Fertilizer Research and Education Program

Final Report

A. Project Information

Project Title	Assessment of Harvested and Sequestered Nitrogen Content to Improve Nitrogen Management in Perennial Crops	
Project leaders	Ms. Charlotte Gallock, P.E., Dr. John Dickey, Dr. Ken Cassman, Dr. Daniel Geisseler	
Grant Number	17-0488	
Project Duration	Start Date: January 1, 2018	End Date: December 31, 2021
Email and Phone	jdickey@plantierra.com (916) 517-2481	
Report Type	Final Report	
Reporting Period	Start Date: January 1, 2018	End Date: December 31, 2021

B. Abstract

Through the Irrigated Lands Regulatory Program (ILRP), the Central Valley Regional Water Quality Control Board (Water Board) requires producers to implement management practices that are protective of groundwater quality and to document the effectiveness of those practices by providing, among other things, information on field nitrogen (N) balances. In addition, the Agricultural Expert Panel convened by the State Water Resources Control Board recommended metrics composed of N applied (A) and N removed (R) to gauge program progress in reducing the mass of leachable N (Burt et al., 2014). To comply with this new reporting requirement, growers and their water quality coalitions need reliable data about N removed from fields in harvested crop materials. Also, growers can use rates of N removal in crops to plan nutrient management programs that reasonably minimize N at risk of leaching below the root zone.

The objective of this project was to assess harvested and sequestered N content for priority crops (with prioritization based on the 2016 N-Concentrations Report and input from other experts). By partnering with commodity organizations, growers, processors, and packers, it was possible to procure hundreds of samples that represent a range of varieties and growing environments for each crop. In most cases, substantial information about source fields, such as age of perennial crops, crop management, variety, yield,

quality, and dates of bloom or planting, were acquired and related to results. In this way, some of the factors that affect N content of the harvest can be investigated and explained. Updated conversion factors for 11 crops were incorporated into a 2021 N-Concentrations Report and the Yield to N-Removed Calculator (http://agmpep.com/calc-y2r/). Phase 2 of this project is already funded and will include approximately 33 additional crops.

C. Introduction

The Water Board now requires growers to document the effectiveness of management practices to minimize nitrate leaching by providing, among other things, information on field N balance components. In addition, the Agricultural Expert Panel convened by the State Water Resources Control Board recommended regional programmatic metrics derived from N applied and N removed in crop yield and other material. The purpose of these metrics is to gauge program progress in reducing the mass of leachable N (Burt et al., 2014). This approach was incorporated into the General Order for growers within the Tulare Lake Basin by the Water Board, requiring that A and R for fields in areas with highly vulnerable groundwater be reported to the Water Board by the Coalitions. To comply with this requirement, growers and their coalitions need reliable information about the N content of crop portions removed from the field, so that reported yields can be accurately converted into N removal rates. Also, growers can use rates of N removal in crops to help plan nutrient management programs that reasonably minimize N at risk of leaching below the root zone.

With the participation of several cooperating coalitions, the SSJV MPEP Committee contracted and worked with Dr. Daniel Geisseler of UC Davis to complete and publish usable, literature-based yield-to-N-removed conversion factors for 72 crops, representing more than 98% of Central Valley irrigated lands. The report, *Nitrogen Concentrations in Harvested Plant Parts - A Literature Overview* (N-concentrations Report), was prepared by Dr. Geisseler (2016). Although completed, this report was essentially the first phase of this study, and helped to orient subsequent work, including all the work described herein.

The N-concentrations Report noted that some of the conversion factors were based on datasets that were small, more than 20 years old, or from outside the Central Valley, and / or reflected cultivars, yields, cropping systems, and soil types other than those common under contemporary Central Valley conditions. The N-concentrations Report showed that well-established coefficients are available for only 10 of the 72 crops, accounting for approximately 12 percent of irrigated lands in the Central Valley. Further, there are even fewer data on the amount of N sequestered into perennial crop biomass, which growers need to know when planning N fertilizer programs for younger orchards, groves, and vineyards during rapid early growth of perennial tissues. To refine coefficients for the remaining 62 crops from the N-concentrations Report, additional data needed to be obtained from analysis of recent crop samples from Central Valley fields over several years.

