Nitrogen concentrations in harvested plant parts – Update 03/2025

Includes updated values for

- **Cherry**
- **Corn, sweet**
- **Garlic, fresh market**
- **Grapes, Table**
- **Grapes, Wine**
- **Melons, Cantaloupe**
- **Melons, Honeydew**
- **Melons, Water**
- **Olives, Table**
- **Onion, fresh market**
- **Pepper, Bell**
- **Potato**
- **Squash**
- **Tomato, fresh market**

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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 and difference of N applied to N removed are key metrics 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 third update of a 2016 report, which was a review of available data. Samples for cherries, sweet corn, fresh market garlic, grapes (table and wine), melons (cantaloupe, honeydew, watermelons), table olives, fresh market onions, bell pepper, potatoes, squash and fresh market tomatoes were collected from Central Valley locations between 2021 and 2024. All samples were analyzed for total N by dry combustion at UC Davis. Our own analyses for cherries and potatoes were supplemented with data from recent Central Valley field trials.

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	
		34.6	lbs N/bale of lint (500 lb)		
Cotton - Pima	02/2024	**51.7**	lbs N/ton lint, seed & trash	8.0	
		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	
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	03/2025	**7.43**	lbs/ton of fresh ears	15.8	11
Cucumbers		**2.16**	lbs/ton of fresh weight	17.4	
Garlic - fresh market	03/2025	**16.42**	lbs/ton of fresh weight	20.4	12
Lettuce, Iceberg		**2.63**	lbs/ton of fresh weight	16.7	
Lettuce, Romaine		**3.62**	lbs/ton of fresh weight	13.7	
Melons, Cantaloupe	03/2025	**4.07**	lbs/ton of melons	28.1	15
Melons, Honeydew	03/2025	**2.72**	lbs/ton of melons	21.6	16
Melons, Watermelons	03/2025	**2.25**	lbs/ton of melons	24.1	17
Onions - fresh market	03/2025	**2.43**	lbs/ton of fresh weight	23.0	19
Pepper, Bell	03/2025	**3.32**	lbs/ton of fresh weight	23.0	20
Potatoes	03/2025	**6.48**	lbs/ton of fresh weight	27.4	21
Pumpkins		**7.36**	lbs/ton of fresh weight	10.1	
Squashes	03/2025	**4.17**	lbs/ton of fresh weight	30.2	23
Sweet potatoes		**4.74**	lbs/ton of fresh weight	16.8	
Tomatoes, fresh market	03/2025	**2.77**	lbs/ton of fresh weight	18.8	24
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	03/2025	**5.97**	lbs/ton of fruits	37.7	9
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	03/2025	**2.28**	lbs/ton of grapes	25.0	13
Grapes - Wine	03/2025	**3.43**	lbs/ton of grapes	30.8	14
Kiwis	02/2024	**3.57**	lbs/ton of fruits	15.0	
Lemons	02/2024	**3.49**	lbs/ton of fruits	10.4	
Mandarins	02/2024	**4.31**	lbs/ton of fruits	10.9	
Nectarines	02/2024	**3.83**	lbs/ton of fruits	24.2	
Olives - Table	03/2025	**7.12**	lbs/ton of olives	12.2	18
Oranges - Navel	02/2024	**3.61**	lbs/ton of fruits	15.1	
Oranges - Valencia	02/2024	**4.66**	lbs/ton of fruits	20.1	
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 and difference of N applied to N removed are key metrics 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 third update of the 2016 report and includes results for cherries, sweet corn, fresh market garlic, grapes (table and wine), melons (cantaloupe, honeydew, watermelons), table olives, fresh market onions, bell pepper, potatoes, squash and fresh market tomatoes.

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 to stabilize them until processing commenced.

When no packing facility could be found to supply samples, samples were sourced from collaborating growers or fresh produce markets when the crop origin could be verified as the Central Valley. The present report includes updated N removal coefficients for cherries, sweet corn, fresh market garlic, grapes (table and wine), melons (cantaloupe, honeydew, watermelons), table olives, fresh market onions, bell pepper, potatoes, squash and fresh market tomatoes. Samples were collected from Central Valley locations between 2021 and 2024. All samples were analyzed for total N by dry combustion at UC Davis. Our own analyses for cherries and potatoes were supplemented with values from recent Central Valley field trials.

