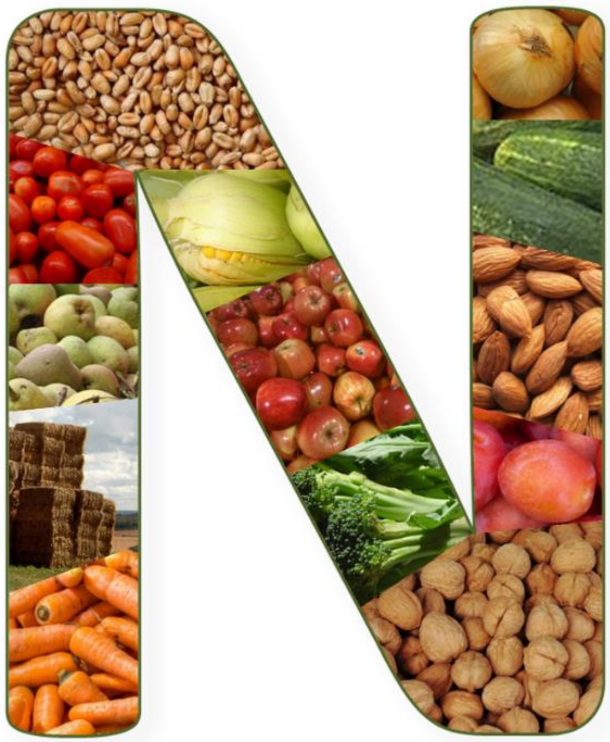
Nitrogen concentrations in harvested plant parts – Update 03/2021



Includes updated values for

- Carrots
- Corn for silage
- Cotton
- Peaches
- Pistachios
- Plums
- Pomegranates
- Tomatoes, processing
- Safflower
- Sunflower
- Walnuts
- Perennial parts of trees

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Content

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Acknowledgments

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Summary

Nitrogen (N) balances in agricultural fields are important components of the Central Valley Irrigated Lands Regulatory Program. The ratio of N applied to N removed is a key metric for the Central Valley Regional Water Quality Control Board. The approach involves growers reporting applied N and yield to the water quality coalitions. The coalitions in turn convert yield to N removed and report various statistics to the Water Quality Control Board. Nitrogen accumulated into perennial plant tissues may also be counted as “removed”. For these calculations, reliable values of N concentrations in the harvested parts and perennial tissues of crops are needed.

The present report is an update of a similar 2016 report. Samples for carrots, silage corn, peaches, pistachios, plums, pomegranates, sunflower, safflower, and processing tomatoes were collected from Central Valley locations between 2017 and 2020 and analyzed for total N. In addition, recently published data for cotton, walnuts and N in perennial parts of almonds were included.

The updated values are highlighted in Tables 1-3. The results of the analyses are presented and discussed in more detail starting on page 10.

Table 1: Overview of N concentrations in harvested plant parts of field crops. The highlighted commodities are those updated in this report.

Commodity	Last update	N in harvested plant parts		CV (%)	Page
Alfalfa - Hay		**62.3**	lbs N/ton @ 12% moisture	12.5	
Alfalfa - Silage		**24.0**	lbs N/ton @ 65% moisture	17.5	
Barley - Grain		**33.6**	lbs N/ton @ 12% moisture	14.6	
Barley - Straw		**15.4**	lbs N/ton @ 12% moisture	31.3	
Beans, dry - Blackeye		**73.0**	lbs N/ton @ 12% moisture	10.4	
Beans, dry - Garbanzo		**67.2**	lbs N/ton @ 12% moisture	11.3	
Beans, dry - Lima		**72.3**	lbs N/ton @ 12% moisture	5.4	
Corn - Grain		**24.0**	lbs N/ton @ 15.5% moisture	20.8	
Corn - Silage	03/2021	**7.53**	lbs N/ton @ 70% moisture	10.9	11
Cotton	03/2021	**43.4**	lbs N/ton lint & seed	16.1	13
Fescue, Tall - Hay		**50.8**	lbs N/ton @ 12% moisture	16.2	
Oat - Grain		**37.7**	lbs N/ton @ 12% moisture	9.6	
Oat - Straw		**14.8**	lbs N/ton @ 12% moisture	34.7	
Oat - Hay		**21.7**	lbs N/ton @ 12% moisture	18.2	
Orchard Grass - Hay		**54.5**	lbs N/ton @ 12% moisture	20.0	
Ryegrass, Perennial - Hay		**54.9**	lbs N/ton @ 12% moisture	16.8	
Safflower	03/2021	**51.7**	lbs N/ton @ 8% moisture	10.2	23
Sorghum - Grain		**33.0**	lbs N/ton @ 13.5% moisture	29.7	
Sorghum - Silage		**7.34**	lbs N/ton @ 65% moisture	21.0	
Sunflower	03/2021	**63.2**	lbs N/ton @ 8% moisture	11.1	25
Triticale - Grain		**40.4**	lbs N/ton @ 12% moisture	13.0	
Triticale - Straw		**11.5**	lbs N/ton @ 12% moisture	38.3	
Triticale - Silage		**9.03**	lbs N/ton @ 70% moisture	13.7	
Wheat, common - Grain		**43.0**	lbs N/ton @ 12% moisture	10.3	
Wheat - Straw		**13.8**	lbs N/ton @ 12% moisture	33.0	
Wheat - Silage		**10.5**	lbs N/ton @ 70% moisture	18.6	
Wheat, durum - Grain		**42.1**	lbs N/ton @ 12% moisture	3.7	

Table 2: Overview of N concentrations in harvested plant parts of vegetables. The highlighted commodities are those updated in this report.

