# Nitrogen concentrations in harvested plant parts - A literature overview

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2016

**Content**



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**Last update:** 12/02/2016

## Acknowledgments

This report was written with support from the Kings River Watershed Coalition. I thank Irfan Ainuddin and Patricia Lazicki, from the Department of Land Air and Water Resources at UC Davis, as well as John Dickey and Andrea Schmid, PlanTierra LLC, Davis, for help with data analysis and comments on drafts of the report.

Drafts of the summaries for individual crops were sent to UCCE specialists and farm advisors for review. I'd like to thank the following reviewers for their valuable comments (in alphabetical order):

- Aegerter, Brenna, Ph.D., UCCE Farm Advisor, San Joaquin County
- Arpaia, Mary Lu, Ph.D., UCCE Specialist for Subtropical Horticulture, Kearney Agricultural Research and Extension Center, Parlier
- Biscaro, Andre, UCCE Farm Advisor, Ventura County
- Brown, Patrick, Ph.D., Professor Department of Plant Sciences, UC Davis
- Clark, Nicholas, UCCE Farm Advisor, Kings, Fresno & Tulare counties
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- Stoddard, C. Scott, UCCE Farm Advisor, Merced & Madera counties
- Wilson, Rob, UCCE Farm Advisor and Director Intermountain Research & Extension Center, Tulelake

## Summary

Nitrogen (N) balances in agricultural fields are an important component of the Central Valley Irrigated Lands Regulatory Program. The ratio of N applied to N removed is a key metric for the State and Central Valley Regional Water Boards. The approach involves growers reporting applied N and yield to the water quality coalitions (Coalitions). The Coalitions in turn will transform these data into the quotient N applied/N removed, which will be reported along with the applied N to the Central Valley Regional Water Board. To make these transformations, the Coalitions need reliable values of N concentrations in the harvested parts of crops. For the present report, we mined the scientific literature for data on N concentrations in harvested crop parts. The report contains information for crops that cumulatively occupy 99% of the irrigated acreage in the Central Valley.

For each commodity, we calculated the weighted mean N concentration across the datasets that were included in the analysis. Furthermore, we report the standard deviation, coefficient of variation (CV), and range of the results.

Nitrogen concentrations are expressed in lbs/ton at a moisture content common for the individual commodities at harvest. The report also includes an assessment of the relevance of the available data, based on number of observations, variability, and geographic origin. The amount of data available from California varies considerably among crops. For some crops, extensive datasets were available, while for many other crops only few if any values could be found. Therefore, for many crops, the dataset should be supplemented with additional samples from Central Valley fields to support a robust estimate of the N concentrations in harvested plant parts.

A number of factors can affect the N concentration in harvested plant parts. For most crops included in this report, year of harvest, N availability and variety contributed most to the observed variability. These factors seem to affect N concentrations in field crops, vegetables and tree crops equally. Other factors, such as fruit size, dry matter content of the harvested plant part, percent marketable yield, or growth stage when harvested may also be important for some crops. An overview of the data can be found in Tables 1 through 3.

Calculating the amount of N removed based on yield and average N concentration has some limitations unrelated to the quality of the data: (i) As N concentrations in harvested crop parts can vary considerably from one year to the next, the calculated value for N removed is only accurate on a multi-year basis, but may not be accurate for a specific year. (ii) For most crops where marketable yield is reported and cull or trash is removed in a processing facility, the calculated amount of N removed underestimate the actual amount, the difference being the N in cull or trash. (iii) For perennial crops, N accumulation in perennial tissue (e.g. trunk, roots, or branches) is not included in the value.

