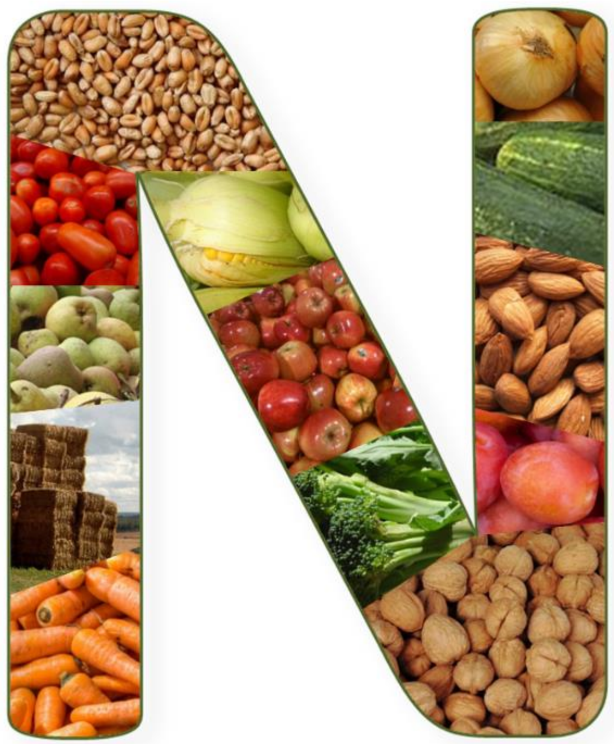
Nitrogen concentrations in harvested plant parts – Update 02/2024

