Understanding Decision-Making of Citrus and Raisin Grape Growers and Adoption of Nitrogen Management Practices

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Summary
Adoption of nitrogen (N) management practices is paramount to meeting the demand of regulatory agencies to reduce N loading into surface and groundwater of California. However, there is inadequate information on the current rate of adoption and little understanding of the barriers to more complete adoption. This project aims to quantify the use of N management practices and characterize benefits and challenges by growers in order to enhance future research, education and outreach programs. The findings will help guide practice and policy for citrus and raisin grapes in the Southern San Joaquin Valley (SSJV). Our objectives were 1) to develop a quantitative understanding of key influences and barriers to adoption of N management practices for citrus and raisin grape growers in the regions represented by the SSJV water quality coalitions; 2) to distribute, collect and aggregate survey data from growers during water quality coalitions meetings; 3) to analyze response data to determine key differences between citrus and raisin grape grower adoption of N management practices and; 4) to conduct interviews with UC advisors and specialists of citrus and raisin grape to gain insights into grower survey responses.

Average parcel size and ownership were the same between citrus and raisin grape growers but, parcel irrigation system and water source were significantly different. Citrus growers report using more microirrigation and access to multiple water sources while raisin grape growers report using more surface irrigation and groundwater as the primary water source. All fertilizer practices as well as soil sampling consistently exceeded adoption rates of 50% or greater for all growers. Adoption of fertilizer practices, soil sampling and irrigation practices were significantly greater for citrus growers compared to raisin grape growers, though raisin grape growers report significantly higher adoption of cover crops. Cost, technical knowledge and uncertainty were the main challenges identified in this survey. Raisin grape growers report significantly higher uncertainty to fertilizer practices while citrus growers report significantly greater lack of efficacy for soil practices. Yield and quality were the primary benefits associated with all N management practices. Furthermore, citrus growers identified meeting regulations as a benefit significantly more frequently than raisin grape growers. The primary information sources identified by all growers in this survey were pest control advisors (PCAs), followed by their water quality coalition and UC Cooperative Extension. In general growers that utilize more information sources adopt more practices. Lastly, well head protection practices had been adopted by a majority of growers.

Problem

Adoption of nitrogen (N) management practices by California growers is a required step to reduce N movement to surface and groundwater, and maintaining economically viable cropping systems. The Irrigated Lands Regulatory Program (ILRP) features management practices as a means to protect water quality. Research over the past decades has identified many promising N management practices that can improve recovery of fertilizer into crops. These practices include the use of N budgets to balance N inputs and outputs for individual fields; implementation of the "4R's" (right N rate, time, place, and source) to guide fertilization strategy; the use of leaf and soil N sampling for verification of crop nutrient status and residual soil N; appropriate integration of fertilizers with irrigation; enhancing soil health to improve nutrient retention and recovery; and deployment and careful management of micro-irrigation systems for efficient water use. Despite progress in the development of N management practices, there is insufficient understanding regarding the current rate of and barriers to practice adoption.

Approach

In January and February 2018, we attended nine (9) annual grower meeting locations hosted by the seven (7) water quality coalitions that constitute the Southern San Joaquin Valley (SSJV) Management Practices Evaluation Program (MPEP), leading to 532 grower survey responses (Table 1). The survey tool (see Appendix) asked growers to consider their largest most important parcel and report 1) demographic information like crop type, parcel size, ownership, irrigation system and water source; 2) adoption of N management practices like use of a nitrogen (N) budget, split fertilizer N application, leaf N sampling, accounting for nitrate (NO_3^-) in irrigation water, soil sampling for residual NO_3^-, use of cover crops, use of organic matter amendments, irrigation scheduling by evapotranspiration (ET), measuring water stress with a pressure chamber, deployment of soil sensors and taking measurements of irrigation distribution uniformity; 3) challenges associated with fertilizer, soil and irrigation practices like cost of the practice, labor requirements, need for supplies, requirement for technical knowledge, lack of efficacy, and overall uncertainty; 4) benefits from fertilizer, soil and irrigation practices like improved N use efficiency, improved water use efficiency, improved soil health, compliance with regulations, and improved crop yield or quality; and 5) use of information sources like county agricultural commissioners, UC Cooperative Extension, certified crop advisors, pest control advisors, water quality coalitions, NRCS/resource conservation districts (RCD), industry associations or grower peers.