**Table 1:** Overview of N concentrations in harvested plant parts of field crops.

| Commodity | N in harvested plant parts | | # of observations | | CV (%) | Page |
|---|---|---|---|---|---|---|
| | | | California | Total | | |
| Alfalfa - Hay | **62.3** | lbs N/ton @ 12% moisture | 49 | 49 | 12.5 | 14 |
| Alfalfa - Silage | **24.0** | lbs N/ton @ 65% moisture | 6 | 6 | 17.5 | 16 |
| Barley - Grain | **33.6** | lbs N/ton @ 12% moisture | 4 | 61 | 14.6 | 18 |
| Barley - Straw | **15.4** | lbs N/ton @ 12% moisture | 0 | 970 | 31.3 | 20 |
| Beans, dry - Blackeye | **73.0** | lbs N/ton @ 12% moisture | 1 | 164 | 10.4 | 22 |
| Beans, dry - Garbanzo | **67.2** | lbs N/ton @ 12% moisture | 2 | 108 | 11.3 | 24 |
| Beans, dry - Lima | **72.3** | lbs N/ton @ 12% moisture | 2 | 75 | 5.4 | 26 |
| Corn - Grain | **24.0** | lbs N/ton @ 15.5% moisture | 0 | 1775 | 20.8 | 28 |
| Corn - Silage | **7.56** | lbs N/ton @ 70% moisture | 71 | 71 | 10.5 | 30 |
| Cotton | **43.7** | lbs N/ton lint & seed | 27 | 80 | 29.5 | 32 |
| Fescue, Tall - Hay | **50.8** | lbs N/ton @ 12% moisture | 260 | 260 | 16.2 | 34 |
| Oat - Grain | **37.7** | lbs N/ton @ 12% moisture | 0 | 134 | 9.6 | 36 |
| Oat - Straw | **14.8** | lbs N/ton @ 12% moisture | 2 | 526 | 34.7 | 38 |
| Oat - Hay | **21.7** | lbs N/ton @ 12% moisture | 49 | 49 | 18.2 | 40 |
| Orchard Grass - Hay | **54.5** | lbs N/ton @ 12% moisture | 60 | 60 | 20.0 | 42 |
| Ryegrass, Perennial - Hay | **54.9** | lbs N/ton @ 12% moisture | 60 | 60 | 16.8 | 44 |
| Safflower | **56.8** | lbs N/ton @ 8% moisture | 12 | 149 | 20.0 | 46 |
| Sorghum - Grain | **33.0** | lbs N/ton @ 13.5% moisture | 0 | 256 | 29.7 | 48 |
| Sorghum - Silage | **7.34** | lbs N/ton @ 65% moisture | 260 | 260 | 21.0 | 50 |
| Sunflower | **54.1** | lbs N/ton @ 8% moisture | 0 | 208 | 14.3 | 52 |
| Triticale - Grain | **40.4** | lbs N/ton @ 12% moisture | 51 | 51 | 13.0 | 54 |
| Triticale - Straw | **11.5** | lbs N/ton @ 12% moisture | 0 | 102 | 38.3 | 56 |
| Triticale - Silage | **9.03** | lbs N/ton @ 70% moisture | 19 | 19 | 13.7 | 58 |
| Wheat, common - Grain | **43.0** | lbs N/ton @ 12% moisture | 113 | 113 | 10.3 | 60 |
| Wheat - Straw | **13.8** | lbs N/ton @ 12% moisture | 3 | 494 | 33.0 | 62 |
| Wheat - Silage | **10.5** | lbs N/ton @ 70% moisture | 39 | 39 | 18.6 | 64 |
| Wheat, durum - Grain | **42.1** | lbs N/ton @ 12% moisture | 41 | 41 | 3.7 | 66 |

**Table 2:** Overview of N concentrations in harvested plant parts of vegetables.

| Commodity | N in harvested plant parts | | # of observations | | CV (%) | Page |
|---|---|---|---|---|---|---|
| | | | California | Total | | |
| Asparagus | **5.85** | lbs N/ton of fresh spears | 2 | 19 | 14.0 | 68 |
| Beans, green (snap beans) | **5.78** | lbs/ton of fresh weight | 1 | 122 | 25.7 | 70 |
| Broccoli | **11.2** | lbs N/ton of fresh weight | 15 | 46 | 20.4 | 72 |
| Carrots | **3.29** | lbs/ton of fresh weight | 1 | 167 | 22.4 | 74 |
| Corn, sweet | **7.17** | lbs/ton of fresh ears | 0 | 50 | 13.1 | 76 |
| Cucumbers | **2.16** | lbs/ton of fresh weight | 1 | 10 | 17.4 | 78 |
| Garlic | **15.1** | lbs/ton of fresh weight | 1 | 12 | 19.5 | 80 |
| Lettuce, Iceberg | **2.63** | lbs/ton of fresh weight | 45 | 68 | 16.7 | 82 |
| Lettuce, Romaine | **3.62** | lbs/ton of fresh weight | 14 | 26 | 13.7 | 84 |
| Melons, Cantaloupe | **4.87** | lbs/ton of melons | 1 | 31 | 15.5 | 86 |
| Melons, Honeydew | **2.95** | lbs/ton of melons | 1 | 12 | 22.1 | 88 |
| Melons, Watermelons | **1.39** | lbs/ton of melons | 1 | 6 | 23.9 | 90 |
| Onions | **3.94** | lbs/ton of fresh weight | 13 | 45 | 19.7 | 92 |
| Pepper, Bell | **3.31** | lbs/ton of fresh weight | 6 | 40 | 7.9 | 94 |
| Potatoes | **6.24** | lbs/ton of fresh weight | 5 | 64 | 13.6 | 96 |
| Pumpkin | **7.36** | lbs/ton of fresh weight | 1 | 13 | 10.1 | 98 |
| Squash | **3.67** | lbs/ton of fresh weight | 11 | 74 | 22.4 | 100 |
| Sweet potatoes | **4.74** | lbs/ton of fresh weight | 11 | 23 | 16.8 | 102 |
| Tomatoes, fresh market | **2.61** | lbs/ton of fresh weight | 1 | 34 | 16.5 | 104 |
| Tomatoes, processing | **2.73** | lbs/ton of fresh weight | 24 | 24 | 11.1 | 106 |