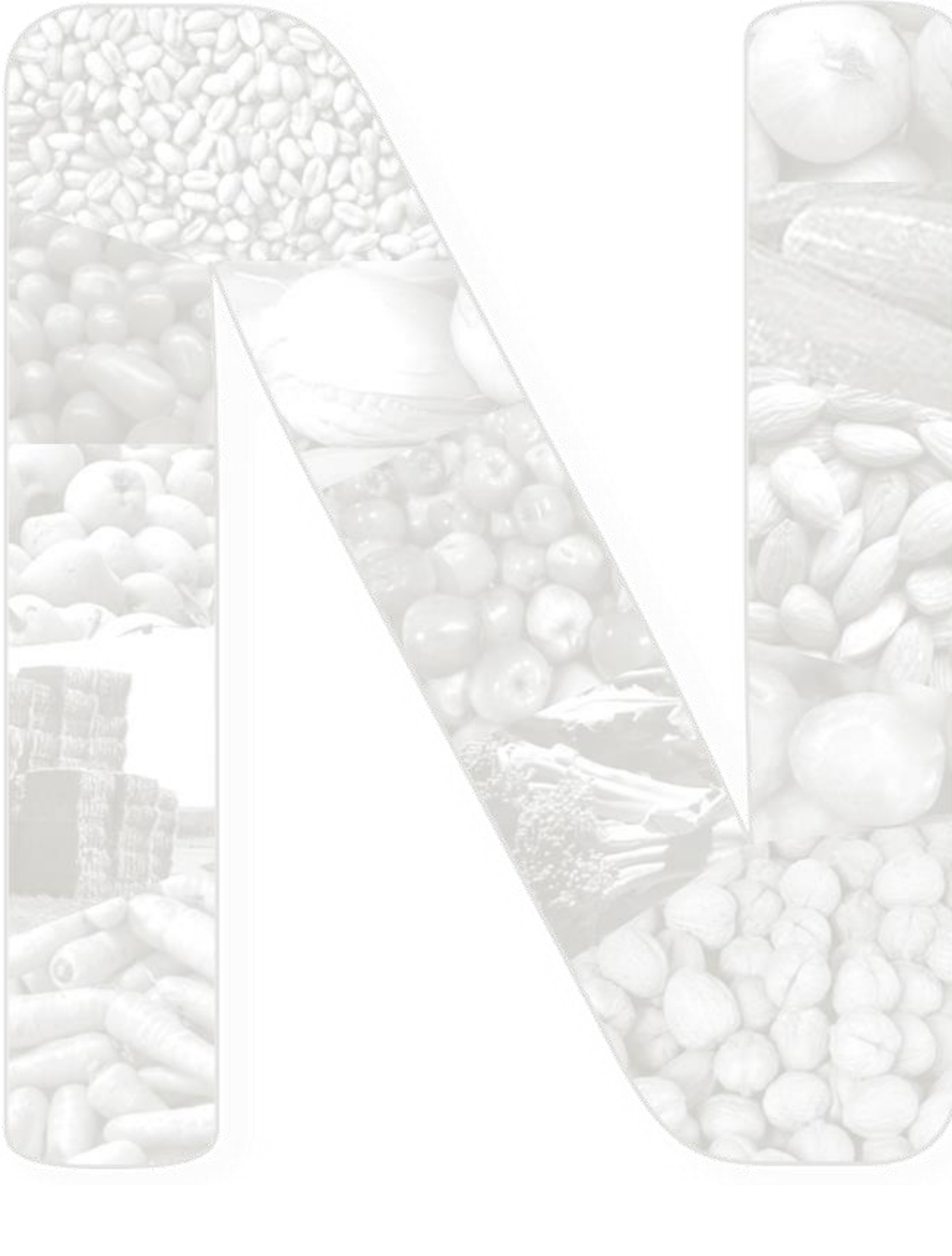


Includes updated values for

- Cotton – Acala
- Cotton – Pima
- Kiwi
- Lemons
- Mandarins
- Nectarines
- Oranges – Navel
- Oranges – Valencia
- Sorghum – Grain
- Perennial parts of cherry and citrus trees

Daniel Geisseler

February 28, 2024



Content

About the Author:

Daniel Geisseler is a University of California Cooperative Extension Specialist in the Department of Land, Air and Water Resources at the University of California, Davis. The focus of his research and outreach is nutrient management in cropping systems. An overview of his team's projects can be found at http://geisseler.ucdavis.edu/

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 the second update of a 2016 report, which was a review of available data. Samples for kiwis, lemons, mandarins, oranges and nectarines were collected from Central Valley locations between 2020 and 2023. Samples for grain sorghum were obtained from a 2021 variety trial at three Central Valley locations. All samples were analyzed for total N by dry combustion at UC Davis. In addition, recently published data for Pima cotton and N in perennial parts of cherry and citrus trees are included in this report.

The updated values are highlighted in Tables 1-3. The results of the analyses are presented and discussed in more detail starting on page 9. This report, as well as the previous reports, can be accessed at http://geisseler.ucdavis.edu/Project_N_Removal.html.

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	
Cotton - Acala	02/2024	**49.9**	lbs N/ton lint, seed & trash	18.1	9
		34.6	lbs N/bale of lint (500 lb)		
Cotton - Pima	02/2024	**51.7**	lbs N/ton lint, seed & trash	8.0	11
		33.7	lbs N/bale of lint (500 lb)		
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	
Sorghum - Grain	02/2024	**35.2**	lbs N/ton @ 13.5% moisture	14.2	21
Sorghum - Silage		**7.34**	lbs N/ton @ 65% moisture	21.0	
Sunflower	03/2021	**63.2**	lbs N/ton @ 8% moisture	11.1	
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. No updated values for vegetables are included 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	
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	
Pumpkins		**7.36**	lbs/ton of fresh weight	10.1	
Squashes		**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	