The focus of this study was citrus and raisin grape growers. We received 153 responses from citrus growers, or 9.4% of the estimated 1,628 citrus growers in the SSJV MPEP region, and 97 responses from raisin grape growers, or 11.9% of the estimated 813 raisin grape growers in the SSJV MPEP region (Table 2). A total of 282 growers indicated another crop on their survey including nuts, fruits, table grapes, annual row crops vegetables and irrigated pasture. All responses were collected as paper surveys and organized in a database for coding and analysis. Responses were partitioned between citrus and raisin growers and contrasted for significant differences ($p < 0.05$) with a Chi-squared test. We combined the 532 responses from this survey with 460 from our project conducted in the San Joaquin County and Delta, and East San Joaquin Valley water quality coalitions (hereafter, North San Joaquin Valley or NSJV; see CDFA FREP Project 16-0621-SA). We conducted logistic modeling on the combined survey response data (not shown here) to determine key variables influencing grower decision-making and adoption of N management practices.

After data analysis and summary, we conducted four (4) interviews with UC Cooperative Extension farm advisors and specialists with expertise in citrus and raisin. All interviewees consented to their interviews being identified in this report. In 2019, we interviewed George Zhuang, UC Viticulture Farm Advisor in Fresno County on January 17th, Greg Douhan, UC Area Citrus Advisor in Tulare County on February 4th, Craig Kallsen, UC Farm Advisor in Kern County on February 28th and Matthew Fidelibus, UC Cooperative Extension Specialist on March 7th.

Results

Demographics

Operational characteristics of grower-selected parcels were the same between citrus and raisin growers for parcel size and land ownership but, different for irrigation and water source (Figure 1). For both citrus and raisin growers, 60% of parcels are under 50 acres, and 90% of parcels are owned by the grower. There were highly significant differences in irrigation systems between citrus and raisin, with more than 90% of citrus growers adopting microirrigation; whereas, 50% of raisin grape growers adopting microirrigation systems and 50% adopting surface irrigation systems. Raisin grape growers also report significantly greater use of groundwater as their only water source, compared to citrus growers who report greater access to both surface and groundwater sources. UC experts suggest citrus trees use more water than raisin grape vines and thus, rely more heavily on microirrigation compared to surface irrigation to optimize their efficiency. Furthermore, more research has gone into the development of raisin grape rootstocks that have greater salt resistance, allowing growers to utilize more saline groundwater.

Adoption

Overall trends in adoption of N management practices were comparable across NSJV and the SSJV growers surveyed in this study (Khalsa et al. *unpublished data*). Adoption of fertilizer practices, soil sampling and irrigation practices were significantly greater for citrus growers compared to raisin grape growers. However, all the fertilizer practices and soil sampling consistently exceeded adoption rates of 50% for both citrus and raisin (Figure 2). The one deviation from this trend was raisin grape growers report significantly higher adoption rates of cover crops. Our UC colleagues report comparable fertilizer N rates between citrus and raisin so, greater crop N use does not explain higher adoption of fertilizer practices. However, upon examination of grower returns based on commodity prices, citrus is valued more highly than raisins. According to National Agricultural Statistical Service in 2016, average gross return was $10,600 per acre for citrus and $3,300 per acre for raisins. Thus, citrus growers have more financial capital to invest in developing management strategies. Furthermore, our UC colleagues point out the important role on-farm crop advisors like PCAs and CCAs play in citrus production leading to more specialization and greater attention to specific practices. The higher adoption of cover crops by raisin grape growers may be due to cover crops posing a frost risk that is unacceptable in citrus production.

Challenges

For all growers, practice challenges were identified by less than 40% of respondents for nearly all practices and challenges. Cost, technical knowledge and uncertainty were the main challenges identified across all practices in this survey (Figure 3). Raisin grape growers report significantly higher uncertainty about fertilizer practices, which helps explain lower adoption compared to citrus growers. Citrus growers report significantly lower efficacy for soil practices compared to raisin

grape growers while raisin grape growers report lower uncertainty for soil practices, which may explain their greater adoption of cover crops and organic matter practices.

Benefits

Improved crop yield and quality were the primary benefits associated with all N management practices. While there were some differences in grower response of benefits for individual practices, differences between citrus and raisin grape growers were more variable (Figure 4). Nitrogen use, soil health and water use were the primary benefits identified for fertilizer, soil and irrigation practices, respectively. However, citrus growers reported significantly higher rates of water use benefits for fertilizer and soil practices than did raisin grape growers. Furthermore, citrus growers identified meeting regulations as a benefit significantly more often than raisin grape growers for all N management practices. UC experts suggest citrus as an industry is more organized than the raisin industry, and organizations like the Citrus Research Board and Citrus Mutual conduct more outreach to their growers about the goals of regulatory programs aimed at reducing N loading to groundwater. As a result, citrus growers may be more aware of N management practices that can be employed to effect change and/or improve regulatory outcomes.

