Assessing Almond Growers' Nutritional Programs

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Abstract

The nutritional information provided by the University of California established critical values for almonds may be outdated and insufficient. In December 2006, researchers at the University of California, Davis conducted focus groups with a sample of almond growers, nutrition consultants, farm advisors, and representatives from the California Environmental Protection Agency, the California Air Resources Board, and the Almond Board of California. The focus groups were designed to collect information relating to factors affecting growers' nutrition decisions, priorities in education and research relating to plant nutrition, and expected consequences of environmental regulation to the almond industry. Stakeholders identified numerous problems with the UC critical values, including the short window of time in which tissue samples can be collected, difficulty in collecting tissue samples that account for spatial variability across a field, and dissatisfaction with the values' reliance upon average nutritional status. Participants were also concerned that critical values may be over-simplified, failing to account for complex interactions occurring on orchards. Some growers respond to uncertainties about the critical values by applying large amounts of fertilizer in order to obtain nutritional values well about the UC-recommended values. Many stakeholders voiced concern about the future of the almond industry in light of impending environmental regulations, since there is a lack of good data on which to base nutritional limits. Stakeholders identified university research as a way to protect the industry from over-regulation and described their priorities for research topics. Based on the focus group results, researchers surveyed 1800 randomly-selected almond growers in June 2007 about their plant nutrition programs in order to assess the nutrition practices of the industry, identify

opportunities for improvement, and target research and extension needs. Analysis of the survey data demonstrates that the majority of respondents, and particularly those respondents with large almond acreage, use fertigation to apply nitrogen, apply nitrogen coincident with periods of maximal plant demand, and collect annual tissue samples. While these results suggest compliance with best available management practices and are likely to result in good nutrient use efficiency, survey results also suggest that growers are uncertain about current practices used to monitor orchard nutrient status and would value additional information to enable greater precision in rate and timing of fertilizer application.

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I. Introduction

University of California-established critical values (CVs) for determination of almond and pistachio nutrient status and the methods used to manage fertilization in almonds and pistachios may be outdated; specifically, UC recommendations may not adequately reflect the significant changes in orchard management, fertilizer formulations, and application technologies or the increasing demands for environmental stewardship that have occurred in the almond and pistachio industries in recent years. The research conducted from the 1950s through the 1980s has not been adequately reexamined in recent years and has not been adapted to the modern production context, and laboratory methodologies have not kept pace with advances in extraction procedures and analytical techniques (Sumner 2006). Efforts to develop best management practices (BMPs) for nitrogen management in almonds have been hampered by an inadequate research base and by the state's diversity of almond-growing conditions, which make identifying best practices difficult. In the absence of viable and well-regarded standards and guidelines for nutrient management, growers may not have the resources needed to use fertilizers wisely.

There is a good deal of uncertainty about current practices and standards for plant nutrition in almond and pistachio production. Further, there has not been a significant review of the 'state of the industry' and no meaningful consideration of where future investment of educational, outreach or research activities should be directed in the field of plant nutrition for almonds and pistachios. In an effort to fill this information gap, researchers from the University of California, Davis (UC Davis), with the support of the

Almond Board of California, California Department of Food and Agriculture (CDFA), and California Pistachio Board, surveyed almond and pistachio growers to investigate growers' current fertilization practices, factors influencing fertilization decisions, and growers' priorities and concerns relating to future research and outreach programs.

A meaningful assessment of the current state of plant nutrition knowledge could not be conducted without a detailed consultation process, so we coordinated focus groups with industry stakeholders in order to identify current practices, concerns, and needs in almond nutrition. The information collected from the focus groups was used to inform the content of a survey that was subsequently administered to a larger population of almond and pistachio growers. With the data from the focus groups and survey, UC researchers hope to collate existing information and BMPs and design a new research and extension initiative to increase the efficiency of fertilizer usage and guide subsequent nutrition research and education programs. This paper presents only analyses of the almond-based focus groups and surveys, although equivalent information was collected from pistachio growers during the same time period.

Mail surveys are commonly utilized by UC researchers and extension agents to investigate agricultural industries. Agricultural researchers have recently used mail surveys to pursue a variety of goals, from investigating the state of California's cattle industry in light of economic change (Andersen et al. 2002) to assessing the pest management decision-making processes of cotton and almond growers (Brodt et al. 2005, 2007). Interpretation of these survey results has allowed researchers to predict future industry trends, identify stakeholder needs, and assess how future extension and research efforts can be tailored to meet these needs (Andersen et al. 2002, Brodt et al. 2005, 2007).

Despite the ease of their administration and the benefits of collecting data from many stakeholders in a single research effort, mail surveys do not always provide researchers with easily-interpretable results. In Brodt et al.'s investigation of cotton growers (2007), for example, researchers were unable to determine, based on questions about adoption of individual practices, whether growers exhibited multi-dimensional understandings of their farms as agroecosystems. The authors ascertained that in-depth interviews would be a more useful tool than mail surveys to collect this type of information. Focus group studies are a proven and verifiable research procedure, developed from nondirective interview methods of the 1930s, to obtain qualitative information from participants in discussions led by skilled interviewers. The open-ended approach of focus groups allows participants to share experiences and attitudes, conveying their true thoughts and feelings while providing data that are of specific interest to the researcher (Krueger and Casey 2000).

Although many types of exploratory interviews are called "focus groups" in casual conversation, Krueger and Casey (2000) define focus group studies as procedures involving multiple discussion groups, ranging in size from four to twelve people each and led by a moderator who is not in a position of power or influence. Participants within each group have something in common, and care is taken to avoid mixing people with different levels of expertise. Results are analyzed across the multiple groups to identify patterns and themes (Krueger and Casey 2000). We conducted three focus groups for each study, and each group was roughly homogenous in composition, comprised either of growers, chemical consultants, or farm advisors. Since information was collected from only one of each group type for each study, we did not have adequate samples to analyze across multiple groups of farmers, chemical consultants, or farm advisors, and it was not possible for us to compare and contrast between stakeholder types. Only with multiple groups of each type would we know whether we reached saturation, the point at which the full range of ideas has been heard, and draw conclusions about stakeholder types with some certainty (Krueger and Casey 2000). Instead, when saturation was reached across the groups, we drew conclusions about stakeholders in general but not linked to stakeholder type.

We followed Krueger and Casey's "long-table approach" to data analysis (2000) for the focus groups, relying initially on field notes and supplementing our research with a tape-based analysis approach to fill in details. In accordance with the long-table method, we identified field notes with colors to indicate which group had provided the information, physically cut the notes apart, and placed the clippings of similar concepts together. When ideas came up repeatedly, we considered these themes to be of importance, and we structured our written report and survey questions around these themes (Krueger and Casey 2000). Focus groups are a proven and established procedure for collecting verifiable information about populations, meaning that another researcher provided with the same documents would arrive at similar conclusions (Krueger and Casey 2000).

Focus groups can be a useful method of interviewing stakeholders, saving researchers time as compared with individual interviews by allowing them to hear viewpoints of multiple participants in a single sitting. The group atmosphere of focus groups may also be of benefit to researchers because it allows participants to compare their views to those of others, often leading them to voluntarily change their opinions to align behind well-informed participants, thus increasing the likelihood of reaching consensus (Düvel and Kalanzi 1999). This trend can also be a danger to researchers, however, because there is a possibility of individuals being dominated by others in focus group exercises (Murray and Butler 1994, Düvel and Kalanzi 1999).

In this study, researchers combined focus group and mail survey methods in order to benefit from both the open-ended nature of focus groups and the large number of respondents of a mail survey. The focus group study was conducted at the Almond Industry Conference in Modesto, California in 2006, with a population consisting of almond growers, nutrition consultants, farm advisors, and representatives from the California Environmental Protection Agency, the California Air Resources Board, and the Almond Board of California. Interview questions were 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. Section II of this paper presents selected portions of the focus group study's results, which indicate that stakeholders have identified numerous problems with UC established critical values. Stakeholders identified priorities in future university research that they feel may assist growers in conserving fertilizer while optimizing yields and may help protect the industry from over-regulation, should environmental limits be imposed in the future.

The results of the focus group study were used to inform the content of a survey mailed to 1800 randomly-selected almond growers. The survey was 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 survey's questions were presented roughly in the order of the focus group questions, and for multiple-choice survey questions, answer choices were based upon the concepts discussed by focus group participants.