Sample processing and analysis

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:

Cherries: The flesh, pits, and stems 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 pieces and dried in an oven first at 60 °C and later at 80 °C until the samples reached 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. The stems were dried in an oven at 80 °C until a constant weight was reached. Dried stems were then ground on a small Wiley mill to pass a 1-mm screen and then ball-milled on a paint shaker. The dry flesh, pits, and stems were analyzed separately for total N.

Grapes: Entire clusters, including stems, were first cut into smaller clusters of about 5 grapes and then a subsample was dried in an oven first at 60 °C and later at 80 °C until the samples reached a constant weight, which would take several weeks. The dried samples were first ground with a coffee grinder and then ball-milled on a paint shaker.

Melons: Different processing methods were used. In the 2021 – 2023 sampling period, melon wedges were blended and a subsample was freeze-dried for a week. Freeze-dried samples were then ground on a coffee grinder. In the 2024 sampling period, the freeze dryer was dysfunctional, requiring utilization of the oven method. Melons were cut into wedges and then first dried at 60 °C. The wedges were then blended and a subsample was dried at 80 °C until a constant weight was reached. At each step, samples were weighed before and after drying. The dried samples were then ground with a coffee grinder and ball-milled on a paint shaker.

Garlic, onions, potatoes, bell peppers and squash: Samples were processed following the same protocol. A random subsample of 6-8 were cut into thin slices or wedges 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.

Sweet corn: The husks were removed and the cobs with the grains attached were broken into several pieces. In the first year, husks and cobs were combined for drying and grinding, in the second and third year, the husks were dried, ground and analyzed for total N separately. Drying took place in an oven at 60 °C. The dried samples were first ground on a Wiley mill to pass a 1 mm screen, and then ball-milled on a paint shaker.

Fresh market tomatoes were processed by first blending a random subsample of 3-5 fruits and then freeze-drying a subsample for a week. Freeze-dried samples were ground on a coffee grinder.

Table olives were processed by first crushing the whole fruit (flesh and pit) with a heavy weight. Samples were dried at 60 °C until a constant weight was reached, before being ground using a disc mill. As samples were in the form of an oily paste, a known quantity of cellulose powder was combined using a Micro-Mill II Grinder (Bel-Art Products, Wayne, NJ) for easier handling.

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 reported measures of variability 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 percent of the mean. The CV was also used to determine the contribution of dry matter content and N concentration in the dry matter to the overall variability. 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.

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 of 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.

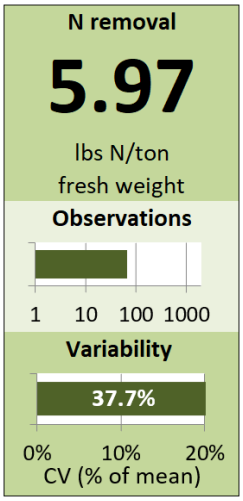
Calculating the amount of N removed based on yield and N concentration will underestimate the amount of N removed for crops where cull or trash is removed from the field but not included in the reported yield. For a more accurate estimate of the total amount of N removed from the field, N in cull or 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

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

Cherries



Data sources

Cherries were purchased multiple times during the season from Central Valley produce markets. 57 samples were collected and analyzed over four seasons from 2021 to 2024. Only cherries that were verified as being from the Central Valley were purchased. The main varieties included Bing (21 samples), Rainier (17), Coral (10) and Brooks (5). One sample each of Hazel, Skeena and Lapins was also included. In addition, results from a project led by Patrick Brown, UC Davis, were included. Trials were conducted in three mature orchards with Bing, Rainier and Coral cherries from 2021 to 2023.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Brown et al., 2023	San Joaquin Co.	3	2021-23	3	9
Own analyses	Central Valley	6	2021	1	6
Own analyses	Central Valley	13	2022	1	13
Own analyses	Central Valley	19	2023	1	19
Own analyses	Central Valley	19	2024	1	19
Overall					**66**

Summary statistics of cherry N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Brown et al., 2023	5.19	0.48*	4.64 - 5.48*	9.2*
Own analyses 2021	7.40	2.06	3.99 - 9.49	27.8
Own analyses 2022	8.80	1.80	5.98 - 12.12	20.5
Own analyses 2023	5.17	1.19	2.76 - 7.00	23.1
Own analyses 2024	4.75	1.52	2.31 - 8.17	32.0
Overall	**5.97**	**2.25**	**2.31 - 12.12**	**37.7**

* Standard deviation, range and CV reflect the variability across three varieties, with the value for each variety being the average of three years.