Information sources

The primary information sources identified by all growers in this survey were the PCA, followed by the water quality coalition and UC Cooperative Extension (Figure 5). Greater specialization of citrus production (as discussed in the Adoption section), and greater regulatory awareness by citrus growers (as discussed in the Benefits section) are supported by significantly higher response for CCAs and industry associations as information sources for citrus compared to raisin grape growers. In general, growers that utilize more information sources adopt more practices.

Well head practices

Well head protection practices were adopted by a majority of all growers, with elimination of standing water adopted by 74% of growers, use of a backflow preventer adopted by 69% of growers and cement pad construction adopted by 92% of growers (Table 3). Furthermore, 61% of growers do not have abandoned wells, 27% of growers report having an abandoned well and following guidelines and 12% of growers report not having completed guidelines yet.

Acknowledgments

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Tables and Figures

Table 1. Meeting locations, dates, percentage (%) of grower surveyed at each meeting out of the total number of surveys collected (532) and total surveys at each meeting in 2018

Location	Date(s)	% Surveyed per Meeting	Total Surveys
Dinuba/Kerman	Feb-7, Feb-16	11.1	59
Sanger	Jan-11	8.3	44
Easton	Jan-19	16.2	86
Selma	Feb-1	13.2	70
Tulare	Jan-23	20.9	111
Tulare	Jan-30	13.9	74
Wasco/Bakersfield	Jan-11, Jan-17	16.5	88

Table 2. Total growers, surveyed growers and percentage (%) of growers surveyed out of the total number of growers in the SSJV MPEP region for citrus, raisin and other growers in 2018

	% Surveyed out of Total	Surveyed Growers	Total Growers
Citrus	9.4	153	1,628
Raisin	11.9	97	813
Other[1]	3.4	282	8,259
Total	5.0	532	10,700[2]

[1]Other = 147 nuts; 45 other fruits (i.e. stone fruit, olives, pomegranate); 24 table grapes; 40 annual crops; 8 pasture and 18 crop type unknowns

[2]Total growers in the SSJV region reported in "Management Practices Evaluation Workplan"

Table 3. Percentage (%) response of all growers using well head protection practices and well head destruction and abandonment practices during January and February 2018

Well Head Protection Practices	Elimination of Standing Water	Backflow Preventer	Cement Pad Construction
% Reponse	73.7	69.3	92.0
Well Head Destruction & Abandonment Practices	**Yes, I followed guidelines**	**No, I have no abandoned wells**	**No, I have not done this yet**
% Reponse	27.3	60.6	12.1