Commodity	Last update	N in harvested plant parts		CV (%)	Page
Asparagus		**5.85**	lbs N/ton of fresh spears	14.0	
Beans, green (snap beans)		**5.78**	lbs/ton of fresh weight	25.7	
Broccoli		**11.2**	lbs N/ton of fresh weight	20.4	
Carrots	03/2021	**2.80**	lbs/ton of fresh weight	22.7	10
Corn, sweet		**7.17**	lbs/ton of fresh ears	13.1	
Cucumbers		**2.16**	lbs/ton of fresh weight	17.4	
Garlic		**15.1**	lbs/ton of fresh weight	19.5	
Lettuce, Iceberg		**2.63**	lbs/ton of fresh weight	16.7	
Lettuce, Romaine		**3.62**	lbs/ton of fresh weight	13.7	
Melons, Cantaloupe		**4.87**	lbs/ton of melons	15.5	
Melons, Honeydew		**2.95**	lbs/ton of melons	22.1	
Melons, Watermelons		**1.39**	lbs/ton of melons	23.9	
Onions		**3.94**	lbs/ton of fresh weight	19.7	
Pepper, Bell		**3.31**	lbs/ton of fresh weight	7.9	
Potatoes		**6.24**	lbs/ton of fresh weight	13.6	
Pumpkin		**7.36**	lbs/ton of fresh weight	10.1	
Squash		**3.67**	lbs/ton of fresh weight	22.4	
Sweet potatoes		**4.74**	lbs/ton of fresh weight	16.8	
Tomatoes, fresh market		**2.61**	lbs/ton of fresh weight	16.5	
Tomatoes, processing	03/2021	**2.92**	lbs/ton of fresh weight	15.0	26

Table 3: Overview of N concentrations in harvested plant parts of tree and vine crops. The highlighted commodities are those updated in this report.

Commodity	Last update	N in harvested plant parts		CV (%)	Page
Almonds		**136**	lbs/ton of kernels	4.1	
Apples		**1.08**	lbs/ton of fruits	35.1	
Apricots		**5.56**	lbs/ton of fruits	114	
Cherries		**4.42**	lbs/ton of fruits	19.8	
Figs		**2.54**	lbs/ton of fruits	18.1	
Grapefruit		**2.96**	lbs/ton of fruits	7.8	
Grapes - Raisins		**10.1**	lbs/ton @ 15% moisture	5.8	
Grapes - Table		**2.26**	lbs/ton of grapes	5.8	
Grapes - Wine		**3.60**	lbs/ton of grapes	13.0	
Lemons		**2.58**	lbs/ton of fruits	10.0	
Nectarines		**3.64**	lbs/ton of fruits	27.1	
Olives		**6.28**	lbs/ton of olives	22.8	
Oranges		**2.96**	lbs/ton of fruits	10.9	
Peaches	03/2021	**3.04**	lbs/ton of fruits	19.0	15
Pears		**1.29**	lbs/ton of fruits	17.9	
Pistachios	03/2021	**20.4**	lbs N/ton net green weight	21.6	17
Plums	03/2021	**2.27**	lbs/ton of fruits	14.5	19
Pomegranate	03/2021	**3.96**	lbs/ton of fruits	15.4	21
Prunes		**11.2**	lbs/ton of dried fruits	16.3	
Tangerines		**2.54**	lbs/ton of fruits	29.2	
Walnuts	03/2021	**31.8**	lbs N/ton of nuts @ 8% moist.	10.9	28

Introduction

The ratio of N applied to N removed is a key metric in the Central Valley Irrigated Lands Regulatory Program (CVILRP). Growers report applied N and yield to agricultural water quality coalitions. The coalitions in turn convert yield to N removed from fields and report various statistics to the Central Valley Regional Water Quality Control Board. Nitrogen accumulated into perennial plant tissues may also be counted as “removed”. For these calculations, reliable values of N concentrations in the harvested parts and perennial tissues of crops are needed.

For a report released in 2016, we mined the scientific literature for data on N concentrations in harvested crop parts with an emphasis on California data (Geisseler, 2016). For many commodities, a robust dataset of recent samples from California was not available. With financial support from the California Department of Food and Agriculture – Fertilizer Research and Education Program (CDFA-FREP) and the help of the Kings River Watershed Coalition, John Dickey and his team at the Southern San Joaquin Valley Management Practices Evaluation Program collected a large number of samples, which were then analyzed in the author’s nutrient management lab at UC Davis. The present report is an update of the 2016 report and includes results from samples collected in California between 2017 and 2020 for carrots, silage corn, peaches, pistachios, plums, pomegranates, sunflower, safflower, and processing tomatoes. In addition, recently published data for cotton, walnuts and N in perennial parts of almonds were included. Data from California that were included in the 2016 report were combined with the new results for these crops, while data based on samples from other regions were removed.

Procedures

Sample acquisition

Sampling protocols containing methods and logistical information were developed and shared with industry partners. Methods generally took advantage of existing steps in production or processing where/when samples are routinely collected, often to assess the quality of the material harvested from a field to help establish equitable pricing and/or to guide subsequent processing, packing, and marketing. Obtaining samples at these steps in production and processing avoided interruption of normal operations at cooperating facilities. Furthermore, since decisions based on these samples are consequential, the industry has designed approaches to produce samples that represent harvested lots or whole fields. In some cases, packed boxes of fruit were provided to represent the fields where they were harvested. Samples were generally refrigerated (for high-moisture commodities like stone fruit) or kept cool and dry (for low-moisture commodities like oilseeds, or dried samples of silage) to stabilize them until processing commenced.

Processing tomato samples were obtained with the help of the Processing Tomato Advisory Board (PTAB) several times during the harvest season at three different grading stations. One station was located in the Sacramento Valley, and the other two in the Tulare Lake Basin. Peach, plum, pistachio, and pomegranate samples were obtained from processing and packing facilities. Safflower samples were obtained from partner growers in the Sacramento Valley and Tulare Lake Basin. Sunflower samples were provided by a seed company, as most of California's sunflower are grown for seed. Carrots were obtained from processing and packing partners in the Tulare Lake Basin. The existing dataset for silage corn was complemented with samples from an irrigation and N rate trial conducted in the Tulare Lake Basin.

Sample processing and analysis

The new samples included in this updated report were all analyzed in the nutrient management lab at UC Davis. Samples for the different commodities were analyzed for total N by dry combustion (Nelson and Sommers, 1996) on an elemental analyzer (Costech Analytical Technologies, Valencia, CA). A standard curve using acetanilide was prepared for each batch of samples. After every 11 samples, an acetanilide sample was analyzed for quality control.