Variability

Across all samples, the variability in N removal was relatively large, with the CV reaching 37.7%. Nitrogen removal differed by variety and year. With 7.1 lbs N /ton, Bing and Brooks had the highest N removal, followed by Rainier (5.4 lbs N/ton) and Coral (4.5 lbs N/ton). These differences were statistically significant, except for Brooks vs. Rainier. However, the number of samples for each variety was relatively small and no information on management practices are available. Furthermore, differences across varieties were small in the dataset by Brown et al. (2023).

Year of harvest had an even stronger effect on N removal. While the N removal of the five Bing samples from 2022 averaged 9.1 lbs N/ton, it averaged only 5.6 lbs N/ton in the eight samples analyzed in 2023. Rainier cherries showed similar differences across years.

Discussion

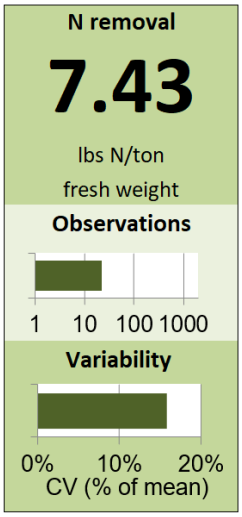
The flesh, pits and stems were analyzed separately. The flesh contributed on average 86% to the total N of the sampled, while pits and stems contributed 12 and 2%, respectively.

The average N removal is based on 57 samples of different varieties collected over four growing seasons. The result can be considered a good estimate of N removed with cherries grown in California. However, the dataset is too small for robust conclusions on differences across varieties.

References

Brown, P., Amaral, D., Camargo, R., 2023. Development of Nutrient Budget and Nutrient Demand Model for Nitrogen Management in Cherry. Final report for CDFA-FREP project 19-0954.

Corn, sweet



Data sources

Sweet corn samples were purchased multiple times during the season from Central Valley produce markets. 22 samples were collected and analyzed over three seasons from 2021 to 2024. Only samples that were verified as being from the Central Valley were purchased. With one exception, samples included husks.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	7	2021	1	7
Own analyses	Central Valley	8	2023	1	8
Own analyses	Central Valley	8	2024	1	8
Overall					**22**

Summary statistics of sweet corn N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2021	8.41	0.91	7.2 - 9.9	10.8
Own analyses 2023	7.18	1.05	5.3 - 8.3	14.6
Own analyses 2024	7.18	1.05	5.3 - 8.3	14.6
Overall	**7.43**	**1.17**	**5.3 - 9.9**	**15.8**

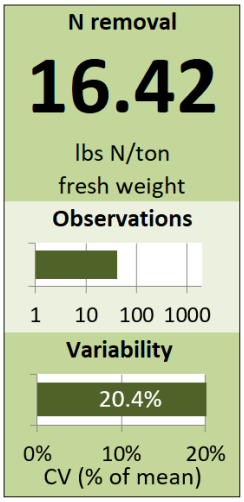
Variability

The variability across samples was moderate. Differences in dry matter content and total N in the dry matter contributes almost equally to the observed variability.

Discussion

On average, 10% of the total N in sweet corn ears was in the husks. The average value for N removed is based on 22 samples collected from different locations in California over three years and can be considered a good estimate of N removed with sweet corn ears from California fields.

Garlic, fresh market



Data sources

Fresh market garlic samples were obtained directly from growers' fields in the San Joaquin Valley (33 samples) and from produce markets across the Central Valley (8 samples). Only garlic that was verified as being from the Central Valley was purchased. 41 samples from the 2023 and 2024 growing season were collected and analyzed.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	24	2023	1	24
Own analyses	Central Valley	17	2024	1	17
Overall					**41**

Summary statistics of fresh market garlic removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2023	16.28	3.83	9.42 - 25.6	23.5
Own analyses 2024	16.60	2.59	12.59 - 20.6	15.6
Overall	**16.42**	**3.34**	**9.42 - 25.6**	**20.4**

Variability

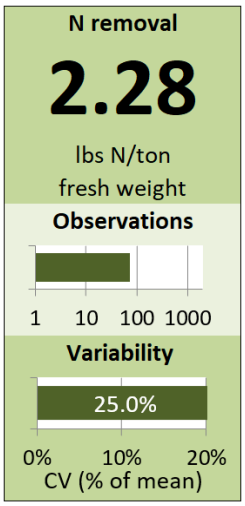
The variability across samples was moderate. Differences in total N contributed slightly more to the observed variability than differences in dry matter content.