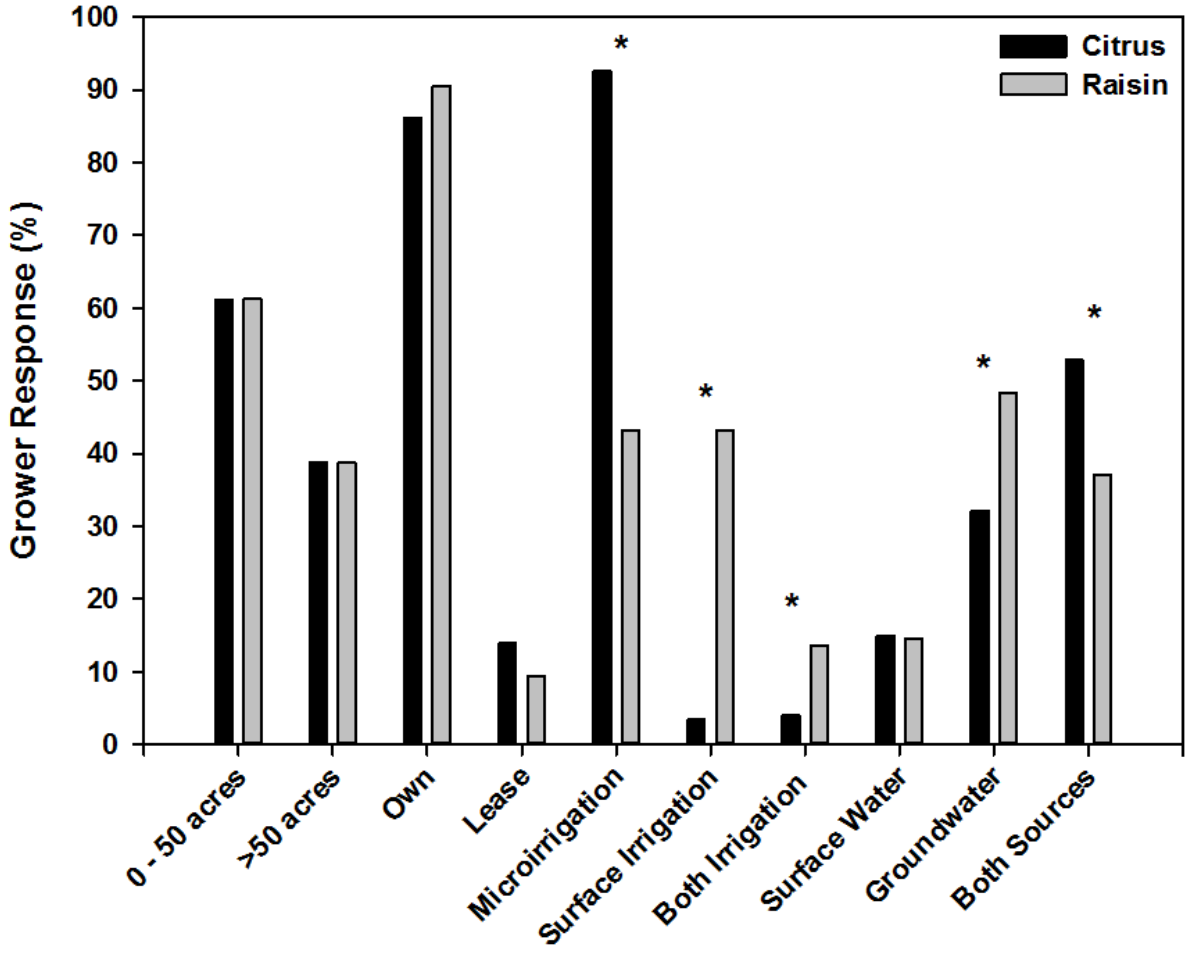

Figure 1. Demographic characteristics of citrus and raisin grape growers include size of parcel, parcel ownership, type of irrigation system and water sources. Significant differences ($p < 0.05$) between citrus and raisin determined by a Chi-squared test are represented by an asterisk (*).