Only finely ground samples can be analyzed on the elemental analyzer. Sample preparation depended on the commodity. Samples were always dried first and then ground to a fine powder. Every time samples were dried, the initial and final weights were recorded to determine the dry matter content. This allowed calculating the N concentration in the fresh weight of the crops. Samples were always mixed thoroughly before taking subsamples to ensure that subsamples were representative of the larger sample. The following procedures were used for the different commodities:

A random subsample of 6-8 carrot roots were sliced lengthwise, and dried in an oven at 60 °C until reaching a constant weight. The dried carrots were first ground on a Wiley mill to pass a 1 mm screen, and then passed through a small disc mill two times.

Silage corn samples were received dry and chopped. They were first ground on a Wiley mill to pass a 1 mm screen. After mixing the ground sample, a subsample was placed in a scintillation vial and ball milled on a paint shaker.

Safflower samples were first dried in an oven at 60 °C until reaching a constant weight. A subsample was then mixed with an equal amount of cellulose powder and first ground on a Micro-Mill II Grinder (Bel-Art Products, Wayne, NJ), followed by ball milling on a paint shaker. Mixing with cellulose was necessary, as analysis by dry combustion requires the material to be a fine powder. Due to their oil content, grinding safflower seeds without cellulose produced a paste. The weight of the cellulose and safflower seeds used was recorded for each sample and used to correct for the N concentration in the safflower seeds. The cellulose powder was also analyzed by dry combustion and found to contain no N. Sunflower samples were processed the same way.

The flesh and pits of peaches and plums were first separated. The pits were dried in an oven at 105 °C, crushed with a heavy weight, ground on a Micro-Mill II Grinder (Bel-Art Products, Wayne, NJ) and ball milled on a paint shaker. The flesh (including the skin) was cut into small pieces and converted to a paste in a food processor. A subsample was freeze-dried and then ball milled on a paint shaker.

Pistachio samples were dried in an oven at 60 °C until a constant weight was reached. They were then ground on a Wiley mill to pass a 1 mm screen. To be able to grind the samples to a fine powder, the were mixed with cellulose as described for safflower and then ground on a Micro-Mill II Grinder (Bel-Art Products, Wayne, NJ), followed by ball milling on a paint shaker.

Random subsamples of 5 fresh pomegranates were sliced into quarters and mixed in a food processor until homogenized. The resulting paste and liquid was dried in an oven at 60 °C until reaching a constant weight. The samples were then ground in a coffee grinder until reaching a dust-like consistency, and ball milled on a paint shaker.

Processing tomato samples were received as juice from the PTAB stations, juice they produce in a blender under vacuum to characterize each load of tomatoes. The samples were mixed well and a subsample was freeze-dried and ball milled on a paint shaker.

Data analysis

Nitrogen concentrations are expressed in lbs/ton at a moisture content common for the commodities at harvest or after drying. For each commodity, we calculated the **mean** of each dataset and the weighted mean among datasets. The weight of a dataset was determined by the number of observations

The measures of variability determined are **standard deviation (SD)** and **range** (smallest and largest value in the dataset). The overall SD in this report represents the pooled SD across the different datasets with more than one observation. If the distribution of the data is approximately normal, then about 68% of the data values are within one SD of the mean, and about 95% are within two SD. To facilitate comparison of different commodities, we calculated the **coefficient of variation (CV)**, which is expressed as the SD in % of the mean. Data presentation followed the outline from the 2016 report.

Results and discussion

Detailed analyses for specific commodities can be found in the second part of this report.

Nitrogen accumulation in permanent tissues of trees

For perennial crops, the value of N removed at harvest does not include N accumulation in perennial tissue (e.g. trunk, roots, or branches). From the point of view of N budgeting, N accumulating in perennial tissue over the years is no longer available and can be considered removed. Based on a literature review of a few studies from California available at the time, we concluded in the 2016 report that the amount of N stored in permanent tree tissue most commonly increases by an average of about 10 to 40 lbs/acre each year. Recently, Patrick Brown and collaborators published values based on their research in almond orchards (Brown et al., 2020). The values represent N demand for leaf and woody biomass (Table 4).

Table 4: Nitrogen demand of almond orchards based on orchard age (Brown et al., 2020)

Age (years)	Nitrogen demand for leaf and woody biomass (lbs/acre)
1	30
2	55
3	65
4	55
5	45
6-15	40
16-25	30

Limitations

Nitrogen concentrations in harvested crop parts can vary considerably from field to field and from one year to the next. The variability statistics provided for each coefficient is an indication of the expected magnitude variation. For a single year, the calculated amount of N removed, and thus the N balance or N ratio, may differ considerably from their actual values.

Calculating the amount of N removed based on yield and N concentration will underestimate the amount of N removed for crops where cull or trash is removed from the field but not included in the reported yield. For a more accurate estimate of the total amount of N removed from the field, N in cull or trash needs to be included (e.g. as a % of the N in the marketable portion of the yield).

Furthermore, reported yields need to be converted to the units and moisture content associated with the crop’s N concentration if different from Tables 1 through 3.

References

Brown, P.H., Saa, S., Muhammad, S., Khalsa, S.D., 2020. Nitrogen Best Management Practices. Available online at: https://www.almonds.com/almond-industry/orchard-management/soil-health-and-nutrients/nutrient-management

Geisseler, D., 2016. Nitrogen concentrations in harvested plant parts - A literature overview. Available online at: http://geisseler.ucdavis.edu/Geisseler_Report_2016_12_02.pdf

Nelson, D.W., Sommers, L.E., 2018. Total carbon, organic carbon, and organic matter, in: Methods of Soil Analysis. John Wiley & Sons, Ltd, pp. 961–1010. doi:10.2136/sssabookser5.3.c34

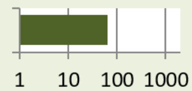
Carrots

N removal

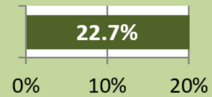
2.80

lbs N/ton
fresh weight

Observations



Variability



Data sources

From 2018 to 2021, carrot samples from 64 Central Valley fields were analyzed. The samples did not include foliage.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	California	14	2018	1	14
Own analyses	California	35	2019	1	35
Own analyses	California	5	2020	1	5
Own analyses	California	10	2021	1	10
Overall					**64**

Summary of carrot N removal data.