D. Objectives

- **Assess N concentration of harvested material removed from fields (N removed [R]) for approximately 22 crops over several growing seasons**. Samples of harvested material were originally planned for 6 crops, but an additional 2 crops were also sampled. Data or samples for three additional crops were obtained from other researchers. Information for the remaining crops were originally planned to come from other research projects (funded separately), but data were not yet available at the completion of Phase 1. We expect these data to become available during Phase 2.
- **Establish values for the annual amount of N sequestered in standing biomass for seven perennial crops.** Tissue samples were originally planned for one crop and data for the remaining crops were to be developed from growth models or to come from other research projects (funded separately). To date, only information for almond trees has been included. Information for additional perennial crops is expected to be included during Phase 2.
- Refine crop yield (Y)-to-R conversion factors, and add N-sequestration rate estimates, for use by growers and grower advisors during nutrient management planning and by coalitions for large-scale performance assessment.
- Promote and enable expanded knowledge and appropriate use of N-removal coefficients and N-sequestration rates (as part of routine N-management planning and evaluation) by growers, grower advisors, and coalitions.

E. Methods

This project developed updated conversion factors for priority crops. Data collection methods are summarized in Table 1. The three methods were developed through extensive discussions with commodity groups, scientists, and producers. For some crops, information came from other research projects. For other crops, sampling and analysis occurred as a part of this Project. Sampling under this Project spanned several seasons to account for variation due to differences in weather conditions that affect yields and N use efficiency. Specific sampling protocols and analysis methods were defined in detail for each crop to account for variability among cultivars, harvest dates, individual fields, and years of harvest. We coordinated with scientists, and grower/packer/shippers to procure samples for analysis, and to manage, summarize, and interpret results. Lab analyses were carried out at UC Davis in Dr. Geisseler's Nutrient Management Lab.

Table 1. Data Collection Methods to Assess Harvested and Sequestered N Concentration in 11 Crops

Method	Crops	Percent of Central Valley Irrigated Acreage
Update Coefficients		
Incorporate existing, available data	English walnut	5.2%
Incorporate new data from sampling and analysis efforts currently in progress and separately funded	corn silage, pima and acala cotton	14.5%
Obtain new data through targeted, new sampling and analysis in collaboration with partner scientists and grower/packer/shippers	carrots, peaches, pistachios, plums, pomegranates, safflower, sunflower, processing tomatoes	11.5%
Estimate N Sequestration in Perennial Tissues		
Incorporate existing, available data	Almonds. Pending data from other deciduous tree crops, almond results provide an estimate.	15.5%
Obtain new data through targeted, new sampling and analysis in collaboration with partner scientists and grower/packer/shippers	No new sampling was performed. These studies have been separately funded, but data have not yet been obtained.	

The three data collection methods were incorporated into the following tasks:

- ***Task 1. Establish sampling protocols and analysis methods, acquire data from others***. The Project team coordinated with resource persons to acquire data (as available) from ongoing and completed studies. The Project team incorporated these data into the database developed as part of Dr. Geisseler's effort for the 2016 N-concentrations Report.

  Sampling and analysis protocols were individually established for carrots, peaches, pistachios, plums, pomegranates, safflower, sunflower, and processing tomatoes. Sampling protocols focused on obtaining sufficiently representative, samples (i.e., representative of environmental, cultural, and varietal variation among harvested blocks, weighting differing conditions in proportion to their predominance), and included directions for sample number, compositing material into a sample, gathering relevant cultural data about the context in which the sample was produced, and sample packaging and shipping. Sample size and sampling periods were reviewed and finalized.