Section III of this paper presents a selection of the survey's results, in which almond grower's nutrition programs are compared with perceived BMPs in order to assess the current state of almond growing and identify potential room for improvement through future outreach activities.

Our mail survey response rate of 30.0% may have been lower than the rate (71%) observed by Dillman (2007) among researchers who used some but not all components of his method due in part to almond growers' frustration with receiving numerous recent requests for their participation in surveys. With a low response rate, it is possible that nonresponse error is high, indicating that respondents are different than nonrespondents

(Dillman 2007). However, our response size is adequate to draw conclusions with ±3.9% sampling error, based upon our estimated population size of 3136 almond growers, a 95% confidence interval, and assumption of maximum variation within the population (see Section V: Appendix). In addition to nonresponse error, measurement error, in which questions are misunderstood by participants or incorrectly answered, is also of concern to survey researchers (Dillman 2007). We attempted to reduce coverage error by revising problematic questions based upon a field test performed with approximately twenty almond growers who voluntarily completed a draft of the survey in Spring 2007. Based upon their comments and researchers' identification of problematic questions that appeared to have been completed improperly, the survey was revised before being distributed to the population in June, 2007.

A one-time, large-scale assessment of stakeholders' needs may be a suboptimal method with which to collect information to inform extension and research efforts because respondents may dramatically change their opinions of perceived needs within only a couple years (Düvel and Kalanzi 1999). UC researchers and extension agents may therefore benefit from future small-scale focus groups with stakeholders to ensure that extension and research projects continue to address the industry's changing needs. With the small amount of time and preparation necessary to involve stakeholders in continued research efforts, it may be possible to accurately and efficiently tailor agricultural projects to meet stakeholders' needs.

II. Focus Group Analysis: Exploring how growers presently use critical values and priorities in future nutrition research

Abstract

The nutritional information provided by the University of California established critical values for almonds may be outdated and insufficient. In December 2006, researchers at the University of California, Davis conducted focus groups with a sample of almond growers, nutrition consultants, farm advisors, and representatives from the California Environmental Protection Agency, the California Air Resources Board, and the Almond Board of California. The focus groups were designed to collect information relating to factors affecting growers' nutrition decisions, priorities in education and research relating to plant nutrition, and expected consequences of environmental regulation to the almond industry. Stakeholders identified numerous problems with the UC critical values, including the short window of time in which tissue samples can be collected, difficulty in collecting tissue samples that account for spatial variability across a field, and dissatisfaction with the values' reliance upon average nutritional status. Participants were also concerned that critical values may be over-simplified, failing to account for complex interactions occurring on orchards. Some growers respond to uncertainties about the critical values by applying large amounts of fertilizer in order to obtain nutritional values well about the UC-recommended values. Many stakeholders voiced concern about the future of the almond industry in light of impending environmental regulations, since there is a lack of good data on which to base nutritional limits. Stakeholders identified university research as a way to protect the industry from over-regulation and described their priorities for research topics.

Background

There is a growing consensus among almond growers, consultants, and University of California (UC) faculty and farm advisors that the UC-established critical values (CVs) for determination of almond nutrient status and the methods used to manage fertilization in almonds may be outdated. Specifically, it is believed that UC recommendations may not adequately reflect the significant changes in orchard management, fertilizer formulations, and application technologies or the increasing demands for environmental stewardship that have occurred in the almond industry in recent years. The research conducted in the 1950s through 1980s has not been adequately reexamined in recent years and has not been adapted to the modern production context, and laboratory methodologies have not kept pace with advances in extraction procedures and analytical techniques (Sumner 2006). Efforts to develop best management practices (BMPs) for nitrogen management in almonds have been hampered by an inadequate research base and by the diversity of almond-growing conditions in the state, which make identifying best practices difficult. In the absence of viable and well-regarded standards and guidelines for nutrient management, growers may not have the resources needed to use fertilizers wisely.

In addition to being possibly outdated, the UC established critical values may be limited in their practical application because they measure nutrient deficiency rather than nutrient status associated with yield optimization, and it is widely accepted that the appearance of visual symptoms of nutrient deficiencies occurs only after growth and productivity have been negatively impacted (Marschner 1995). While this approach to nutrient management may have been appropriate in the past, given difficulties in conducting large scale yield-based experiments and given the nature of the production systems at the time of experimentation, modern production systems and awareness of the environmental impacts of poor fertilization practice may require that nutrients be managed more precisely to eliminate any potential negative impact on plant establishment and yield and the environment.

There is a good deal of uncertainty about current practices and standards for plant nutrition in almond production. Further, there has not been a significant review of the 'state of the industry' and no meaningful consideration of where future investment of educational, outreach or research activities should be directed in the field of plant nutrition for almonds. A meaningful assessment of the current state of plant nutrition knowledge could not be conducted without a detailed consultation process, so we coordinated focus groups with industry stakeholders in order to identify current practices, concerns, and needs in almond nutrition.

Focus groups are a useful tool to rapidly and efficiently gather detailed opinions from stakeholders (UC Health Promotion Workgroup 2002), and sessions can easily be carried out on-site at industry conventions or field days. The results of focus groups provide researchers with the opportunity to hear many directions explored through open-ended discussion, rather than limiting stakeholders to providing only certain types of answers to questions (Krueger and Casey 2000), as may occur in a survey. For our study of the almond industry's nutrition management practices and research needs, we used the information we gathered from the focus groups to inform a survey with a wider, randomly-selected population of almond growers. With the data from the focus groups and survey, UC researchers hope to collate existing information and BMPs and design a new research and extension initiative to increase the efficiency of fertilizer usage and guide subsequent nutrition research and education programs.

Methods

We conducted the focus group study at the Almond Industry Conference in Modesto, California in December, 2006. The sample consisted of 34 almond growers, nutrition consultants, farm advisors, and representatives from the California Environmental Protection Agency (CA EPA), the California Air Resources Board (CA ARB), and the Almond Board of California (ABC). Focus group participants were invited to take part based on the researchers' personal familiarities with growers and consultants who manage farms of various sizes and locations with diverse management practices. Krueger (1994) suggests that focus groups should be homogenous and should range in size from 4 to 12 participants to allow opportunity for individuals to talk and to provide for practical logistics and management. In this study, the three focus groups fell within this range, with 10 to 12 people participating in each group. Each group was roughly homogenous in composition, comprised primarily of growers; chemical consultants; or farm advisors and representatives from the CA EPA, the CA ARB, and the ABC.

Three 90-minute focus groups were conducted; by conducting three focus group sessions, we were able to detect patterns and trends across the groups and increase our chances for a saturated response (Strauss 1987), in which members of multiple groups voice the same idea. Since information was collected from only one of each stakeholder type for each study, we do not have adequate samples to analyze across multiple groups of farmers, chemical consultants, or farm advisors, and it was not possible for us to compare and contrast between stakeholder types. Only with multiple groups of each type would we know whether we reached saturation, the point at which the full range of ideas has been heard, and draw conclusions about stakeholder types with some certainty (Krueger and Casey 2000). Instead, when saturation was reached across the groups, we drew conclusions about stakeholders in general but not linked to stakeholder type.

Field notes were collected to serve as the primary data source, and interviews were audio taped and transcribed, to be consulted as secondary data sources. Each focus group followed a format outlined by Krueger (1994). Two UC researchers attended each focus group, with one moderating the interview while the other took field notes. The researchers had all attended a focus group training workshop and were familiar with topics in plant nutrition. Interview questions were 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.

We followed Krueger and Casey's "long-table approach" (2000), also known as a "bins" approach (Miles and Huberman 1984), to organize the focus group data, relying initially on field notes and supplementing our research with a tape-based analysis approach to fill in details. In accordance with the long-table method, we identified field notes with colors to indicate which group had provided the information, physically cut the notes apart, and placed the clippings of similar concepts together. When ideas came up repeatedly, we considered these themes to be of importance, and we structured our written report and survey questions around these themes. Analysis of focus group data in this way is a proven and established procedure for collecting verifiable information about populations, meaning that another researcher provided with the same documents would arrive at similar conclusions (Krueger and Casey 2000).

Results

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 as 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 UC-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 (see Table 1). 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 CVs 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 CVs related to problems with timing, sampling method, yield maximization, and nutrient interactions.