**Table 3:** Overview of N concentrations in harvested plant parts of tree and vine crops.

| Commodity | N in harvested plant parts | | # of observations | | CV (%) | Page |
|---|---|---|---|---|---|---|
| | | | California | Total | | |
| Almonds | **136** | lbs/ton of kernels | 31 | 31 | 4.1 | 108 |
| Apples | **1.08** | lbs/ton of fruits | 1 | 132 | 35.1 | 110 |
| Apricots | **5.56** | lbs/ton of fruits | 1 | 22 | 114 | 112 |
| Cherries | **4.42** | lbs/ton of fruits | 1 | 24 | 19.8 | 114 |
| Figs | **2.54** | lbs/ton of fruits | 1 | 19 | 18.1 | 116 |
| Grapefruit | **2.96** | lbs/ton of fruits | 26 | 27 | 7.8 | 118 |
| Grapes - Raisins | **10.1** | lbs/ton @ 15% moisture | 16 | 19 | 5.8 | 120 |
| Grapes - Table | **2.26** | lbs/ton of grapes | 16 | 19 | 5.8 | 122 |
| Grapes - Wine | **3.60** | lbs/ton of grapes | 8 | 38 | 13.0 | 124 |
| Lemons | **2.58** | lbs/ton of fruits | 21 | 22 | 10.0 | 126 |
| Nectarines | **3.64** | lbs/ton of fruits | 31 | 41 | 27.1 | 128 |
| Olives | **6.28** | lbs/ton of olives | 6 | 29 | 22.8 | 130 |
| Oranges | **2.96** | lbs/ton of fruits | 26 | 82 | 10.9 | 132 |
| Peaches | **2.26** | lbs/ton of fruits | 5 | 25 | 20.7 | 134 |
| Pears | **1.29** | lbs/ton of fruits | 1 | 64 | 17.9 | 136 |
| Pistachios | **56.1** | lbs N/ton dry yield (CPC) | 11 | 11 | 3.5 | 138 |
| Plums | **2.83** | lbs/ton of fruits | 1 | 11 | 11.2 | 140 |
| Pomegranate | **15.2** | lbs/ton of fruits | 0 | 7 | 15.0 | 142 |
| Prunes | **11.2** | lbs/ton of dried fruits | 18 | 18 | 16.3 | 144 |
| Tangerines | **2.54** | lbs/ton of fruits | 1 | 2 | 29.2 | 146 |
| Walnuts | **31.9** | lbs N/ton with shells | 18 | 18 | 11.2 | 148 |

## Introduction

As part of developing the Central Valley Irrigated Lands Regulatory Program (CVILRP), agricultural water quality coalitions (Coalitions; exclusive of irrigated agriculture covered under the Dairy or California Rice Commission orders) have developed an approach to providing the Central Valley Regional Water Quality Control Board (CVRWQCB) with information on nitrogen (N) balances in agricultural fields. The ratio of N applied to N removed, having been recommended by the Expert Panel convened by the State Water Resources Control Board, is a key metric for the CVRWQCB (ITRC, 2014; CVRWQCB, 2013). The approach involves growers reporting applied N and the quotient N applied/yield to the Coalitions. The Coalitions in turn will transform these data to the quotient N applied/N removed, and report various statistics related to N applied, and to the quotient of N applied/N removed to the CVRWQCB. To make these transformations, the Coalitions need reliable values of N concentrations in the harvested parts of crops.

For this report, we mined the scientific literature (including peer-reviewed articles and research reports) for data on N concentrations in harvested crop parts with emphasis on California data. The report contains information for crops that cumulatively occupy 99% of the irrigated acreage in the Central Valley (see Appendix 1). Rice is covered under the California Rice Commission General Order and was not included in this report. Dairy waste land application fields are similarly covered under the Dairy General Order, are not part of the Coalitions. However, silage from different forage crops is included in this report to cover the acreage on no-dairy farms.

The report also includes an assessment of available data quality, based on the number of observations, variability, and geographic origin.