  As for analysis, it is not possible or effective to grind up the whole sample for many

crops, so removed material was divided into its component parts that were then processed and analyzed separately. The protocols included steps for selection and handling of representative samples, obtaining fresh (harvest) weights, separating harvest components (e.g., peach flesh and pit), processing and drying (or in the case of wet, sugary materials, pureeing and freeze drying) plant parts, grinding dry or freeze dried material, subsampling ground material for analysis, analysis for total N, and assembly of results into N removal or sequestration rates (taking account of standard reporting moisture contents, along with waste material [e.g., peach culls] where applicable). All samples were analyzed at UC Davis in Dr. Geisseler's Nutrient Management lab.

- ***Task 2. Sample and assess harvested and sequestered N concentration***. This task was facilitated by bringing in collaborators with separate funding. Similarly, working with grower/packer/shippers permitted relatively efficient sampling of yield from a broad spectrum of known locations. Crop history, such as location, crop variety and management, were obtained whenever practicable. Where producer anonymity was required, we retained only a general location of the source field. We maintained adequate coordination with these entities to ensure representative sampling and appropriate sample handling, packaging, and shipping.

  Sampling and analysis occurred during the 2018 through 2021 harvest seasons.

- ***Task 3. Interpret results and develop and publish N-concentrations Report update.*** Dr. Geisseler updated the N removed/sequestered database and developed an update of the N-concentrations Report (Geisseler, 2021). The discussion of appropriate use of N-removal estimates describes known limitations of the methodology due to N-concentration variation induced by cultivars, the environment, crop moisture content, and management, as well as unavoidable inefficiencies of translating applied N into plant biomass.

  The removal/sequestration rates were also used to refine N-removal rates embedded in crop growth models in the Soil and Water Assessment Tool (SWAT), which is being used to assess N fate in irrigated agriculture throughout the CV.

- ***Task 4. Develop and publish calculator updates***. This task included revision and refinement of the SSJV MPEP online Y-to-R calculator for use by anyone, but especially by coalitions, growers, and grower advisors. The calculator estimates N removed (R) and the ratio of N applied (A) to N removed (A/R), based on inputs for a single crop or for multiple crops. Growers may also download a workbook version that can be operated locally, which may increase usership by facilitating work with batches of fields at once, and by eliminating concerns about online data privacy.

F. Data/Results

Table 2 provides a summary of N-removed data for samples of harvested material reported in literature and based on samples collected and analyzed throughout this Project. Average nitrogen concentrations are expressed in pounds of N per ton at

moisture contents common for specific crops at harvest (Geisseler, 2016). Background information, such as N applied, crop variety, and planting date, were requested from growers. These ancillary data potentially provide more context to explain variability in the dataset.

Figure 1 compares the coefficients of variation found in the 2016 literature review (Geisseler, 2016) and those resulting from harvested material sampled throughout this Project. Some crops (e.g., pomegranates) have very different N-Removal coefficients than were previously available from the literature, while other crops (e.g., processing tomatoes) are quite similar. N-Removal coefficients for some crops (e.g., pistachios) have changed because the plant parts represented in previous studies were different from what was sampled in this Project. While the coefficients of variation found in this Project vary among crops and years, there is often little difference between their range and what was reported from previous studies. This is notable because samples for many crops were drawn from production fields at commercial processing facilities. Only corn silage samples were from research plots.

Table 2. Summary of Samples Collected, Including Laboratory Results and Literature Comparisons