Source	Summary (lbs/ton of fresh weight)			CV (%)
	mean	SD	Range	
Own analyses 2018	2.78	0.51	2.01 - 4.11	18.4
Own analyses 2019	2.85	0.65	1.61 - 4.69	22.9
Own analyses 2020	2.97	0.81	1.98 - 4.08	27.4
Own analyses 2021	2.55	0.63	1.67 - 3.32	24.7
Overall	**2.80**	**0.63**	**1.61 - 4.69**	**22.7**

Variability

The variability in the dataset is relatively large. The dry matter content ranged from 9.8 and 13.4% and was therefore not a major contributor to the observed variability. The available data do not allow for an in-depth analysis of the factors contributing to the variability.

Discussion

The average value for N removed is based on 64 samples collected from different California fields over several years and can be considered a good estimate of N concentrations in California carrots.

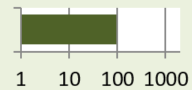
Corn – Silage

N removal

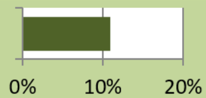
7.53

lbs N/ton
@ 70% moisture

Observations



Variability



Data sources

A total of 96 observations from three California sources were included in the report. In summer 2014, Heguy and Silva-del-Rio from UC Cooperative Extension visited 20 San Joaquin Valley dairy farms during corn silage harvest, and collected a composite sample from five truckloads of corn silage for nutrient analysis. From 1997 to 2011, Peter Robinson, Cooperative Extension Specialist for Dairy Nutrition and Management at UC Davis, collected samples from commercial dairy farms. In both cases, the silage was analyzed for crude protein. The values from these two sources were already included in the 2016 report.

In addition, we received and analyzed samples from a field trial in Fresno County where two varieties, different N application rates and deficit irrigation treatments were compared. The trial was managed by Bob Hutmacher, UCCE Extension Specialist, and Nick Clark, UCCE Farm Advisor for Kings, Tulare and Fresno counties.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Heguy and Silva-del-Rio, 2014	California	20	2014	1	20
Robinson, 2011	California		1997-2011		52
Irrigation & N trial	California	1	2017	1	12
Irrigation & N trial	California	1	2018	1	12
Overall					**96**

Summary statistics of corn silage N removal data.

Source	Summary (lbs N/ton @ 70% moisture)			CV (%)
	mean	SD	Range	
Heguy and Silva-del-Rio, 2014	7.39	0.58	6.0 - 8.4	7.8
Robinson, 2011	7.62	0.87	5.0 - 10.4	11.3
Irrigation & N trial 2017	7.59	0.78	6.8 - 9.5	10.3
Irrigation & N trial 2018	7.32	1.00	5.9 - 8.9	13.6
Overall	**7.53**	**0.82**	**5.0 - 10.4**	**10.9**

Variability

The variability of the data is intermediate with a CV of 10.9% of the mean. Since the samples were collected from a large number of farms in different years, such variability can be expected. A factor that will contribute to variability across field is the moisture content of the silage, since it ranged from 60 to 81% in the two datasets from dairy farms. For this report, the N concentration was calculated for a moisture content of 70%.

In the irrigation and N rate trial, the factors year, irrigation level (ranging from 50 to 100% of ET), and variety had no effect on N concentration in the plants. The trial also included three N application rates, namely 0, 120 and 240 lbs N/acre. Nitrogen concentration in the plants was significantly lower in the zero N treatment, while the other two N treatments did not differ significantly. Since the production of silage corn without N applications is not a common practice in California, the values from the zero N treatment were not included in this report.

Discussion

72 samples were collected from dairy farms in the Central Valley. The dairy farms were not selected based on their silage quality. In addition, the 24 samples from the irrigation and N rate trial provide insight into the effects of different factors on N concentration in silage corn. Therefore, the estimate for N removed can be considered a very good estimate of Central Valley corn silage.

References

Robinson, P., 2011. Assays of individual samples of California feedstuffs. Available online at: http://animalscience.ucdavis.edu/faculty/robinson/Projects_folder/pdf/assays_2010_12.pdf

Heguy, J., Silva-del-Rio, N., 2014. 2014 Corn Silage Audit. Available online at: http://corn.ucanr.edu/files/221127.pdf

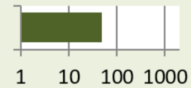
Cotton

N removal

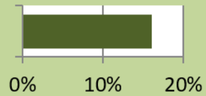
43.4

lbs N/ton
lint & seed

Observations



Variability



Data sources

The data is from N rate trials carried out at different locations in Fresno and Kings County between 1998 and 2000 (Fritschi et al., 2003, 2004) and from trials conducted at the West Side Research and Extension Center from 2006 through 2015. Both Pima and Acala cotton varieties were included.

Relevance

The trials have been carried out at several locations in the main cotton growing area of the Central Valley. The results can be considered a good estimate of the N concentration in cotton from the Central Valley.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Acala					
Fritschi et al., 2003, 2004	California	2	1998-2000	3	20
Hutmacher, 2019	California	1	2006-2015	10	8
Pima					
Fritschi et al., 2003, 2004	California	1	1999-2000	2	7
Hutmacher, 2019	California	1	2006-2015	10	14
Overall					**49**

Summary statistics of cotton N removal data.

Source	Summary (lbs N/ton lint & seed)			CV (%)
	mean	SD	Range	
Acala				
Fritschi et al., 2003, 2004	47.3	9.6	26.3 - 63.2	20.2
Hutmacher, 2019	41.9	2.3	38 - 44	5.5
Pima				
Fritschi et al., 2003, 2004	33.1	6.9	23.3 - 41	20.9
Hutmacher, 2019	43.9	3.1	36 - 48	7.1
Overall	**43.4**	**7.0**	**23.3 - 63.2**	**16.1**

Variability

Fritschi et al. (2004) did not find a clear effect of N application rate on N concentrations in cotton seeds. In their study, carried out in Fresno and Kings County, N application rates ranged from 0 to 200 lbs/acre. In the same study, the N concentration in Pima cotton tended to be lower than that of Acala cotton; however, the difference was not statistically significant. More recent data by Hutmacher (2019) suggest that there is no difference between N concentrations of these two types of cotton.

Discussion

When cotton is harvested, lint and seeds are removed from the field. Across all datasets, 43.4 lbs N were removed from the field per ton of lint and seed. When yield is expressed in tons of lint, about 124 lbs are removed from the field. This conversion is based on the average gin turnout of 35.4% reported by Fritschi et al. (2003, 2004).

