Updating Our Knowledge and Planning for Future Research, Education and Outreach Activities to Optimize the Management of Nutrition in Almond Production

Project No.: **06-HORT9-Brown** **Final Report**

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Interpretive Summary:

There is a growing consensus among UC Faculty and Farm Advisors, consultants and growers that the UC established critical values for determination of almond nutrient status and the methods used to manage fertilization in these crops may be outdated or

underutilized. In the absence of viable and well-regarded standards and guidelines for nutrient management, growers do not have the resources needed to use fertilizers wisely. Our goal was to survey current practices, concerns and needs in almond nutrition in order to identify how nutrition information is presently used by growers and how future research may best assist growers in increasing fertilizer use efficiency. We combined this survey data with existing information and perceived best management practices, in order to provide the content of a new research and extension initiative to increase the efficiency of fertilizer usage. To meet this goal, we conducted small focus groups with industry stakeholders and used the information we gathered to inform the content of surveys we distributed to approximately 1800 randomly-selected almond growers throughout California.

Focus group participants were asked a total of eight questions structured around three areas: 1) factors affecting growers' nutrition decisions, including perceived usefulness of critical values and soil and tissue sampling, 2) priorities in education and research relating to plant nutrition, and 3) expected consequences of environmental regulation to the almond industry. Based largely on the information collected from the focus groups, the written surveys were comprised of 37 multi-part questions to collect data regarding 1) grower demographics 2) fertilization use practices 3) factors affecting nutrition decisions 4) priorities in education and research relating to plant nutrition and 5) expected consequences of environmental regulation to the almond industry.

The information gathered in these surveys will be of great use to researchers and extension agents in future efforts to effectively meet the needs of stakeholders in the almond industry. The data relating to current nutritional practices, especially as they vary between counties and with acreage, may provide insight into strategies to take, should the industries face environmental scrutiny in the future. If most large growers are practicing the most efficient practices identified to date, for instance, it may not be cost-efficient for the state to target the remaining small growers to change their practices, if the overall amount of acreage to be affected would be very small. Future analysis may provide insight as to whether this is the case.

Another useful subset of data is that which relates to grower demand for research on various topics. The University of California now knows that its almond stakeholders would, for the most part, consider research about fertilizer application timing and critical values to be more useful than research about non-fertilizer products and remote sensing. We have collected quantitative data regarding the degree to which critical values are used and the amount of satisfaction with the numbers. This data will all be of great use to us in planning future research projects.

A majority of the originally designed tasks and objectives have been achieved. We conducted three focus groups with at the Almond Industry Conference in Modesto, California (December 2006). In June 2007, we distributed written surveys to over 1800 randomly-selected almond growers, with a response rate of 30.0%. Thus far, we have analyzed the data to explore topics including fertilization usage with respect to potential environmental regulations and perceived best management practices, research and

extension preferences of industry stakeholders, and regional/irrigational trends in fertilizer usage.

Our major short-term goals are to continue analysis of the data and to make it as accessible as possible to stakeholders in the almond industry. We plan to submit articles for publication, present this information at future workshops, and to provide the data in numerous forms on the UC Davis Fruit and Nut Research Information Center website. We aim to have the new section of the website available to users by September 15, at which time we will widely advertise its existence to industry stakeholders.

Materials and Methods:

General: Conduct focus group interviews and distribute surveys to collect information regarding almond nutritional practices, concerns, and needs.

Task 1 - To conduct a focus group interview (FGI's) among selected stakeholders to identify current practices, concerns and needs in almond nutrition management.

- Task 1.1: Focus Group Design
    - Completed 11/06
- Task 1.2: Conduct focus group meetings.
    - Completed 12/06

Task 2 - To design and conduct a statistically sound and informative survey instrument to identify current practices, concerns and needs in almond nutrition management.

- Task 2.1: Analyze, prepare survey questions, submit draft survey for field test, and obtain required human subjects research approval.
    - Completed 04/07
- Task 2.2: Design questionnaire for mailing and online submission. Mail survey.
    - Completed 06/07
- Task 2.3: Analyze survey results.
    - Ongoing

Task 3 - Design and conduct two regional nutrition workshops and simultaneous focus group interviews to update knowledge in nutrition management and further define concerns and needs in almond nutrition management.

- Material presented at following workshops to date:
    - Almond Conference: Keynote Speaker and Almond Research Presentation 12/05/07, Modesto. (400 and 300 attendees)
    - FREP Meeting 11/23/07, Tulare. (400 attendees)
    - WPHA Meeting, 11/29/07, Sacramento (80 Attendees)
    - California Agronomy Society Meeting, 02/07. (150 Attendees)
- Ongoing: determining whether additional data collection through focus group interviews will provide useful information for content development of research projects and extension efforts.

Task 4 - Collate and analyze existing information, survey and workshop findings and use this data to design an extension initiative to increase the efficiency of fertilizer usage and guide the development of new nutrition research and education programs.

- Ongoing: Collaborating with web designers for Fruit and Nut Research Information Center (www.fruitsandnuts.ucdavis.edu) to provide survey results to stakeholders in interactive format as graphs and tables describing topics of interest.

Results and Discussion:

Most almond growers perform nutrition practices considered to be progressive and/or efficient, such as collecting tissue samples at least once per year, collecting soil samples at least once per year, applying nitrogen with fertigation (where irrigation methods allow), and applying nutrients foliarly. Almond growers who do not perform frequent tissue sampling cited expense and perceived invaluable results as their primary reasons. Very few almond growers apply nitrogen fertilizer in the winter months, when plants are not actively taking up nitrogen from the soil. Many almond growers apply nitrogen fertilizer in more than once during the season, a practice which is perceived to be nutritionally efficient.

There is a positive relationship between the amount of acreage an almond grower manages and the likelihood that he or she uses fertigation to apply nitrogen, routinely collects tissue samples, and/or routinely collects soil samples. Simply, larger growers are more likely to perform these practices. Growers from Butte County are significantly less likely than growers from other major almond-producing counties to not use fertigation to apply nitrogen. Growers from Madera are significantly less likely than growers from other major almond-producing counties to not collect regular tissue samples.

Although most almond growers use the UC critical values somewhat or a lot, less than one third of them feel that the critical values are more than “somewhat” adequate to ensure high yields.

Nearly all almond growers feel that plant nutrition is important to ensure high yields. Most almond growers are “somewhat satisfied” with their yields and are satisfied with their current nutrition program. Major reasons why some of them are dissatisfied with their program include lack of money to improve their program, perceived lack of adequate available information, and uncertainty as to how best to improve their program.

Almond growers report relying most heavily on consultants/labs and farm advisors for plant nutrition information, and they base their fertilization decisions mostly on tissue samples and personal history. They generally believe tissue sampling is a more valuable, accurate, and effective means with which to make nutrition decisions than is soil sampling.

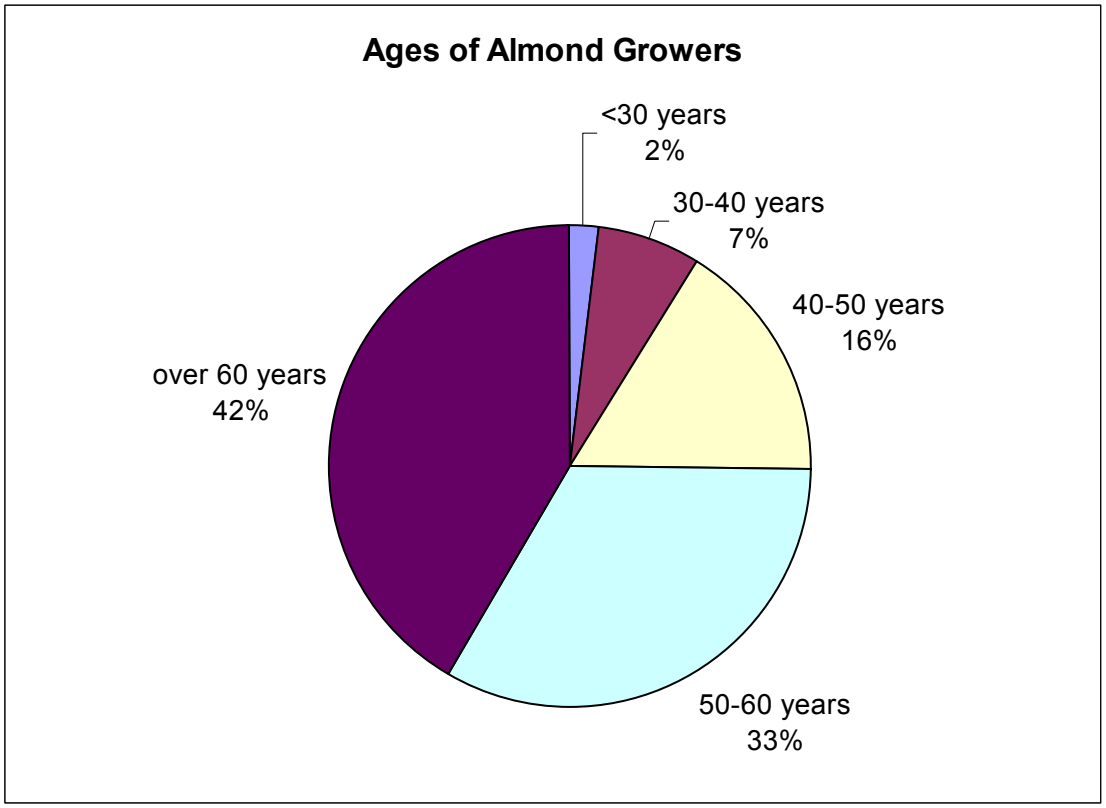
Almond growers reported that better-designed publications, a website to help make personalized decisions, more publications, and more training workshops would all be of approximately equal use to them in the future. They identified printed information as their preferred form of information delivery. Almond growers are most interested in future research about fertilizer application timing, the relationship between nutrition and disease, the accuracy of critical values to ensure they result in maximal yield, leaf sampling techniques that better reflect tree nutrient demand, and tissue sampling techniques and timings that provide in-season guidance for fertilizer decisions.

Most almond growers reported that they consider environmental factors at least most of the time when making fertilizer decisions. They reported that identifying fertilization practices that optimize yield will be of great importance in order to meet future environmental standards. Most almond growers expect their future nutrition practices to be affected a good deal both by environmental regulations and by market demands for best management practices.

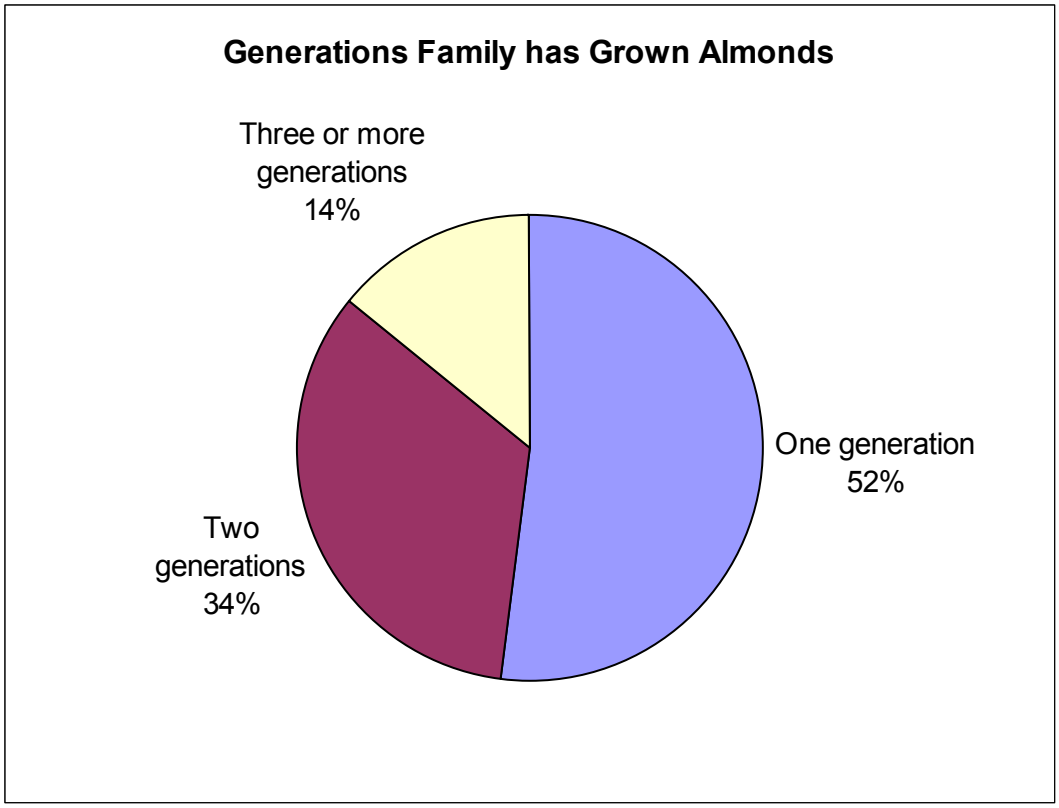
Detailed presentations of data are on the following pages.

Topic 1: Grower Demographic Data

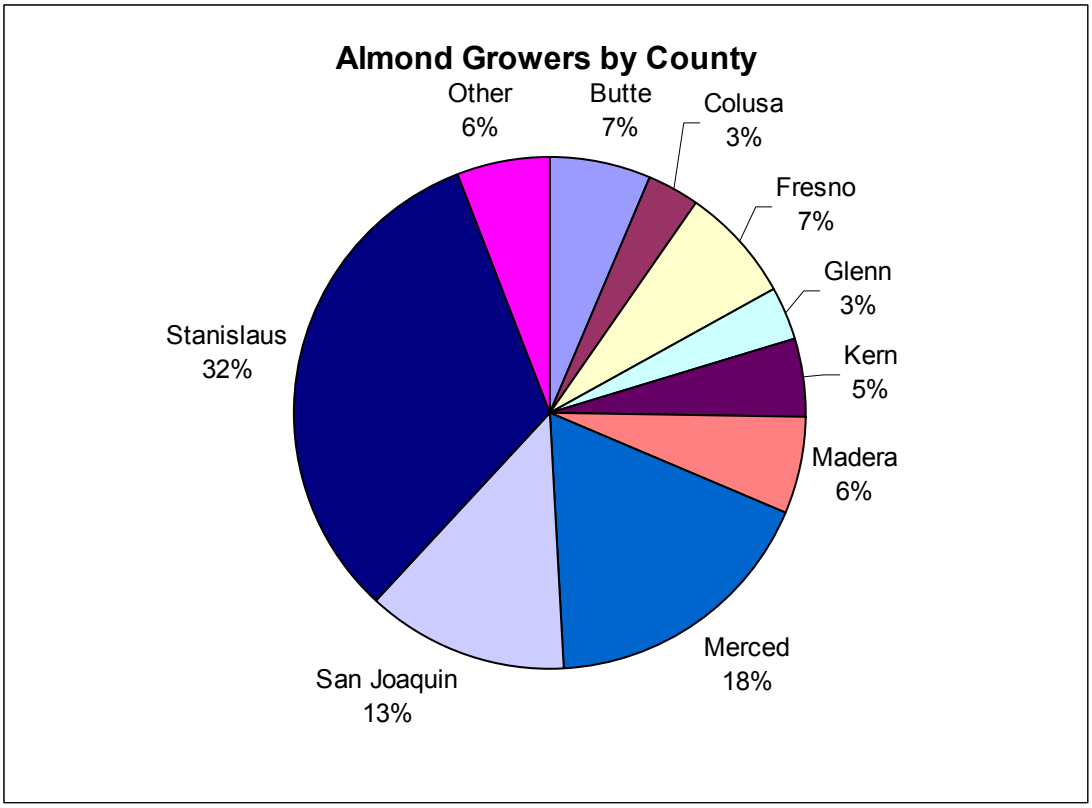
Data were collected relating to growers' demographics. 2% of respondents (10 growers) were under 30 years of age, 7% (36 growers) were 30-40 years old, 16% (86 growers) were 40-50 years old, 33% (174 growers) were 50-60 years old, and 42% (216 growers) were over 60 years old.