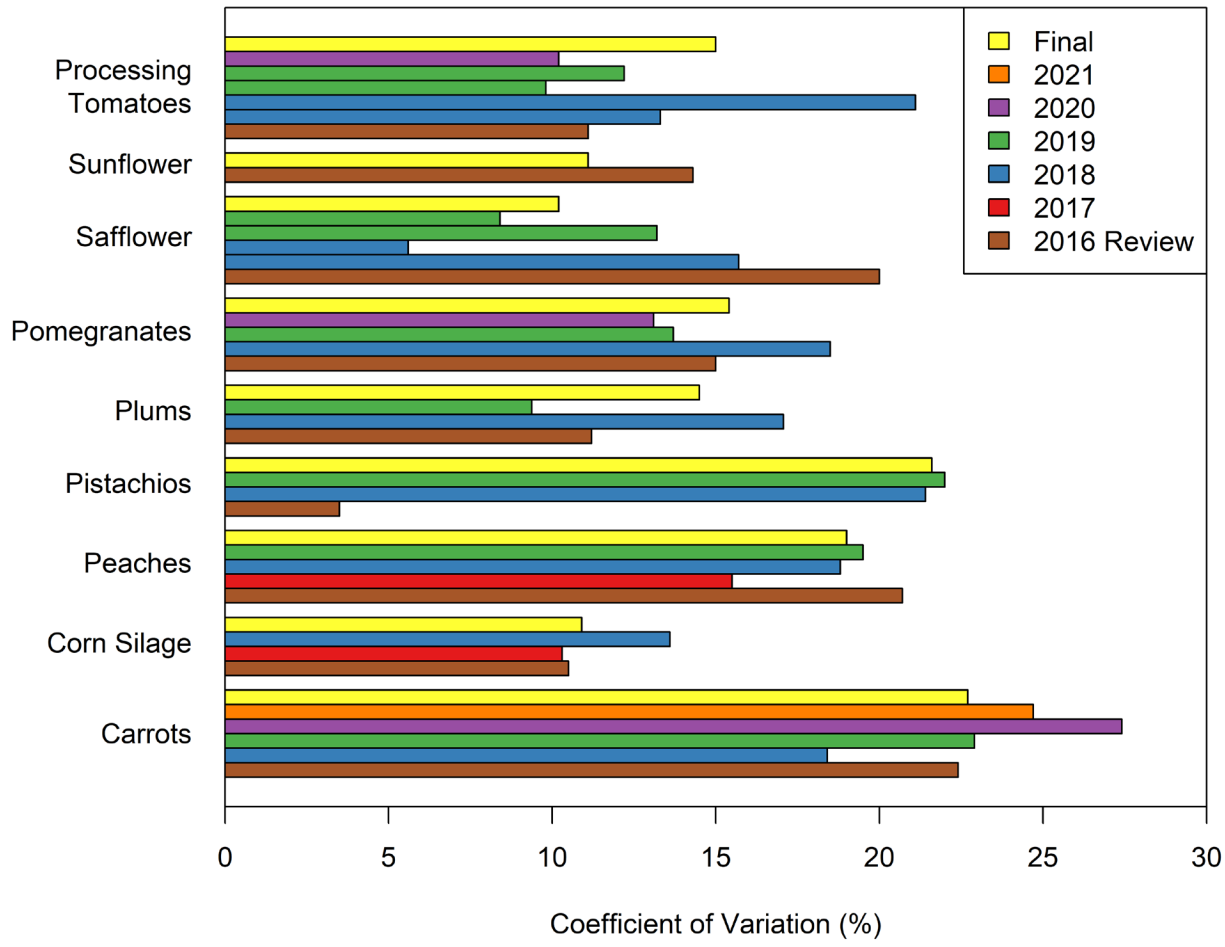
Crop		This Project				2016 Literature Review		Background Info
		Year	# Of samples	Avg. Lbs N/ton	CV (%)	Avg. Lbs N/ton	CV (%)	
Carrots		2018	14	2.78	18.4			6
		2019	35	2.85	22.9			
		2020	5	2.97	27.4			
		2021	10	2.55	24.7			
		Final	**64**	**2.80**	**22.7**	*3.29*	*22.4*	
Corn Silage		1997-2011	52	7.62	11.3			
		2014	20	7.39	7.8			
		2017	12	7.59	10.3			12
		2018	12	7.32	13.6			12
		Final	**96**	**7.53**	**10.9**	*7.56*	*10.5*	
Cotton	Acala	1998-2000	20	47.3	20.2			
	Acala	2006-2015	8	41.9	5.5			
	Pima	1999-2000	7	33.1	20.9			
	Pima	2006-2015	14	43.9	7.1			
		Final	**49**	**43.4**	**16.1**	*43.7*	*29.5*	
Peaches		1992	2	2.35	12.6			
		1994	3	2.04	28.9			
		2017	8	3.62	15.5			
		2018	36	3.18	18.8			36
		2019	32	2.86	19.5			
		Final	**81**	**3.04**	**19.0**	*2.26*	*20.7*	
Pistachios[1]		2018	97	20.4	21.4			
		2019	59	20.4	22.0			
		Final	**156**	**20.4**	**21.6**	*56.1*	*3.5*	
Pistachio trash[2]		2018-2019	7	15.0	33.5			
Plums		1992	1	2.84				
		2018	12	2.44	17.06			12
		2019	11	2.04	9.38			
		Final	**24**	**2.27**	**14.5**	*2.83*	*11.2*	
Pomegranates		2018	11	4.41	18.5			
		2019	19	3.45	13.7			
		2020	10	4.41	13.1			
		Final	**40**	**3.96**	**15.4**	*15.2*	*15.0*	