Discussion

28 samples were collected with the leaves. Removing the leaves from the field increased the removal coefficient by 9.5% to 17.98 lbs N/ton of fresh garlic bulbs.

The average value for N removed is based on 41 samples collected from different locations in the San Joaquin Valley over two years and can be considered a good estimate of N removed with fresh market garlic from California fields.

Grapes - Table



Data sources

Table grape samples obtained from growers, packers, and shippers in the San Joaquin Valley. Samples were also were purchased multiple times during the season from Central Valley produce markets. Only samples that were verified as being from the Central Valley were purchased. 73 samples were analyzed for three seasons from 2022 to 2024.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	19	2022	1	19
Own analyses	Central Valley	37	2023	1	37
Own analyses	Central Valley	17	2024	1	17
Overall					**73**

Summary statistics of table grape N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2022	2.27	0.33	1.79 - 3.21	14.7
Own analyses 2023	2.12	0.58	1.06 - 3.39	27.5
Own analyses 2024	2.64	0.61	1.34 - 3.91	23.0
Overall	**2.28**	**0.57**	**1.06 - 3.91**	**25.0**

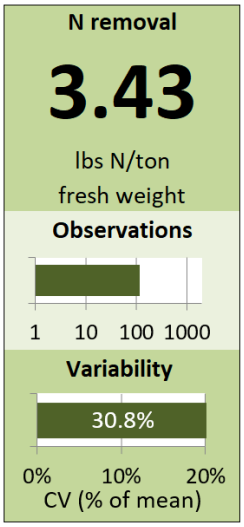
Variability

The variability was relatively large across the entire dataset. Nitrogen concentration in the dry matter was more variable than dry matter content. The N removal value did not differ significantly between black, green, and red varieties.

Discussion

Samples were obtained from many different vineyards over three growing seasons. Red, black, and green varieties spanning early, mid, and late season harvests were included. The average value for N removed can be considered a good estimate of N removed with table grapes from California.

Grapes - Wine



Data sources

Wine grape samples were obtained from vineyards in the Central Valley. 116 samples were analyzed, of which 46 were red varieties and 70 white varieties. The dataset included 10 red varieties and 6 white varieties. Cabernet Sauvignon, Merlot and Zinfandel were the dominant red varieties in the dataset, while white varieties were dominated by Chardonnay, Pinot Gris and Sauvignon Blanc.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	12	2022	1	12
Own analyses	Central Valley	54	2023	1	54
Own analyses	Central Valley	50	2024	1	50
Overall					**116**

Summary statistics of wine grape N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2022	4.71	0.51	3.79 - 5.36	10.9
Own analyses 2023	3.13	0.85	1.93 - 6.2	27.2
Own analyses 2024	3.44	1.13	1.78 - 6.47	32.8
Overall	**3.43**	**1.06**	**1.78 - 6.47**	**30.8**

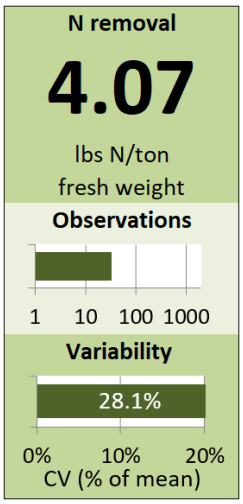
Variability

The variability in the dataset was relatively large. On average, red varieties had a higher N removal value (3.76 lbs N/ton of fresh weight) than white varieties (3.17 lbs N/ton of fresh weight). However, this difference may be the result of the varieties and regions included. A more systematic sampling approach would be needed to determine with confidence whether there are differences across varieties. The variability across red varieties and white varieties was equally pronounced. Even across samples of the same variety, relatively large differences in the N removal values were observed.