52% of respondents (272 growers) are first-generation growers, 34% (178 growers) are in families that have grown almonds for two generations, and 14% (74 growers) are in families that have grown almonds for three or more generations.



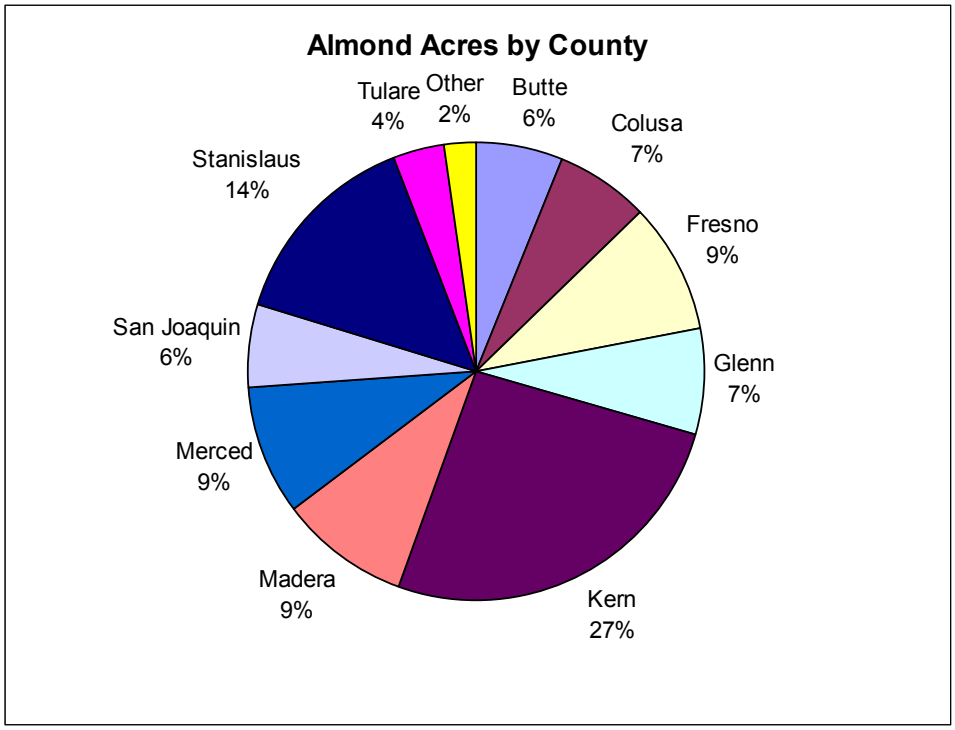
Growers were asked to report the primary county in which they grow almonds. Most respondents grow almonds primarily in Stanislaus County (32%, 168 growers), Merced County (18%, 93 growers), and San Joaquin County (13%, 67 growers).



Almond Growers by County

County	# growers	% total
Butte	34	7
Colusa	16	3
Fresno	38	7
Glenn	17	3
Kern	26	5
Madera	32	6
Merced	93	18
Kings	6	1
San Joaquin	67	13
San Luis Obispo	1	0
Solano	1	0.00
Stanislaus	168	32
Sutter	5	1
Tulare	8	2
Yolo	9	2
Total	521	

By acreage, respondents grow almonds primarily in Kern County (27%, 35,620 acres), Stanislaus County (14%, 19379 acres), Merced County (9%, 12,747 acres), Fresno County (9%, 12,563 acres), and Madera County (9%, 12,553 acres). An example of a contributor to the skewed distribution between growers by county and acreage by county is the single respondent who grows almonds primarily in Kern County and reports almond acreage of 14,618 acres.



Almond Acres by County

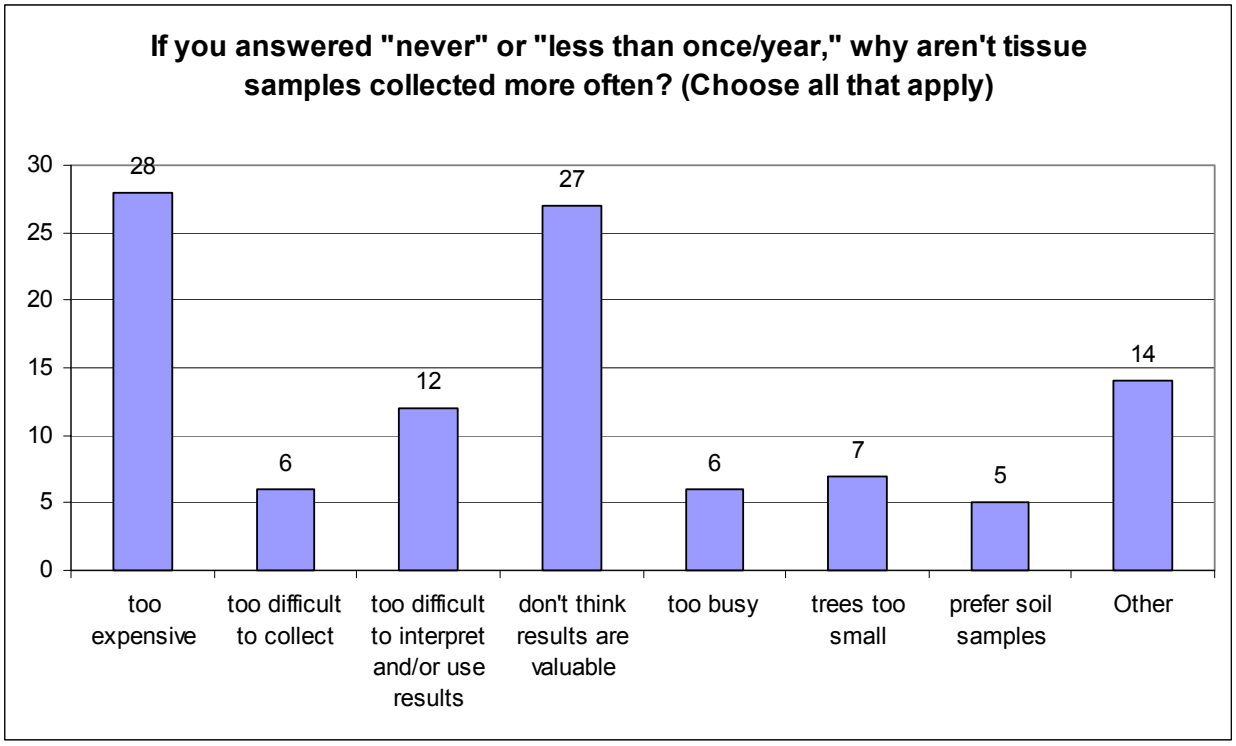
County	# acres	% total
Butte	8328	6
Colusa	8999	7
Fresno	12563	9
Glenn	10162	7
Kern	35620	26
Madera	12553	9
Merced	12747	9
Kings	715	1
San Joaquin	7968	6
San Luis	7	0
Solano	300	0
Stanislaus	19379	14
Sutter	1110	1
Tulare	5077	4
Yolo	918	1
Total	136446	

Topic 2: Almond Fertilization Use Practices

77% of respondents (405 almond growers) collect tissue samples at least once per year. Growers who collect tissue samples less than once per year cited expense (28 almond growers) and disbelief in value of results (27 almond growers) as major reasons why they do not collect tissue samples more often.

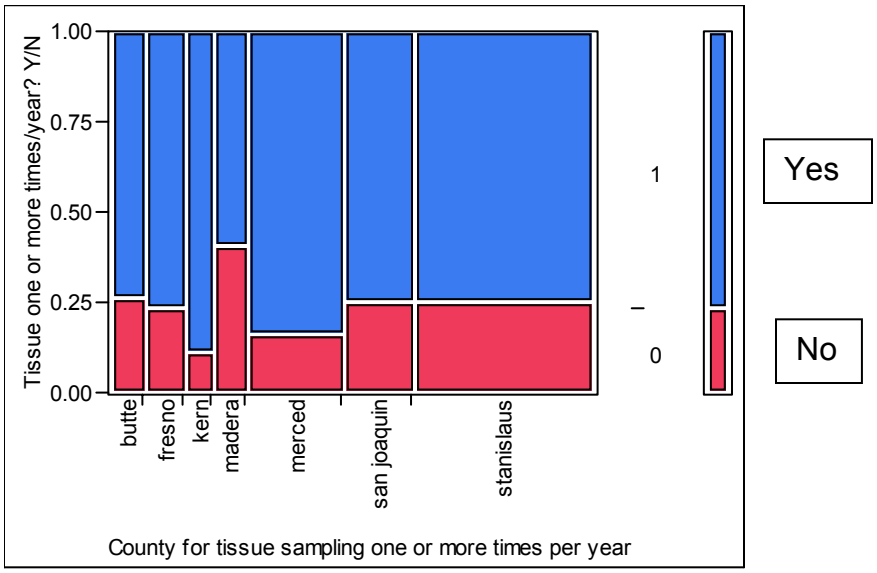
Frequency with Which Almond Growers Collect Plant Tissue Samples.

	# respondents	% total
Never	40	8
Less than once/year	43	8
Once/year	307	58
More than once/year	98	19
When problems are detected	32	6
I don't know	5	1
Total	525	



There is a positive relationship between the number of almond acres a grower manages and the likelihood that he or she collects tissue samples at least once per year. Growers with fewer than 20 almond acres are significantly more likely than average not to collect tissue samples at least once per year ($p<0.001$), while growers with greater than 250 almond acres are significantly more likely than average to collect tissue samples ($p<0.001$).

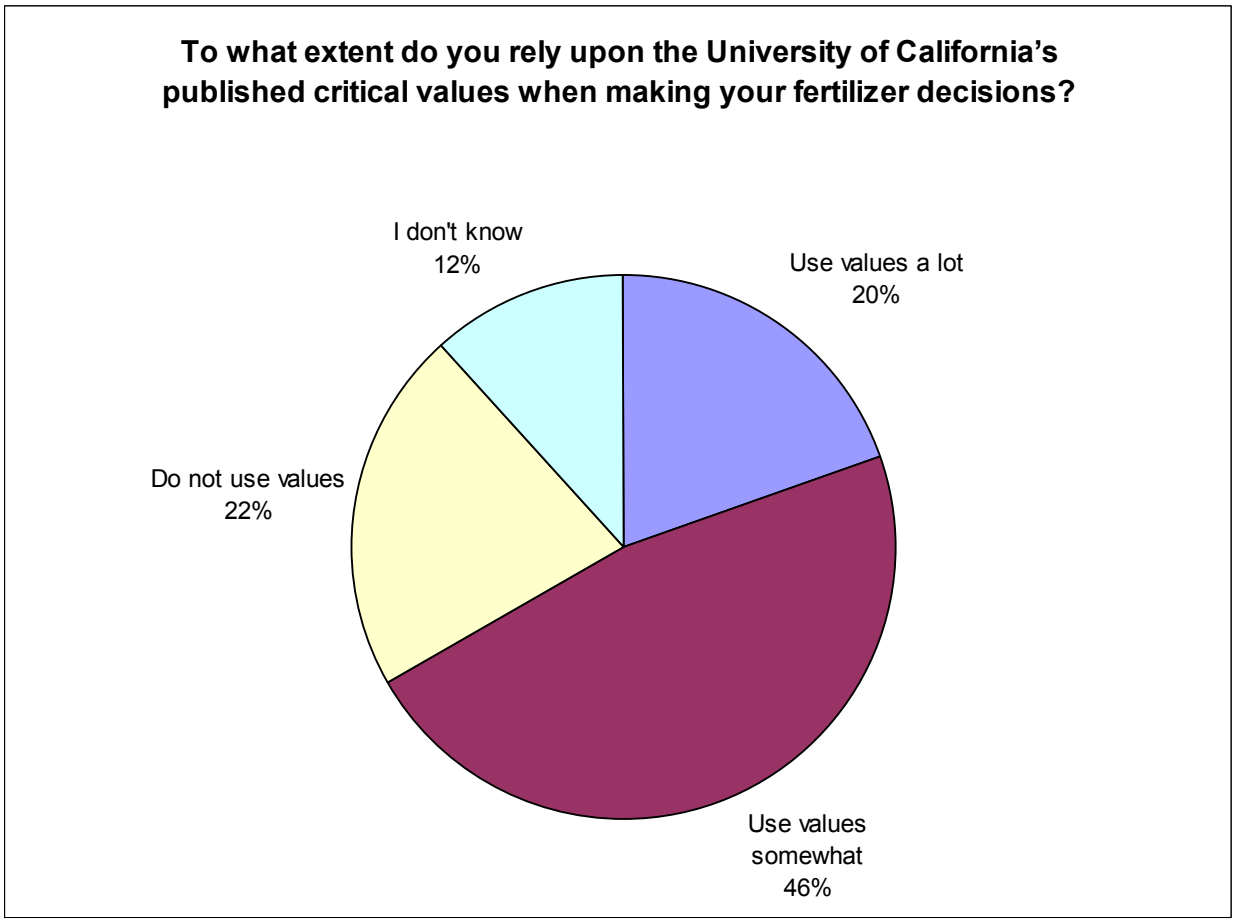
The following graph depicts the major counties in which almonds are grown, with red blocks representing the proportion of growers who do not collect tissue samples at least once per year and the blue blocks representing the proportion of growers who do. Growers from Madera county are significantly more likely than average to not collect tissue samples at least once per year ($p<0.05$).