Safflower	1994-1995	12	48.8	14.6			
Sacramento Valley	2018	25	49.0	15.7			some
Tulare Lake Basin	2018	49	52.0	5.6			some
Sacramento Valley	2019	10	56.1	13.2			some
Tulare Lake Basin	2019	44	52.8	8.4			some
	Final	**140**	**51.7**	**10.2**	*56.8*	*20.0*	
Sunflower	**2019/Final**	**24**	**63.2**	**11.1**	54.1	14.3	
Tomatoes	2007-2008	8	3.0	9.4			
(processing)	2013	14	2.52	12.4			
	2015	2	3.12	10.7			
Sacramento Valley	2018	28	3.08	13.3			10
Tulare Lake Basin	2018	59	2.78	21.1			
Sacramento Valley	2019	30	3.05	9.8			10
Tulare Lake Basin	2019	49	2.98	12.2			
Tulare Lake Basin	2020	5	3.31	10.2			
	Final	**195**	**2.92**	**15.0**	*2.73*	*11.1*	
Walnuts	1985-1990	6	40.5	10.7			
	2013	6	26.9	9.5			
	2014	6	29.0	5.6			
	2015	6	30.7	14.4			
	Final	**24**	**31.8**	**10.9**	*31.9*	*11.2*	

[1] The basis of pistachio N content was changed from the marketed portion considered in 2016 to green pistachios as they arrive for processing from the field. For a typical rate of turnout, this coefficient is effectively equivalent to the old one, other than the change in basis.

[2] Pistachio trash N content was highly variable meaning more samples are required to improve the estimate. Furthermore, currently robust estimates of the average amount of trash removed from the field per unit of yield do not exist.

Figure 1. Coefficients of Variation of Initial Literature Review and Subsequent Sampling



G. Discussion and Conclusions

These new data will supplement existing datasets with results for additional recent, local, samples from fields across the Central Valley over three growing seasons. With these results, growers now have more reliable information with respect to crop N requirements that can help refine N-management planning. Furthermore, growers, coalitions, and the Water Board may more accurately assess progress in the reduction of leachable N in agricultural systems across the Central Valley.

This project assessed the N concentration of harvested material removed from fields for 11 crops over three growing seasons. Initial plans involved the collection and analysis of samples of harvested materials from six (6) crops. However, through coordination with commodity groups, researchers, and growers, hundreds of samples were collected for eight (8) crops. Furthermore, of these eight crops, data for three (pistachio, processing

tomato, and pomegranate) were initially planned to be compiled from existing or planned studies, though additional samples from fields throughout a vast production area for each crop were procured and analyzed as part of this project.

As shown in Table 2, in some cases (e.g., corn silage, cotton, and walnuts) the N-removal coefficient changed little after integration of new data obtained by this project, while values for other crops (e.g., peaches and pomegranates) changed substantially. Differences in updated conversion factors can be caused by many variables related to how relevant and comprehensive the previously used data were to current Central Valley conditions. Regardless of whether the coefficient changed considerably or not, the collection and integration of current data from the Central Valley that span differing climates, soils, management practices, and years, provides a clearer picture of N removal dynamics within Central Valley agriculture.