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	
Grapefruits		**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	
Kiwis	02/2024	**3.57**	lbs/ton of fruits	15.0	13
Lemons	02/2024	**3.49**	lbs/ton of fruits	10.4	14
Mandarins	02/2024	**4.31**	lbs/ton of fruits	10.9	15
Nectarines	02/2024	**3.83**	lbs/ton of fruits	24.2	16
Olives		**6.28**	lbs/ton of olives	22.8	
Oranges - Navel	02/2024	**3.61**	lbs/ton of fruits	15.1	17
Oranges - Valencia	02/2024	**4.66**	lbs/ton of fruits	20.1	19
Peaches	03/2021	**3.04**	lbs/ton of fruits	19.0	
Pears		**1.29**	lbs/ton of fruits	17.9	
Pistachios	03/2021	**20.4**	lbs N/ton net green weight	21.6	
Plums	03/2021	**2.27**	lbs/ton of fruits	14.5	
Pomegranates	03/2021	**3.96**	lbs/ton of fruits	15.4	
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	

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, Ken Miller, and their team at the Southern San Joaquin Valley Management Practices Evaluation Program, a large number of samples were collected and then processed in the author’s nutrient management lab at UC Davis. The present report is the second update of the 2016 report, the first being released in March 2021, and includes results for kiwis, lemons, mandarins, oranges, nectarines, and grain sorghum. In addition, recently published data for cotton and N in perennial parts of cherry and citrus trees were included.

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. Samples were generally refrigerated (for high-moisture commodities like citrus, nectarines and kiwis) or kept cool and dry (for low-moisture commodities like sorghum grain) to stabilize them until processing commenced.

Citrus and kiwi samples were obtained from processing and packing facilities, while nectarines were sourced from different fresh fruit markets. Sorghum grain samples were obtained from a variety trial conducted in 2021 at three locations in Yolo and Fresno counties.

Sample processing and analysis

Kiwi, citrus, nectarine, and sorghum samples were processed in the nutrient management lab at UC Davis. All samples were analyzed for total N by dry combustion (Nelson and Sommers, 1996) either in the nutrient management lab or the UC Davis Analytical Laboratory. 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:

Kiwi samples were cut into small slices and dried in an oven at 60 °C until reaching a constant weight. The dried samples were first ground on a Wiley mill to pass a 1-mm screen and then ball-milled on a paint shaker.

Sorghum grains were first dried in an oven at 60 °C until reaching a constant weight. They were then ground on a Micro-Mill II Grinder (Bel-Art Products, Wayne, NJ), followed by ball-milling on a paint shaker.

The flesh and pits of nectarines 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.

Citrus samples were cut into small pieces and homogenized in a food processor. 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, 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. Recent 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 excluded.

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 currently include N accumulation in perennial tissue (e.g. trunk, roots, or branches). However, for N budgeting purposes, N accumulated in perennial tissue each year is considered to be N removed, as it is no longer available, and needs to be added to the N removed with harvested commodities for an estimate of total N 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. New information for cherries and citrus trees has recently become available.

Nitrogen accumulation in permanent tissue of cherry trees

Preliminary data from years 1 and 2 of a 3-year study by Patrick Brown and collaborators suggest that the N requirement for cherry tree development (perennial biomass accumulation) in mature trees averages 28.3 lbs/acre in orchards with a planting density of 120 trees per acre (Brown et al., 2022). The team obtained total nutrient amounts per tree by multiplying the dry weight of each tree organ by its nutrient concentration and then summing the nutrient content of the different tree organs. The value is an average of six trees excavated in 2020-2021 for each of three cultivars (Rainier, Coral and Bing).

Nitrogen accumulation in permanent tissue of citrus trees

Citrus trees, being evergreen trees, retain most of their leaves year-round and do not recycle N accumulated in leaves on an annual basis. Therefore, N removed with permanent tissue includes N in woody tissue as well as N in leaf biomass. The amount of N needed for leaf and branch growth is high when the plants are young and rapidly growing, and decreases as the plant ages (Muhammad et al., 2018). Young trees have high shoot production and leaf growth, while shoot and leaf production continues at a much lower rate in mature trees. A 1- to 5-year-old tree with a total canopy size of up to 250 ft^3 accumulates 0.07 lb N/year for every 50 ft^3 increase in canopy size. In most commercial orchards this corresponds to 5 to 30 lb N/ac per year. Mature trees that are older than 8 years and have a canopy volume of 1,000 to 1,500 ft^3 require 0.04 lb N/year for every 50 ft^3 increase in canopy size. This corresponds to 5 to 20 lb N/ac per year in most commercial orchards (Muhammad et al., 2018).