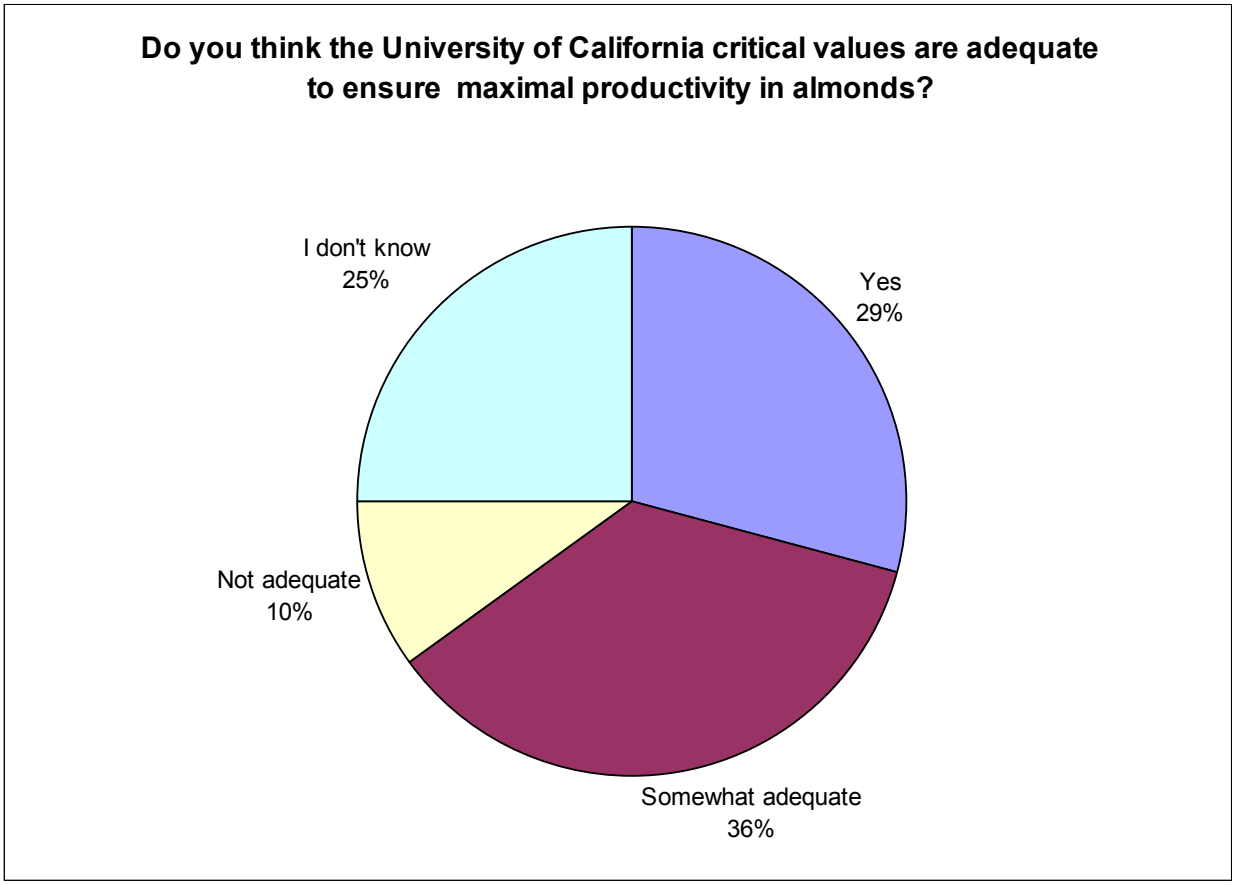
There is no significant relationship between a grower's concern for the environment (based on his answer to a question about how often he/she considers the environment when making nutrition management decisions) and his/her likelihood to collect tissue samples at least once per year ($p=0.74$).

There is also no significant relationship between a grower's opinion that plant nutrition is extremely/very important vs. important/somewhat/not important to ensure high yields in almonds and his/her likelihood to collect tissue samples at least once per year ($p=0.13$).

20% of respondents (100 growers) rely on the UC critical values for almond a lot, 46% (239 growers) rely on the values somewhat, and 22% (110 growers) do not use the values.

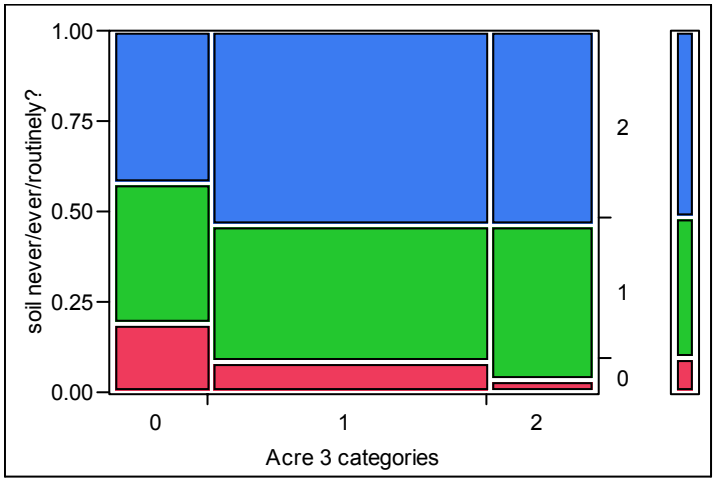


29% of respondents (150 almond growers) think the UC critical values are adequate to ensure maximal productivity in almonds, 36% (183 growers) think they are somewhat adequate, 10% (51 growers) think they are not adequate, and 25% (128 growers) do not know whether they are adequate.

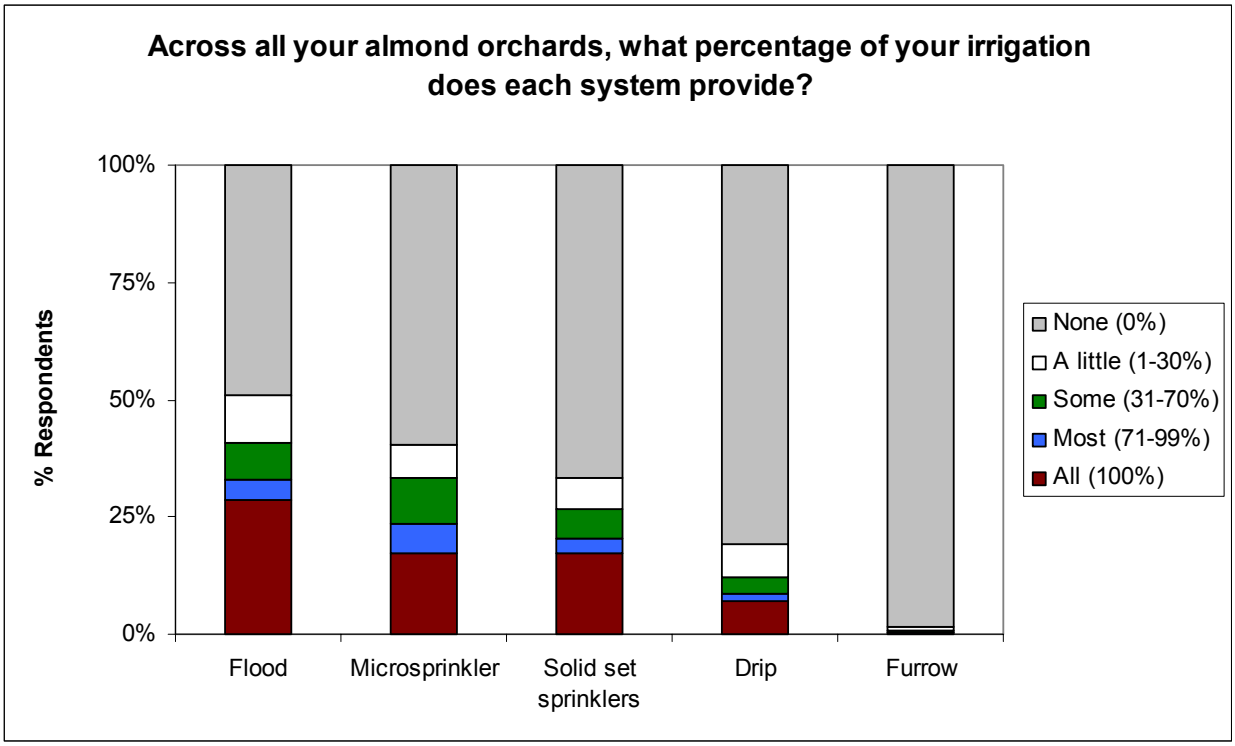


51% of respondents (255 almond growers) collect soil samples routinely, while 39% (193 growers) collect soil samples only at orchard establishment and/or when problems are detected, and 10% (51 growers) never collect soil samples.

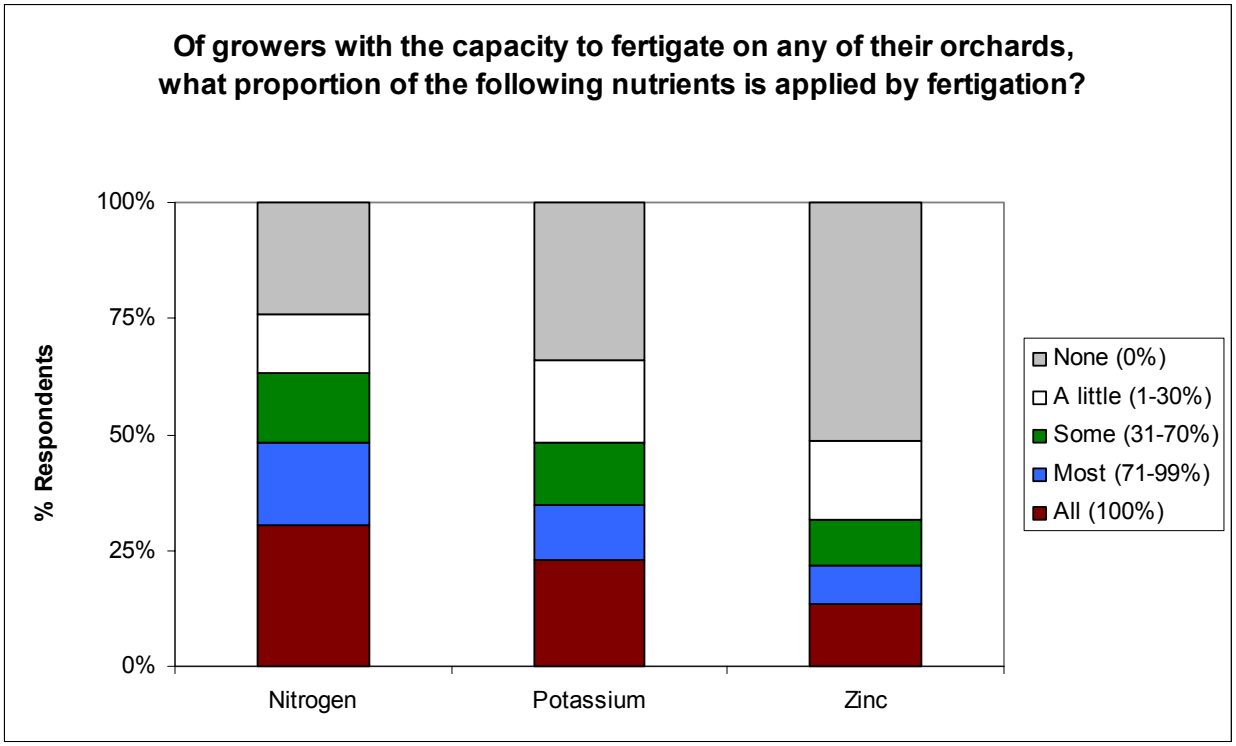
The following figure depicts the frequency with which growers in three acreage categories ("0" = <20 acres, "1" = 20-250 acres, "2" = >250 acres) never collect soil samples (red), collect only at orchard establishment and/or when problems are detected (green), and collect soil samples routinely (blue). Almond growers with fewer than 20 total acres are significantly more likely than average ($p<0.01$) to never use soil sampling on their orchards, and growers with more than 250 acres are significantly less likely than average ($p<0.05$) to never use soil sampling on their orchards.



There is no difference in likelihood to collect soil samples between major almond-producing counties. Almond growers reported the proportion of irrigation delivered by flood, microsprinklers, solid set sprinklers, drip, and furrow irrigation as is displayed below.

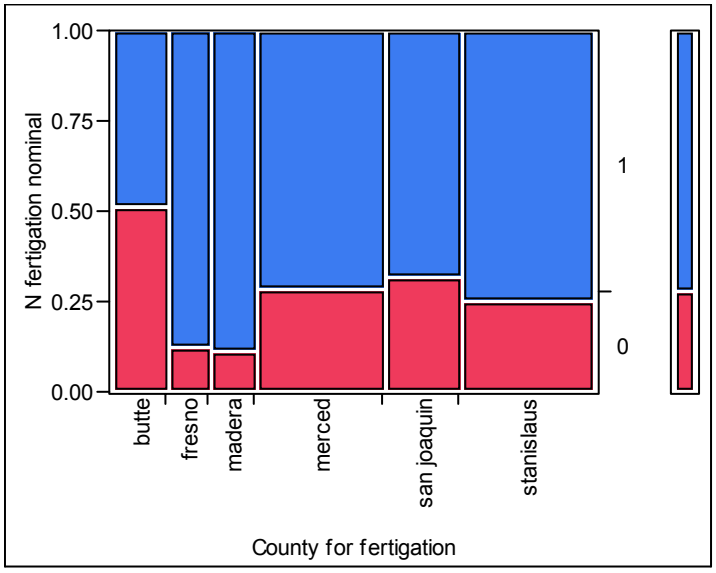

Across all your almond orchards, what percentage of your irrigation does each system provide?
% Respondents
100%
75%
50%
25%
0%
Flood
Microsprinkler
Solid set sprinklers
Drip
Furrow
None (0%)
A little (1-30%)
Some (31-70%)
Most (71-99%)
All (100%)

Of almond growers with the capacity to utilize fertigation (those who do not irrigate all of their fields entirely with flood irrigation), 76% (265 growers) use fertigation to apply at least some of their nitrogen fertilizer, 66% (222 growers) use fertigation to apply at least some potassium, and 49% (157 growers) use fertigation to apply at least some zinc fertilizer. Almond growers who answered "I don't know" or left that portion of the question blank have been excluded from analysis.

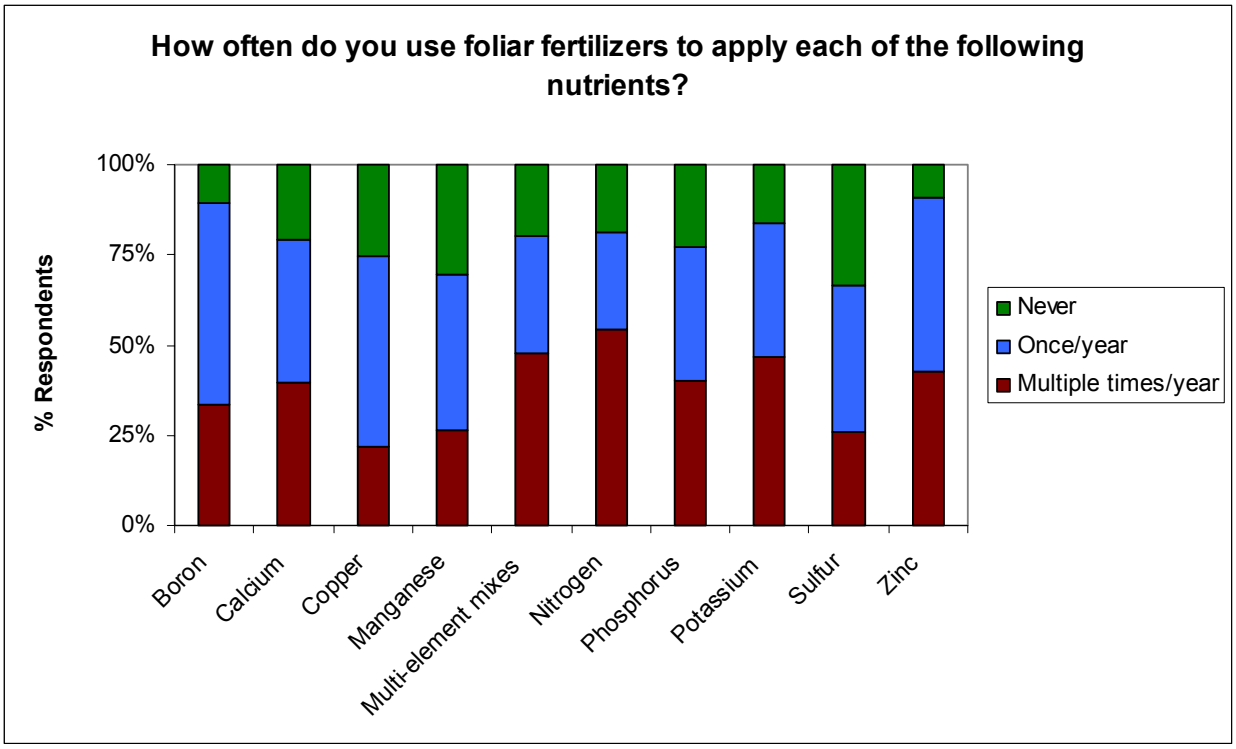


Of almond growers with the capacity to use fertigation, there was a positive relationship between total acreage owned and likelihood to apply some or all nitrogen fertilizer with fertigation. Growers with 19 or fewer acres were significantly more likely than most growers to not utilize fertigation to apply nitrogen ($p<0.05$), and growers with greater than or equal to 250 acres were significantly more likely than most growers to utilize fertigation to apply nitrogen ($p<0.05$).