Values for the annual amount of N sequestered in standing biomass were compiled for almonds based on existing data. Unforeseen challenges prevented the collection in data for the remaining 6 perennial crops. However, information for these crops may be addressed under Phase 2 of the project. Phase 2 includes updating conversion factors for approximately 33 additional crops. By partnering with commodity organizations, growers, processors, packers, and retailers, it is possible to procure hundreds of samples that represent a range of varieties and growing environments for each crop. Currently, samples are planned to be or are being collected and analyzed for apricots, nectarines, cherries, Valencia and Navel oranges, lemons, tangelos, grapefruit, figs, table grapes, table olives, raisins, sweet corn, corn grain, sorghum grain, non-alfalfa hay/haylage, cantaloupe, honeydew, watermelon, summer squash, cucumber, onion, garlic, potato, sweet potato, fresh market tomato and bell pepper.

Two main objectives related to this project include the refinement of Y-to-R conversion factors and the promotion and enablement of expanded knowledge and appropriate use of N-removal coefficients and N-sequestration rates (as part of routine N-management planning and evaluation) by growers, grower advisors, and coalitions. These goals were achieved under Tasks 3 and 4. Specifically, Dr. Geisseler updated the N removed/sequestered database and developed an update of the N-concentrations Report (Geisseler, 2021). Furthermore, the updated N removal coefficients were integrated into the N removal calculator (http://agmpep.com/calc-y2r/) for public use. Outreach activities outlined in Section J. also support the objectives of this project. As more information continues to be developed under Phase 2, these resources will continue to be expanded for use throughout the Central Valley.

Though our colleagues at the Central Coast Regional Board and in UCCE, we have shared lessons from this project with those performing similar work in other areas. In particular, Drs. Geisseler and Dickey carefully reviewed draft protocols for site-specific N removal sampling by growers, which is an option in that region.

H. Challenges

Challenge	Corrective Action and/or Project Change/Lessons Learned
Difficulty in obtaining raisin samples.	Added other crops. Reached out to additional raisin operations. Samples are currently being collected under Phase 2.
Difficulty in obtaining information on other crops from existing datasets and/or planned and funded projects	Added other crops. Directly collected and analyzed samples. Plan to obtain outstanding information as a part of Phase 2.

I. Project Impact

The N-removal coefficients developed as a part of this Project are usable by growers, grower advisors, scientists, coalitions, and regulators. The information will directly and indirectly contribute to better N-management decisions and more accurate evaluations of environmental performance of agricultural fields. Known limitations of the coefficients such as variation induced by cultivars, the environment, crop moisture content, and management, as well as unavoidable inefficiencies of translating applied N into plant biomass, are described to inform appropriate use. The coefficients have been incorporated into N-management calculators available on the SSJV MPEP website (http://agmpep.com/calc-y2r/) to enable users to plan N management, and to facilitate evaluating environmental performance of agricultural regions. In addition to environmental benefits of reducing the mass of leachable N, improved N management should benefit growers' returns by helping stabilize yields in the high range, improving fertilizer efficiency, and managing regulatory obligations through documentable, improved performance.

With the results from this Project, growers may more readily plan field-specific N programs, and coalitions and the Water Boards may more accurately assess regional progress in the reduction of leachable N in agricultural systems across the CV. This will help protect groundwater quality by attenuating agricultural nitrate leaching where needed, and ultimately slowing, halting, or reversing degradation of groundwater quality. Within the SSJV and the adjacent Salinas Valley, approximately 254,000 people currently depend on groundwater for their drinking water supply, and that number is anticipated to grow along with the regions' populations. In addition, because the knowledge and tools developed as a part of this Project are transferable to other regions and states with similar environmental quality concerns and cropping systems, groundwater quality could become better protected in those locations as well.

