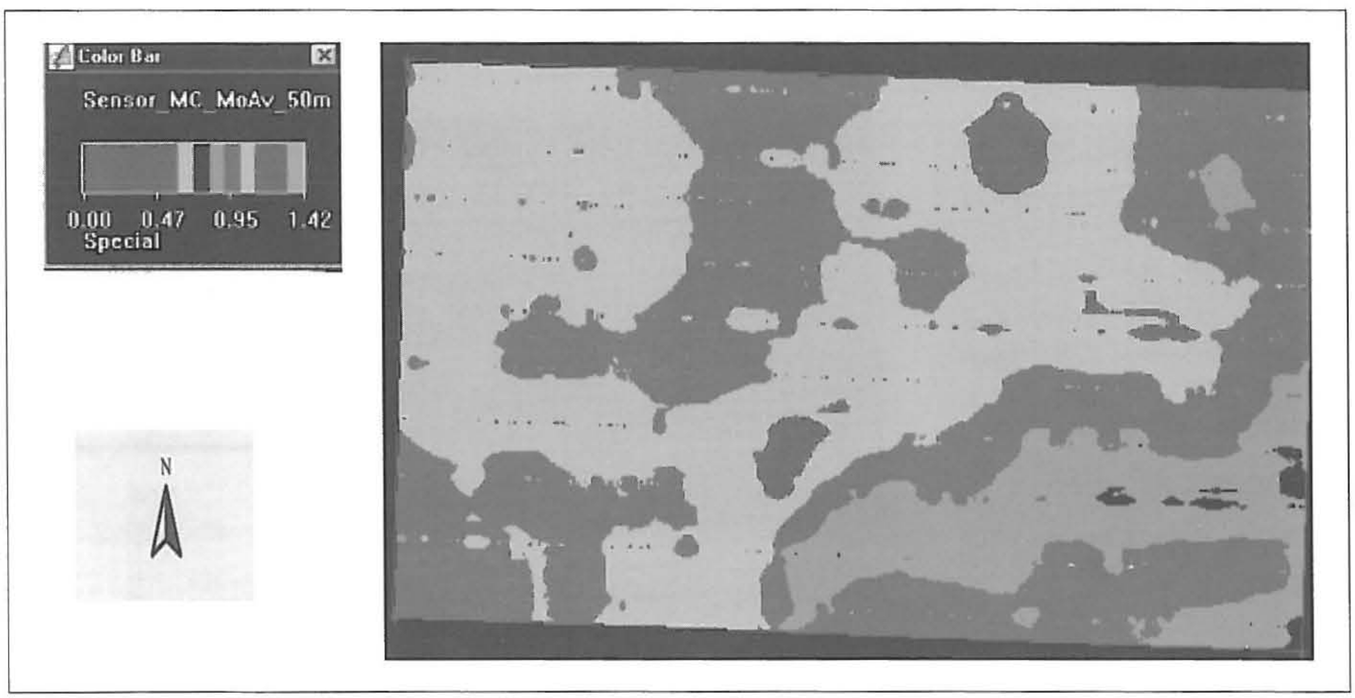

Figure 2. Distribution of soil moisture content (MC) across the field. Moisture content was measured using moisture-GPS-based technology sensors. Eighty acres of a pistachio orchard at Paramount Farming company was used for the study. 18-22% of soil moisture was detected across the field. MC will be measured under field stress conditions.