Limitations

Nitrogen concentrations in harvested crop parts can vary considerably from field to field and from one year to the next. For the commodities included in this report, it was not uncommon for the highest value being twice as large as the lowest value measured. The variability statistics provided for each coefficient indicates the expected magnitude variation. For a single year, the calculated amount of N removed from a specific field, 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 (for example as a percent of the N in the marketable portion of the yield). For the commodities included in this report, cull and trash is minimal.

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.

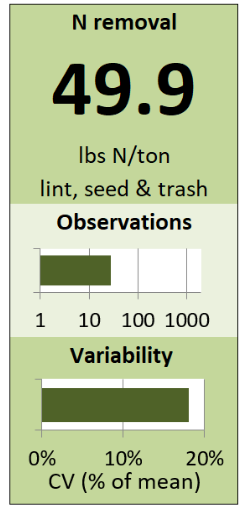
References

Brown, P., Camargo, R., Amaral D., 2022. Development of Nutrient Budget and Nutrient Demand Model for Nitrogen Management in Cherry. CDFA-FREP Conference Proceedings 2022, 2 31-35. Available online at: https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/2022_proceedings.pdf

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

Muhammad, S., S. Khalsa, S.D., and Brown, P.H., 2018. Nitrogen Management in Citrus and Avocado. https://ciwr.ucanr.edu/files/283980.pdf

Cotton - Acala



Data sources

The data are 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.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Fritschi et al., 2003, 2004	California	2	1998-2000	3	20
Hutmacher, 2019	California	1	2006-2015	10	8
Overall					**28**

Summary statistics of Acala cotton N removal data.

Source	Summary (lbs N/ton lint & seed)			CV (%)
	mean	SD	Range	
Fritschi et al., 2003, 2004	47.28	9.6	26.3 - 63.2	20.2
Hutmacher, 2019	41.90	2.3	38 - 44	5.5
Overall	**45.74**	**8.3**	**26.3 - 63.2**	**18.1**

When cotton is harvested, lint and seeds are removed from the field. When yield is expressed in tons of lint, about 127 lbs N/ton of lint are removed from the field, based on the average gin turnout in these studies of 36%.

N removal in gin trash

These N removal values do not include N removed with gin trash, which leaves the field and is separated from the seed and lint during the ginning process. Based on N-rate trials conducted from 2019 to 2021 at the UC West Side Research and Extension Center, Bob Hutmacher (personal communication) found that gin trash amounts per unit harvest weight varied with defoliation efficacy, year and crop maturity. On average, 155 lb of gin trash per bale of lint were removed from the field with Upland cotton. The gin trash had an average N concentration of 1.85%.

Based on these average values, the estimated average amount of N removed with gin trash is 2.87 lbs N per bale of lint, or 11.5 lbs N/ton of lint. This value corresponds to 4.13 lbs N/ton lint & seed.

Therefore, the average total amount of N removed with lint, seed and trash equals:

- ⇨ **49.9 lbs N/ton lint & seed**

  or

- ⇨ **138.5 lbs/ton of lint (34.6 lbs N/bale of lint)**

Variability

Nitrogen concentrations ranged from 26.3 to 63.2 lbs/ton of lint & seed. With a CV of 18.1%, the variability within the dataset is relatively high. 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, while in the studies reported by Hutmacher (2019), N fertilizer application rates ranged from 110 to 160 lbs/acre.

Discussion

All values in this updated report are from studies carried out in California and can be considered good representations of N concentrations expected in primary cotton growing regions of California.

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.