J. Outreach Activities Summary

The N removed coefficients refined by the Project feed into several outreach processes and tools. Outreach processes into which the N removed coefficients are directly incorporated include the following:

- The peer-reviewed Crop Yield to Nitrogen Removed Calculator (also known as the Y-to-R Calculator) is published at https://agmpep.com/calc-y2r/. It was developed based on conversion factors developed by Geisseler (2016). The calculator can be used by growers and advisers with anticipated or actual yield information to estimate N removed (R) and the ratio of N applied (A) to N removed (A/R). Results can be calculated on inputs for a single crop or for multiple crops. Recent updates include clarification on reporting units and plant parts, as well as plant parts in which N removal is considered.
- Nitrogen Management Plan (NMP) Summary Report yield data are processed by coalitions with N removed coefficients, and then reported back to growers so that they can check to make sure that they are properly accounting for N removal as they plan N applications. Coefficients used by coalitions reflect updates from this Project.
- NMP Summary Report data from throughout the Central Valley are analyzed from an agronomic perspective. The results are then shared with commodity groups and grower/grower advisor communities, so that they can evaluate the meaning of what growers have reported, relative to future nutrient management study and outreach. The N removal coefficients are employed directly in calculation of the N balance in this analysis. This is a key parameter that reflects the maximum mass of leachable N.

Additional outreach activities include:

- A project summary is posted here on the SSJV MPEP website (http://agmpep.com). The website is shared by the SSJV MPEP Committee with the over 9,000 growers in the member coalitions.
- A poster, *Nitrogen and Dry Matter Accumulation in Peaches,* was presented at the Annual Conference of the Fertilizer Research and Education Program / Western Plant Health Association, November 1-2, 2017. This poster was focused on work completed prior to the FREP award, but is nonetheless relevant to the overall project to improve N removal rates. The poster is available here.
- A poster, *Working with Commodity Groups, Processors, and Packers to Procure Representative Crop Samples to Assess Harvest Nitrogen Content,* was presented at the 2018 FREP Conference. Annual Conference of the Fertilizer Research and Education Program / Western Plant Health Association, October 22-24, 2018. The poster is available here. The abstract and an associated handout are included in Attachment 1.
- In October 2020, a presentation was given at the FREP conference which focused on the potential uses of N-Removal information, as well as an overview of our methodology and available results.

K. References

Agricultural Expert Panel. 2014. *Recommendations to the State Water Resources Control Board pertaining to the Irrigated Lands Regulatory Program*. In fulfillment of SBX2 1 of the California Legislature. September 9.

Geisseler, Daniel. 2016. Nitrogen Concentrations in Harvested Plant Parts – A Literature Overview. UC+Davis.

Geisseler, Daniel. 2021. Nitrogen Concentrations in Harvested Plant Parts – A Literature Overview. UC+Davis.

Niederholzer, F.J.A., T.M. DeJong, J.-ˇL. Saenz, T.T. Muraoka, and S.A. Weinbaum. 2001. Effectiveness of Fall versus Spring Soil Fertilization of Field-ˇgrown Peach Trees. J. Amer. Soc. Hort. Sci. 125(5):644–648.

Rufat, J. and T.M. DeJong. 2001. Estimating seasonal nitrogen dynamics in peach trees in response to nitrogen availability. Tree Physiology 21, 1133–1140.

L. Appendix

Two appendices are provided:

- Appendix A: Geisseler Report – 2021
- Appendix B: Sampling Protocols

M. Factsheet

1. **Project Title**: Assessment of Harvested and Sequestered Nitrogen Content to Improve Nitrogen Management in Perennial Crops

2. **Grant Agreement Number:** 17-0488

3. **Project Leaders**: Ms. Charlotte Gallock, P.E (SSJV MPEP Committee)., Dr. John Dickey and Dr. Ken Cassman (MPEP Technical Team), and Dr. Daniel Geisseler (UC Davis)

4. **Start Year/End Year**: 2018/2021

5. **Location:** Various locations in the Central Valley

6. **Counties where research was performed**: Samples were collected from multiple counties across the Central Valley (CV) including Fresno, Glenn, Kern, Kings, Madera, Merced, Sacramento, San Joaquin, Solano, Sutter, Stanislaus, Tulare, and Yolo counties.