Stakeholders repeatedly cited timing as a limitation to using CVs to inform nutrient management decisions on orchards (see Table 1). Participants expressed concerns about CVs' reliance upon 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 believed 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 CVs by growers who sample in the wrong month. Critical values were also thought 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.

Saturated Topic	Sample context in which topic was discussed by each focus group		
	A: Growers	B: Industry members	C: Farm Advisors
Accuracy of CVs	Don't think CVs are accurate.	Don't think CVs are accurate.	x
	CVs give guidance for some nutrients.	CVs are better than nothing.	CVs provide general guidelines.
Timing of tissue Sampling	Values are only for June and July.	Year-round decisions must be based on values from the first 10 days of July.	Deficiences present in other months may not appear in July.
Interactions affecting nutrients	CVs should consider nutrient interactions.	Researchers should determine ratio of nutrients relative to each other for optimum growth.	Researchers should assess how elements work with plants.
	Production regime affects nutrient levels.	Foliar vs. other application methods affects nutrient levels.	Research of other variables (such as irrigation method) could lead to better understanding of how nutrients fluctuate.
Specific nutrients	Concerned with potassium.	People use more than the CV levels of potassium.	Research trials showed that CVs aren't far off for potassium, but the industry disagrees. More trials needed.
	Concerned with zinc: leaf analysis doesn't help.	x	Can't use leaf analysis for zinc because of foliar applications and because zinc is not held in leaves.
	Boron levels are questionable	x	In some orchards, boron CVs appear too high, and in others they appear to be correct.
Challenges with sampling method and applying information	x	Values fluctuate: the same person taking a sample could get two different results.	Growers and consultants may not recognize margin for error in lab analyses
	Unsure of how lab results relate back to CVs.	x	Labs provide average values.
	how do CVs tie in with yield maximization?	CVs aren't designed to maximize yields	x
Development of personal CVs	Some growers rely on consultants to give them information about CVs.	Some labs use modified CVs or interpret CVs independently.	Different labs have their own interpretations of the UC CVs.

Table 1. Topics addressed by each focus group (growers, industry members, and Farm Advisors) when asked their opinions about the effectiveness of UC CVs. Accuracy of CVs, timing of tissue sampling, interactions affecting nutrients, specific nutrients, challenges with sampling methods and applying information, and development of personal CVs were discussed by members of all focus groups, indicating that "saturation" was reached. Specific points raised by members of each focus group demonstrate the context in which the saturated topic was discussed. An "x" indicates a sub-topic not recorded in the transcript of a particular focus group; however, since information was collected from only one of each group type for each study, it is not possible for us to compare and contrast between stakeholder types.

Another major topic of discussion of CVs related to the difficulties of accurately sampling plant tissue to measure nutrient levels (see Table 1). Participants were concerned with sampling inaccuracies due to spatial variation across orchards or 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 sizes of the orchards 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 dissatisfied with the CVs' dependencies on average values (see Table 1). 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 nearly 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 (see Table 1).

Many participants were unclear about how a grower could practically apply the information provided by CVs to an orchard's nutrition management program (see Table

1). 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 CVs. 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 CVs and yield maximization was also discussed. As one grower 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 CVs to inform nutrition management, participants in all focus groups were concerned that the established CVs ignore interactions between nutrients in an orchard (see Table 1). Participants cited the importance of conducting high-yield research of multiple nutrients simultaneously to understand complex situations in which the CV 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....”

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 (see Table 1). Some participants believed 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 on 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?" Another consultant observed:

> "There needs to be better education on what antagonizes, or what uses up. I mean, you put phosphorus on, your zinc goes down. You put boron on, your calcium goes in a different direction. You put more calcium on, your boron goes in a different direction…. We should be thinking in terms of more than just a single shot of calcium, a single shot of boron."
>
> --Consultant

Implications

Input from 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 may have a negative economic effect on growers, if their improved yields do not meet the costs of increased fertilization inputs. Negative environmental effects could occur in 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 UC’s obligation to look out for impacts to growers and feel the university should communicate the results of its future research projects with the EPA. 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.

> “I mean, sometimes, we tend to over-farm our trees a little bit. We had a couple plots up on a hill earlier this year, and all those trees were just yellow for about a month. And I threw everything but the kitchen sink in, and finally I just quit, and then they just greened up on their own.”
>
> --Grower

Recommendations

Focus group participants prioritized a number of considerations for future research in almond nutrition management. While research for established CVs 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 growers 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 BMPs 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 adopted, 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.

III. Survey Analysis: Almond growers' nutrition programs are assessed and compared with theorized best management practices

Abstract

Fertilizer use in Californian agriculture has been under recent scrutiny for its possible impacts on air, surface water, and ground water quality. In June 2007, researchers at the University of California, Davis surveyed 1800 almond growers about their plant nutrition programs in order to assess the nutrition practices of the industry, identify opportunities for improvement, and target research and extension needs. Analysis of the survey data demonstrates that the majority of respondents, and particularly those respondents with large almond acreage, use fertigation to apply nitrogen, apply nitrogen coincident with periods of maximal plant demand, and collect annual tissue samples. While these results suggest compliance with best available management practices and are likely to result in good nutrient use efficiency, survey results also suggest that growers are uncertain about current practices used to monitor orchard nutrient status and would value additional information to enable greater precision in rate and timing of fertilizer application.

Background

Nitrogen (N) is a key mineral element for the global food supply (Vitousek et al. 1997, Hirel et al. 2007), and adding nitrogen fertilizer to crops is a fundamental step in producing commercially-viable agricultural products. However, nitrogen that is not taken up by plants or retained in soil organic matter will "leak" from agricultural systems, contributing to environmental challenges such as greenhouse gas (GHG) emissions in the form of nitrous oxide (N_2O, Veltholf et al. 2009) and watershed pollution in the form of high concentrations of nitrate (NO_3) in water (Domagalski et al. 2008).

In 2006, the State of California identified GHG reduction as a major goal and passed the Assembly Bill No. 32 to reduce GHG emissions to 1990 levels by 2020, a reduction of about 25% (California Air Resource Board 2006). Industries utilizing nitrogen have attracted policymakers' attention as potential emissions reducers because a single unit of N_2O gas is equivalent in potency to approximately 300 units of carbon dioxide (CO_2) gas (Intergovernmental Panel on Climate Change 1995). In 2004, the California Air Resource Board concluded, based on the limited data available, that agricultural soils were the largest source of N_2O in California, accounting for 50% of the state's total N_2O emissions, with 60% of those emissions related to the use of synthetic fertilizers (California Air Resource Board 2006). Because of nitrous oxide's global warming potential, even modest reductions in its emission could contribute meaningfully to reduced GHG emissions by 2020.

Soil nitrate concentrations can increase significantly when applied and mineralized nitrogen levels exceed plant N use. Nitrate in run-off from heavily-fertilized agricultural land can reach rivers and streams, raising concerns about drinking water quality and eutrophication of water bodies (Fenn et al. 1998). Burow et al. (1998) found that a high proportion of groundwater samples from under almond orchards exceeded the maximum contaminant level of NO_3-N (10mg/L, Environmental Protection Agency 2006), reflecting high levels of nitrogen applications. Almonds represent California's fifth-largest agricultural commodity (in percentage of state total farm receipts, United States Department of Agriculture--Economic Research Service 2009), and the industry has grown to include more than 6,000 almond growers and 615,000 bearing acres (Almond Board of California 2008). Nitrogen management in almond has been subject to much research, and a summary of conventional practice is presented in the Almond Production Manual (Micke 1996).

The addition of any nitrogen source to a soil increases the potential for both nitrous oxide generation and nitrate leaching. To minimize this potential, management practices that reduce total nitrogen inputs, increase the utilization of the applied nitrogen by crops, and enhance the stability of nitrogen in the soil must be developed and adopted. The principles and practices underlying the development of fertilizer best management practices (BMPs) for nitrogen have recently been summarized by Bruulsema et al. (2008); these include (a) the use of soil or plant testing to define crop nutrient status and (b) the application of the right amount of fertilizer (c) coincident with the time of greatest crop demand and (d) placed in a location and form that maximize the potential for uptake and minimize the potential for loss from the system. In agricultural systems where explicit experimental data and fertilization guidelines are poorly developed, fertilization practices that approach these ideal characteristics represent best available management practice and are most likely to optimize nitrogen use efficiency when contrasted with other approaches. Given the absence of specific nutrition management guidelines for almond, we theorize that these principles can be best be applied under current production constraints through 1) use of fertigation to enable nitrogen placement in the zone of greatest root activity, 2) the application of nitrogen coincident with periods of greatest nutrient demand, and 3) use of tissue sampling and analysis to monitor nutrient levels in trees.