All values in this updated report are from studies carried out in California and can be considered a good estimate of N concentration in California cotton. Currently ongoing studies will allow further improvements of the average values. With a larger dataset, it may be possible to determine with certainty whether Acala and Pima cotton differ in their N removal.

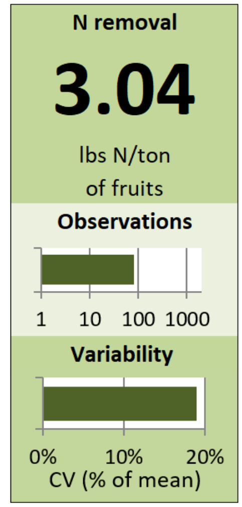
References

Fritschi, F.B., Roberts, B.A., Travis, R.L., Rains, D.W., Hutmacher, R.B., 2003. Response of irrigated Acala and Pima cotton to nitrogen fertilization: growth, dry matter partitioning, and yield. Agronomy Journal 95, 133-146.

Fritschi, F.B., Roberts, B.A., Travis, R.L., Rains, D.W., Hutmacher, R.B., 2004. Seasonal nitrogen concentration, uptake, and partitioning pattern of irrigated Acala and Pima cotton as influenced by nitrogen fertility level. Crop Science 44, 516–527.

Hutmacher, B., 2019. Comparing nitrogen management practices for Pima and Acala cotton under San Joaquin Valley growing conditions. 2019 Proceedings of the California Plant and Soil Conference, 118-121.

Peaches



Data sources

From 2017 to 2019, 76 samples from commercial orchards in the Central Valley were analyzed. Values from two California studies, which were already part of the 2016 report, were included in the present update. With five observations, these two studies constitute only 6% of the observations in this update.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Niederholzer et al., 2001; Saenz et al., 1997	California	1	1994	1	3
Weinbaum et al., 1992	California				2
Own analyses	California	8	2017	1	8
Own analyses	California	36	2018	1	36
Own analyses	California	32	2019	1	32
Overall					**81**

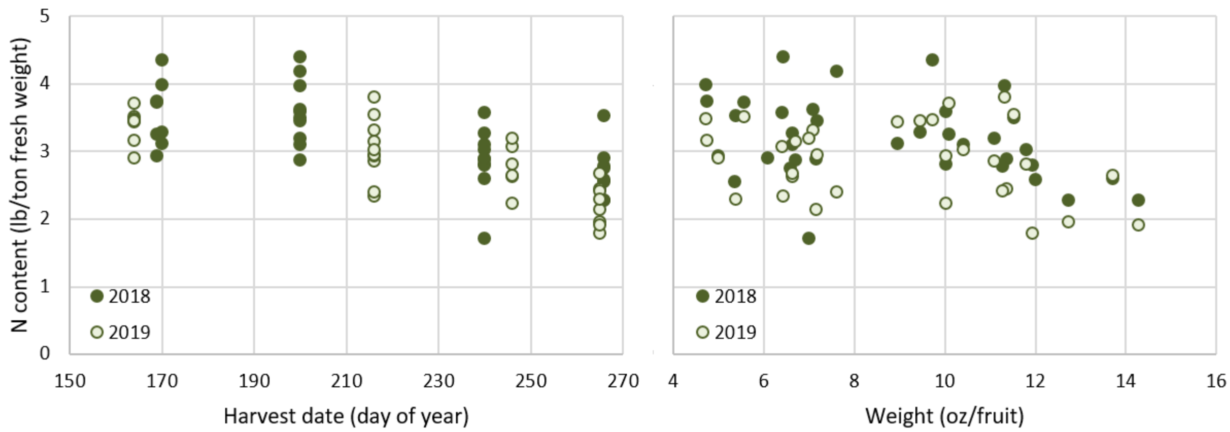
Summary statistics of peach N removal data.

Source	Summary (lbs/ton of fruits)			CV (%)
	mean	SD	Range	
Niederholzer et al., 2001; Saenz et al., 1997	2.04	0.59	1.39 - 2.55	28.9
Weinbaum et al., 1992	2.35	0.30	2.14 - 2.56	12.6
Own analyses 2017	3.62	0.56	2.93 - 4.35	15.5
Own analyses 2018	3.18	0.60	1.71 - 4.40	18.8
Own analyses 2019	2.86	0.56	1.78 - 3.81	19.5
Overall	**3.04**	**0.58**	**1.39 - 4.40**	**19.0**

Variability

The variability in the dataset is relatively large. Nitrogen content in fresh fruits was lower late in the season than during the early season. Across the entire dataset, N content decreased significantly by 0.0107 percent points per day between early June (day of year 160) and mid-September (day of year 260). However, the variability across orchards harvested around the same time was large (see Figure below). The N content in the fruits also decreased with increasing fresh weight per fruit. Even though this trend was statistically significant, the large variability due to other factors would probably obscure any advantage to tailoring N concentration assumptions to the timing of harvest.

Niederholzer et al. (2001) found that N fertilization considerably increases the N concentration in peaches.



Effect of harvest date and fruit weight on N content in fresh fruits.

Discussion

The average value for N removed is based on 81 samples collected from different California orchards and can be considered a good estimate of N concentrations in California peaches.

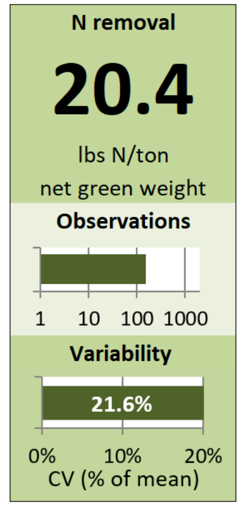
References

Niederholzer, F.J.A., DeJong, T.M., Saenz, J.-L., Muraoka, T.T., Weinbaum, S.A., 2001. Effectiveness of fall versus spring soil fertilization of field-grown peach trees. Journal of the American Society for Horticultural Science 125, 644-648.

Saenz, J. L., DeJong, T.M., Weinbaum, S.A., 1997. Nitrogen stimulated increases in peach yields are associated with extended fruit development period and increased fruit sink capacity. Journal of the American Society for Horticultural Science 122, 772-777.