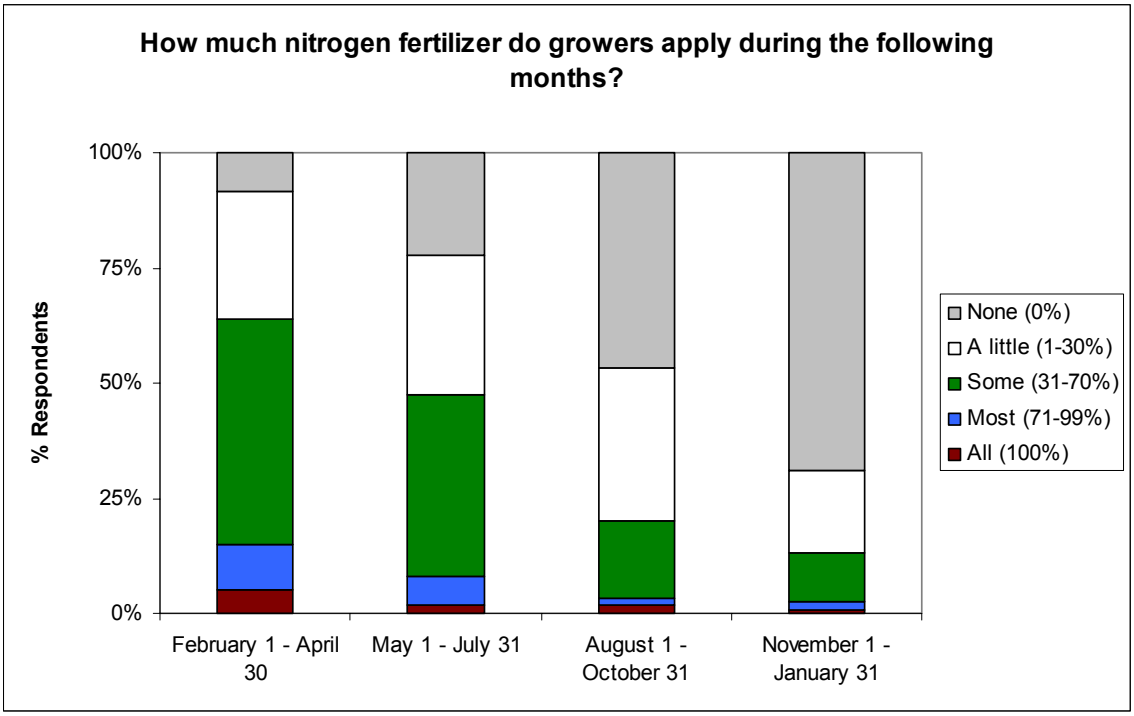
The following graph depicts the major counties in which fertigation is an option for nitrogen application by almond growers, with red blocks representing the proportion of growers who do not apply nitrogen by fertigation and the blue blocks representing the proportion who do apply nitrogen by fertigation. Growers from Butte County are significantly more likely than most growers to not use fertigation to apply nitrogen ($p<0.05$).



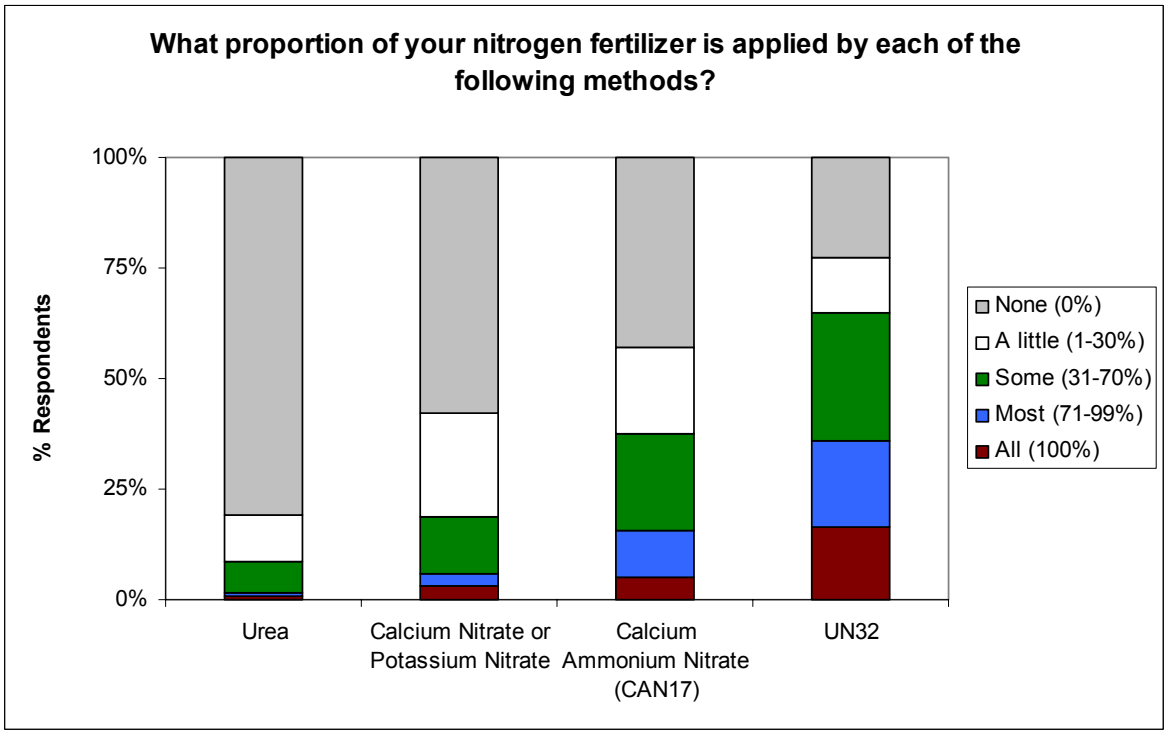
Excluding almond growers who answered “I don’t know” or left the question blank (approximately 25% of respondents for most elements), most almond growers apply boron, calcium, copper, manganese, multi-element mixes, nitrogen, phosphorus, potassium, sulfur, and/or zinc at least once per year.



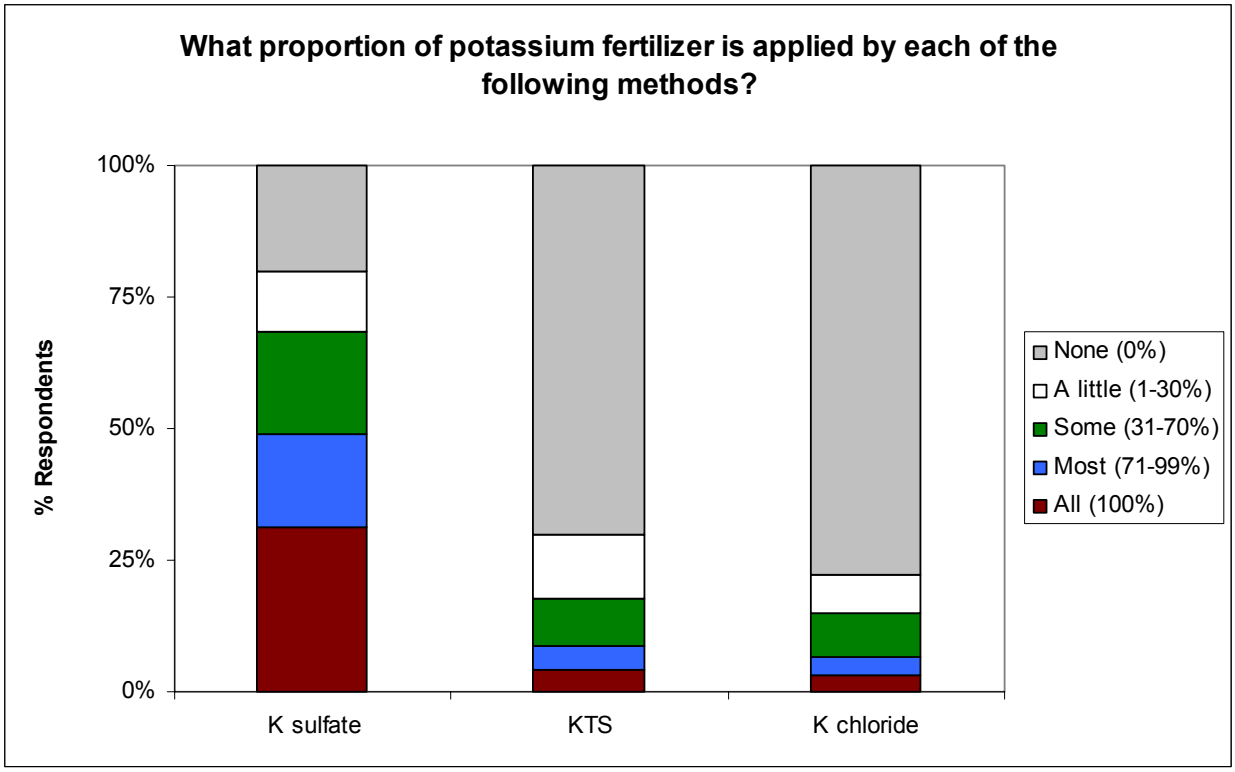
Almond growers apply much of their nitrogen fertilizer in spring (February through April), and they apply the least nitrogen during the winter (November through January). Many growers apply nitrogen fertilizer more than once per season.



Almond growers apply much of their nitrogen in the form of UN32, followed by calcium ammonium nitrate, calcium nitrate or potassium nitrate, and urea.

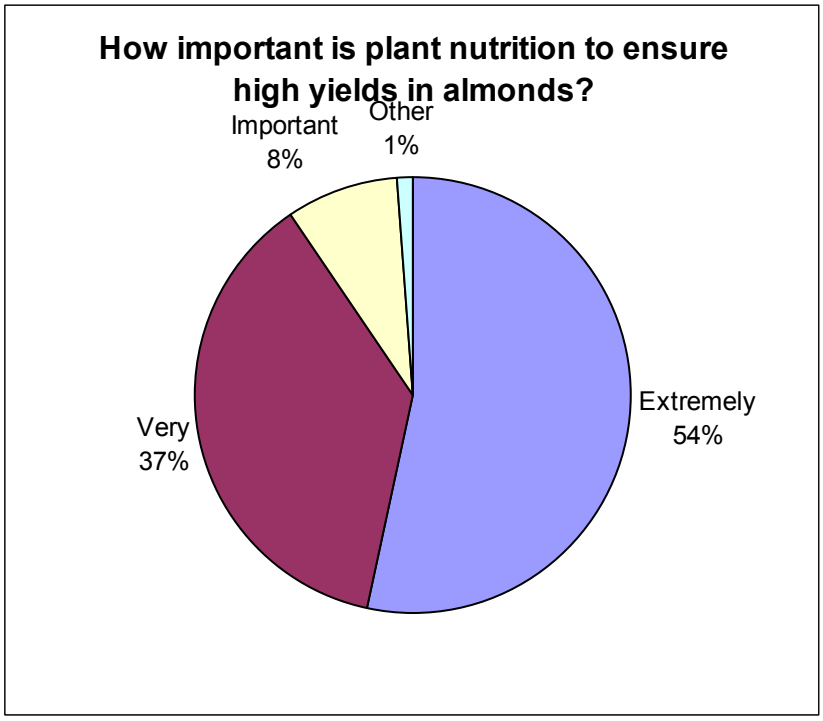


Almond growers apply most of their potassium as K sulfate, followed by KTS and K chloride.

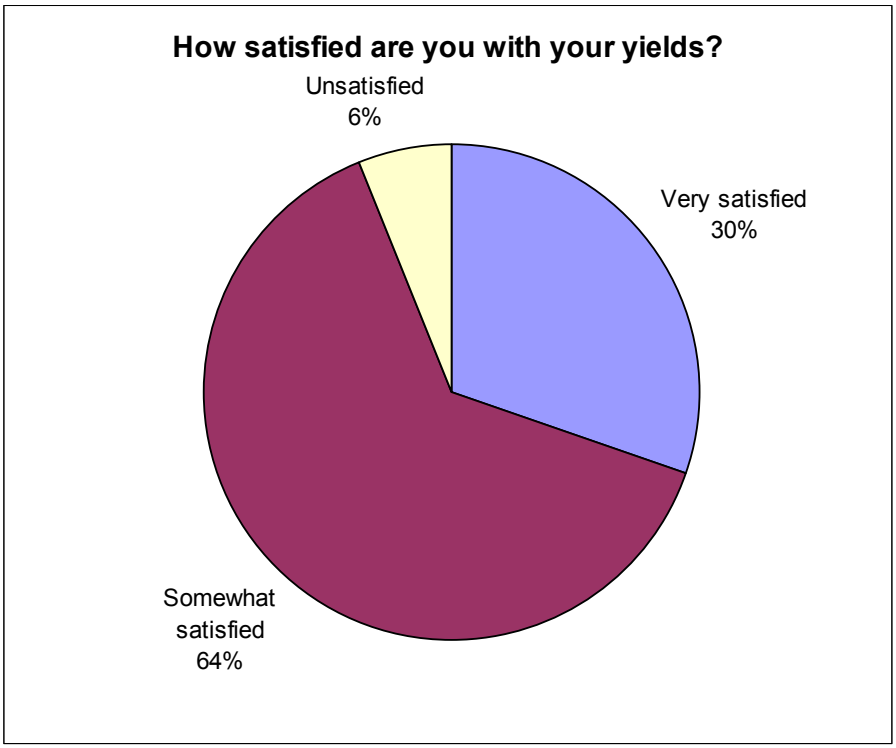


Topic 3: Factors Affecting Almond Nutrition Decisions

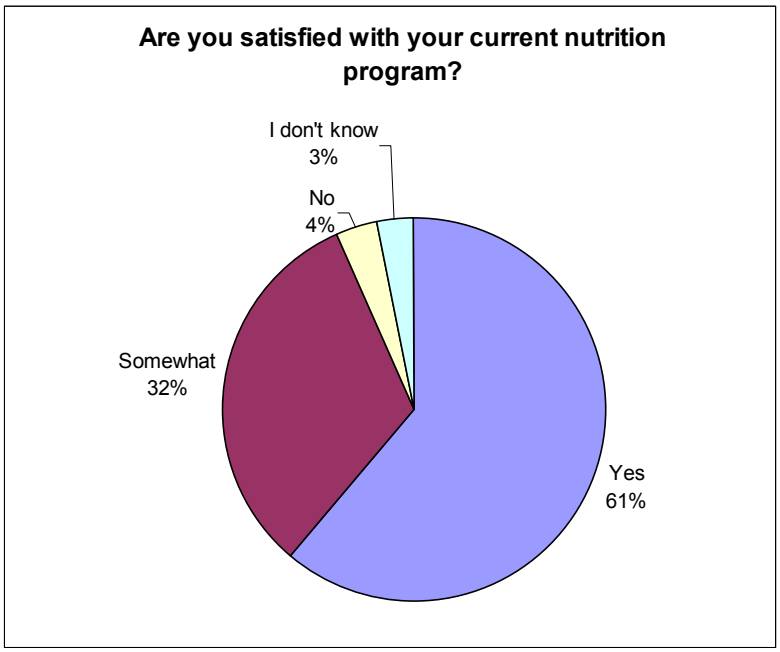
54% of respondents (280 almond growers) reported that they think plant nutrition is extremely important to ensure high yields in almonds, 37% (195 growers) reported that they think it is very important, 8% (43 growers) reported that they think it is important, 0.6% (3 growers) reported that they think it is somewhat important, and 0.2% (1 grower) reported that it is not important.