In June 2007, researchers at the University of California, Davis (UC Davis) surveyed almond growers to assess current practices, concerns, and needs in almond nutrition.

This article focuses on comparisons between respondents' practices and the set of theorized BMPs described above. We also present the number of acres of almonds grown by respondents who do not adhere to the perceived best practices in order to inform potential extension efforts related to nutrient use efficiency.

Methods

We designed and distributed a survey comprised of 37 multi-part questions to collect data regarding grower demographics (18 questions), fertilization use practices (11 questions), factors affecting fertilization decisions (2 questions), priorities in education and research relating to plant nutrition (3 questions), and expected consequences of environmental regulation to the almond industry (3 questions). The questions were largely based on information collected through preliminary focus group sessions held in 2006 at the Almond Industry Conference in Modesto, California, in which three concurrent focus groups were conducted with growers; chemical consultants; farm advisors; and/or representatives from the California Environmental Protection Agency, the California Air Resources Board, and the Almond Board of California.

The survey population consisted of 1800 almond growers from 18 counties throughout California, whose names were randomly selected from a database of 3060 growers from pesticide use databases. Although all organic almond growers registered with California Certified Organic Farmers (n=76) were also surveyed, their results are not presented in this thesis. Guided by standard protocol (Dillman 2007), postcards were mailed in April

2007 to draw growers' attention to the forthcoming survey, surveys were mailed in June 2007, and second copies of the survey were mailed in August 2007 to growers who had not yet responded. Growers were given the option of completing the survey by mail or online. Surveys were coded to maintain anonymity of respondents and to ensure that online respondents were members of the randomly-selected sample.

To assess fertilizer N use in almond orchards, we compared growers' current practices with the theoretical set of BMPs derived from existing knowledge, focus groups, email consultations with informed individuals in the industry, and the concepts presented by Bruulsema et al. (2008). Although many practices other than those discussed here have been applied in other cropping systems and may aid in achieving enhanced nitrogen use efficiency, none have been adequately validated in almond; for this investigation, therefore, we focused upon three practices that are currently available and for which grower compliance is measurable: 1) using fertigation to apply some or all nitrogen fertilizer in orchards (where irrigation methods permit), 2) applying nitrogen fertilizer with perceived optimal seasonality, and 3) using annual tissue sampling to monitor nutrient levels in trees.

We identified fertigation, in which fertilizer is applied through an orchard's irrigation system, as a theorized BMP because it allows for multiple in-season applications, targeted timing, and synchrony with irrigation, potentially reducing fertilizer usage and optimizing efficiency.

Optimized timing of nitrogen applications ensures nitrogen is available to trees when they are actively taking up nutrients. Research suggests that the pattern of nutrient demand during a cropping cycle closely matches the rate of nutrient accumulation in the almond crop once nutrient reserves in the perennial tissue have been depleted (Weinbaum et al. 1980, 1990). Thus, under Californian conditions, nutrient uptake in almond trees commences following full leaf expansion in March or early April, increases during periods of rapid fruit development, is maximal during nut filling and prior to full maturity, and declines once fruit reach full maturity, with minimal nutrient uptake occurring during leaf senescence or dormancy If growers are to make nutrients available to trees at optimal times, therefore, seasonality of nutrient application involves the greatest amount of nutrients applied in summer months, a smaller portion of nutrients applied in spring and autumn months, and no nutrients applied in winter months. For the seasonality analysis, we calculated each grower's deviation from this schedule of nutrient uptake; scores ranged from 2 to 10, with 10 assigned to growers who apply with "optimal seasonality" and the lowest possible score of 2 assigned to growers who apply 100% of nitrogen fertilizer in the winter (see Section V: Appendix).

In deciduous tree production, leaf sampling and analysis and comparison with established standards, or critical values (CVs), represents the primary tool for fertilizer decision making (Brown and Uriu 1996). Annual tissue sampling, when properly performed and analyzed, may provide growers with useful information about trees' nutrient status and demand, allowing them to adjust their nitrogen applications accordingly.

Data was analyzed with X^2 analysis ($\alpha=0.05$), and logistic regression was used for answers rated on a Likert Scale. Blank and "I don't know" answers were excluded from analyses. Analysis of the data was performed using JMP 7 statistical software (SAS Institute Inc. 1989-2007).

Results

RESPONSE RATE

Of the 1800 recipients randomly selected from the pesticide use database, 529 completed the survey, and 38 recipients informed us that they no longer grow almonds, for an overall response rate of 30.0% (529/1762). Our mail survey response rate of 30.0% may have been lower than the rate (71%) observed by Dillman amongst researchers who used some but not all components of his method (Dillman 2007) due in part to almond growers' frustration with receiving numerous recent requests for their participation in surveys. With a low response rate, it is possible that nonresponse error is high, indicating that respondents are different than nonrespondents (Dillman 2007). However, our response size is adequate to draw conclusions with ±3.9% sampling error, based upon our estimated population size of 3136 almond growers, a 95% confidence interval, and assumption of maximum variation within the population (Appendix).

GENERAL DEMOGRAPHIC TRAITS OF GROWERS

Most respondents (62%, see Figure 1) grow under 100 acres of almonds, while 17% grow 100-249 acres of almonds, 14% grow 250-749 acres, and 7% grow 750 or more acres of almonds.

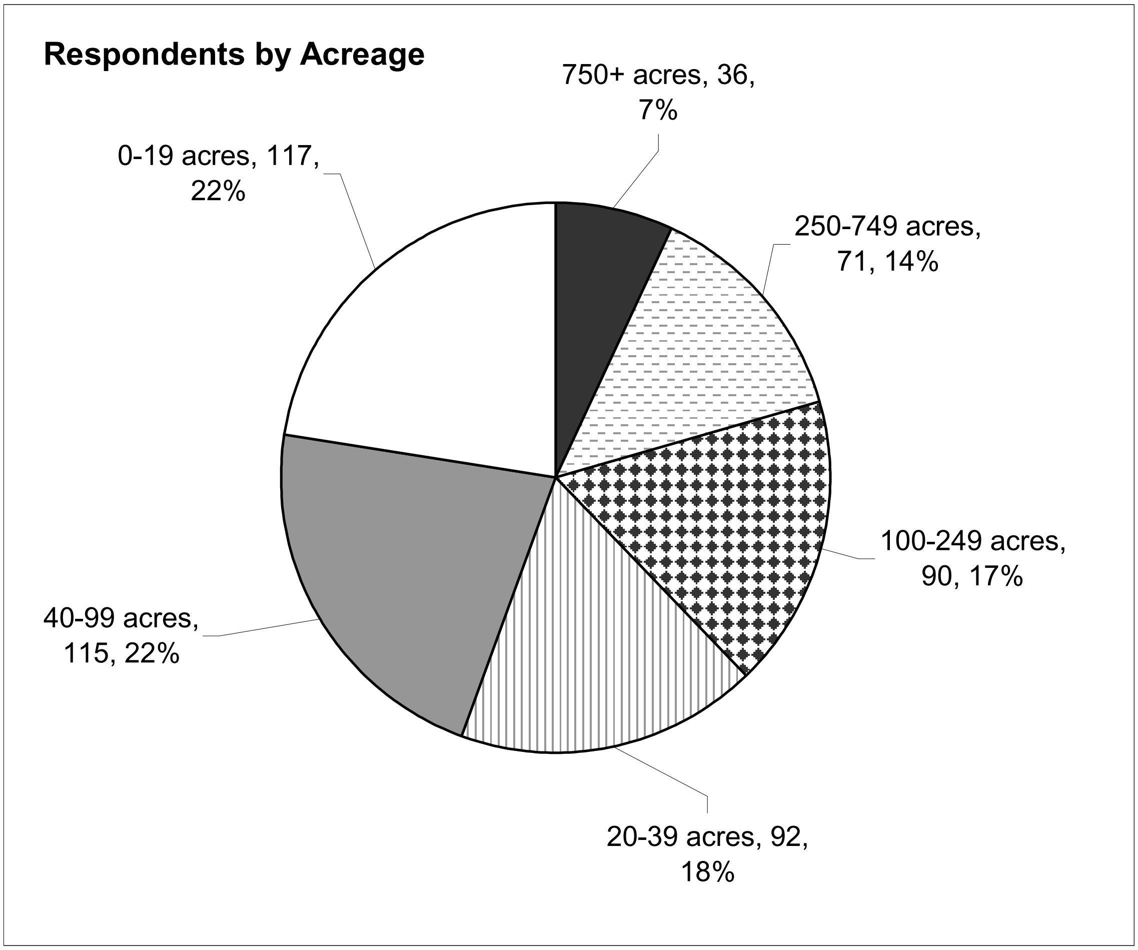

Figure 1. Number almond acres grown by each respondent. Values indicate number and percentage of respondents in each almond acreage group.