Discussion

The N removal value is based on 116 samples collected over three seasons from a large number of vineyards. The sample included a total of 16 grape varieties. The average N removal values is a robust estimate of N removed with wine grapes grown in the Central Valley. Even though the total sample size is large with 116 samples analyzed, it is too small to suggest using different N removal values based on grape color or variety.

Melons, Cantaloupe



Data sources

Cantaloupe melons were purchased multiple times during the season from produce markets across the Central Valley. 33 samples were collected and analyzed over four seasons from 2021 to 2024. Only melons that were verified as being from the Central Valley were purchased.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	5	2021	1	5
Own analyses	Central Valley	4	2022	1	4
Own analyses	Central Valley	19	2023	1	19
Own analyses	Central Valley	5	2024	1	5
Overall					**33**

Summary statistics of cantaloupe melon N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2021	5.47	1.36	4.50 - 7.82	25.0
Own analyses 2022	3.27	1.42	1.38 - 4.63	43.3
Own analyses 2023	4.08	0.80	2.72 - 5.67	19.6
Own analyses 2024	3.25	0.50	2.49 - 3.85	15.5
Overall	**4.07**	**1.14**	**1.38 - 7.82**	**28.1**

Variability

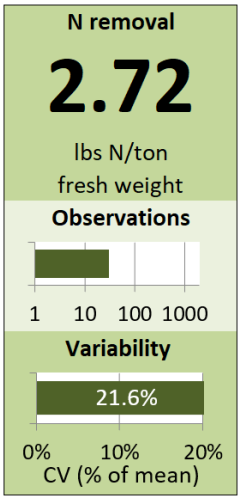
Compared to other commodities, the variability in the dataset is relatively high. Differences in total N in the dry matter and the dry matter content contributed almost equally to the observed variability. Differences from one year to the other were pronounced.

One reason for the high variability is that, due to logistics, each sample consisted of only 1-3 melons. While individual samples cannot be considered representative of the field they came from, the average N removal value is unbiased and therefore reflects N removal across the Central Valley.

Discussion

The average value for N removed is based on 33 samples collected from different locations in California over four years and can be considered a good estimate of N removed with cantaloupe melons from California fields.

Melons, Honeydew



Data sources

Honeydew melons were purchased multiple times during the season from produce markets across the Central Valley. 31 samples were collected and analyzed over four seasons from 2021 to 2024. Only melons that were verified as being from the Central Valley were purchased.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	2	2021	1	2
Own analyses	Central Valley	4	2022	1	4
Own analyses	Central Valley	18	2023	1	18
Own analyses	Central Valley	7	2024	1	7
Overall					**31**

Summary statistics of honeydew melons N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2021	2.03	0.05	1.99 - 2.06	2.3
Own analyses 2022	2.75	0.73	1.67 - 3.17	26.4
Own analyses 2023	2.81	0.55	2.11 - 4.45	19.7
Own analyses 2024	2.69	0.65	1.52 - 3.64	24.1
Overall	**2.72**	**0.59**	**1.52 - 4.45**	**21.6**

Variability

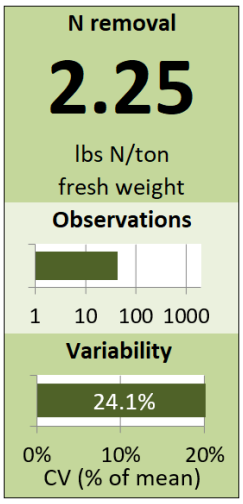
Compared to other commodities, the variability in the dataset is relatively high. Differences in total N in the dry matter contributed more to the observed variability than the dry matter content.

One reason for the high variability is that, due to logistics, each sample consisted of only 1-3 melons. While individual samples cannot be considered representative of the field they came from, the average N removal value is unbiased and therefore reflects N removal across the Central Valley.

Discussion

Nitrogen removed with honeydew melons was significantly lower than N removed with cantaloupes (see previous page). Therefore, using different N removal coefficients for these two types of melon is recommended. The average value for N removed is based on 31 samples collected from different locations in California over four years and can be considered a good estimate of N removed with honeydew melons from California fields.