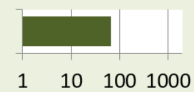
Cotton - Pima

N removal

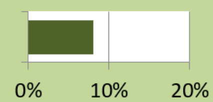
51.7

lbs N/ton
lint, seed & trash

Observations



Variability



CV (% of mean)

Data sources

The data are from three sources: (i) Nitrogen rate trials carried out at different locations in Fresno and Kings County between 1999 and 2000 (Fritschi et al., 2003, 2004); (ii) trials conducted at the West Side Research and Extension Center from 2006 through 2015; and (iii) trials conducted between 2019 and 2021 with three varieties at 5 locations in Fresno, Kings, Kern and Merced counties.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Fritschi et al., 2003, 2004	California	1	1999-2000	2	7
Hutmacher, 2019	California	1	2006-2015	10	14
Hutmacher, 2023	California	5	2019-2021	3	45
Overall					**66**

Summary statistics of Pima cotton N removal data.

Source	Summary (lbs N/ton lint & seed)			CV (%)
	mean	SD	Range	
Fritschi et al., 2003, 2004	33.13	6.9	23.3 – 41.0	20.9
Hutmacher, 2019	43.90	3.1	36 - 48	7.1
Hutmacher, 2023	49.90	3.3	43.6 - 59.4	6.6
Overall	**46.85**	**3.8**	**23.3 - 59.4**	**8.0**

When cotton is harvested, lint and seeds are removed from the field. When yield is expressed in tons of lint, about 122 lbs of N/ton of lint are removed from the field across all datasets, based on the average gin turnout in these studies of 38.4%.

N removal in gin trash

These N removal values do not include N removed with gin trash, which leaves the field and is separated from the seed and lint during the ginning process. Generally, there is more gin trash with Pima cotton compared to Upland varieties, due to greater difficulty in completely defoliating Pima cotton. In the 3-year study, Bob Hutmacher (2023) found that Pima gin trash amounts per unit harvest weight were variable based on efficacy of defoliation, year, and maturity of crop. From his on-farm field studies, he estimated that the average amount of N removed with gin trash is 3.15 lbs N per bale of lint, or 12.6 lbs N/ton of lint. This value corresponds to 4.84 lbs N/ton lint & seed.

Therefore, the average total amount of N removed with lint, seed and trash in these studies equals:

⇨ **51.7 lbs N/ton lint & seed**

or

⇨ **134.6 lbs/ton of lint (33.7 lbs N/bale of lint)**

Variability

Nitrogen concentrations ranged from 23.3 to 59.4 lbs/ton of lint & seed. With a CV of 8.0%, the variability within the dataset is relatively small. 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, while in the studies reported by Hutmacher (2019, 2023), N fertilizer application rates ranged from 120 to 190 lbs N/acre.

Discussion

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 Pima cotton grown in California.

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.

Hutmacher, B., 2023. A summary of the data was provided by Bob Hutmacher. Data from the first two years of the 3-year trials have been included in the Proceedings of the CDFA_FREP Conference in 2021 (https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/2021_proceedings_10222021.pdf) and 2022 (https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/2022_proceedings.pdf).

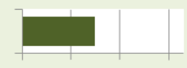
Kiwi

N removal

3.57

lbs N/ton
fresh weight

Observations



Variability

Data sources

A total of 31 samples collected from orchards in the Tulare Lake Basin over two seasons were analyzed. The samples were harvested in 2021 and 2022.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	California	16	2021	1	16
Own analyses	California	15	2022	1	15
Overall					**31**

Summary statistics of kiwi N removal data.

Source	Summary (lbs/ton of fruits)			CV (%)
	mean	SD	Range	
Own analyses 2021	3.93	0.39	3.36 - 4.70	10.0
Own analyses 2022	3.19	0.39	2.24 - 3.75	12.2
Overall	**3.57**	**0.54**	**2.24 - 4.70**	**15.0**

Variability

The variability in the dataset is moderate. The dry matter content averaged 14.3% and was less variable than N concentration in the dry matter, which averaged 1.25%.