## Procedures

### *Data search*

For the literature search, we first focused on scientific papers and reports from California. When only few observations were available, we expanded the search to include studies completed in other parts of the U.S., Europe, and finally globally. When experiments included more than one treatment, the results from individual treatments, if reported, were entered into the database as separate observations. No attempt was made to identify treatments that best reflect crop management practices and conditions in the Central Valley. When no, or only few, observations from studies were available, we also included data from two online databases. These were:

(1) The NRCS Nutrient Tool (http://plants.usda.gov/npk/main), which allows users to calculate the amount of N, P and K removed in harvested crops. The database includes a large number of commodities. For vegetables, data from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" (Howard et al., 1962) was used to populate the database. While values are from California, the bulletin was published more than 50 years ago and may not fully represent modern varieties grown in current systems. For fruits, the database is populated with values from the USDA

publication "Composition of foods, fruits and fruit juices, raw, processed, prepared" (USDA, 1982), which appears to be a precursor of the online Food Composition Database (see next paragraph).

(2) The USDA Food Composition Database (https://ndb.nal.usda.gov/ndb/foods), which includes protein contents of the edible portion of fruits and vegetables. For commodities where the harvested parts are identical to the edible parts, this database is a valuable resource, as it also includes information about the sample size and the variability of the data. However, no background information about the samples is available (e.g. origin or production method).

The International Plant Nutrition Institute (IPNI) Nutrient Removal Calculator (https://www.ipni.net/app/calculator/home) used data compiled from a global dataset. The geographic origin of the data is reported for some crops, but not the reference. For this report, we did not include data from the IPNI database.

The crops that cumulatively occupy 99% of the irrigated acreage in the Central Valley were selected based on USDA survey date for 2012 (https://quickstats.nass.usda.gov/; see Appendix 1).

*Data analysis*

Nitrogen concentrations are expressed in lbs/ton at a moisture content common for the commodities at harvest. For vegetables and fruits, this is generally the fresh weight. Where appropriate, the moisture content is given in the tables. This is mainly the case for field crops, where studies generally report N concentration in the dry matter. These values were converted to dry matter at a common moisture content at harvest for this report. For crops where cull is left in the field and only the marketable portion of the yield leaves the field, the values in the table refer to the marketable yield. However, if separation of total yield into marketable yield and cull takes place afterwards in a processing facility, the value in the table refers to the total yield that was removed from the field. No adjustments were made to account for cull that is not left behind in the field, with two exceptions: The value for almonds refers to the amount of N removed with the entire fruit (shell, hull and kernel) expressed in tons of kernel yield. The other exception is pistachios, where the N is expressed in lbs/ton of dry yield (CPC). For perennial crops, the values reported refer to N concentrations in harvested plant parts. Nitrogen removed with prunings or N accumulated in perennial plant is not included. For a discussion about N accumulation in perennial tissues of orchard trees, see "Nitrogen accumulation in permanent tissues of trees" below.

A number of studies and datasets reported crude protein. The standard method to measure crude protein is to determine the N content of the material and multiply it by 6.25. This conversion factor reflects the average N content of amino acids. An exception is wheat, where a conversion factor of N x 5.7 is used to calculate its crude protein content (Undersander, 1993; Gwirtz et al., 2006). Unless the authors reported a different factor, protein was converted to N with these factors.

For each commodity, we calculated the **mean** of each dataset and the weighted mean among datasets. The weight of a dataset is determined by the number of observations. For example, a dataset with 20 observations has 10 times more weight than a dataset with only two 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.

In this report, the pooled SD as well as the range need to be considered as estimates, since in some studies the average values of multiple observations were reported without values for individual observations. In these cases, the calculated SD and range tend to underestimate the true variability of the dataset.

To facilitate comparison of different commodities, we calculated the **coefficient of variation (CV)**, which is expressed as the SD in % of the mean. Using CV instead of SD simplifies comparison of the variability among datasets with different means, even though variability of any dataset depends on the design of the study and the number of factors included. For example, we would expect the variability to be smaller for a variety trial that is completed at one site for one year compared with a variety trial that includes multiple sites and years.

*Presentation of the data*

For a quick overview, the key data for each crop are presented in a box in the top right corner of the page (Figure 1). The box contains the average value for N removed and the number of observations contributing to this estimate. A dark green bar indicates that a majority of the values are from studies in California, while a light green bar is used for crops where data are mainly from elsewhere. The variability of the data is included as the CV.

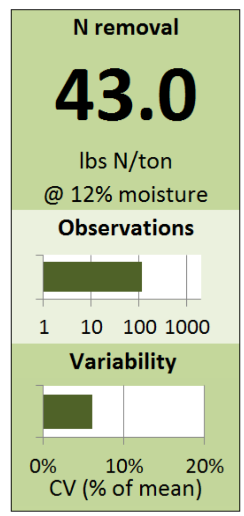


**Figure 1:** Summary box for wheat grain.

For each commodity, two tables are included. The first lists the references, as well as the locations and years of the studies. Also included is the number of observations that contributed to the average. For example, if a study was completed at two sites over three years, then the number of observations would be 6 (i.e., 2 x 3). If three different varieties had been examined at each location, then the number of observations would be 18 (i.e., 2 sites x 3 years x 3 varieties). The second table presents the results of the data analysis described above.