Melons, Watermelons



Data sources

Watermelons were purchased multiple times during the season from produce markets across the Central Valley. 44 samples were collected and analyzed over four seasons from 2021 to 2024. Only watermelons that were verified as being from the Central Valley were purchased.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	5	2021	1	5
Own analyses	Central Valley	5	2022	1	5
Own analyses	Central Valley	14	2023	1	14
Own analyses	Central Valley	20	2024	1	20
Overall					**44**

Summary statistics of watermelon N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2021	3.00	0.57	2.35 - 3.73	18.8
Own analyses 2022	2.68	0.42	2.25 - 3.28	15.9
Own analyses 2023	2.17	0.49	1.48 - 2.99	22.3
Own analyses 2024	2.01	0.37	1.43 - 2.83	18.5
Overall	**2.25**	**0.54**	**1.43 - 3.73**	**24.1**

Variability

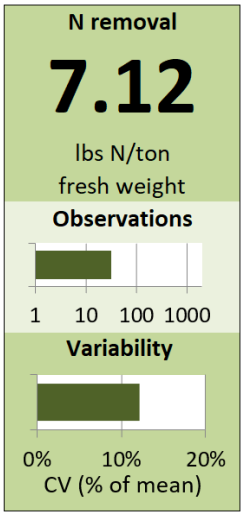
Compared to other commodities, the variability in the dataset is relatively high. Differences in total N in the dry matter contributed more to the observed variability than the dry matter content. The variability in both dry matter content and N concentration was higher than the variability in the N removal value. This was due to the fact that watermelons with a higher dry matter content tended to have a lower N concentration in the dry matter and vice versa.

One reason for the high variability is that, due to logistics, each sample consisted of only 1-2 melons. While individual samples cannot be considered representative of the field they came from, the average N removal value is unbiased and therefore reflects N removal across the Central Valley.

Discussion

The average value for N removed is based on 44 samples collected from different locations in California over four years and can be considered a good estimate of N removed with watermelons from California fields.

Olives - Table



Data sources

Table olive samples were obtained from different orchards in Tulare County. 32 samples of 'Manzanillo' olives were analyzed over three growing seasons. Samples were obtained from processors and Elizabeth Fichtner, UC Cooperative Extension Tulare County.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	13	2021	1	13
Own analyses	Central Valley	7	2022	1	7
Own analyses	Central Valley	12	2023	1	12
Overall					**32**

Summary statistics of table olive N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2021	7.10	0.61	5.62 - 8.08	8.5
Own analyses 2022	6.71	1.62	3.16 - 7.85	24.1
Own analyses 2023	7.39	0.33	6.56 - 7.89	4.4
Overall	**7.12**	**0.87**	**3.16 - 8.08**	**12.2**

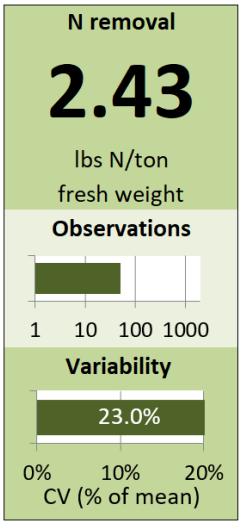
Variability

The variability across samples was relatively low. Except for one sample with a very low N concentration, the N removal values were all between 5.62 and 8.08 lbs N/ ton of fresh weight.

Discussion

The average value for N removed is based on 32 samples collected from different orchards in Tulare County over three years and can be considered a good estimate of N removed with table olives.

Onions, fresh market



Data sources

Fresh market onions were obtained directly from growers' fields in the San Joaquin Valley and from produce markets across the Central Valley. Only onions that were verified as being from the Central Valley were purchased. 50 samples were collected and analyzed, with 49 of these sampled from the 2023 and 2024 harvests.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	1	2022	1	1
Own analyses	Central Valley	20	2023	1	20
Own analyses	Central Valley	29	2024	1	29
Overall					**50**

Summary statistics of fresh market onion N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2022	1.74			
Own analyses 2023	2.45	0.52	1.74 - 3.59	21.4
Own analyses 2024	2.44	0.58	1.40 - 4.05	24.0
Overall	**2.43**	**0.56**	**1.40 - 4.05**	**23.0**

Variability

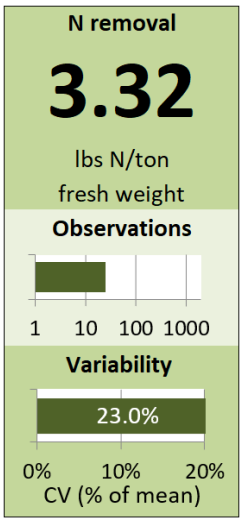
With a CV of 23%, the variability of the dataset was relatively large. Differences in N concentration in the dry matter and dry matter content contributed approximately the same to the overall variability.