Weinbaum, S.A., Johnson, R.S., DeJong, T.M., 1992. Causes and consequences of overfertilization in orchards. HortTechnology 2, 112-121.

Pistachio



Data sources

In 2018 and 2019, 156 samples from commercial orchards were analyzed for total N. The samples were obtained from trucks arriving for processing. The N concentration is expressed in lbs/ton net green weight. The 2016 report included values from a study carried out by Patrick Brown and his team in four orchards in the southern San Joaquin Valley between 2009 and 2011. These values are not included in this report, as the N content was expressed in lbs/ton dry yield (CPC), which is based on samples of in-shell pistachios.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	California	97	2018	1	97
Own analyses	California	59	2019	1	59
Overall					**156**

Summary statistics of pistachio N removal data.

Source	Summary (lbs/ton net green weight)			CV (%)
	mean	SD	Range	
Own analyses 2018	20.4	4.35	11.9 - 35.5	21.4
Own analyses 2019	20.4	4.50	8.0 - 27.8	22.0
Overall	**20.4**	**4.41**	**8.0 - 35.5**	**21.6**

Trash

The samples we received were free of trash, such as leaves, branches and empty shells. In addition to the pistachio samples, we also received 7 trash samples. **On average, trash contained 15 lbs N/ton**. However, the variability was high with values ranging from 8.7 - 24.1 lbs/ton. At this time, we do not have estimates of the average amount of trash removed from the field per unit yield.

Variability

The variability in the dataset is relatively high. Two factors contribute to the variability. First, the dry matter content of the pistachios ranged from 35 to 65%. Second, the N concentration in the dry pistachios ranged from 1.0 to 3.3%. With a larger range in values, variability in N concentration contributed more to the observed variability. Both moisture and N concentration depend on environmental conditions and management practices. The available data do not allow for a more detailed analysis.

Discussion

The value is a very good estimate for N removed in pistachios in the Central Valley. An estimate of the N removed with trash will require more a robust value of the N concentration in trash and an estimate of ratio between the weights of trash and net green pistachios.

Plums

N removal

2.27

lbs N/ton of fruits

Observations

Variability

Data sources

From 2017 to 2019, 23 samples from commercial orchards in the Central Valley were analyzed for total N. Data from one California study that was part of the 2016 report was also included in this update.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Weinbaum et al., 1992	California				1
Own analyses	California	12	2018	1	12
Own analyses	California	11	2019	2	11
Overall					**24**

Summary statistics of plum N removal data.

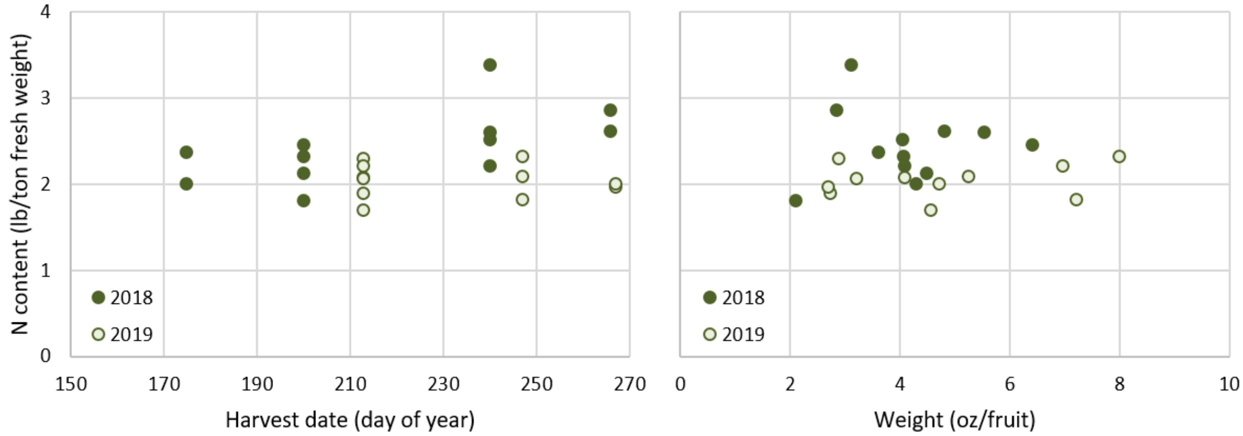
Source	Summary (lbs/ton of fruits)			
	mean	SD	Range	CV (%)
Weinbaum et al., 1992	2.84			
Own analyses 2018	2.44	0.42	1.8 - 3.39	17.06
Own analyses 2019	2.04	0.19	1.7 - 2.31	9.38
Overall	**2.27**	**0.33**	**1.70-3.39**	**14.5**

Variability

Nitrogen concentrations ranged from 1.7 to 3.4 lbs/ton. With a CV of 14.5%, the variability within the dataset is moderate. In contrast to peaches, harvest date and fruit weight had no significant effect on the N concentration in the fruits (see Figures below).

Discussion

The average N concentration in this update is based on 24 samples from the Central Valley. The number of samples is smaller than for some of the other crops. However, each sample represents a different orchard or size class from the same orchard. Therefore, the average concentration is a relatively good estimate of N concentrations in California plums.



Effect of harvest date and fruit weight on N content in fresh fruits.

References

Weinbaum, S.A., Johnson, R.S., DeJong, T.M., 1992. Causes and consequences of overfertilization in orchards. HortTechnology 2, 112-121.

Pomegranate

N removal

3.96

lbs N/ton of fruits

Observations

Variability

Data sources

From 2018 to 2020, we analyzed 40 pomegranate samples from commercial orchards in California.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	California	11	2018	1	11
Own analyses	California	19	2019	1	19
Own analyses	California	10	2020	1	10
Overall					**40**

Summary statistics of pomegranate N removal data.