For each commodity, we describe the data sources and discuss the relevance of the dataset including variability of the data. The assessment of the relevance is based on the study locations, sample size and the years the samples were collected to give an indication how well the experimental conditions represent current conditions in the Central Valley. When detailed data are available, we discuss the major factors contributing to observed variability within or among different studies in the dataset.

## Results and discussion

Detailed analyses for specific crops can be found in the second part of this report. The following sections provide a brief overview and highlight some general trends.

### *Data available for field crops*

The availability of relevant data varies considerably among field crops. A very good dataset is available for wheat from the annual UC variety trials conducted at several locations. Data from variety trials in California were also available for hay from cool season grasses and oat, silage from sorghum, wheat and triticale, as well as triticale grain. Some of these variety trials have not been carried out at multiple locations or over several years. Annual variety trials are also conducted for triticale and barley. In these cases however, the protein concentration in the grain is not determined. Variety trials are a valuable source for representative N concentrations of plant parts harvested in the Central Valley. They also allow for periodic updates of the dataset to take into account new varieties or changing production practices. In collaboration with the trial management, it may be possible to include analyses of N concentrations when this is not part of the standard protocol. One point that needs to be kept in mind is that variety trials may underestimate the variability encountered among growers' fields, as the crops in the trials are grown under rather uniform conditions which do not reflect the broader range of management practices found in commercial fields.

Good datasets from California were also available for some other crops, namely alfalfa hay and silage, corn silage, and cotton. For other field crops, very little information was available from California and most values included in our analysis were from elsewhere. In these cases, the values reported may not be a good estimate of the N concentration in crops harvested in the Central Valley.

### *Data available for vegetables*

With few exceptions, very little data about N concentrations in vegetables were available from California. One of the exceptions is processing tomatoes, where three studies reported values from multiple sites in the Central Valley. Thanks to a study carried out in the Salinas Valley, an extensive dataset for lettuce N concentrations was also available. However, no data from the Central Valley could be found. For vegetables where the entire harvested plant part is edible, the USDA Food Composition Database is a valuable resource. The database includes values for vegetables sold in the U.S. However, no information is available about the origin of the samples analyzed. We also included values from the NRCS Crop Nutrient Tool. For vegetables, as mentioned previously, the values in this online database are taken from a publication by Howard et al. (1962). While the values are from California, the bulletin was published more than 50 years ago and may not represent modern varieties grown with current management practices.

*Data available for trees and vines*

The amount of data available from California for tree crops varies considerably. Recent projects have investigated the amount of N removed with almonds, pistachios and prunes in the Central Valley and extensive datasets are available.

A good amount of data from California is also available for citrus, nectarines, raisins, and table grapes. However, in some cases, the studies were carried out quite a while ago and few factors that potentially affect N concentrations were investigated. For these crops, the database needs to be expanded to obtain a robust dataset and to strengthen the confidence in the estimate.

For the other tree crops included in this report, few, if any, observations from California are available. In these cases, the values reported may not be a good estimate for crops harvested in the Central Valley.

*Nitrogen accumulation in permanent tissues of trees*

In addition to the N removed with harvested fruits and nuts, N also accumulates in permanent tree tissue, such as roots, trunk and branches. Nutrient contents of permanent tree tissues are most commonly determined by excavating whole trees and analyzing tree parts. Only a few studies from California are available:

Excavating 12-year old 'Nonpareil' almond trees in an orchard in Kern County, Muhammad et al. (2015) found that the N content in permanent tissue increased between 20 and 40 lbs/acre in one year. Rufat and deJong (1998) excavated 7-year old 'O'Henry' peach trees in Winters. The total N in the trees ranged from 50 to 65 lbs/acre. Assuming a linear increase in perennial N over the years, this would translate into an annual accumulation of 7-9 lbs N/acre. Similarly, 15-year-old 'Hartely' walnut trees in an Oakdale orchard contained 235 lbs N/acre, which corresponds to an average annual increase of 16 lbs N/acre (Weinbaum et al., 1991; Weinbaum and van Kessel, 1998). In an orchard in Madera, 22-year old 'Kerman' pistachio trees contained between 303 and 415 lbs N/acre, which corresponds to an increase of 15-21 lbs N/acre per year (Rosecrance et al., 1996). In the same study the authors found that the total N in permanent tissue decreased by 378 g/tree in an 'on' year, while it increased by 456 g during an 'off' year. On average, this results in an increase of 39 g N/tree, or 11.6 lbs N/acre per year. Based on this short list of studies, the amount of N stored in permanent tree tissue most commonly increases by an average of about 10 to 40 lbs/acre each year. However, many factors, such as species, age, N availability, current yield and previous year's yield, affect the amount of N that is newly stored in permanent tissue each year.