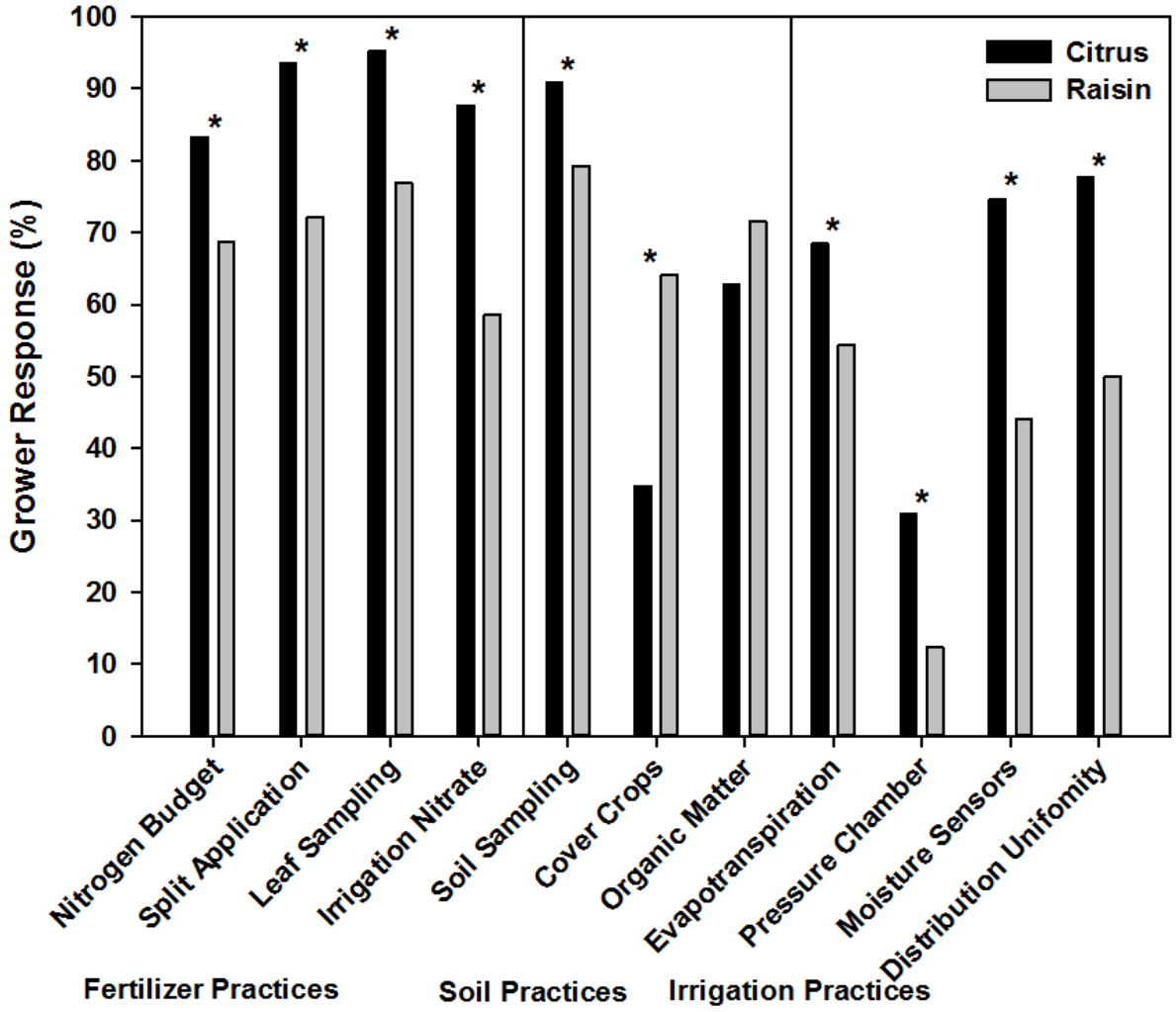

Figure 2. Adoption of practices by citrus and raisin grape growers. Fertilizer practices include use of a nitrogen (N) budget, split fertilizer N application, leaf N sampling, and accounting for nitrate (NO_3^-) in irrigation water. Soil practices include soil sampling for residual NO_3^-, use of cover crops, and use of organic matter amendments. Irrigation practices include irrigation scheduling by evapotranspiration (ET), measuring water stress with a pressure chamber, deployment of soil sensors and measuring distribution uniformity. Significant differences ($p < 0.05$) between citrus and raisin determined by a Chi-squared test are represented by an asterisk (*).