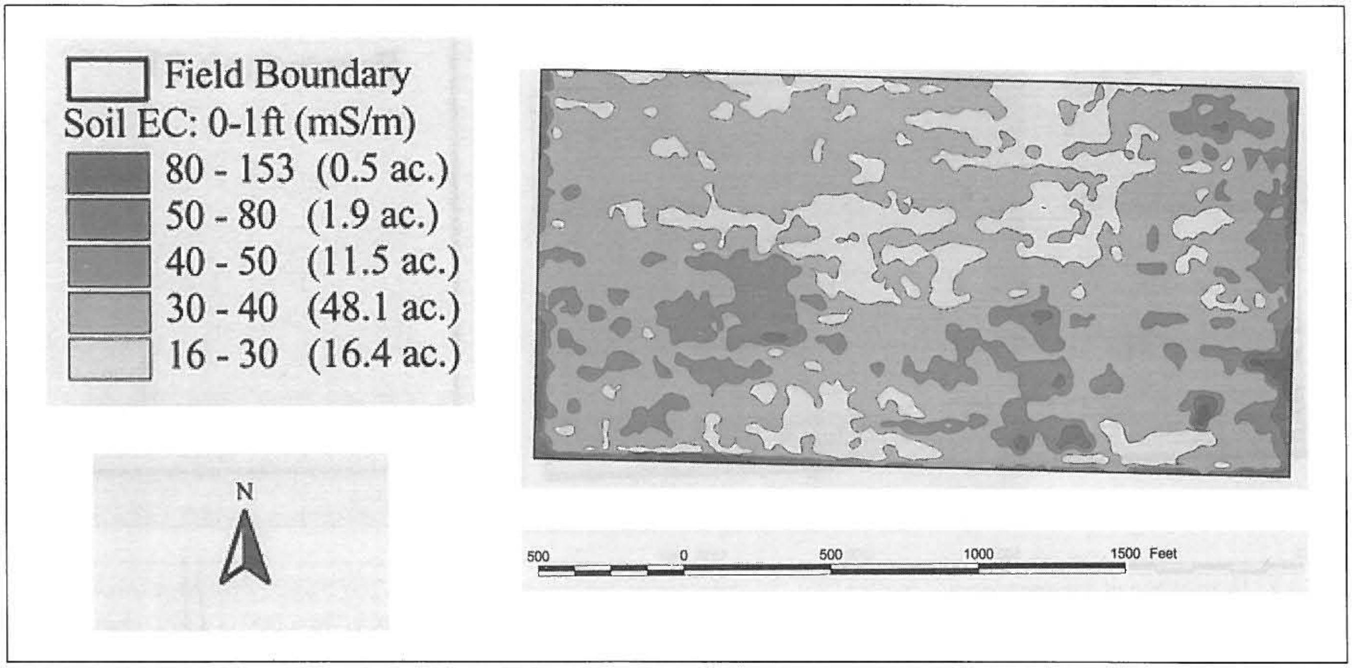

Figure 3. Electrical conductivity (EC) across the field. EC was measured using GPS-based technology sensors. Eighty acres of a pistachio orchard at Paramount Farming company was used for the study. At 1-foot deep, EC ranges from 16-153 mS/m. Soil samples will be takes from low and high EC for further investigation.

In summary, the use of precision orchard management will result in the development of a more sophisticated agricultural system, will allow for profound improvements in efficiency, and will encourage growers to view an orchards as an integrated ecological system. Further, the capacity to easily determine yield will provide researchers, growers and extension agents a greatly improved ability to conduct research, and test new management strategies. The ability for growers to easily test new technologies on their own fields is essential for the adoption of best management practices.

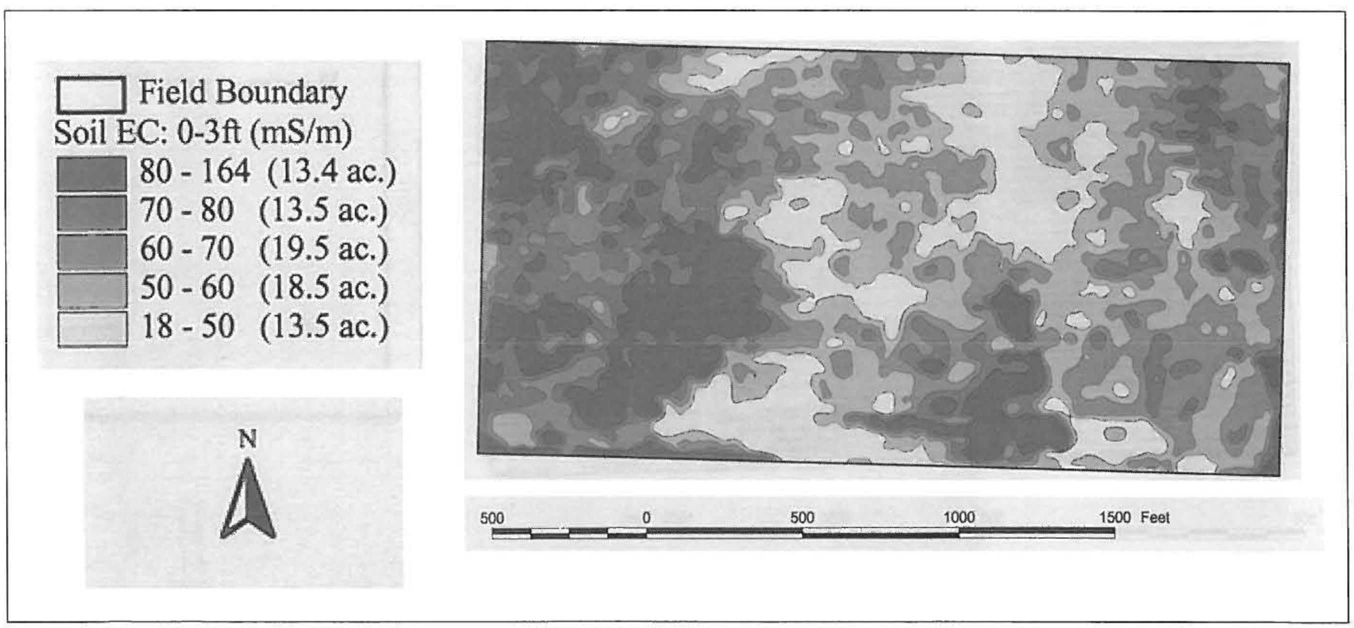

Figure 4. Electrical conductivity (EC) across the field. EC was measured using GPS-based technology sensors. Eighty acres of a pistachio orchard at Paramount Farming company was used for the study. At 3-foot deep, EC ranges from 18 to 164 mS/m. Data are being analyzed.

When we have enough information, we will plan and conduct workshops on precision harvesting and site-specific management, to be conducted at Paramount Farming and elsewhere. This will be in addition to participation in field days organized by farm advisors, talks to grower groups, presentation to the annual Pistachio Commission meetings, and presentation at the annual CDFA-FREP meeting.