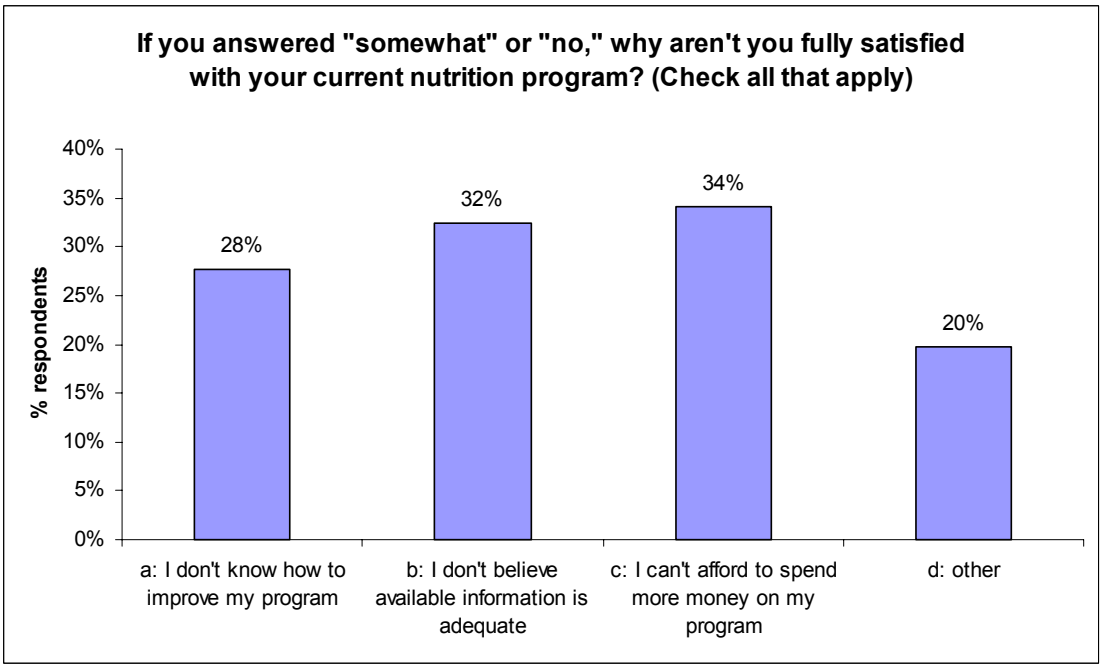


30% of respondents (156 almond growers) reported that they were very satisfied with their yields, 64% (330 growers) reported that they were somewhat satisfied with their yields, and 6% (31 growers) reported that they were unsatisfied with their yields.

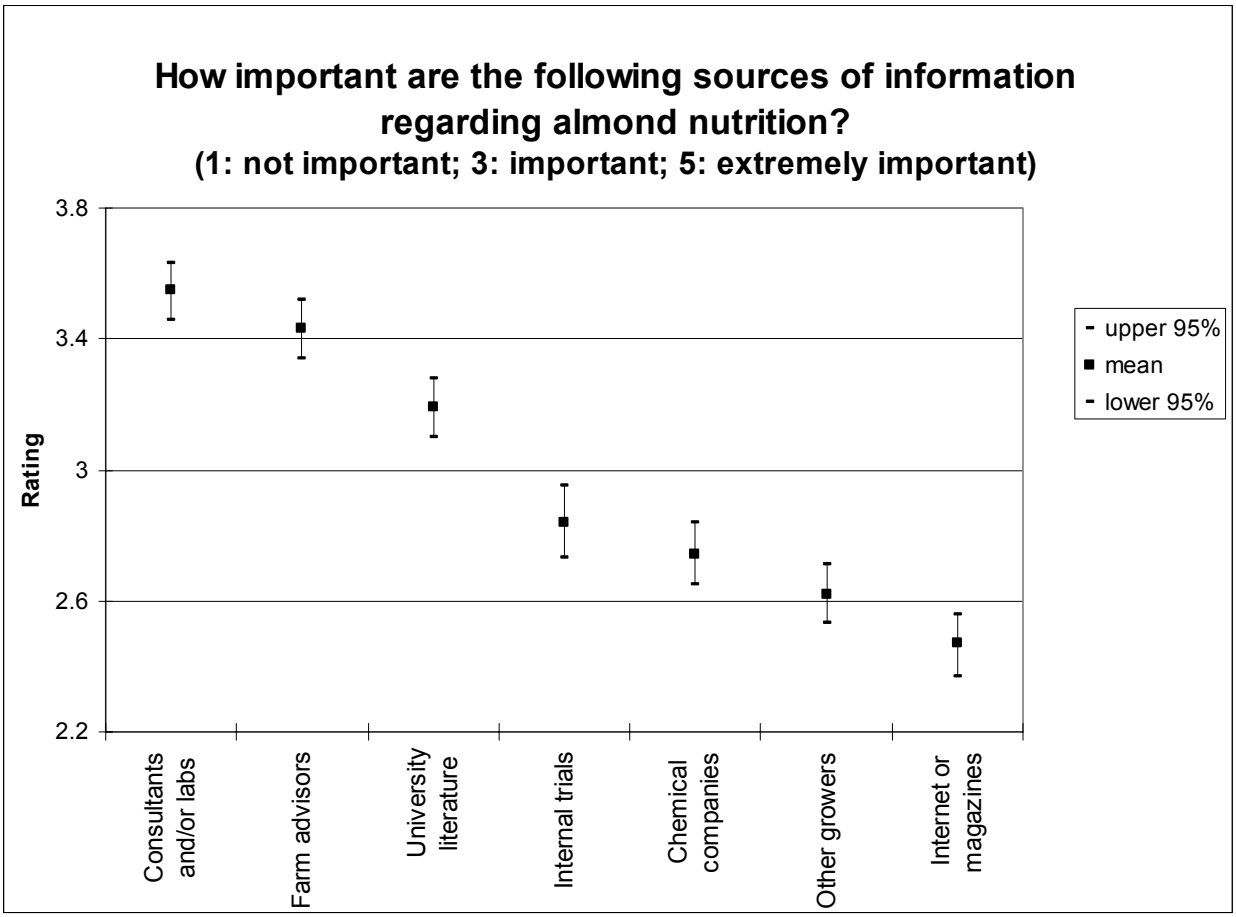


61% of respondents (318 almond growers) reported that they are satisfied with their current nutrition program, 32% (168 growers) reported that they are somewhat satisfied, and 4% (19 growers) reported that they were not satisfied. When asked why they were not satisfied or were only somewhat satisfied with their current nutrition programs, almond growers reported that they couldn't afford to spend more money on their program (34%), that they didn't believe the available nutrition information is adequate (32%), and/or that they didn't know how to improve their program (28%).

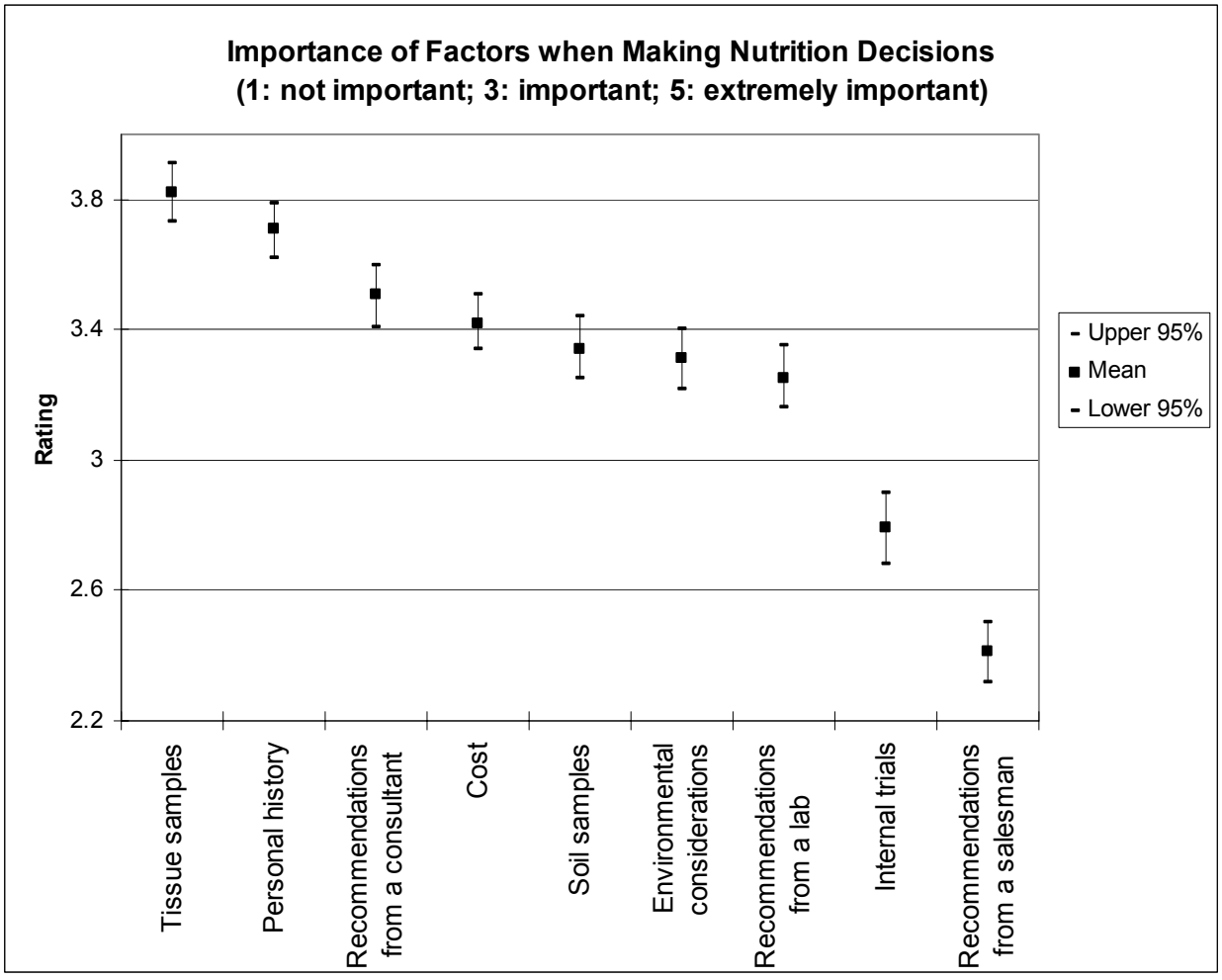




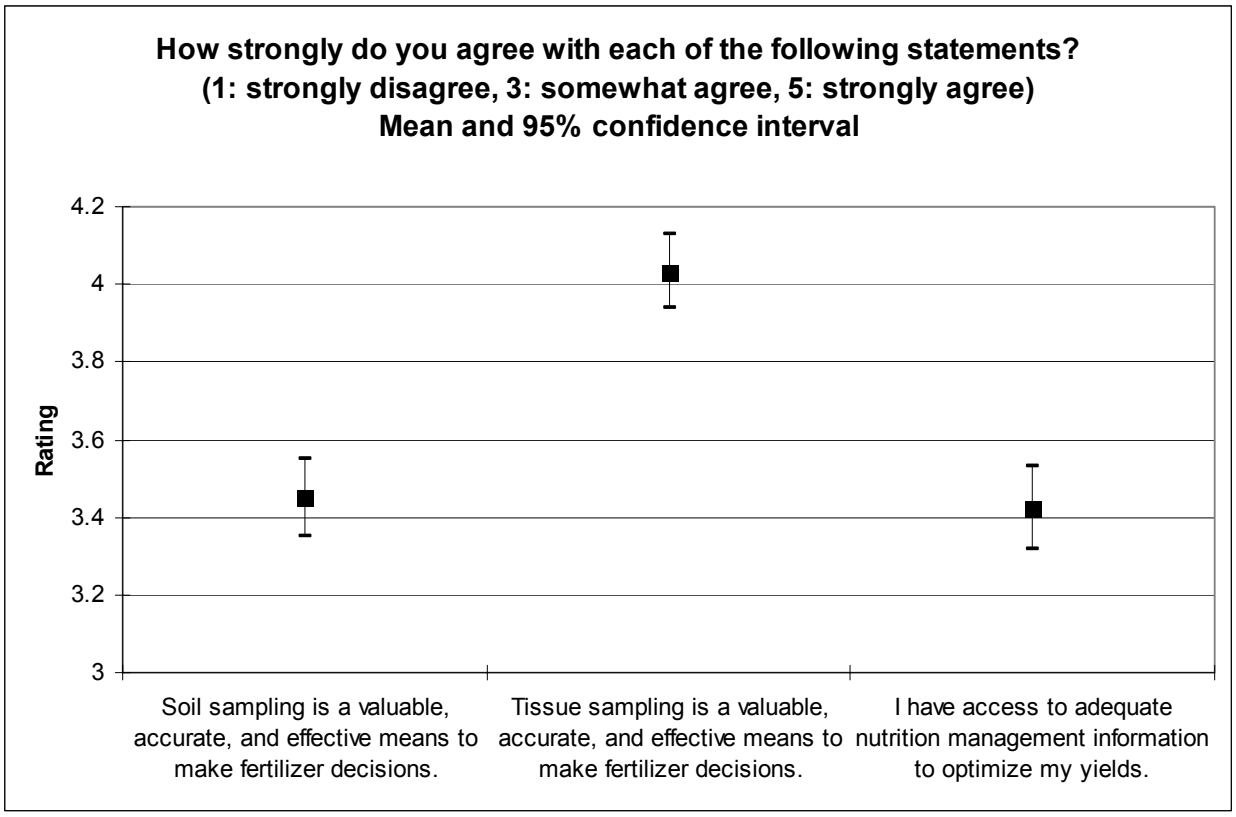
Respondents rated chemical consultants and/or labs as their most important source of information regarding almond nutrition (mean score=3.55/5), followed by farm advisors (3.43/5) and university literature (3.19/5).