Discussion

Samples from 7 fields included the leaves. Removing the leaves from the field increased the removal coefficient by 4.0% to 2.53 lbs N/ton of fresh onion bulbs.

Fresh market onions had an average dry matter content of 5.41% and N concentration in the dry matter of 2.37%. The average value for N removed is based on 50 samples collected from different fields in the San Joaquin Valley over two seasons. It can be considered a good estimate of N removed with fresh market onions.

Pepper - Bell



Data sources

Bell peppers were sourced from growers in the San Joaquin Valley and purchased multiple times during the season from produce markets across the Central Valley. 25 samples were collected and analyzed over four seasons from 2021 to 2024. Only peppers that were verified as being from the Central Valley were purchased. 15 green pepper samples and 10 red pepper samples were analyzed.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	10	2021	1	10
Own analyses	Central Valley	5	2022	1	5
Own analyses	Central Valley	4	2023	1	4
Own analyses	Central Valley	6	2024	1	6
Overall					**25**

Summary statistics of bell pepper N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2021	3.93	0.66	3.01 - 4.91	16.7
Own analyses 2022	3.10	0.46	2.75 - 3.89	14.7
Own analyses 2023	3.02	0.71	2.48 - 4.06	23.4
Own analyses 2024	2.68	0.42	2.12 - 3.08	15.8
Overall	**3.32**	**0.76**	**2.12 - 4.91**	**23.0**

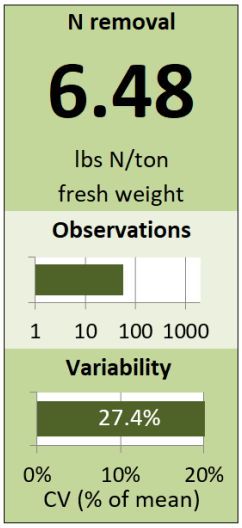
Variability

With 3.84 lbs N/ton of fresh weight, red peppers had a significantly higher average N removal value than green peppers, which averaged 2.97 lbs N/ton of fresh weight. The difference was due to a 30% higher dry matter content of red bell peppers, while the N concentration in the dry matter was slightly higher in green peppers.

Discussion

The average value for N removed is based on 25 samples over four seasons and can be considered a good estimate of N removed with bell peppers. A larger sample size would need to be analyzed to determine whether using different N removal values for red and green bell pepper is warranted.

Potatoes



Data sources

Potato samples came from different sources. 25 samples were from field trial in Kern County conducted by Brian Marsh, UC Cooperative Extension. Each observation represents a different field. 33 samples were obtained from growers' fields directly, from shippers or purchased at produce markets. Only potatoes that were verified as being from the Central Valley were purchased.

The samples analyzed in our lab were collected over three seasons, from 2022 to 2024.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Marsh, 2016	Kern Co.	8	2014	1	8
Marsh, 2019a	Kern Co.	8	2016	1	8
Marsh, 2019b	Kern Co.	9	2016	1	9
Own analyses	Central Valley	4	2022	1	4
Own analyses	Central Valley	17	2023	1	17
Own analyses	Central Valley	12	2024	1	12
Overall					**58**

Summary statistics of potato N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Marsh, 2016	5.09	1.15	3.93 - 7.33	22.7
Marsh, 2019a	6.63	1.86	3.40 - 8.41	28.0
Marsh, 2019b	9.04	0.50	8.29 - 9.91	5.6
Own analyses 2022	5.50	1.19	4.68 - 7.26	21.6
Own analyses 2023	5.83	1.18	4.31 - 8.64	20.2
Own analyses 2024	6.65	1.72	4.07 - 10.4	25.8
Overall	**6.48**	**1.78**	**3.40 - 10.4**	**27.4**

Variability

The variability is relatively high. Dry matter content and N concentration in the dry matter contributed almost equally to the observed variability.

Discussion

The N removal value is based on 58 samples. Comparing the results reported by Marsh (2016, 2019a and 2019b) and the results from our own analyses did not differ significantly. The N removal value is a good estimate of N removed with potatoes grown in the Central Valley.