Source	Summary (lbs/ton of fruits)			CV (%)
	mean	SD	Range	
Own analyses 2018	4.41	0.81	3.36 - 5.92	18.5
Own analyses 2019	3.45	0.47	2.48 - 4.10	13.7
Own analyses 2020	4.41	0.58	3.90 - 5.63	13.1
Overall	**3.96**	**0.61**	**2.48 – 5.92**	**15.4**

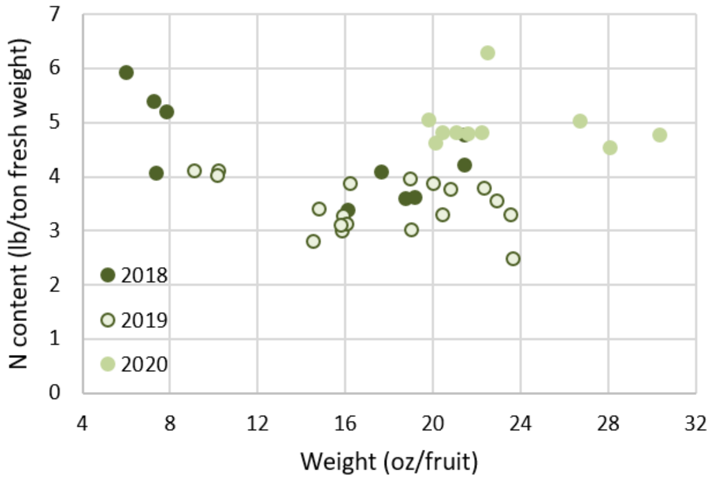
Variability

Nitrogen concentrations ranged from 2.5 to 5.9 lbs/ton. With a CV of 15.4%, the variability within the dataset is moderate.

The weight of fruits can vary considerably, ranging in our dataset from 6 to 32 oz. per fruit. However, there was no correlation between fruit weight and the N concentration in the fruits (see Figure below).

Discussion

The average N concentration in this update is based on 40 samples from California collected at different times over three seasons. Each sample represents a different orchard or block. Therefore, the average concentration is a good estimate of N concentrations in California pomegranates.



Relationship between N in fruits and fruit weight.

Safflower

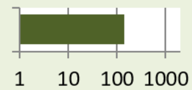
N removal

51.7

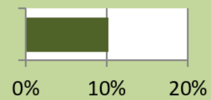
lbs N/ton

@ 8% moisture

Observations



Variability



Data sources

In 2018 and 2019, we analyzed samples from 128 fields located in the Sacramento Valley and Tulare Lake Basin. Only one study included in the 2016 report was from California (Cavero et al., 1999). This study was carried out at UC Davis and N removal data was obtained directly from the lead author. The values from that study are included in the present update. The other sources in the original report from outside California are not included here.

Data sources and number of observations. Samples received from fields in the Sacramento Valley and Tulare Lake Basin are shown on separate lines.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Cavero et al., 1999	Sacramento Valley	1	1994-95	2	12
Own analyses	Sacramento Valley	1	2018	1	25
Own analyses	Tulare Lake Basin	2	2018	2	49
Own analyses	Sacramento Valley	3	2019	3	10
Own analyses	Tulare Lake Basin	4	2019	4	44
Overall					**140**

Summary statistics of safflower N removal data. Samples received from fields in the Sacramento Valley (SV) and Tulare Lake Basin *(TL) are shown on separate lines.*

Source	Summary (lbs N/ton at 8% moisture)			
	mean	SD	Range	CV (%)
Cavero et al., 1999	48.8	7.1	34.8 - 58.6	14.6
Own analyses SV 2018	49.0	7.7	34.8 - 58.4	15.7
Own analyses TL 2018	52.0	2.9	42.5 - 58.1	5.6
Own analyses SV 2019	56.1	7.4	39.2 - 64.1	13.2
Own analyses TL 2019	52.8	4.4	41.5 – 63.0	8.4
Overall	**51.7**	**5.3**	**34.8 - 64.1**	**10.2**

Variability

With an overall CV of 10.2%, the variability in the dataset was relatively low, even though the N concentrations ranged from 34.8 to 64.1 lbs/ton. Year of harvest and location (Sacramento Valley vs. Tulare Lake Basin) had a small and non-significant effect on N concentration in safflower seeds.

Discussion

The updated value for N removed is based on 140 samples from the Central Valley. Of these, 128 samples were collected from different commercial fields in 2018 and 2019. Therefore, the updated value is a very good estimate of safflower N removal from California fields.

References

Cavero, J., Plant, R.E., Shennan, C., Friedman, D.B., Williams, J.R., Kiniry, J.R., Benson, V.W., 1999. Modeling nitrogen cycling in tomato-safflower and tomato-wheat rotations. Agricultural Systems 60, 123-135.

Sunflower

N removal

63.2

lbs N/ton

@ 8% moisture

Observations

Variability

Data sources

A total of 24 samples from Central Valley fields were received from the 2019 harvest and analyzed. The samples included broken seeds and small pieces of trash.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	California	24	2019	1	24
Overall					**24**

Summary statistics of sunflower N removal data.

Source	Summary (lbs N/ton @ 8% moisture)			CV (%)
	mean	SD	Range	
Own analyses 2019	63.2	7.02	42.6 - 75.3	11.1
Overall	**63.2**	**7.02**	**42.6 - 75.3**	**11.1**

Variability

With a CV of 11.1%, the variability in the dataset is relatively small, even though the values range from 42.6 to 75.3 lbs N/ton.

Discussion

The updated value is based on 24 samples from the Central Valley. None of the values included in the 2016 report were from California and are not included in this update. The average value is a reasonable estimate of the N removed at harvest. Including additional samples from different years would improve the estimate.

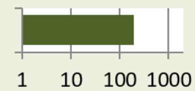
Tomato, processing

N removal

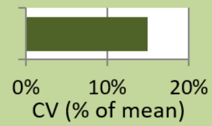
2.92

lbs N/ton
fresh weight

Observations



Variability



Data sources

From 2018 to 2020, 171 samples were collected from different commercial fields in the Sacramento Valley and Tulare Lake Basin. We obtained subsamples from PTAB samples taken at the stations for quality analyses. The samples are representative of a load. However, from several fields we obtained samples from multiple loads. The variability among different loads from the same field was small. When multiple samples from a field were obtained, only the average N concentration of the samples from that field is used in this report.

In addition, three studies that were already included in the 2016 report are included in this update. These studies were all carried out recently in commercial fields across the Central Valley. The total number of observations in these studies was 24, with each observation representing a different commercial field.