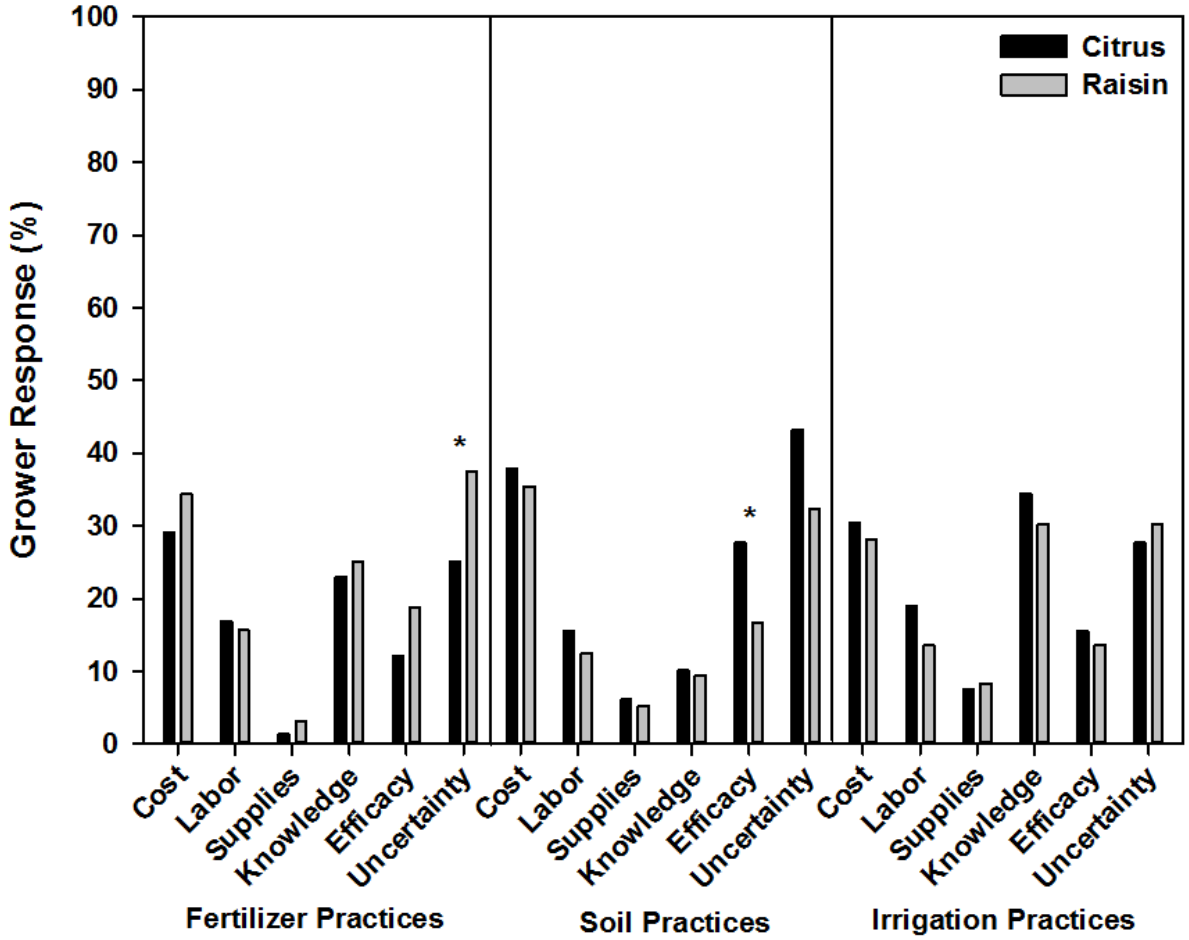

Figure 3. Challenges for fertilizer, soil and irrigation practices by citrus and raisin grape growers include cost of the practice, labor requirements, necessity for supplies, requirement for technical knowledge, lack of efficacy and overall uncertainty. Significant differences ($p < 0.05$) between citrus and raisin determined by a Chi-squared test are represented by an asterisk (*).

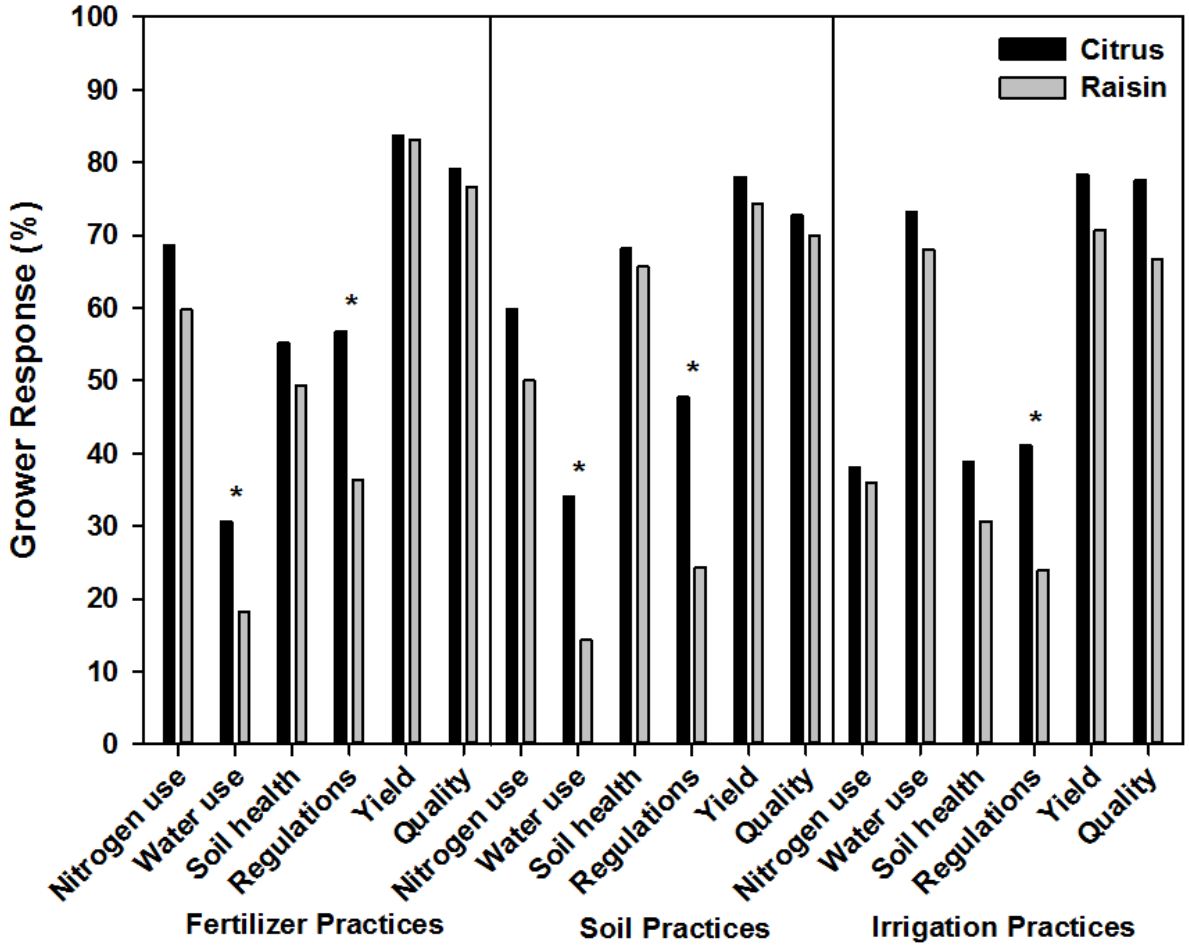

Figure 4. Benefits from fertilizer, soil and irrigation practices by citrus and raisin grape growers include improved nitrogen (N) use efficiency, improved water use efficiency, improved soil health, satisfaction of regulations, and improved yield or quality. Significant differences ($p < 0.05$) between citrus and raisin determined by a Chi-squared test are represented by an asterisk (*).