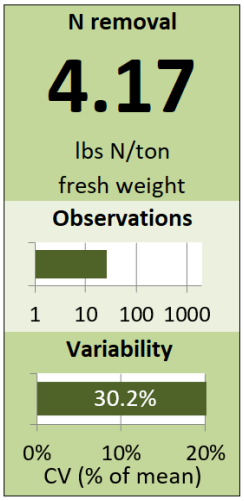
References

Marsh, B., 2016. An Investigation of Current Potato Nitrogen Fertility Programs' Contribution to Ground Water Contamination." International Journal of Agricultural and Biosystems Engineering 10(3): 138-144.

Marsh, B., 2019a. An Evaluation of Nitrogen Fertility Management in Commercial Potato Fields. International Journal of Agriculture, Forestry and Life Science. 3:1, 52-63.

Marsh, B., 2019b. Irrigation and Nitrogen Fertilizer Rate Impacts on Soil Nitrate in Potato Production. Communications in Soil Science and Plant Analysis. 50, 1811-1820. https://doi.org/10.1080/00103624.2019.1635146

Squash



Data sources

Squash samples were purchased multiple times during the season from produce markets across the Central Valley. 26 samples were collected and analyzed over three seasons from 2021 to 2023. Only squashes that were verified as being from the Central Valley were purchased. The dataset included acorn squash (4 samples) butternut squash (13) spaghetti squash (7) and zucchini (2).

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	6	2021	1	6
Own analyses	Central Valley	5	2022	1	5
Own analyses	Central Valley	15	2023	1	15
Overall					**26**

Summary statistics of squash N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2021	5.29	1.59	3.18 - 7.72	30.0
Own analyses 2022	4.18	1.37	3.02 - 6.24	32.9
Own analyses 2023	3.72	0.80	2.41 - 5.06	21.5
Overall	**4.17**	**1.26**	**2.41 - 7.72**	**30.2**

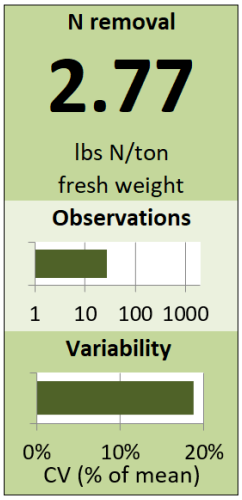
Variability

The variability in the dataset was relatively large. Type of squash contributed to the overall variability. The N removal value of acorn and butternut squash was equal reaching 4.38 lbs N/ton of fresh weight. N removed with spaghetti squash was significantly lower (3.29 lbs N/ton of fresh weight). N removal with zucchini was highest, however, the value is based on only two samples.

Discussion

Our data suggest that there may be differences in N removal by types of squash. However, the sample size for individual types was small. A larger sample size would need to be analyzed to determine whether using different N removal values for different squash types is warranted.

Tomato, fresh market



Data sources

Fresh market tomatoes were purchased multiple times during the season from produce markets across the Central Valley. 27 samples were collected and analyzed over three seasons from 2021 to 2023. Only tomatoes that were verified as being from the Central Valley were purchased.

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Own analyses	Central Valley	9	2021	1	9
Own analyses	Central Valley	2	2022	1	2
Own analyses	Central Valley	16	2023	1	16
Overall					**27**

Summary statistics of fresh market tomato N removal data.

Source	Summary (lbs/ton of fresh weight)			
	mean	SD	Range	CV (%)
Own analyses 2021	3.04	0.46	2.24 - 3.55	15.0
Own analyses 2022	3.14	0.74	2.62 - 3.67	23.6
Own analyses 2023	2.57	0.46	1.72 - 3.31	18.0
Overall	**2.77**	**0.52**	**1.72 - 3.67**	**18.8**

Variability

The variability in the dataset was moderate. Variability in dry matter content and N concentration in the dry matter contributed equally to the observed variability.

Discussion

With 2.77 lbs N/ton fresh weight, the N removed with fresh market tomatoes is slightly lower than the value for processing tomatoes (2.92 lbs N/ton fresh weight).

The average value for N removed is based on 27 samples collected from different produce markets across the Central Valley over three seasons. It can be considered a good estimate of N removed with fresh market tomatoes.