Discussion

The average value for N removed is based on 31 samples collected from different California orchards over two years and can be considered a good estimate of N content in California kiwi.

Lemons

N removal

3.49

lbs N/ton
fresh weight

Observations

Variability

Data sources

A total of 48 samples collected from orchards in the Tulare Lake Basin over three seasons from 2021 to 2023 were analyzed. Samples from California which were used for the 2016 report are not included here, as they were collected between 1950 and 1974 and may not reflect current conditions.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	California	25	2021	1	25
Own analyses	California	10	2022	1	10
Own analyses	California	13	2023	1	13
Overall					**48**

Summary statistics of lemon N removal data.

Source	Summary (lbs N/ton of fruits)			
	mean	SD	Range	CV (%)
Own analyses 2021	3.52	0.24	3.14 - 4.26	6.8
Own analyses 2022	3.79	0.24	3.36 - 4.18	6.2
Own analyses 2023	3.19	0.43	2.59 - 3.86	13.6
Overall	**3.49**	**0.36**	**2.59 - 4.26**	**10.4**

Variability

With values ranging from 2.59 to 4.26 lb N/ton of fruits and a CV of 10.4%, the variability of the dataset is relatively low. Dry matter content of the fresh fruits averaged 14.8% and was slightly less variable than N concentration in the dry matter, which averaged 1.19%.

Discussion

The measured N content of 3.49 lb/ton of fruits is higher than the average value included in the 2016 report (2.58 lb/ton of fruits), which was based on samples collected between 1950 and 1975. The increase may be due to different varieties and management practices. Furthermore, N concentrations in the older samples were likely determined by the Kjeldahl method, which can result in lower values than dry combustion (Bremner, 1996).

The average value for N removed is based on 48 samples collected from different California orchards over three seasons and can be considered a good estimate of the current N content in California lemon.

References

Bremner, J.M., 1996. Nitrogen Total. p. 1085-1121 in: Sparks, D.L. et al., Methods of Soil Analysis – Part 3, Chemical Methods. SSSA and ASA, Madison, Wisconsin.

Update: February, 2024

Mandarins

N removal

4.31

lbs N/ton
fresh weight

Observations

Variability

Data sources

51 samples harvested in 2022 and 2023 in commercial orchards in the Tulare Lake Basin were analyzed. The 2016 report included two values for tangerines, none of them from California. These values were not included in this report.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	California	40	2022	1	40
Own analyses	California	11	2023	1	11
Overall					**51**

Summary statistics of mandarin N removal data.

Source	Summary (lbs N/ton of fruits)			
	mean	SD	Range	CV (%)
Own analyses 2022	4.28	0.48	3.37 - 5.20	11.2
Own analyses 2023	4.44	0.45	3.88 - 5.34	10.1
Overall	**4.31**	**0.47**	**3.37 - 5.34**	**10.9**

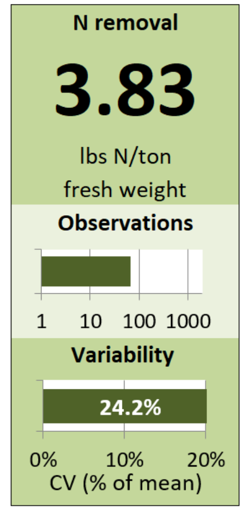
Variability

Nitrogen contents ranged from 3.37 to 5.34 lbs/ton of fruits. With a CV of 10.9%, the variability within the dataset is relatively low. The dry matter content of the fruits, which averaged 17.3%, was slightly less variable than the N concentration in the dry matter, which averaged 1.25%.

Discussion

The average value for N removed is based on 51 samples collected from different California orchards and can be considered a good estimate of N concentrations in California mandarins.