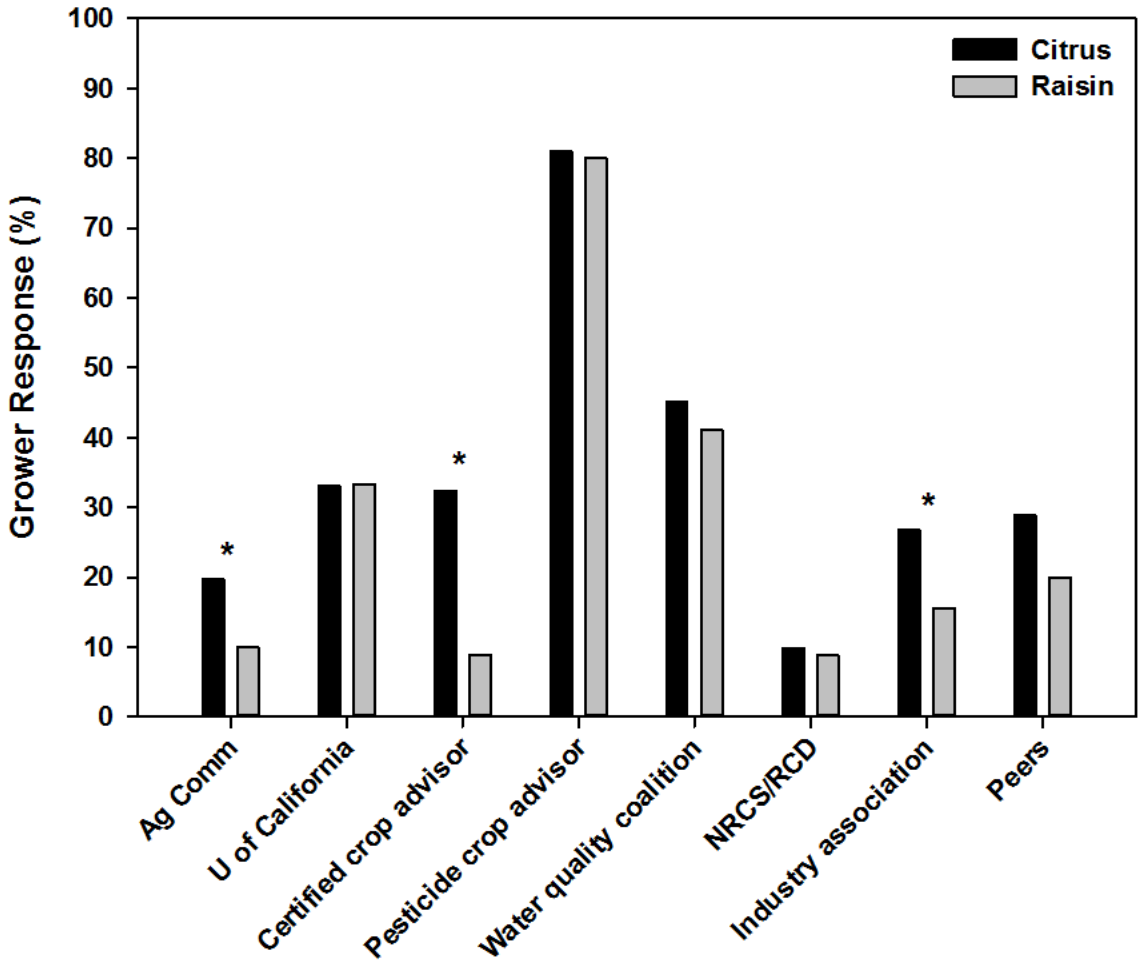

Figure 5. Information sources for nitrogen (N) management practices by citrus and raisin grape growers include county agricultural commissioners, UC cooperative extension, certified crop advisors, pesticide crop advisors, water quality coalitions, NRCS/Resource conservation districts (RCD), industry associations or grower peers. Significant differences ($p < 0.05$) between citrus and raisin determined by a Chi-squared test are represented by an asterisk (*).

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Appendix

Grower Survey on Nitrogen Management

Southern San Joaquin Valley (SSJV) Management Practices Evaluation Program (MPEP)

About this Survey: This UC Davis survey is part of a large-scale study across the Central Valley to investigate nitrogen (N) management in a variety of crops. **All data from this survey will be kept anonymous; your privacy is our priority.**

1) What crop do you grow on your largest field?