Respondents rated tissue samples as the most important factor when making almond nutrition decisions (mean score=3.82/5), followed by personal history (3.71/5), recommendations from a consultant (3.51/5), cost (3.42/5), soil samples (3.34/5), environmental considerations (3.31/5), and recommendations from a lab (3.25/5).

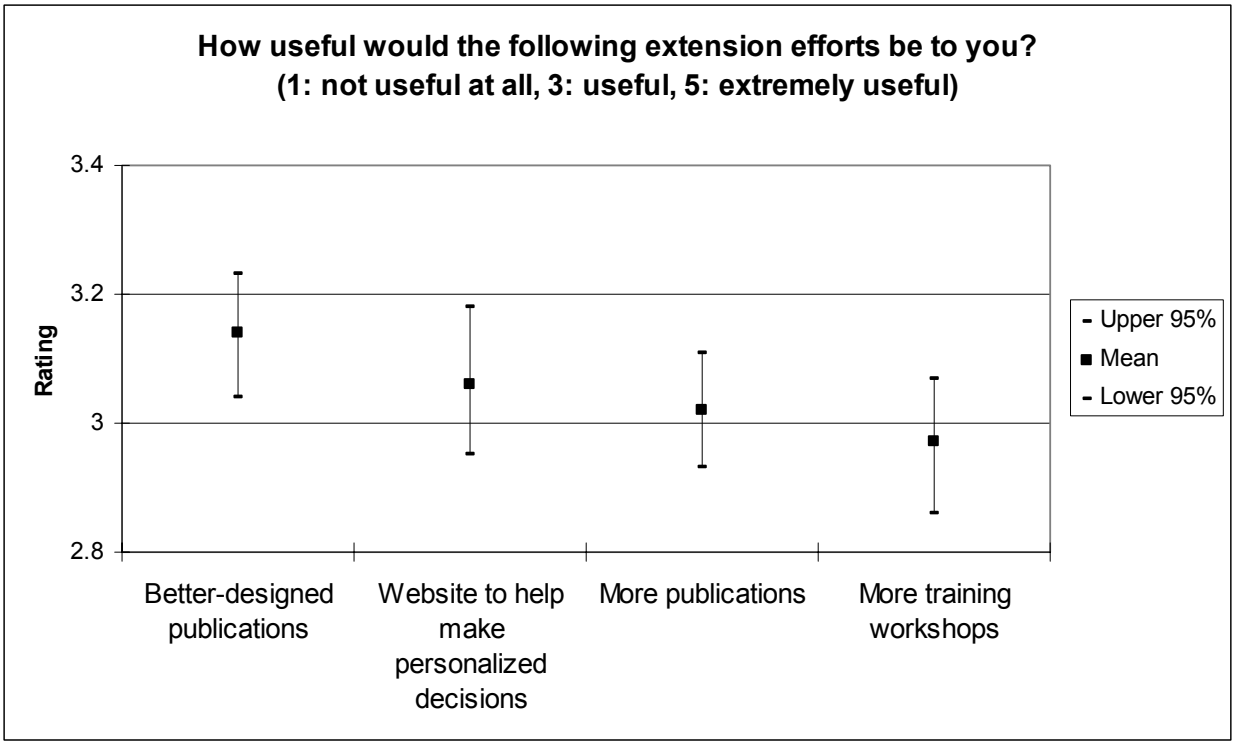


Almond growers most strongly agreed with the statement “tissue sampling is a valuable, accurate, and effective means to make fertilizer decisions” (mean score=4.03/5), followed by the statements “soil sampling is a valuable, accurate, and effective means to make fertilizer decisions” (3.45/5), and “I have access to adequate nutrition management information to optimize my yields” (3.42/5).

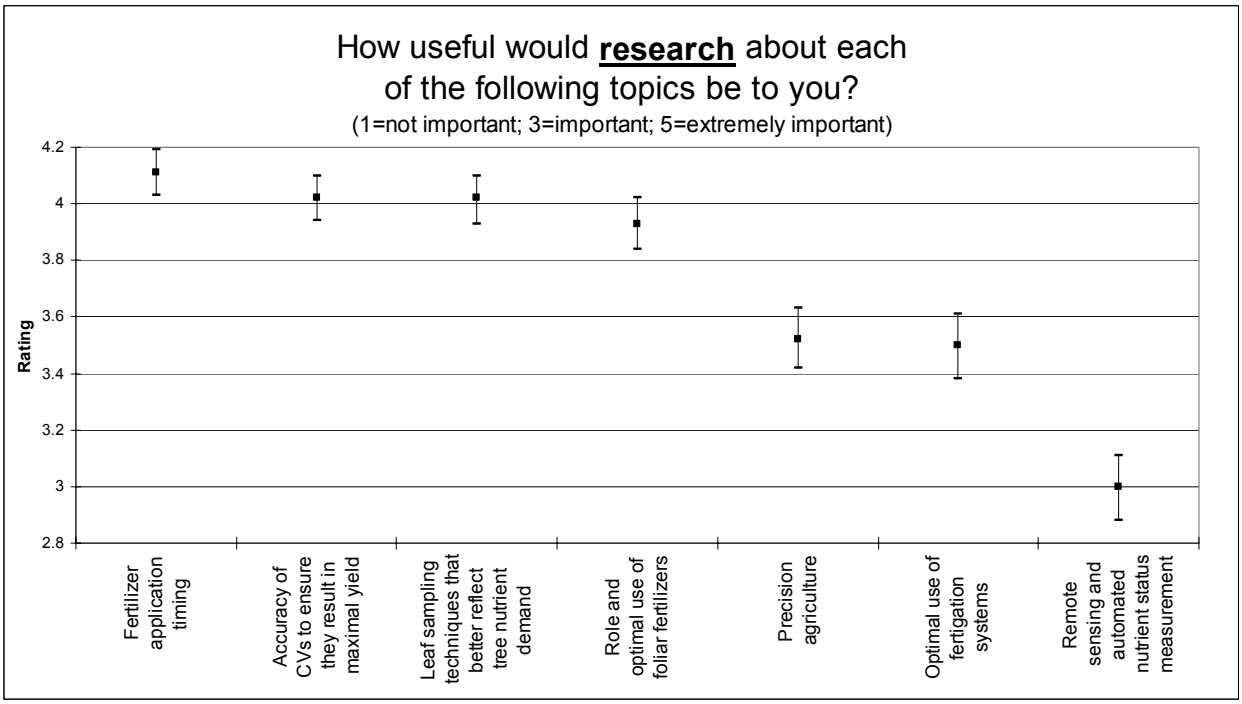


Topic 4: Priorities in Education and Research Relating to Almond Plant Nutrition

Almond growers reported that better-designed publications, a website to help make personalized decisions, more publications, and more training workshops would all be of approximately equal use to them in the future.



Respondents identified research about fertilizer application timing for almond as being very useful to them (mean score=4.11/5), along with research about the relationship between nutrition and disease (4.03/5), the accuracy of critical values to ensure they result in maximal yield (4.02/5), leaf sampling techniques that better reflect tree nutrient demand (4.02/5), and tissue sampling techniques and timings that provide in-season guidance for fertilizer decisions (3.98/5). Respondents were significantly less interested in research about precision agriculture (3.52/5), the optimal use of fertigation systems (3.50/5), the effectiveness of non-fertilizer foliar and soil products (3.19/5), and remote sensing and automated nutrient status measurement (3.00/5). Only selected categories are displayed in the following graph.

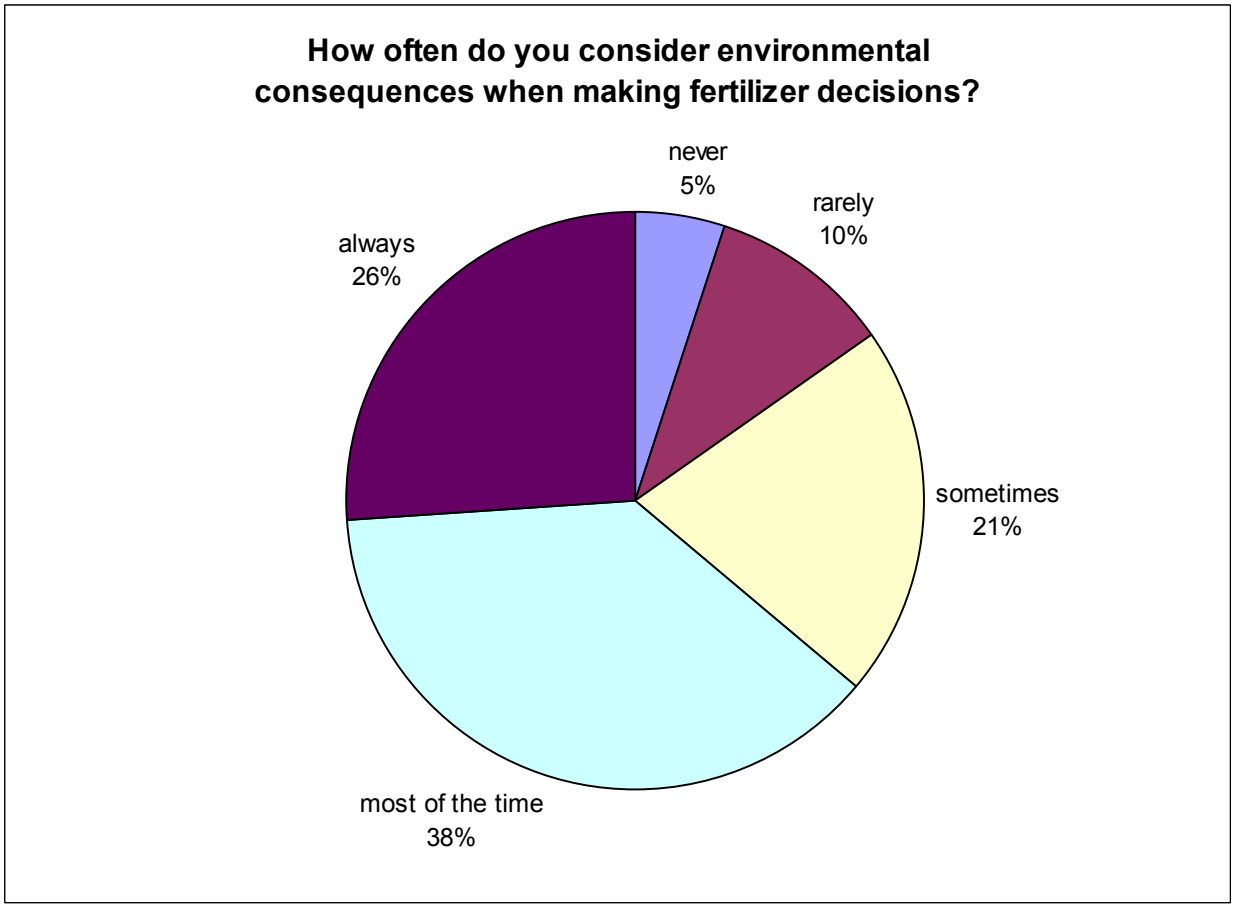


Usefulness of Research Topics to Almond Growers
(mean score out of possible 5 points)

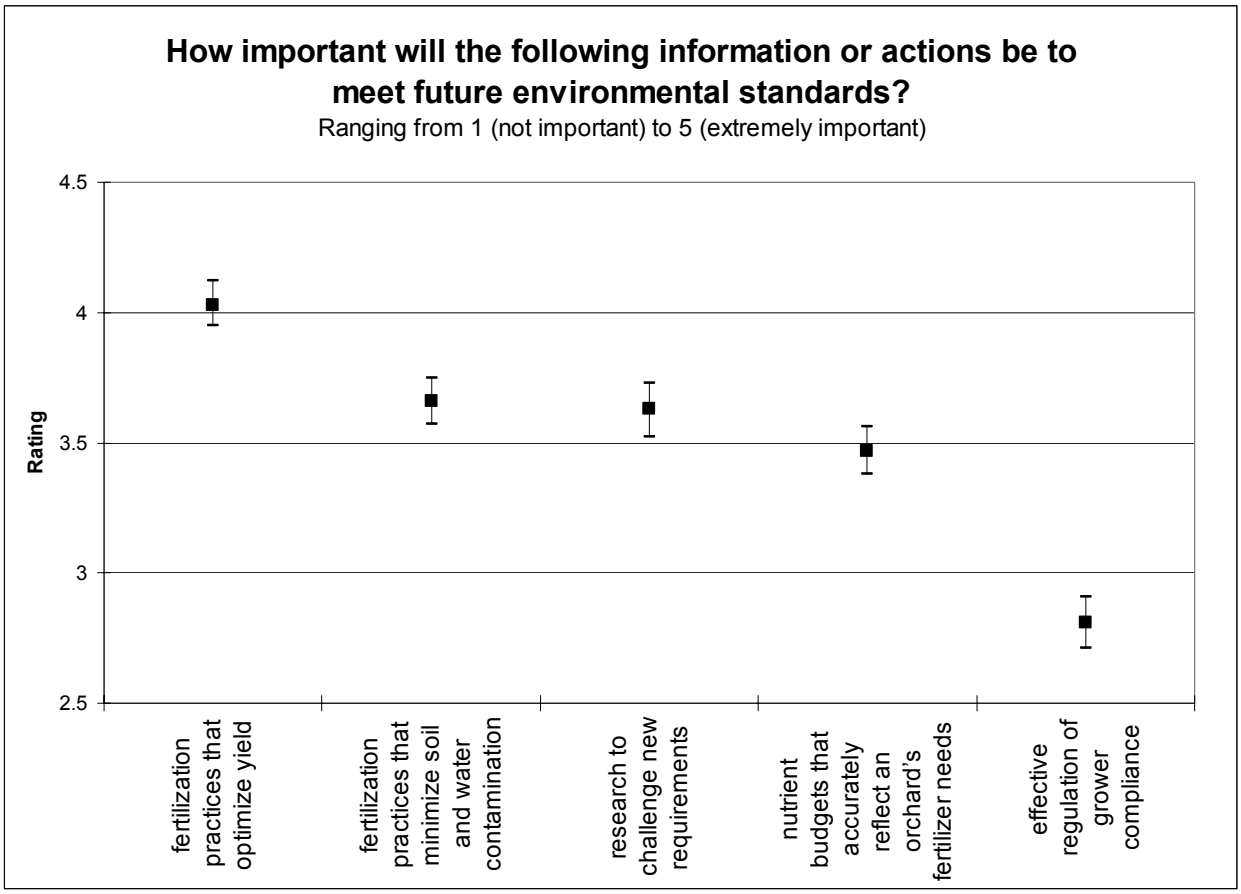
	Mean
Fertilizer application timing	4.11
Relationship between nutrition and disease	4.03
Accuracy of CVs to ensure they result in maximal yield	4.02
Leaf sampling techniques that better reflect tree nutrient demand	4.02
Tissue sampling techniques and timings that provide in-season guidance for fertilizer decisions	3.98
Role and optimal use of foliar fertilizers	3.93
Relationship between fertilization and irrigation	3.88
Nutrition management in problem soils	3.85
Interactions between nutrients	3.8
Fertilization practices to optimize orchard establishment	3.76
Precision agriculture	3.52
Optimal use of fertigation systems	3.5
Effectiveness of non-fertilizer foliar and soil products	3.19
Remote sensing and automated nutrient status measurement	3