Nectarines



Data sources

36 samples harvested in 2021 and 2022 in commercial orchards in the Central Valley were analyzed. Different white and yellow varieties were included. Values from a 3-year N rate trial from California with 'Flavortop' and 'Fantasia' nectarines were also included (Weinbaum et al., 1992). Little information is available about this trial, which was already part of the 2016 report. With 31 observations, this trial contributes 46% of the observations in this report.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Weinbaum et al., 1992	California	2		3	31
Own analyses	California	13	2021	1	13
Own analyses	California	23	2022	1	23
Overall					**67**

Summary statistics of nectarine N removal data.

Source	Summary (lbs N/ton of fruits)			CV (%)
	mean	SD	Range	
Weinbaum et al., 1992	4.05	1.05	1.94 - 5.55	26.1
Own analyses 2021	4.29	0.84	3.30 - 6.27	19.6
Own analyses 2022	3.29	0.78	1.79 - 4.59	23.6
Overall	**3.83**	**0.93**	**1.79 - 6.27**	**24.2**

Variability

Nitrogen contents ranged from 1.79 to 6.27 lbs/ton of fruits. With a CV of 24.2%, the variability within the dataset is relatively high. Both dry matter content and N concentration in the flesh and pits contributed to the variability.

Discussion

On average, 9.6% of the total N in the fruits were in the pits. The percentage of total N in the pits was not correlated with fruit size.

The average value for N removed is based on 67 samples collected from different California orchards over several years and can be considered a good estimate of N concentrations in California nectarines.

References

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

Oranges - Navel

N removal

3.61

lbs N/ton
fresh weight

Observations

Variability

Data sources

A total of 106 samples harvested in 2020 and 2021 in commercial orchards in the Tulare Lake Basin were analyzed. In addition, results from a study by Patrick Brown and Doug Amaral (Brown and Amaral, 2020) were included. Their study was conducted in two orchards in Fresno and Tulare County in 2018 and 2019. Samples from California which were used for the 2016 report are not included in this analysis, as they were collected between 1950 and 1974 and may not reflect current conditions.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	California	35	2020	1	35
Own analyses	California	71	2021	1	71
Brown and Amaral, 2020	California	2	2018-2019	2	4
Overall					**110**

Summary statistics of Navel orange N removal data.

Source	Summary (lbs N/ton)			CV (%)
	mean	SD	Range	
Own analyses 2020	3.78	0.57	2.80 - 4.99	15.1
Own analyses 2021	3.56	0.54	2.32 - 4.90	15.2
Brown and Amaral, 2020	2.96	0.39	2.56 - 3.39	13.2
Overall	**3.61**	**0.57**	**2.32 - 4.99**	**15.7**

Variability

The variability in the dataset is moderate. For the 106 samples analyzed in our lab, the dry matter content averaged 18.1% and was less variable than the N concentration in the dry matter, which averaged 1.03%.

Discussion

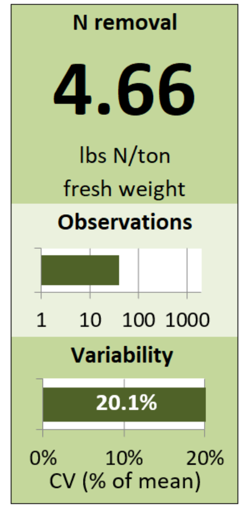
The value for oranges in the 2016 report was 2.96 lbs/ton of fruit. Our analysis indicates that N removed with oranges from California orchards under current conditions is higher than the value in the 2016 literature review. Differences in management practices and analytical methods may have contributed to higher values in oranges (see lemons). Furthermore, our analysis revealed that values for Navel oranges were lower than those for Valencia oranges.

The average value for N removed is based on 110 samples collected from different California orchards over several seasons. It can be considered a good estimate of N concentrations in California Navel oranges.

References

Brown, P. and Amaral, D., 2020. Developing nutrient budget and early spring nutrient prediction model for nutrient management in citrus. CDFA-FREP Conference Proceedings 2020, 41-45. Available online at: https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/Proceedings_2020.pdf. Additional data needed to calculate N removal was provided by Doug Amaral in 2023.