- ☐ Citrus
- ☐ Table grapes
- ☐ Raisin grapes
- ☐ Nuts
- ☐ Stone fruit
- ☐ Vegetables/ melons
- ☐ Field/ row crops
- ☐ Other_____

2) How many acres is the largest field of your crop type? *(Check the best answer)*

- ☐ 0-50 acres
- ☐ 51-100 acres
- ☐ 101-250 acres
- ☐ >250 acres

3) For the largest field of your crop type do you…*(Check all that apply)*

- ☐ Own the land
- ☐ Lease the land
- ☐ Manage the land

4) How do you irrigate the largest field of your crop type? *(Check all that apply)*

- ☐ Surface irrigation (furrow, border strip and/or level basin)
- ☐ Sprinkler irrigation (hand lines, wheel lines, solid-set, linear move and/or big guns)
- ☐ Micro Irrigation (drip, microsprinklers, microspray and/or subsurface drip)

5) What water source(s) do you use to irrigate the largest field of your crop type? *(Check all that apply)*

- ☐ District surface water delivery
- ☐ Groundwater
- ☐ Riparian water

6) How often do you use the following practices on the largest field of your crop type? *(Check the best answer)*

Practices	Regularly Use when appropriate	Use irregularly	Tried and Discontinued	Considered but, never Tried	Never Considered
Nutrient Management					
Use a N budget to determine fertilizer rates	☐	☐	☐	☐	☐
Split fertilizer applications	☐	☐	☐	☐	☐
Leaf sampling to verify plant-nutrient status	☐	☐	☐	☐	☐
Test irrigation water for nitrate	☐	☐	☐	☐	☐
Soil Fertility Management					
Soil sampling and analysis to determine residual soil nitrate	☐	☐	☐	☐	☐
Cover crops	☐	☐	☐	☐	☐
Use of organic matter (compost or manure)	☐	☐	☐	☐	☐
Irrigation Management					
Evapotranspiration (ET) to schedule irrigation	☐	☐	☐	☐	☐
Pressure chamber to measure water stress	☐	☐	☐	☐	☐
Use of moisture probe or soil sensors	☐	☐	☐	☐	☐
Test irrigation for distribution uniformity	☐	☐	☐	☐	☐

7) For the same set of practices, please indicate if the listed challenges hinder, discourage or inhibit your implementation of the practice. *(Check all that apply)*

Practices	Cost	Labor Intensive	Supplies	Technical Knowledge	Lack of efficacy	No challenges
Nutrient Management						
Use a N budget to determine fertilizer rates	☐	☐	☐	☐	☐	☐
Split fertilizer applications	☐	☐	☐	☐	☐	☐
Leaf sampling to verify plant-nutrient status	☐	☐	☐	☐	☐	☐
Test irrigation water for nitrate	☐	☐	☐	☐	☐	☐
Soil Fertility Management						
Soil sampling and analysis to determine residual soil nitrate	☐	☐	☐	☐	☐	☐
Cover crops	☐	☐	☐	☐	☐	☐
Use of organic matter (compost or manure)	☐	☐	☐	☐	☐	☐
Irrigation Management						
Evapotranspiration (ET) to schedule irrigation	☐	☐	☐	☐	☐	☐
Pressure chamber to measure water stress	☐	☐	☐	☐	☐	☐
Use of moisture probe or soil sensors	☐	☐	☐	☐	☐	☐
Test irrigation for distribution uniformity	☐	☐	☐	☐	☐	☐

8) When making decisions regarding the above practices, what benefits do you consider? *(Check all that apply)*

Practices	N use efficiency	Water savings	Improve soil health	Meet regulations	Improve crop yield	Improve crop quality
Nutrient Management	☐	☐	☐	☐	☐	☐
Soil Fertility Management	☐	☐	☐	☐	☐	☐
Irrigation Management	☐	☐	☐	☐	☐	☐

9) Have you implemented the following well head protection practices? *(Check all that apply)*

☐ Cement Pad Construction ☐ Elimination of Standing Water ☐ Backflow Preventer

10) Have you implemented well destruction and abandonment practices? *(Check the best answer)*

☐ Yes, I followed guidelines. ☐ No, I have no abandoned wells. ☐ No, I haven't done this yet.

11) Which coalition are you a member of? *(Check all that apply)*

☐ Buena Vista ☐ Cawelo Water District ☐ Kaweah Basin
☐ Kern River ☐ Kings River
☐ Tule Basin ☐ Westside

12) From what sources do you seek information on nitrogen management practices? *(Check all that apply)*

☐ Ag. Commissioner ☐ PCA ☐ NRCS/RCD
☐ UC Extension ☐ CCA ☐ Industry/Grower assoc.
☐ Certified Agronomist ☐ Water Quality Coalition ☐ Other growers/Peers