Topic 5: Expected Consequences of Environmental Regulations to the Almond Industry

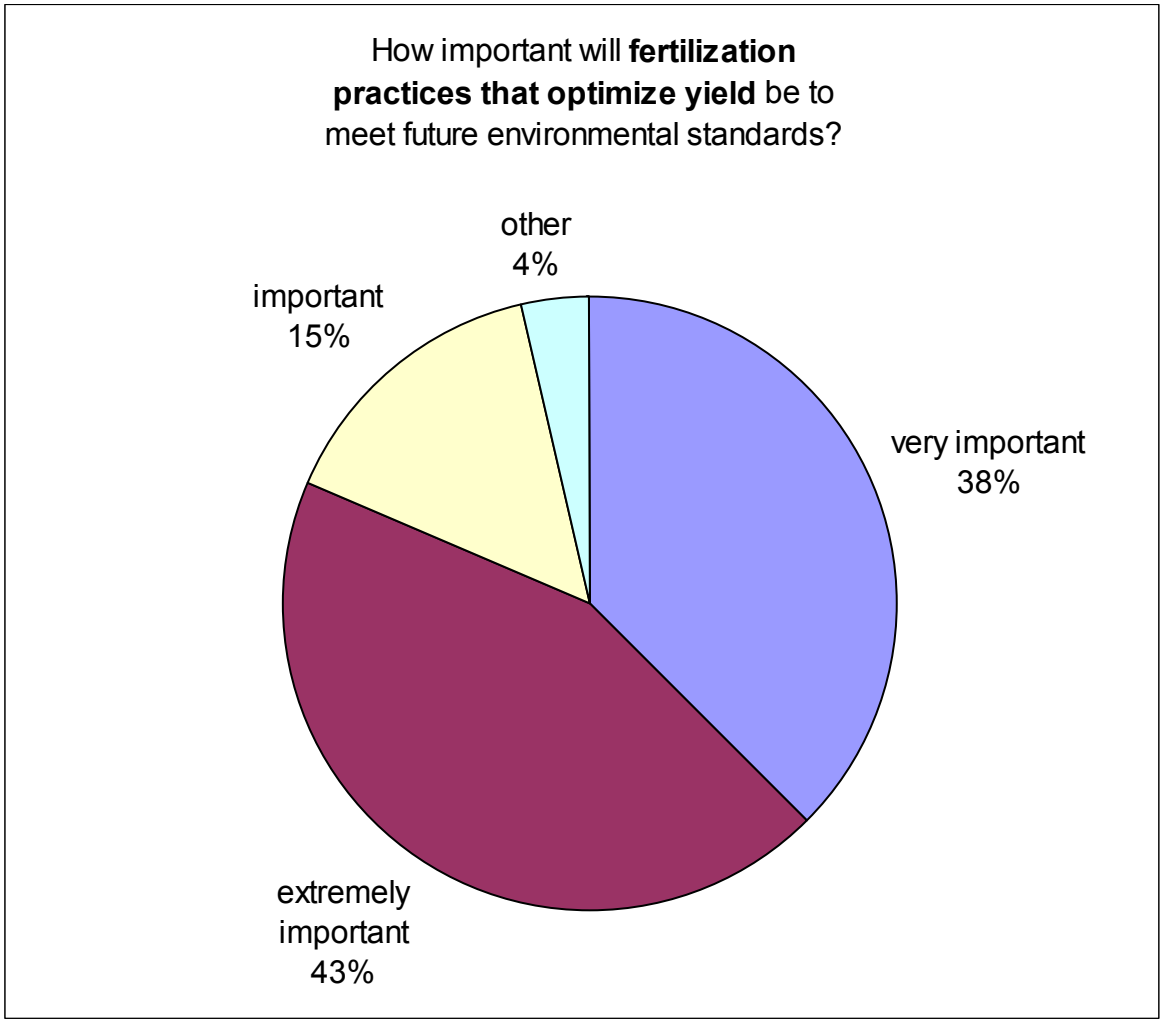
26% of respondents (130 Almond growers) reported that they always consider environmental consequences when making fertilizer decisions, 38% (190 growers) reported that they consider environmental consequences most of the time), 21% (104 growers) consider them sometimes, 10% (51 growers) rarely consider them, and 5% (25 growers) never consider them.



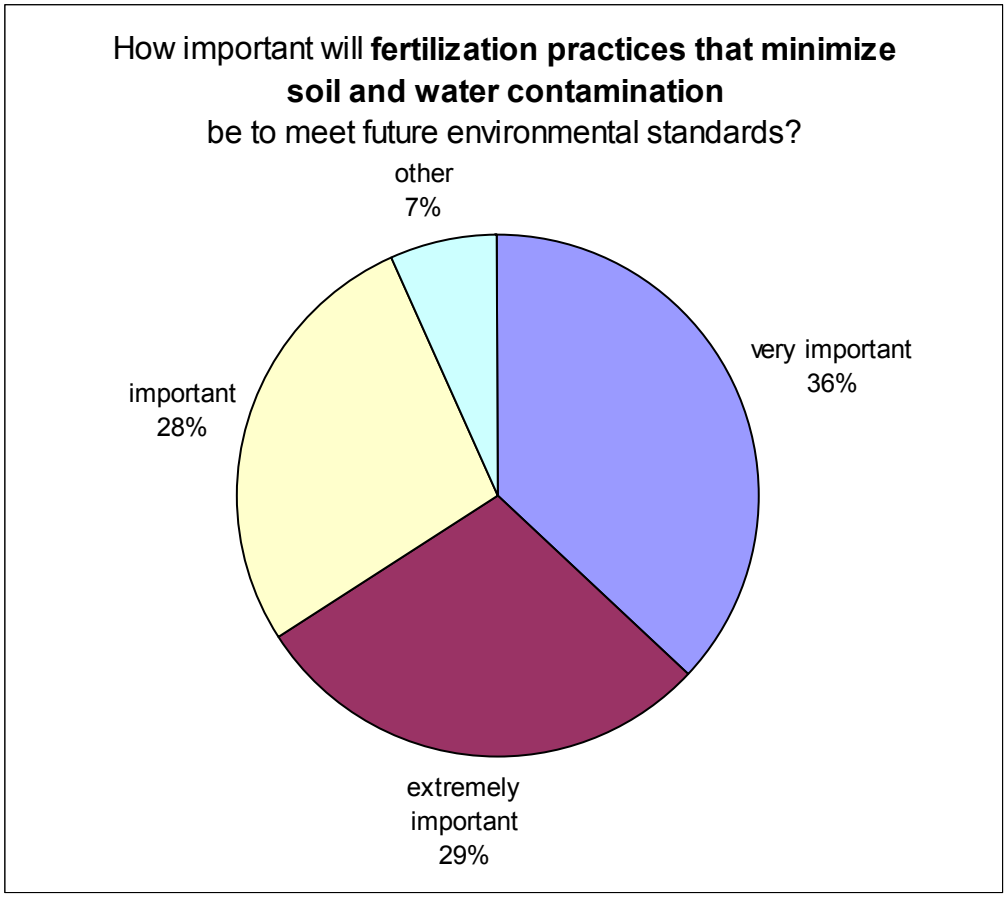
Almond growers reported identifying fertilization practices that optimize yield will be of the most importance to them (4.03/5) in order to meet future environmental standards, followed by identifying fertilization practices that minimize soil and water contamination (3.66/5), performing research to challenge new requirements (3.63/5), and creating nutrient budgets that accurately reflect an orchard's fertilizer needs (3.47/5). Growers identify the effective regulation of grower compliance as being comparatively less important (2.81/5) to them in order to meet future environmental standards.



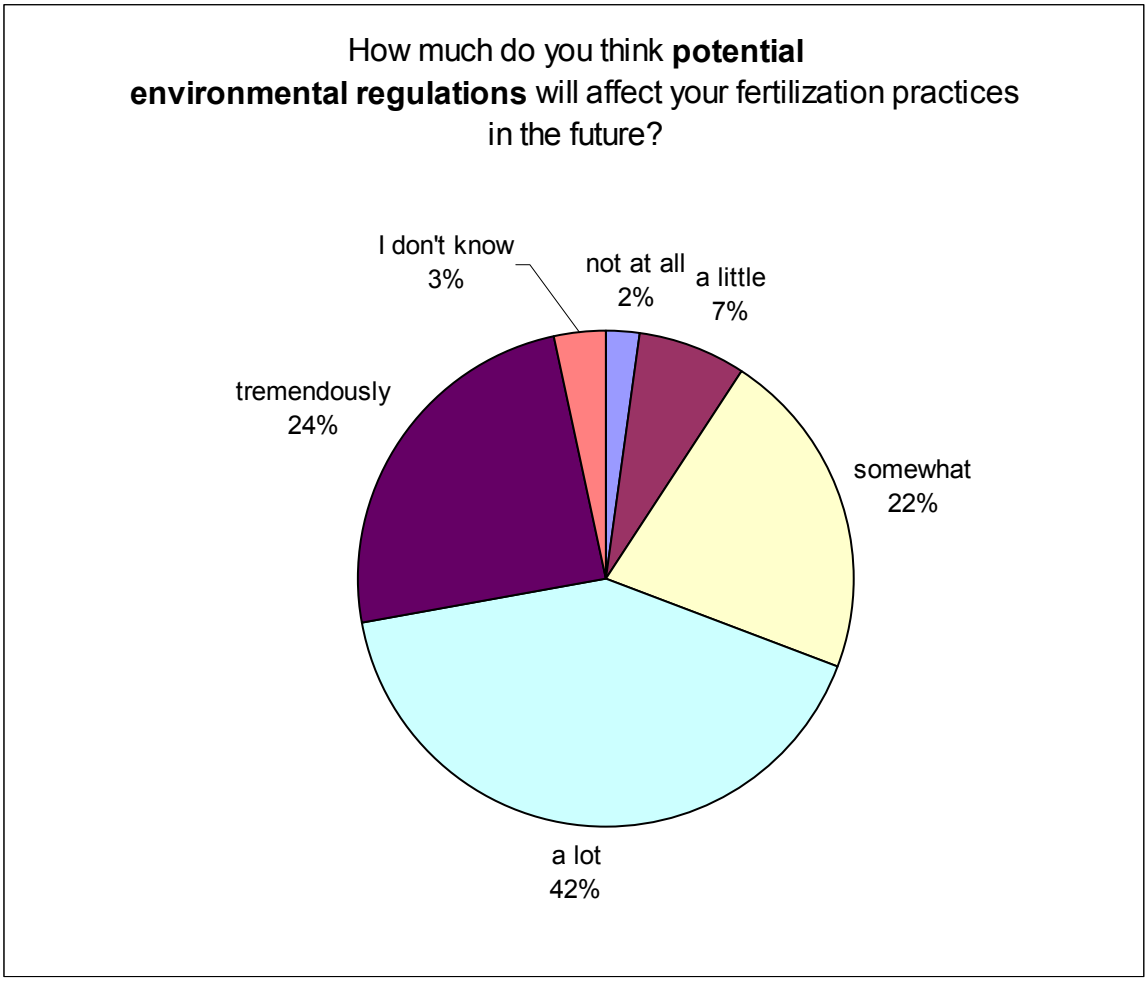
43% of respondents (218 almond growers) reported that identifying fertilization practices that optimize yield will be extremely important to meeting future environmental standards, 38% (187 growers) reported that they will be very important, 15% (75 growers) reported that they will be important, 2% (11 growers) reported that they will be somewhat important, and <1% (3 growers) think they will not be important.



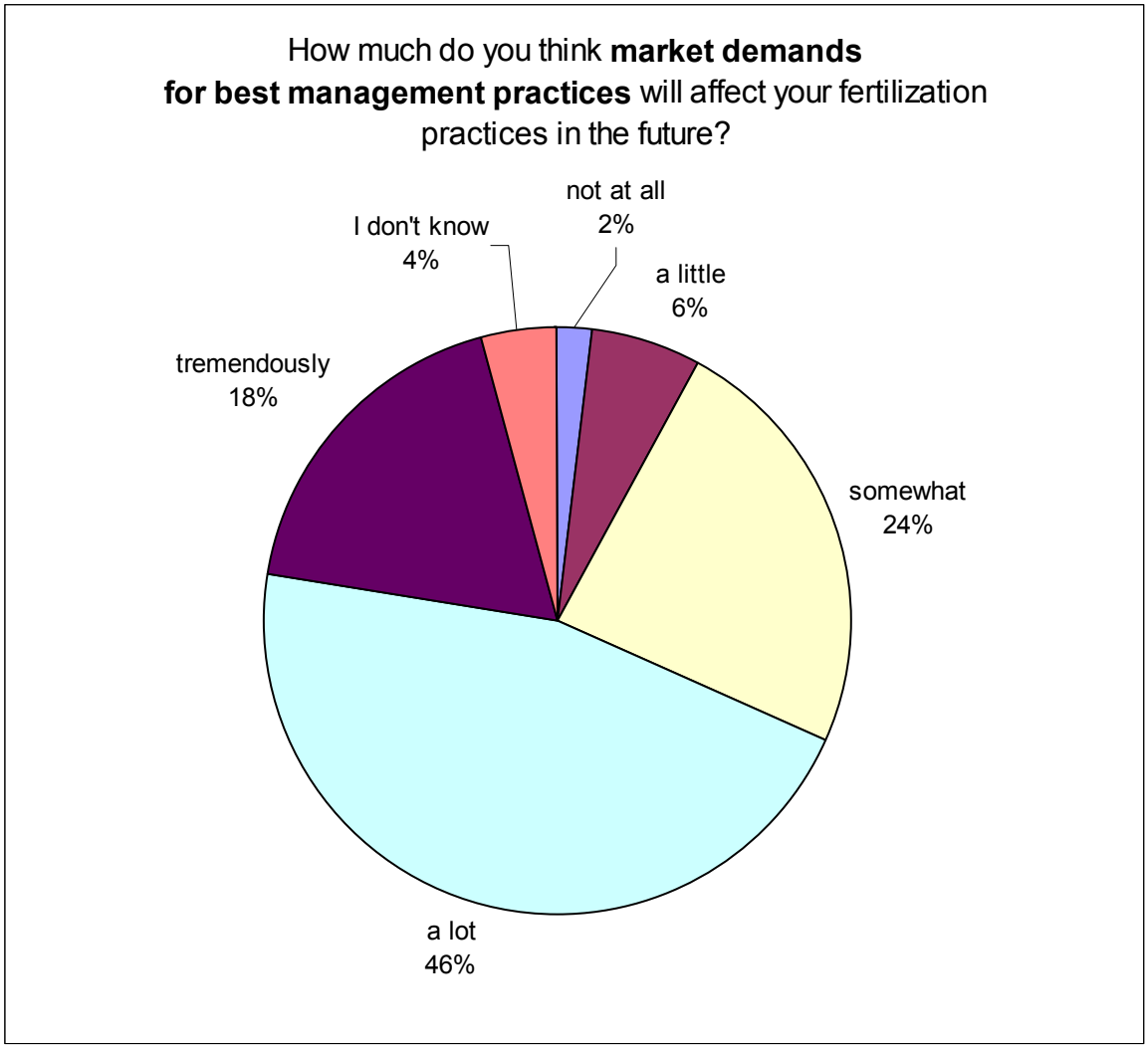
29% of respondents (144 almond growers) reported identifying fertilization practices that minimize soil and water contamination will be extremely important to meeting future environmental standards, 36% (185 growers) reported that it will be very important, 28% (138 growers) reported that it will be important, 4% (22 growers) reported that it will be somewhat important, and 1% (6 growers) reported that it will not be important.