Oranges - Valencia



Data sources

A total of 39 samples harvested in 2020 and 2021 in commercial orchards in the Tulare Lake Basin were analyzed. With the exception of one sample from a study, published in 2008 (Krueger and Arpaia, 2008), other samples from California that were used for the 2016 report are not included in this analysis, as they were collected between 1950 and 1974 and may not reflect current conditions.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Krueger and Arpaia, 2008	California	1	2004	1	1
Own analyses	California	10	2020	1	10
Own analyses	California	29	2021	1	29
Overall					**40**

Summary statistics of Valencia orange N removal data.

Source	Summary (lbs N/ton of fruit)			
	mean	SD	Range	CV (%)
Krueger and Arpaia, 2008	3.26			
Own analyses 2020	5.21	0.42	4.50 - 5.98	8.0
Own analyses 2021	4.52	1.00	3.38 - 6.50	22.2
Overall	**4.66**	**0.94**	**3.26 - 6.50**	**20.1**

Variability

Nitrogen concentrations ranged from 3.26 to 6.50 lbs/ton of fruits. With a CV of 20.1%, the variability within the dataset is relatively high. Across the samples harvested in 2021 and 2122, the dry matter content averaged 20.6% and was slightly less variable than the N concentration in the dry matter, which averaged 1.11%.

Discussion

The value for oranges in the 2016 report was 2.96 lb/ton of fruit. Our analysis indicates that N removed with oranges from California orchards under current conditions is higher than the value in the 2016 literature review. Differences in management practices and analytical methods may have contributed to higher values in oranges (see lemons). Furthermore, our analysis revealed that values for Valencia oranges were higher than those for Navel oranges.

The average value for N removed is based on 40 samples collected from different California orchards. It can be considered a good estimate of N concentrations in California Valencia oranges.

References

Krueger, R.R., Arpaia, M.L., 2008. Seasonal uptake of nutrients by mature field-grown 'Valencia' (*Citrus sinensis* O.) trees in California. Proceedings of the International Society of Citriculture, 588-594. Complemented with unpublished data.

Sorghum - Grain

N removal

35.2

lbs N/ton
fresh weight

Observations

Variability

Data sources

We analyzed a total of 216 samples from a variety trial conducted at UC Davis (Yolo County), the Kearney Agricultural Research and Extension Center (KARE; Fresno County) and the West Side Research and Extension Center (WREC; Fresno County) in 2020. For varieties that were grown in replicated plots at the same location, the average of the replicates was calculated and used for data analysis. The number of varieties grown in Davis, WREC, and KARE was 21, 21, and 42, respectively, for a total of 84 observations.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	KARE	42	2020	1	42
Own analyses	Davis	21	2020	1	21
Own analyses	WREC	21	2020	1	21
Overall					**84**

Summary statistics of grain sorghum N removal data.

Source	Summary (lbs N/ton @ 13.5% moisture)			
	mean	SD	Range	CV (%)
Own analyses, KARE	35.8	4.16	28.8 - 45.7	11.6
Own analyses, Davis	29.6	2.83	24.0 - 37.2	9.6
Own analyses, WREC	39.4	2.80	33.8 - 44.3	7.1
Overall	**35.2**	**5.00**	**24.0 - 45.7**	**14.2**

Variability

With a CV of 14.2%, the variability within the dataset is moderate. The trial from which the samples for this analysis were obtained was carried out at three locations. With the large number of varieties grown, the trial provides a very good assessment of the variability in N removal with sorghum grain.

Discussion

The average value of 35.2 lb/ton at 13.5% moisture is very close to the 33 lb/ton from a global synthesis by Ciampitti and Vara Prasad (2016). The average value for N removed in this report can be considered a good estimate of for N removed with sorghum grain in California.

References

Ciampitti, I.A., Vara Prasad, P.V., 2016. Historical synthesis – Analysis of changes in grain nitrogen dynamics in sorghum. Frontiers in Plant Science 7, 1–11.