7. **Highlights**

- To comply with ILRP requirements, growers need reliable data about N removed from fields in harvested crop materials.
- Samples for nine crops were collected from CV locations between 2017 and 2020 and analyzed for total N.
- Recently published data for cotton, walnuts, and N in perennial parts of almonds were also included.
- Updated conversion factors for 11 crops (31%) of CV irrigated acreage were developed. Phase 2 will include approx. 33 additional crops.

8. **Introduction**. The Water Board requires growers to document the effectiveness of management practices to minimize nitrate leaching by providing, among other things, information on field N balance components. To comply with this requirement, growers need reliable information about the N content of crop portions removed from the field, so that reported yields can be accurately converted into N removal rates. Also, growers can use rates of N removal in crops to help plan nutrient management programs that reasonably minimize N at risk of leaching below the root zone. To provide this information, sampling and analysis was necessary to develop N removed conversion factors reflective of contemporary Central Valley conditions.

9. **Methods/Management**. For some crops, information came from other research projects. For other crops, sampling and analysis occurred as a part of this Project. Sampling under this Project spanned several seasons to account for variation due to differences in weather conditions that affect yields and N use efficiency. Specific sampling protocols and analysis methods were defined in detail for each crop to account for variability among cultivars, harvest dates, individual fields, and years of harvest. We

coordinated with scientists, and grower/packer/shippers to procure samples for analysis, and to manage, summarize, and interpret results.

10. **Findings**. The N-removal coefficients developed as a part of this Project are usable by growers, grower advisors, scientists, and regulators, contributing to better N-management decisions and more accurate evaluations of environmental performance of agricultural fields. Findings are displayed in Table 1.

Table 1. Summary of Samples Collected, Including Laboratory Results and Literature Comparisons

Crop	This Project				2016 Literature Review		Background Info
	Year range of samples	# Of samples	Avg. Lbs N/ton	CV (%)	Avg. Lbs N/ton	CV (%)	
Carrots	**2018-2021**	**64**	**2.80**	**22.7**	*3.29*	*22.4*	6
Corn Silage	**1997-2018**	**96**	**7.53**	**10.9**	*7.56*	*10.5*	24
Cotton	**1998-2015**	**49**	**43.4**	**16.1**	*43.7*	*29.5*	
Peaches	**1992-2019**	**81**	**3.04**	**19.0**	*2.26*	*20.7*	36
Pistachios[1]	**2018-2019**	**156**	**20.4**	**21.6**	*56.1*	*3.5*	
Pistachio trash[2]	2018-2019	7	15.0	33.5			
Plums	**1992-2019**	**24**	**2.27**	**14.5**	*2.83*	*11.2*	12
Pomegranates	**2018-2019**	**40**	**3.96**	**15.4**	*15.2*	*15.0*	
Safflower	**1994-2019**	**140**	**51.7**	**10.2**	*56.8*	*20.0*	some
Sunflower	**2019**	**24**	**63.2**	**11.1**	54.1	14.3	
Tomatoes, Processing	**2007-2020**	**195**	**2.92**	**15.0**	*2.73*	*11.1*	20
Walnuts	**1985-2015**	**24**	**31.8**	**10.9**	*31.9*	*11.2*	

[1] The basis of pistachio N content was changed from the marketed portion considered in 2016 to green pistachios as they arrive for processing from the field. For a typical rate of turnout, this coefficient is effectively equivalent to the old one, other than the change in basis.

[2] Pistachio trash N content was highly variable meaning more samples are required to improve the estimate. Furthermore, currently robust estimates of the average amount of trash removed from the field per unit of yield do not exist.

N. Copy of the Product/Result

Not applicable

Appendix A.
Nitrogen Concentrations in Harvested Plant Parts (update 03/2021)

Appendix B.
Sampling Protocols