Growers were asked to report the primary county in which they grow almonds. Most respondents grow almonds primarily in Stanislaus County (32%, see Figure 2), Merced County (18%), or San Joaquin County (13%).

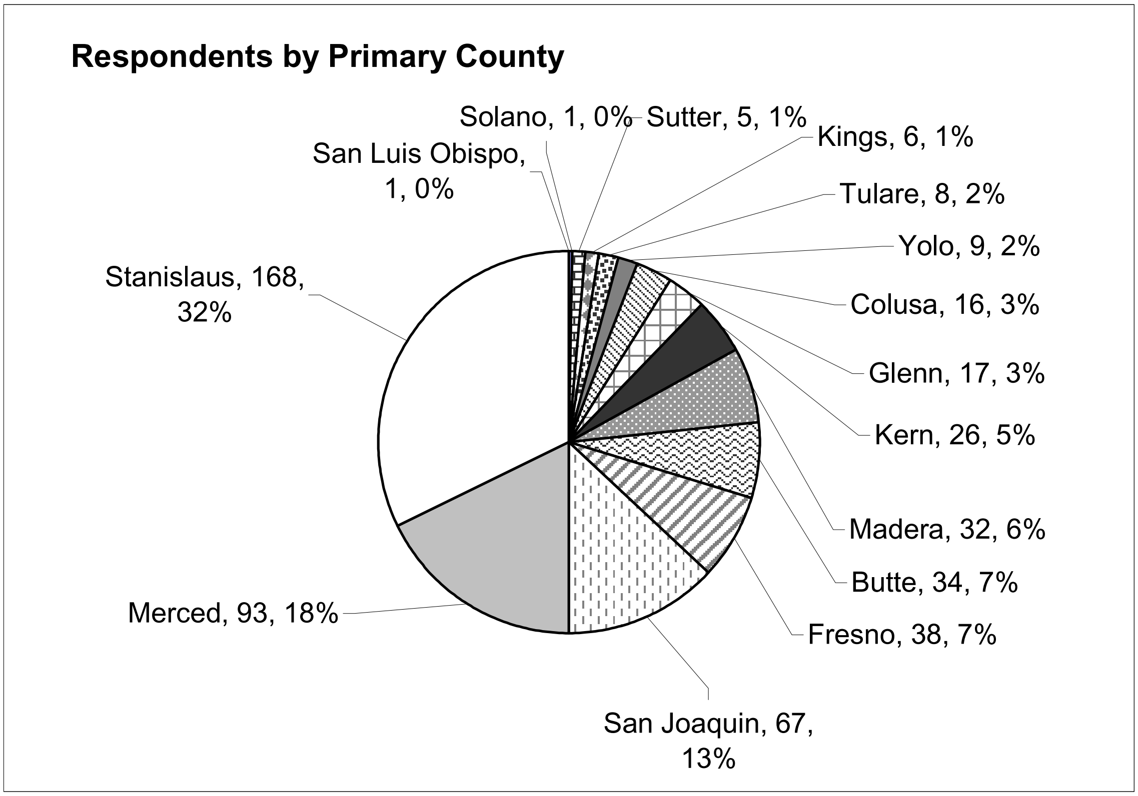

Figure 2. Proportion of almond growers by county. Values indicate number of respondents who identified each county as the primary county in which they grow almonds, followed by the percentage of respondents who identified each county as the primary county in which they grow almonds.

Of the 529 randomly-selected recipients, seven grow some or all of their almonds organically, so we analyzed their responses separately; results of the organic population are not presented in this thesis. By county, the random sample of survey recipients was representative of the whole population, as the selected recipients of each county represented a roughly equal proportion of growers as the whole population (X^2=6.98, p=0.935).

NITROGEN FERTIGATION

Most respondents (69.6%, see Figure 3A) apply any or all of their nitrogen fertilizer by fertigation. Of the remaining 30.4% of respondents who do not use fertigation to apply nitrogen, 45.1% (13.7% of all respondents, see Figure 3A) are unable to do so because they irrigate entirely by flooding or furrow and cannot inject fertilizer into the irrigation system. Over half of the growers (54.9%) who do not use fertigation to apply nitrogen have the potential to adopt the practice; they represent 16.7% (see Figure 3A) of all respondents. A small portion (6.4%; 5 of 78) of these growers use fertigation to apply potassium and/or zinc fertilizer, but not nitrogen.

Among all growers with the capacity to fertigate, there is a significant relationship between likelihood to fertigate and acreage ($p<0.001$, see Table 2). Growers with fewer than 20 acres are less likely to use fertigation to apply nitrogen (61.2%, see Table 2), while those with 250 or more acres are more likely to use fertigation to apply nitrogen (94.1%). Due to this trend of larger growers being likelier to fertigate, the proportion of acres managed by a grower who practices fertigation is higher than the proportion of growers who use the practice (see Figure 3B). Fertigation is used to apply any or all nitrogen fertilizer by growers who manage 91.2% of almond acreage (see Figure 3B), and adoption of fertigation by growers who do not currently use the practice but have the capability to do so is only possible on 5.7% of acreage.