24% of respondents (121 almond growers) think that potential environmental regulations will affect their fertilization practices tremendously in the future, 42% (206 growers) think they will affect their practices a lot, 22% (108 growers) think they will affect their practices somewhat, 7% (35 growers) think they will affect their practices a little, and only 2% (11 growers) think they will not affect their future practices.



18% of respondents (91 almond growers) think that market demands for best management practices will affect their fertilization practices tremendously in the future, 46% (228 growers) think they will affect them a lot, 24% (117 growers) think they will affect them somewhat, 6% (30 growers) think they will affect them a little, and only 2% (10 growers) think they will not affect them at all.



There was no significant difference in the overall means of almond growers' concerns about the effects of potential environmental regulations (mean rating=3.53/5) and the effects of market demands for best management practices (3.51/5) on their future fertilization practices.

Recent Publications:

Preparation of publications for this project has begun, and the first article based on this data will be submitted for publication summer 2008.

Updating Our Knowledge and Planning for Future Research, Education and Outreach Activities to Optimize the Management of Nutrition in Almond and Pistachio Production

Project No.: 06-HORT9-Brown **Interim Report**

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Interpretive Summary:

There is a growing consensus among UC Faculty and Farm Advisors, consultants and growers that the UC established critical values for determination of Almond and Pistachio nutrient status and the methods used to manage fertilization in these crops may be outdated or underutilized. In the absence of viable and well-regarded standards and guidelines for nutrient management, growers do not have the resources needed to use fertilizers wisely. Our goal is to survey current practices, concerns and needs in Almond and Pistachio nutrition, collate existing information and best management practices and design a new research and extension initiative to increase the efficiency of fertilizer usage and guide subsequent nutrition research and education programs. To meet this goal, we conducted small focus groups with industry stakeholders and used the information we gathered to inform the content of surveys we distributed to approximately 1800 randomly-selected Almond growers and 300 Pistachio growers throughout California.

Objectives:

- To conduct a focus group interview (FGI's) among selected stakeholders to identify current practices, concerns and needs in Almond and Pistachio nutrition management.
- To design and conduct a statistically sound and informative survey instrument to identify current practices, concerns and needs in Almond and Pistachio nutrition management.
- To design and conduct two regional nutrition workshops and simultaneous focus group interviews to update knowledge in nutrition management and further define concerns and needs in Almond and Pistachio nutrition management.
- To collate and analyze existing information, survey and workshop findings and use this data to design an extension initiative to increase the efficiency of fertilizer usage and guide the development of new nutrition research and education programs.

Materials and Methods:

Focus Groups

In preparation for the focus group interviews, Dr. Brown and Trexler trained facilitators and developed the following eight questions to ask during the focus group interviews:

1. Where do growers obtain information about fertilizer use?
2. How do you think growers make fertilizer decisions?
3. Are you familiar with the University of California published critical values for almond/pistachio production? If yes, do you think the information they provide is adequate?
4. How do you think the plant nutrition educational needs of the pistachio industry can be satisfied?

5. What do you believe is the role for non-traditional fertilizer and "plant growth" products in pistachio production? *(Non-traditional: all materials other than salts and EDTA chelates)*
6. What do you think should be the top priorities for future research in plant nutrition of pistachios?
7. UC Davis is designing a research survey of stakeholders in the pistachio industry. What kinds of information would be important for us to gather?
8. How will new or potential regulations on environmental protection and good agricultural practices impact nutrition management?

In December 2006 and January 2007, we conducted a total of six focus group interviews with selected Almond and Pistachio stakeholders to identify current practices, concerns and needs in Almond and Pistachio nutrition management. Each focus group was comprised of between eight and twelve participants, and each session lasted ninety minutes. Focus groups were moderated by trained facilitators, and participants' answers were noted by trained transcribers as well as recorded on tape. At the end of each focus group, the transcriber read the group's notes aloud to give participants the opportunity to add to or clarify what had been said.

Surveys

We synthesized information from the focus groups by categorizing participants' responses in order to identify "saturated" concepts, in which the same idea was expressed by participants in numerous focus groups. Based on the results of the focus groups, we designed surveys to distribute to randomly-selected Almond and Pistachio growers in order to provide us with statistically sound, quantitative answers to our questions of growers' current practices, concerns, and needs in the field of plant nutrition. The surveys are 15 pages long and contain 37 questions. An online version of the survey may be viewed at http://education.ucdavis.edu/research/nutsurvey/ .

In April 2007, we submitted a draft of our survey to approximately thirty Almond growers to run a field test. Based upon the responses we received, we made slight revisions to the survey in order to make the questions as clear as possible. We received IRB approval to send the surveys in June 2007.

From a database of approximately 6000 Almond growers, we randomly selected 1800 growers to whom we mailed surveys in early July 2007. We mailed surveys to 300 Pistachio growers; since there is a smaller population of Pistachio than Almond growers in the state, we chose to conduct a census of the entire population of Pistachio growers, so no random selection of names occurred. Respondents were provided with written copies of the surveys and return envelopes, and they were also informed of the option to take the survey online.

In late July, reminder postcards will be sent to survey recipients who have not yet returned their surveys in order to encourage them to respond. In early August, additional copies of the surveys will be sent to recipients who have not yet returned their surveys, in case their original questionnaire was misplaced. If practical, we may

subsequently conduct follow-up phone calls with those recipients who still have not returned their surveys in order to maximize the rate of response.

In September 2007, Dr. Brown and Dr. Trexler with a team of graduate students will collate, analyze and categorize responses. Responses will be used to design the subsequent regional workshops to ensure the workshop program is relevant and attractive. Responses will be used to guide the focus group interviews that will occur during the workshop.

Results and Discussion:

Focus groups

Stakeholders identified three primary sources of information that growers depend upon when making decisions related to nutrition management. Participants in all focus groups identified universities and other farmers and important sources of information, but most stakeholders expressed that private consultants are many growers' first line of information. Although private consultants may have superceded extension agents as the primary point of contact with many almond growers, complex relationships exist between growers, universities, and consultants, since a private consultant's recommendation may be based upon UC research. In this way, research developed by the university may still be of great importance to the almond industry, even if the information it provides is disseminated to growers through a privately-hired source.

When asked their opinions about the effectiveness of the University of California's established critical values, participants in all focus groups expressed that the values are better than nothing and may provide a general guideline for nutrition management program. The focus groups comprised primarily of growers and chemical consultants talked at length about concerns with the accuracy of values and whether they are outdated, with one grower stating, "Aren't there varieties now that weren't there thirty years ago? 'Cause that's when a lot of this stuff was developed." Stakeholders confirmed our belief that the industry is concerned with the suitability of the established critical values to inform modern nutrition management practices, questioning whether the values have kept up with changes in production related to yields and planting densities. The primary concerns participants expressed about critical values related to problems with timing, sampling method, yield maximization, and nutrient interactions.

Stakeholders repeatedly cited timing as a limitation to using critical values to inform nutrient management decisions on orchards. Participants were concerned that critical values relate to nutrient levels in plant tissue during only a ten-day period in July. Although sampling is supposed to occur during this period to allow nutrient levels to be measured when they have reached a plateau, some participants were concerned with the accuracy of this sampling method, stating that weekly samples would be necessary to ensure the plateau had been reached. Another problem with the small sampling window is that information is not available for other times of the year, so growers find themselves "flying blind" much of the time. Participants prioritized future research projects that would allow growers to measure nutrient levels during the critical time of the year between dormancy and leaf production. Other participants were concerned

with misuse of the critical values by growers who sample in the wrong month. Critical values were also identified to be of little use for those nutrients in which deficiencies may stand out in other months but look normal when tissue samples are collected in July.

Another major topic of discussion of critical values related to the difficulties of accurately sampling plant tissue to measure nutrient levels. In addition to problems with the timing of tissue collection, participants were also concerned with sampling inaccuracies due to spatial variation across orchards or even within trees, creating the possibility that "you could pick one [leaf] with your left hand and one with your right hand and get two different numbers." Participants stressed that the small sample sizes relative to the size of the orchard mask variability, and growers or consultants may be unaware of the large margin of error associated with the lab results. If an orchard's number drops from one year to the next, growers and consultants may unnecessarily apply more fertilizer in the future, even if the change was not significant.

Many participants were also dissatisfied with the critical values' dependencies on average values. As one farm advisor expressed, if the critical level for a tree is 2.2, a grower might aim for an average level of 2.5 across his orchard to ensure that few of his trees are below the critical level. As another farm advisor explained, "If the average is 2.2, it's likely that there are some 2.0, and there are some 2.4." Since an orchard-wide average of above a critical level may be associated with half of the orchard's trees falling below that critical level, participants felt there was a disconnect between tree-scale sampling and orchard-wide nutrition optimization. One consultant called tree replicates "almost meaningless," and participants in all focus groups prioritized future research addressing tree variability and nutrient status on the landscape scale.

Many participants were unclear about how a grower could practically apply the information provided by critical values to an orchards' nutrition management program. In cases of lab tests indicating nutrient deficiencies, it was unclear to some participants what steps should be taken to remedy the problem, and they questioned how lab results relate to critical values. Participants questioned the best remedy for an orchard slightly deficient in a particular nutrient and highlighted this as an important field for future research. The relationship between critical values and yield maximization was also discussed. As one grower simply stated, "Obviously, those levels show when you have symptoms, but they don't show what impact they have on yield, and that's the question a lot of people ask." Growers are interested in optimizing their trees' performances, rather than managing their orchards just above a critical level.

In addition to citing the practical problems of timing, sampling, and yield maximization when using critical values to inform nutrition management, participants in all focus groups were concerned that the established critical values ignore interactions between nutrients in an orchard. Participants cited the importance of conducting high-yield research of multiple nutrients simultaneously to understand complex situations in which the critical value for one element may depend upon the level of another element. Some participants suggested the development of ideal ratios between nutrients, since too much nitrogen can throw off an orchard's potassium balance, or a drop in zinc

occurs with an increase in phosphorus. As one consultant expressed, it has been the industry's tendency to improve yields with the application of more nitrogen, "but maybe if they'd added some other nutrient, the roots would have gone better, or more [nitrogen]would have been utilized, or something else."

Concerns about interactions went beyond just those between nutrients in an orchard, and many participants expressed interest in research focusing upon relationships between plant nutrition and external factors such as fertilizer application method, soil type, propensity to disease, and irrigation method. Some participants believed felt that fertilizer use efficiency is closely related to the irrigation system, and water mobilizes the nutrients, but they would like to see more research on the topic. Questions about irrigation particularly focused in the cases of micro and drip irrigation, in which roots grow closer to the surface than with other irrigation methods, causing one consultant to ask, "If our technology has changed how the tree grows, should we be changing our application technique to go along with it?"

The focus group participants confirmed our beliefs that there are numerous uncertainties as to which nutrition management practices will optimize almond production. Without viable management standards providing growers with clear information about how to best balance yields, production costs, and environmental considerations, many growers have responded by increasing the level of fertilizer they apply in order to avoid deficiencies. "We've been farming these fertilizers pretty hard," expressed one grower. "I'll bet you if you looked at the amount of spray we've put on in the last five years, it's probably higher than at any time in the industry. And I think it's time to reevaluate that." Participants expressed that when laboratories provide growers with average nutrient levels for trees in their region, growers may respond by trying to push their trees' levels higher in an effort to be better than average. The results of over-fertilization could be felt economically by growers, whose improved yields may not meet the costs of increased fertilization inputs, and environmentally by surrounding communities, should the excess nutrients runoff from farms or leach into groundwater.

Participants in all focus groups expressed concern about impending regulations on the almond industry, worrying that environmental pressures will be extreme. As one grower asked, "Environmentally, what are those critical levels? Are we putting on excess nitrogen? Are we contaminating the groundwater? What are the optimum levels that we should be applying? We don't have the relationship between those and what yield is returned. All we have is 30- or 40-year-old data, and that's not adequate." Participants feared that regulations based on the outdated values, which do not relate to modern cultivars, will "handcuff the growers" and prevent them from being able to grow high-yielding crops. One farm advisor worried that when regulations are created, regulators will "grab for the first thing on the shelf," which he described as a "pretty sloppy" nitrogen budget. Currently, there are few sources of information related to almond nutrition management to help the industry address this problem.

In all focus groups, participants felt future university research provides the primary opportunity to ensure that environmental regulations on the almond industry will be based upon viable nutrition management practices that will not seriously detriment the

industry economically. As one consultant stated, "Having strong data about what the nutrient needs of the trees are, under what conditions, ultimately can help us take a stronger stand, should the push-back come." Participants cited the University of California's obligation to look out for impacts to growers and feel the university should communicate the results of its future research projects with the Environmental Protection Agency. New research to bring "scientific proof back into the picture" has the potential to inform growers of best management practices and to justify those practices, should environmental regulation occur.

Focus group participants prioritized a number of considerations for future research in almond nutrition management. While research for established critical values was based upon single nutrients evaluated on a tree-wide scale, participants in the focus groups called for a systems-based approach to research in which interactions between nutrients and external factors are investigated on an orchard-wide scale. The established critical values are reductionistic by nature, but farmers manage their orchards systematically and require a solution that allows laboratory results to clearly inform management practices.

An integrated approach to nutrition management research, in which investigators consider multiple elements and factors simultaneously on a large scale, will serve stakeholders in California's almond industry economically and environmentally. By identifying best management practices relating to modern cultivars and technology, researchers will provide growers with the opportunity to optimize yields without wasting money on excess fertilizer that does not provide adequate economic returns. The research will also serve to protect the industry when environmental regulations are created, giving stakeholders hard data with which to justify their fertilization practices. This focus group study demonstrated a clear and immediate need for a new approach to nutrition management research in almonds, so growers will have adequate information to make decisions that will optimize their yields without causing environmental degradation to surrounding communities.

Surveys

To date, we have received over 250 completed almond surveys and approximately 40 completed pistachio surveys. Since we are waiting to receive more surveys, we have not yet begun to analyze the results of the surveys.

Recent Publications:

We are presently preparing an article describing the results of the focus groups.