*Factors contributing to differences in N concentrations*

A number of factors can affect the N concentration in harvested plant parts (Table 4). For most crops included in this report, year of harvest, N availability and variety contributed most to the observed variability. These factors seem to affect N concentrations in field crops, vegetables and tree crops equally.

When the variability across years is high, calculating the amount N removed based on yield and an average N concentration provides a good estimate of the N removed when averaged over several years, but may not accurately reflect the amount of N removed in a specific year.

In general, the N concentration seems to vary least in crops where only seeds with a low moisture content are harvested. The variability tends to be higher when the entire plant is harvested. The N concentration of crops that are harvested several times per year (e.g. hay and silage) can vary considerably, as the season and the stage at which the plants are cut also affect N concentration.

The N concentration in straw varies considerably, more than for any other commodity. A major factor affecting straw N concentration is the level of N fertilization. However, compared to grains, the amount of N removed with straw of grain crops is small.

For stone fruits and possibly olives, the fruit size, which affects the proportion of flesh to pit, is an important factor contributing to the variability in N concentrations in whole fruits. Another factor that may affect N in fruits and nuts is the type of rootstock. However, hardly any information is available to test this hypothesis.

For crops where the entire yield is removed from the field, but only the marketable yield is known, the percentage of marketable yield also affects the accuracy of the estimated N removal, as N is also removed with non-marketable fruits or vegetables (see "Data analysis" above for a more detailed discussion).

**Table 4:** Major factors affecting N concentration in the harvested parts of crops.

| Factor | Crops likely affected |
|---|---|
| Year-to-year variability | Most or all crops |
| Variety | Most or all crops |
| Site (soil properties, local climate, crop management) | Most or all crops |
| N availability | Most or all crops (small or no effect in beans and other legumes) |
| Availability of other nutrients | Most or all crops |
| Dry matter content of the harvested plant part | Silage, onions, possibly crops with low dry matter content when grown under deficit irrigation |
| Fruit size | Stone fruits, olives |
| Percent marketable yield | Crops where total yield is removed from fields, but only marketable yield is reported |
| Growth stage when harvested | Forage crops harvested for hay or silage |
| Season and stage when cut | Hay and silage of crops that are cut multiple times each year |
| Rootstock | Trees and vines |

*Improving the dataset*

The number of crops where an extensive dataset from the central Valley is available is relatively small. For most crops, the dataset needs to be expanded with additional samples from Central Valley fields for a robust estimate of the N concentrations in harvested plant parts.

For crops where a relatively good dataset from California is available, it may only be necessary to collect a limited number of samples to include additional varieties or locations in the dataset.

For some crops, such as corn grain, sorghum grain or straw, little data are available from California, while large datasets have been compiled elsewhere. In these cases, a sampling strategy could be to sample a small number of fields first to determine whether the values from existing datasets are good estimates for crops harvested in the Central Valley. If this is not the case, additional samples from a larger number of fields may be needed for a representative estimate of their N concentrations in the Central Valley.

For some crops, values from California are available, but the samples were collected decades ago or represent only a very limited number of locations or varieties. In these cases, the dataset should be updated and expanded. For many crops, however, few to no observations are available and a complete dataset needs to be generated.

The variability of the N concentration also affects the sampling protocol. In general, the larger the variability, the more fields need to be included in the sample for a robust and reliable estimate. When the variability across years is high, samples need to be collected over a period of several years for a robust estimate of the average N removed at harvest. By collecting background information, such as variety, N application, yield, fruit size, or location, the major factors affecting N concentrations can be identified. This information will be valuable to guide future improvements and refinements of the database.

*Limitations*

Nitrogen concentrations in harvested crop parts can vary considerably from one year to the next. For a single year, the calculated amount of N removed, and thus the ratio between N applied to N removed, may differ considerably from the actual amount or ratio. The high year-to-year variability supports the Agricultural Expert Panel recommendation to evaluate the annual data on a multi-year basis (ITRC, 2014).

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 an 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).

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. An estimate of N accumulation in perennial tissue needs to be added to the amount of N removed with harvested plant parts.