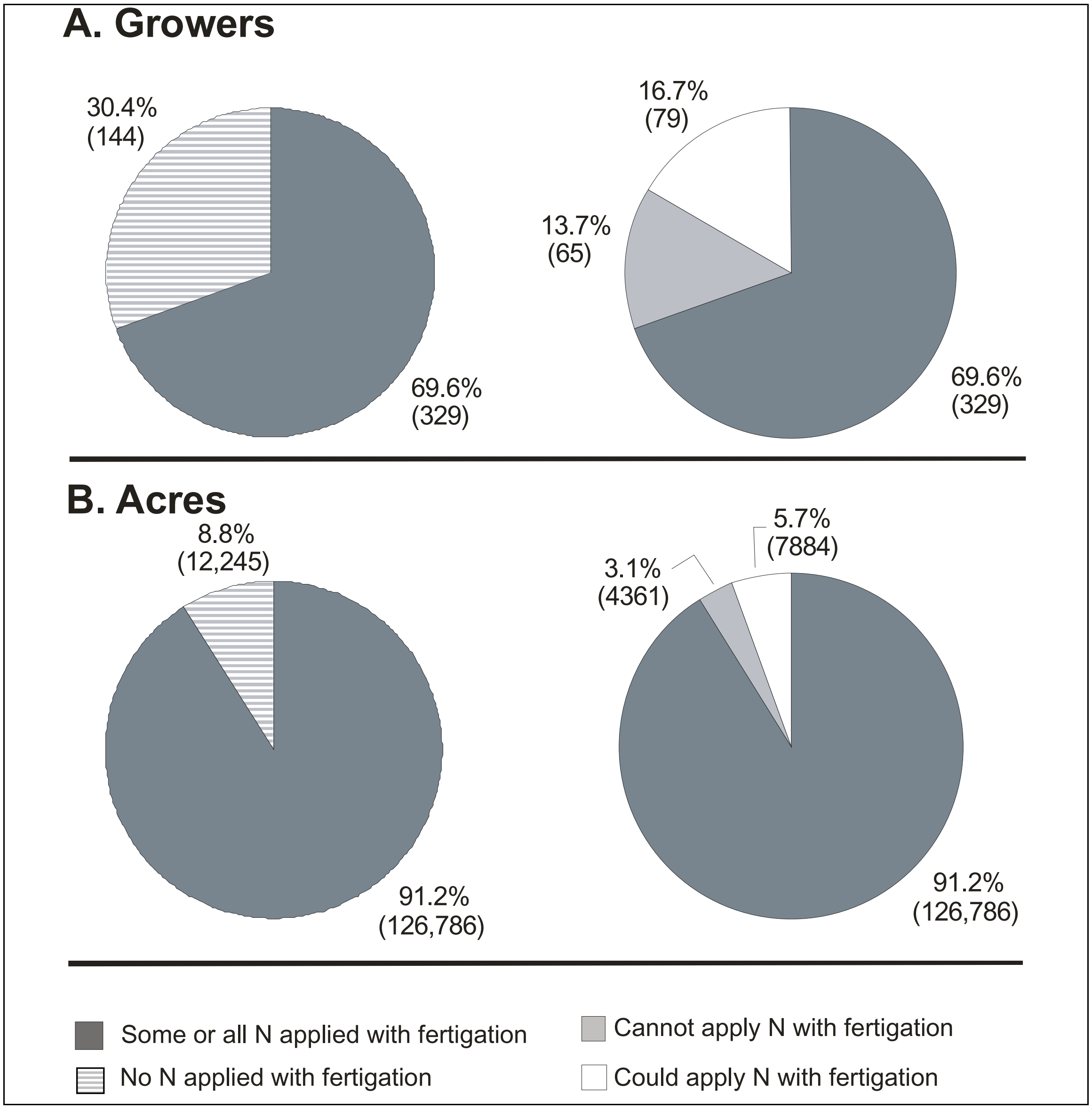

Figure 3. Proportion of growers and acres with nitrogen applied by fertigation. Pale gray solid shading represents land irrigated entirely by flood or furrow, for which fertigation is not possible. A. % growers (number growers in parentheses) who apply some or all nitrogen fertilizer with fertigation. B. % acres (number acres in parentheses) managed by a grower who applies some or all nitrogen fertilizer with fertigation.

	All growers	By acreage			
		< 20 acres	20-249 acres	≥ 250 acres	p-value
Apply N with fertigation *(if irrigation system permits)*	80.6% (329/408)	61.2% (30/49)	63.8% (136/189)	94.1% (96/102)	<0.001
High seasonal score	65.0% (294/452)	57.1% (48/84)	63.3% (167/264)	77.2% (61/79)	0.008
Collect tissue samples at least once annually	79.4% (396/499)	61.0% (64/105)	82.0% (232/283)	90.7% (98/108)	< 0.001

Table 2. Proportion of growers and acres performing each theorized best management practice.

SEASONALITY OF NITROGEN APPLICATIONS

We classified seasonal scores of 7 or greater as "good" (65.0% of respondents, mean=7.13, SD=1.61, see Table 2) and seasonal scores of 6 or below as "poor" (35.0%). Poor seasonal scores correspond to growers whose seasonal fertilization practices differ dramatically from the schedule devised based on the research of Weinbaum et al. (1980, 1990), as detailed in the Appendix (see Section V).

The distribution of seasonal scores differed significantly with acreage (p=0.008, see Table 2), as growers with fewer than 20 acres are less likely to have good seasonal scores (57.1% with good seasonal scores, see Table 2), and growers with 250 or more acres are more likely to have good seasonal scores (77.2% with good seasonal scores). Due to this trend, only 23.5% of acreage (28,021 of 199,422 acres) is managed by a grower with a poor seasonal score.

TISSUE SAMPLING

Most respondents (79.4%, see Table 2) use tissue sampling on their orchards at least once per year, and very few (7.6%; 38 of 499) never use tissue sampling. Of growers who don't use tissue sampling at least once per year, 21.4% (22 of 103) collect tissue samples when problems are detected. Growers who collect tissue samples less than once per year cited “expense” (31.9%; 22 of 69) and “difficulty in interpreting and/or using results” (15.9%; 11 of 69) as major reasons why they do not collect tissue samples more often.

The distribution of likelihood to collect tissue samples at least once per year differed significantly with acreage ($p<0.001$, see Table 2): growers with fewer than 20 acres are less likely to collect tissue samples at least once annually (61.0%, see Table 2), while those with 250 or more acres are more likely to collect tissue samples at least once annually (90.7%). Due to this trend, only 10.6% of acres are managed by a grower who does not collect tissue samples at least once per year.

SATISFACTION WITH CURRENT FERTILITY MANAGEMENT PRACTICES

Although 61.3% of respondents stated that they are satisfied with their current nutritional management practices (315 of 514), only 29.5% (149 of 505) consider UC CVs fully adequate to ensure maximal productivity. When rating the importance of five activities relating to potential environmental regulations on a scale of 1 to 5 (with 1 designated as “not important,” 2 as “a little important,” 3 as “somewhat important,” 4 as “very important”, and 5 as “extremely important”), most growers identified three activities to be “very” or “extremely” important (median value of 4 or greater, see Table 3), including “identifying fertilization practices that optimize yields.” When rating a list of 14 potential research topics on a scale of 1 to 5 (with 1 designated as “not useful,” 2 as “a little useful”, 3 as “somewhat useful,” 4 as “very useful,” and 5 as “extremely useful”), most growers selected eight topics to be "very" or "extremely" useful (median value of 4 or greater, see Table 4), including "fertilizer application timing."

Importance of actions (rated 1 to 5)				
	Median	**Mean**	**SD**	**n**
Identifying fertilization practices that optimize yields	4	4.03	0.85	358
Identifying fertilization practices that minimize soil and water contamination	4	3.66	0.92	367
Conducting research to challenge new requirements	4	3.63	1.02	350
Creating nutrient budgets that accurately reflect an ochard's fertilizer needs	3	3.47	0.85	357
Effectively regulating grower compliance	3	2.81	0.94	350

Table 3. Importance of information or actions to meet potential environmental standards, rated from 1 ("not important") through 5 ("extremely important"). Median score of 4 indicates most respondents consider information/action to be "very" or "extremely" important.

Usefulness of research topics (rated 1 to 5)				
	Median	Mean	SD	n
Fertilizer application timing	4	3.90	0.90	345
Leaf sampling techniques that better reflect tree nutrient demand	4	3.83	0.95	352
Relationship between nutrition and disease	4	3.81	0.89	349
Accuray of critical values to ensure they result in maximal yield	4	3.79	0.89	349
Tissue sampling techniques that better reflect tree nutrient demand	4	3.76	1.01	339
Role and optimal use of foliar fertilizers	4	3.71	0.97	340
Relationship between fertilization and irgation	4	3.65	0.99	353
soils	4	3.57	1.11	337
Interactions between nutrients	3.5	3.55	0.93	340
Fertilization practices to optimize orchard establishment	3	3.46	0.95	340
Precision agriculture (site-specific fertilization)	3	3.20	1.06	339
Optimal use of fertigation systems	3	3.20	1.20	336
Effectiveness of non-fertilizer foliar and soil products	3	2.78	1.13	348
Remote sensing and automated nutrient status measurement	3	2.67	1.12	349

Table 4. Usefulness of future University of California research topics, rated from 1 (“not useful”) through 5 (“extremely useful”). Median score of 4 indicates most respondents consider research topic to be “very” or “extremely” useful.

Implications

The results and trends revealed by the survey results will be of use to extension farm advisors as they create future outreach programs to reduce nitrogen loss and increase efficiency from almond production. Almond growers with fewer than 20 acres, for example, are less likely to apply nitrogen with fertigation, apply nitrogen with good seasonal timing, or collect annual tissue samples (see Table 2). It may therefore be effective to target small almond growers with educational programs focused on nutrition management.

The observation that small growers are less likely to use the theorized BMPs may indicate that extension activities are not optimally tailored to these groups. External factors may also constrain the adoption of theorized BMPs by these individuals. The cost, availability, and functionality of fertigation technologies for small growers may be constraints and may suggest that targeted financial incentives to develop or employ small-scale fertigation systems will be needed to enhance adoption. Since growers with large acreage are more likely than most to have adopted the practices addressed in this paper, the perceived progressive practices of large growers dominate the acreage of California almond orchards.