Data sources and number of observations. Samples received from fields in the Sacramento Valley and San Joaquin Valley are shown on separate lines.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Hartz and Bottoms, 2009	Central Valley	7	2007-2008	2	8
Aegerter, 2015	Central Valley	2	2015	1	2
Lazcano, 2015	Central Valley	14	2013	1	14
Own analyses	Sacramento V.	28	2018	1	28
Own analyses	Tulare Lake Basin	59	2018	1	59
Own analyses	Sacramento V.	30	2019	1	30
Own analyses	Tulare Lake Basin	49	2019	1	49
Own analyses	Tulare Lake Basin	5	2020	1	5
Overall					**195**

Variability

Nitrogen concentrations ranged from 1.3 to 4.0 lbs/ton. However, out of the 171 samples analyzed for this report, only 7 had N concentrations below 2 lbs/ton. Each observation in the dataset represents a commercial field, meaning the overall variability is due to crop management, variety harvested and differences in environmental conditions. In the dataset analyzed for this study, we did not observe significant differences due to year or location (Sacramento Valley vs. Tulare Lake Basin).

Summary statistics of processing tomato N removal data. Samples received from fields in the Sacramento Valley (SV) and Tulare Lake Basin (TL) are shown on separate lines.

Source	Summary (lbs N/ton fresh weight)			
	mean	SD	Range	CV (%)
Hartz and Bottoms, 2009	3.00	0.28	2.6 - 3.3	9.4
Aegerter, 2015	3.12	0.34	2.8 - 3.6	10.7
Lazcano, 2015	2.52	0.31	1.9 - 3.1	12.4
Own analyses SV 2018	3.08	0.41	2.3 - 3.9	13.3
Own analyses TL 2018	2.78	0.59	1.3 - 4.0	21.1
Own analyses SV 2019	3.05	0.30	2.3 - 3.6	9.8
Own analyses TL 2019	2.98	0.36	1.7 - 3.6	12.2
Own Analyses TL 2020	3.31	0.34	2.8 - 3.7	10.2
Overall	**2.92**	**0.44**	**1.3 – 4.0**	**15.0**

Discussion

With 195 observations, the sample size is large. Each sample is from a different commercial field in the Central Valley. Therefore, the average value is a very good estimate for processing tomatoes harvested in the Central Valley.

References

Aegerter, B., 2015. Potential for improved fertigation efficiency via field-based sensing devices. Report submitted to the California Tomato Research Institute. Available online at: http://tomatonet.org/img/uploadedFiles/AnnualReports/2015%20CTRI%20Annual%20Project%20Report.pdf Complemented with unpublished data.

Hartz, T.K., Bottoms, T.G., 2009. Nitrogen Requirements of Drip-irrigated Processing Tomatoes. HortScience 44, 1988-1993.

Lazcano, C., Wade, J., Horwath, W.R., Burger, M., 2015. Soil sampling protocol reliably estimates preplant NO_3^- in SDI tomatoes. California Agriculture 69, 222-229. Available online at: http://ucanr.edu/repositoryfiles/cav6904p222-159746.pdf

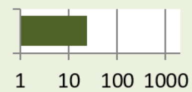
Walnuts

N removal

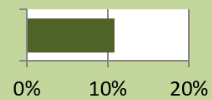
31.8

lbs N/ton of nuts

Observations



Variability



Data sources

Two studies from California were included in this report. Weinbaum et al. (1991) carried out a study in a 'Hartley' orchard in Stanislaus County from 1985 to 1990. More recently, Pope et al. (2016) determined N concentrations in 'Chandler' and 'Tulare' walnuts in three orchards in the Central Valley over a period of three years. The values reported here are for N removed with fruits (hull, shell and kernel), expressed per ton of nut yield (shell and kernel). The 2016 report included results from the 2013 and 2014 harvests of the trial conducted at different locations in the Central Valley. For this updated report, the results from the 2016 harvest were added.

Relevance

The observations in the table are from two studies carried out in the Central Valley and are a good estimate of the N removed with walnuts. However, it is important to note that the average values of the two studies differ considerably.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Weinbaum et al., 1991	Stanislaus	1	1985-90	6	6
Pope et al., 2016	Central Valley	3	2013	1	6
Pope et al., 2016	Central Valley	3	2014	1	6
Pope et al., 2016	Central Valley	3	2015	1	6
Overall		**1**			**24**

Summary statistics of walnut N removal data.

Source	Summary (lbs/ton of in-shell nuts @ 8% moisture)			
	mean	SD	Range	CV (%)
Weinbaum et al., 1991	40.5	4.34	34.0 - 46.4	10.7
Pope et al., 2016 (year 2013)	26.9	2.56	23.2 - 30.2	9.5
Pope et al., 2016 (year 2014)	29.0	1.63	26.5 - 31.1	5.6
Pope et al., 2016 (year 2015)	30.7	4.42	23.4 - 35.4	14.4
Overall	**31.8**	**3.45**	**23.2 - 46.4**	**10.9**

Variability

In the study by Pope et al. (2016), walnut N concentration did not differ significantly across the three years of the study, across sites or between 'Chandler' and 'Tulare' walnuts. On average 28.9 lbs N/ton were removed with ‘Chandler’ walnuts, while ‘Tulare’ walnuts removed 28.8 lbs N/ton. Differences across locations contributed most to the observed variability. The variability in N concentration reported by Weinbaum et al. (1991) is caused by differences among years. This trial did not include different fertilization rates or varieties.

Discussion

The dataset is based on two studies carried out in the Central Valley over nine years. The more recent study by Pope et al. (2016) contributed 75% of the values in this report and the variability of the dataset was low despite the fact that different varieties, years and locations were included. Therefore, even though the values of the two studies differ, the average value in this report can be considered a good estimate of N removed with California walnuts.

References

Weinbaum, S.A., Murooka, T.T., Gatlin, P.B., Kelley, K., 1991. Utilization of fertilizer N by walnut trees. The Walnut Marketing Board of California. Walnut Research Reports 1991, 317-334. Available online at: http://walnutresearch.ucdavis.edu/1991/1991_317.pdf

Pope, K., DeJong, T., Brown, P., Lampinen, B., Hopmans, J., Fulton, A., Buchner, R., Grant J., Laca, E., 2016. Development of a nutrient budget approach and optimization of fertilizer management in walnut. Walnut Research Reports 2015. Available online at: https://ucanr.edu/sites/cawalnut/category/Nitrogen/?repository=67350&a=165272