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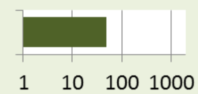
# Alfalfa – Hay

N removal

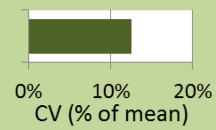
**62.3**

lbs N/ton
@ 12% moisture

**Observations**




**Variability**




## Data sources

Alfalfa hay samples were collected by Peter Robinson, Cooperative Extension Specialist for Dairy Nutrition and Management at UC Davis. A total of 49 samples were taken from commercial dairy farms in California between 1997 and 2011 (Robinson, 2011). The samples were analyzed for crude protein (CP) in the dry matter. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

The dairies were not selected based on their silage quality and the samples were taken fairly recently. Therefore, this set of samples can be considered to represent alfalfa hay quality in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Robinson, 2011 | California | | 1997-2011 | | 49 |
| **Overall** | | | | | **49** |

*Summary statistics of alfalfa hay N removal data.*

| Source | Summary (lbs N/ton @ 12% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Robinson, 2011 | 62.3 | 7.8 | 49.3 - 82.5 | 12.5 |
| **Overall** | **62.3** | **7.8** | **49.3 - 82.5** | **12.5** |

## Variability

While the range is relatively large, with the highest N concentration measured being almost twice as high as the lowest value, the variability is intermediate with a CV of 12.5% of the mean.

The protein concentration of alfalfa decreases with maturity (Putnam et al., 2007). In field trials in northern California, Orloff et al. (2002) found that the CP concentration decreased by 0.2 percent points per day as alfalfa matured from the late vegetative pre-bud stage to full bloom. Crude protein concentration of alfalfa also varies with season. Data collected over 3 years in Fresno County revealed that CP is highest in spring for the first cutting, lowest in summer and intermediate in fall (Putnam et al., 2007).

## Discussion

The dataset used for this report can be considered a very good estimate of alfalfa hay produced in California. However, the samples were taken at the dairy operation and not in the field. Therefore, the hay may have been produced in different regions of the state. In general, alfalfa grown in the Central Valley tends to have a higher N content than alfalfa grown under cooler conditions, such as in the Intermountain area (Putnam, personal communication). To address this issue, the present dataset should be expanded with values from Central Valley fields. To obtain a robust estimate of the average N content of alfalfa hay, samples need to be taken from different cuts over a period of several years.

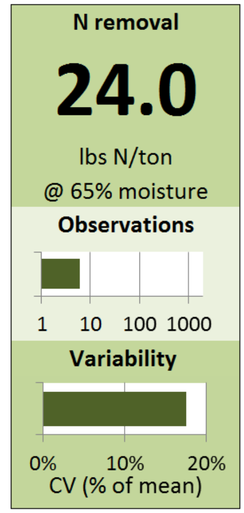
## References


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

Orloff, S.B., Putnam, D.H., Blank, S.C., 2002. Proper harvest timing can improve returns for intermountain alfalfa. California Agriculture 56, 202-207. Available online at: http://calag.ucanr.edu/archive/?article=ca.v056n06p202

Putnam, D.H., Robinson, P., DePeters, E., 2007. Forage Quality and Testing. In: Summers, C.G., Putnam, D.H. (Eds.) Irrigated Alfalfa Management for Mediterranean and Desert Zones. Chapter 16. University of California Agriculture and Natural Resources, Publication 8310. Available online at: http://alfalfa.ucdavis.edu/IrrigatedAlfalfa

# Alfalfa – Silage




## Data sources

Alfalfa silage samples were collected by Peter Robinson, Cooperative Extension Specialist for Dairy Nutrition and Management at UC Davis. A total of 6 samples were taken from commercial dairy farms in California between 1997 and 2011 (Robinson, 2011). The samples were analyzed for crude protein (CP) in the dry matter. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

The dairies were not selected based on their silage quality and the samples were taken fairly recently. Therefore, this set of samples can be considered to represent alfalfa silage quality in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Robinson, 2011 | California | | 1997-2011 | | 6 |
| **Overall** | | | | | **6** |

*Summary statistics of alfalfa silage N removal data.*

| Source | Summary (lbs N/ton @ 65% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Robinson, 2011 | 24.0 | 4.2 | 18.5 - 27.6 | 17.5 |
| **Overall** | **24.0** | **4.2** | **18.5 - 27.6** | **17.5** |

## Variability

The variability is larger than for alfalfa hay, while the range of values is smaller. Both may be due to the smaller number of silage samples included. Factors that contribute to the high variability are growth stage when cut, harvest season and moisture content of the silage. In the samples analyzed by Peter Robinson, the moisture content ranged from 25 to 40%.

## Discussion

The dataset used for this report can be considered a very good estimate of alfalfa silage produced in California. Due to its high moisture content, silage is not transported as far as hay; therefore, it is likely that the silage samples analyzed were harvested in the Central Valley. However, due to the large variability, a larger number of samples is needed for a robust estimate of the average amount of N removed with alfalfa silage. With only six samples, the sample size is currently too small and needs to be increased to improve the confidence in the estimate.