The practices investigated here simply represent our best current understanding of actions to achieve nitrogen use efficiency consistent with the principles presented by Bruulsema et al. (2008). Likewise, this survey did not attempt to identify whether growers fertigate properly, add appropriate amounts of nitrogen, or correctly use the results of tissue sample analyses to formulate their fertility programs, so it remains unclear if the use of the best available practice is actually resulting in satisfactory efficacy of N use. Uncertainty about practical applications of tissue analyses exists even for the most informed growers, since experimental trials examining the relationship between leaf tissue analysis and crop yield in almond are very limited (Weinbaum et al. 1980, Weinbaum et al. 1990, Brown and Uriu 1996, Meyer 1996); no long-term experiments in mature trees have effectively demonstrated the use of leaf analysis to optimize fertilization regimes and nitrogen use efficiency; and it is difficult to obtain representative tissue samples in a perennial species due to substantial within-tree, between-tree, and within-field variability (Lilleland and Brown 1943, Righetti et al. 1990, Sanchez and Righetti 1990, Perica 2001).

This paper has addressed only three management practices believed to contribute to N use efficiency; there are many other practices, however, that can theoretically contribute to nitrogen efficiency in the almond industry that were not considered here and for which there is an inadequate research basis. Unlike the three practices investigated in this paper, these other practices (including, but not limited to, soil sampling; selection of the proper nitrogen form given seasonal timing and the stage of the crop; determining nitrogen rates by tree age, potential yields, and past yields; and balancing leaf levels of other nutrients to gain maximum benefits of applied nitrogen) are not widely practiced in California's almond industry, so compliance was not investigated.

Creation of N_2O and NO_3 is unavoidable in agricultural settings and will occur on even the best-managed land. Almond productivity cannot be maintained in the absence of fertilization, so any nitrogen mitigation program must focus on increasing the efficiency with which applied nitrogen is used. The results of this survey illustrate that most almond growers, and the large majority of acreage, currently employ theorized-best fertilization practices, and the industry would value new information about a wide breadth of topics relating to nutrition management. While these results can be viewed as largely positive, new research and extension programs to develop integrated best management of nutrients in almond and to address the actions and research topics growers identified as highly important should be deployed on the basis of these findings.

IV. Implications: UC's role in almond nutrition research

For decades, indicators have existed that suggest the University of California-established critical values (CVs) for almond do not meet the almond industry's needs. Furthermore, it appears growers are not fully satisfied with the almond nutrition information that has been collected by UC researchers. These indicators include (1) growers' tendency to "overshoot" the CVs when determining fertilization amounts; (2) growers' widely-held stance that the CVs are out of date; (3) the increasing and prevalent role of chemical consultants as major information providers; and (4) the stakeholders' concern that if future environmental regulations are based upon the critical values, California's almond industry may not be able to thrive. This research project allowed us to confirm the existence of these phenomena and assess the effectiveness of UC researchers in providing the almond industry with useful, relevant information regarding plant nutrition. Finally, this research aided in the development of informed recommendations about ways in which the UC can in the future better maintain its role as the leading provider of almond nutrition information.

This research was undertaken by UC Davis researchers in an effort to investigate almond growers' current fertilization practices, factors influencing their fertilization decisions, and almond growers' priorities and concerns relating to future research and outreach programs. Prior to this research project, there was a good deal of uncertainty about current practices and standards for plant nutrition in almond production, and there had not been a significant review of the 'state of the industry' and no meaningful consideration of where future investment of educational, outreach, or research activities should be directed in the field of plant nutrition for almonds and pistachios.

The focus group component of the research project served as an opportunity to collect a broad range of ideas to open-ended questions from a variety of stakeholders (i.e., almond growers, nutrition consultants, farm advisors, and representatives from the California Environmental Protection Agency, the California Air Resources Board, and the Almond Board of California). Focus group participants identified numerous problems with the UC CVs, including the short window of time in which tissue samples can be collected, difficulty in collecting tissue samples that account for spatial variability across a field, and dissatisfaction with the values' reliance upon average nutritional status (see Table 1). Participants were also concerned that critical values may be over-simplified, failing to account for complex interactions occurring on orchards. In addition, a survey based on the results of the focus group study was mailed to randomly-selected almond growers in order to obtain quantitative information 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 results of the focus group discussions confirmed the existence of the indicators that the UC-established CVs do not fully meet the almond industry's needs. Results demonstrated widespread concern amongst the almond industry about the relevance of

CVs and the difficulties in applying the information they provide to an orchard's nutrition program (see Section II: Focus Group Analysis).

Similarly, the survey data provided quantitative confirmation of these trends among California's almond growers. Although more than half of almond growers (63.2%) expressed full satisfaction with their nutrition programs, only 22.4% of almond growers rely on CVs "a lot" when making fertilizer decisions, and 24.0% of almond growers do not use the CVs at all. These results indicate that most growers have developed alternative methods other than reliance upon CVs for determining fertilization amounts.

However, growers appear to value the information provided by tissue sampling. When rating the importance of factors in making almond nutrition decisions from 1 to 5 (with 1 designated as "not important," 2 as "a little important," 3 as "somewhat important," 4 as "very important", and 5 as "extremely important"), tissue samples were the factor identified by growers as most important with a median value of 4 (see Table 5), and growers feel strongly that tissue sampling is an effective means to make fertilizer decisions with a median value of 4 (see Table 6). The survey data confirm in numerous ways that while most growers collect and rely upon tissue samples, many of these growers use information other than CVs when interpreting the results of the sample analyses.

Importance of factors (rated 1 to 5)				
	Median	**Mean**	**SD**	**n**
Tissue samples	4.00	3.85	1.00	473
Personal history	4.00	3.72	0.91	465
Recommendations from a consultant	4.00	3.53	1.02	463
Cost	3.00	3.43	0.90	430
Soil samples	3.00	3.36	1.07	460
Environmental considerations	3.00	3.31	0.97	448
Recommendations from a lab	3.00	3.27	1.04	444
Internal trials	3.00	2.81	1.14	395
Recommendations from a salesman	2.00	2.44	1.01	448

Table 5. Importance of factors when making almond nutrition decisions on orchards, rated from 1 ("not important") through 5 ("extremely important"). Median and mean values, with standard deviations and sample sizes. "I don't know" and blank answers excluded from analysis.

Agreement with statements (rated 1 to 5)				
	Median	**Mean**	**SD**	**n**
Plant tissue sampling is a valuable, accurate, and effective means to make fertilizer recommendations.	4	4.22	0.88	479
Soil sampling is a valuable, accurate, and effective means to make fertilizer recommendations.	4	3.70	0.98	473
I have access to adequate nutrition management information to optimize my yields.	4	3.68	0.98	456

Table 6. Agreement with statements, rated from 1 ("strongly disagree") through 5 ("strongly agree"). Median and mean values, with standard deviations and sample sizes. "I don't know" and blank answers excluded from analysis.

This trend was further demonstrated by growers' classification of consultants and/or labs as their most important source of information for almond nutrition (when rating importance from 1 to 5, with 1 designated as "not important," 2 as "a little important," 3 as "somewhat important," 4 as "very important", and 5 as "extremely important") with a mean rating of 3.57 (see Table 7), followed by farm advisors (mean rating: 3.26) and university literature (mean rating: 3.21). Although the difference in ratings between consultants and farm advisors is not statistically significant (p=0.076), the simple fact that farm advisors are not the single most important information source is a noteworthy indication that the private sector has identified and filled a substantial hole in the services previously provided by farm advisors to growers. If the relationship between growers and UC researchers is approached from the perspective of customers and service-provider, it is clear that the university researchers have lost some of their “customers” to the private chemical consultants, who may be able to provide more relevant information.

Importance of information sources (rated 1 to 5)				
	Median	**Mean**	**SD**	**n**
Consultants and/or labs	4.00	3.57	0.97	463
Farm advisors	3.50	3.26	1.01	474
University literature	3.00	3.21	0.96	454
Internal trials	3.00	2.85	1.13	394
Chemical companies	3.00	2.76	1.03	471
Other growers	3.00	2.63	0.98	462
Internet or magazines	2.00	2.47	0.98	443

Table 7. Importance of information sources when making almond nutrition decisions on orchards: median and mean values, with standard deviations and sample sizes. “I don’t know” and blank answers excluded from analysis.

RECOMMENDATIONS FOR UCCE TO CONSIDER

Although growers have identified information sources other than UC Cooperative Extension (UCCE) and the UC-established CVs for fertilization guidance, survey results indicate a demonstrated need for more information. Over one-third of growers (36.8%) are not fully satisfied with their nutritional programs, and growers feel more strongly (ANOVA $p<0.001$) that tissue sampling is an effective means with which to make fertilizer decisions with a mean rating of 4.22 (see Table 6) than that they have access to adequate nutrition management information to optimize their yields (mean rating: 3.68). It is clear, then, that critical values are not reasonable minimums for growers; there is a demand and need for better information. The CVs provide no easily-interpretable guidelines to almond growers regarding how to produce high-yielding trees. The challenge to UC researchers, should they choose to attempt to regain their role as the primary information source for the state's almond growers, is to meet the growers' demands for yield-related plant nutrition information. This goal can potentially be accomplished through both research and outreach approaches.

Research approaches may include collection of a new type of data, re-interpretation of existing data, or more frequent focus group and/or survey efforts to identify holes in research before UC loses its position as a primary information source. Performing more frequent surveys and/or focus groups would allow UC researchers to consistently achieve a current perspective of whether they are meeting growers' informational needs. In this way, they would be able to reassess and redesign research goals often enough to avoid allowing major holes to exist in the type of information they provide to growers.

The problems with CVs are both scientific (e.g., too much orchard variability and uncertainty as to how the CVs relate to new varietals) and practical (e.g., how the deficiency-related numbers translate into high yields and how a grower should use the mean values collected from tissue sampling to make decisions about the whole orchard). While redesigning research projects to focus upon yields rather than deficiency could be expensive, it may be possible for UC researchers to creatively re-interpret the existing CVs to better meet growers' information needs. Perhaps, for instance, with understandings of the standard deviations of tissue samples within trees and across orchards, researchers will be able to identify <u>optimal</u>, rather than critical, values based upon the existing data used to develop the CVs. These optimal values could meet growers' need for yield-related recommendations based upon the mean values derived from collecting tissue samples on their orchards.

CHALLENGES TO UC AS PRIMARY INFORMATION PROVIDER

The nature of funding source types may contribute to the difficulties UC researchers face in achieving a role of primary information provider. Private consultants are hired directly by stakeholders, so they receive immediate feedback as to whether the information they provide is useful. Consultants must continually provide useful information, or they will not be hired. UC researchers, on the other hand, may lack this immediate form of feedback, if their grants are issued by a funding agency that serves to separate the researcher from the stakeholder. The funding agency does not necessarily know the stakeholders' most pressing needs when issuing grants, so the projects they approve may not provide information as useful as that provided by private consultants. In conjunction with the nature of the funding source types, new technologies (such as internet databases) have allowed private-sector information providers to shift their research from researcher-driven to stakeholder-driven topics (King and Boehlje 2000). The routine visits with which private consultants or salesmen see growers may also serve to make them of increasing importance to growers as primary information sources, if they are available to growers more frequently than are the university researchers and extension agents (Roseler et al. 1994).

Barriers relating to funding and frequency of interactions may be difficult for UC to overcome, since these issues relate to the nature of the researchers', extension agents', and private consultants' professions. It may not be necessary, however, for UC to recover its position as the single most important information source for almond growers. After all, consultants stay in business by entering the market and immediately identifying the holes that are not being filled by UC researchers. Since these holes are being filled by the private sector, the information is being created and disseminated to those who require it. Therefore, as long as the UC research is of use and relevance to stakeholders, a set-up in which the private sector provides the remaining required information may not be problematic for growers.

A problem that could occur to stakeholders may arise if, while private-sector information providers become more prominent information sources than UCCE agents, they provide stakeholders with information of a less "rich" quality (King and Boehlje 2000) than that provided by university research. Private consultants' ability to reach more people more frequently is coupled with a risk of providing less good information, since the private sector may lack incentives to rigorously evaluate research and to ensure that the information is being interpreted properly by stakeholders, and the private sector's incentives may be less pure than those of UCCE agents. While a private consultant may sell more information to his stakeholders (almond growers) if he or she develops CVs that focus more upon yield maximization than limitation of environmental damage, UC researchers will potentially be held accountable by a broader array of stakeholders, including almond growers, environmental activists, and legislators. The role of UC as agricultural researcher and information provider may therefore continue to be important even if Extension is not able to conduct research or provide information as quickly as its private competitors.

The almond industry is not alone in experiencing this shifting role of university research, as many agricultural industries have witnessed the rise of private-sector information providers and the decline of Extension as sole information provider (Roseler et al. 1994, King and Boehlje 2000). It may be possible for California's almond industry to function effectively in this environment, with private-sector consultants taking on an increasingly important role, allowing almond growers access to the stakeholder-driven information they need provided in an easily interpretable and adaptable format. Although the nature of the UC research may make its results less timely and practically adaptable by growers, the investigations of the underlying science behind agricultural processes will remain of importance due to the lack of incentive to ignore negative externalities of over-fertilization in order to please a customer. Even if it falls in importance to become a secondary information source to growers, UC's investigation of researcher-driven topics will provide important information to a broad array of stakeholders.

V. Appendix

Calculation of Sampling Error

1. Calculating desired sample size based on acceptable sampling error (Dillman 2007)

$$N_s = \frac{(N_p)(p)(1-p)}{(N_p - 1)\left(\frac{B}{C}\right)^2 + (p)(1-p)}$$

2. Calculating sampling error based on sample size (derived from Equation 1)

$$B = \sqrt{\frac{(C^2)(N_p - N_s)(p)(1-p)}{(N_s)(N_p - 1)}}$$

$$B = \sqrt{\frac{(1.96^2)(3136 - 529)(0.5)(1-0.5)}{(529)(3136-1)}} = 0.0388$$

N_s = completed sample size
N_p = size of population
P = Proportion of population expected to choose one of two response categories
B = sampling error
C = Z statistic associated with the confidence level (1.96 corresponds to the 95% level)

Calculation of Seasonal Score

In order to calculate a seasonal score, a grower was awarded points for each period based on the following system:

- 0 points = 0% of nitrogen applied during a seasonal period
- 1 point = applied 1-30% of nitrogen during a seasonal period
- 2 points = applied 31-70% of nitrogen during a seasonal period
- 3 points = applied 71-99% of nitrogen during a seasonal period
- 4 points = applied 100% of nitrogen during a seasonal period

Seasonal periods were defined as follows:

- Winter: November 1 – January 31
- Spring: February 1- April 30
- Summer: May 1 – July 31
- Fall: August 1 – October 31

The scores for each season were then subtracted from the optimal scores identified above and subtracted from ten, as shown here:

seasonal score=10-|spring score-1| - |summer score-2| - |fall score-1| - winter score

For example, Grower A applies 20% of nitrogen in spring, 65% in summer, 15% in fall, and 0% in winter and receives a seasonal score of 10 (see Table 8). Grower B applies 35% of nitrogen in spring, 25% in summer, 25% in fall, and 15% in winter and receives a seasonal score of 7. Grower C applies 50% of nitrogen in spring, 0% in summer, 0% in fall, and 50% in winter and receives a seasonal score of 4. We classified seasonal scores of 7 or greater as "good" and seasonal scores of 6 or below as "poor."

		Spring	**Summer**	**Fall**	**Winter**	***deviation from "optimal"***	***seasonal score (10 - deviation)***
"Optimal"	*points*	***1***	***2***	***1***	***0***		
Grower A	*% applied*	20%	65%	15%	0%		
	points	*1*	*2*	*1*	*0*		
		|***1***-*1*| = 0	|***2***-*2*| = 0	|***1***-*1*| = 0	|***0***-*0*| = 0	0	**10**
Grower B	*% applied*	35%	25%	25%	15%		
	points	*2*	*1*	*1*	*1*		
		|***1***-*2*| = 1	|***2***-*1*| = 1	|***1***-*1*| = 0	|***0***-*1*| = 1	3	**7**
Grower C	*% applied*	50%	0%	0%	50%		
	points	*2*	*0*	*0*	*2*		
		|***1***-*2*| = 1	|***2***-*0*| = 2	|***1***-*0*| = 1	|***0***-*2*| = 2	6	**4**

Table 8. Illustration of seasonal scores (bold font) assigned to three hypothetical growers, based upon the deviation of their seasonal fertilization schedule (*underlined italicized font*) from the theorized "optimal" schedule (***bold italicized font***). "Optimal" schedule based upon the results of Weinbaum et al. (1980, 1990).

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