## 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

# Barley – Grain

**N removal**

**33.6**

lbs N/ton
@ 12% moisture

**Observations**


**Variability**


## Data sources

Five data sources contributed to the analysis. Four samples of barley grain were collected from commercial dairy farms in California between 1997 and 2011 by Peter Robinson, Cooperative Extension Specialist for Dairy Nutrition and Management at UC Davis (Robinson, 2011).

The majority of the observations came from two N rate trials conducted in Colorado and Montana. The remaining two studies were carried out in Italy.

## Relevance

Only four of the 61 observations came from California. However, with the exception of Albrizio et al. (2010), the average values for the different sources were very similar. Therefore, the overall mean in the table may be an acceptable estimate of N concentrations found in barley grain harvested in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Robinson, 2011 | California | | 1997-2011 | | 4 |
| Halvorson and Reule, 2007 | Colorado | 1 | 2001-05 | 3 | 18 |
| Sainju et al., 2013 | Montana | 1 | 2006-11 | 6 | 24 |
| Delogu et al., 1998 | Italy | 1 | 19987-89 | 3 | 9 |
| Albrizio et al., 2010 | Italy | 1 | 2006-08 | 3 | 6 |
| **Overall** | | | | | **61** |

*Summary statistics of barley grain N removal data.*

| Source | Summary (lbs N/ton @ 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Robinson, 2011 | 34.6 | 4.7 | 29.0 - 40.6 | 13.7 |
| Halvorson and Reule, 2007 | 33.0 | 4.2 | 27.9 - 44.8 | 12.9 |
| Sainju et al., 2013 | 36.5 | 5.3 | 27.0 - 48.7 | 14.5 |
| Delogu et al., 1998 | 34.1 | 5.8 | 28.4 - 40.0 | 17.0 |
| Albrizio et al., 2010 | 22.2 | 3.7 | 19.6 - 24.9 | 16.8 |
| **Overall** | **33.6** | **4.9** | **19.6 - 48.7** | **14.6** |

## Variability

The variability within individual studies is relatively large. Sainju et al (2013), as well as Delogu et al. (1998) found a strong increase in grain N concentration with increasing N application rate. In contrast, Halvorson and Reule (2007) did not find a clear correlation between N application rate and grain N concentration over the entire six years of the study. In all four studies included, N concentrations varied considerably from one year to the next.

## Discussion

Only few observations from California were available. Even though the average value reported here may be an acceptable estimate of N concentrations found in barley grain harvested in California, it needs to be confirmed with a larger set of samples collected from fields in the Central Valley. As barley grain N concentration can vary considerably from one year to the next, the samples should be taken over a period of several years to get a robust estimate of the average amount of N removed with barley grain.

## References


Albrizio, R., Todorovic, M., Matic, T., Stellaci, A.M., 2010. Comparing the interactive effects of water and nitrogen on durum wheat and barley grown in a Mediterranean environment. Field Crops Research 155, 179-190.

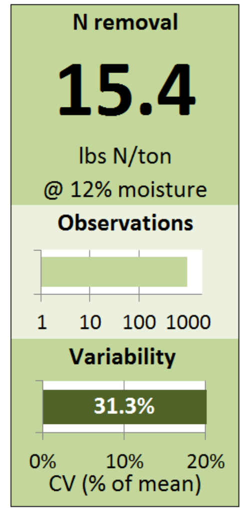
Delogu, G., Cattivelli, L., Pecchioni, N., De Falcis, D., Maggiore, T., Stanca, A.M., 1998. Uptake and agronomic efficiency in winter barley and winter wheat. European Journal of Agronomy 9, 11-20.

Halvorson, A.D., Reule, C.A., 2007. Irrigated, no-till corn and barley response to nitrogen in northern Colorado. Agronomy Journal 99, 1521-1529.

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

Sainju, U.M., Lenssen, A.W., Barsotti, J.L., 2013. Dryland malt barley yield and quality affected by tillage, cropping sequence and nitrogen fertilization. Agronomy Journal 105, 329-340.

# Barley – Straw




## Data sources

The largest dataset included in this report is a compilation of data from analyses performed by the Alberta and Saskatchewan Feed Test Laboratories in Canada (McCartney et al., 2006). The data reported by Mathison et al. (1999) is from a variety trial conducted in Alberta, Canada, which was carried out over two years at three locations. These two datasets combined contributed 97% of the observations. In addition, three other studies from Canada and a dataset from Wisconsin were included. All datasets reported crude protein content of barley straw to assess the nutritive value of straw as an animal feed. For this report, the N concentrations were calculated by dividing crude protein values by 6.25. With the exception of Mathison et al. (1999), the reports did not include information about barley management in the field.

## Relevance

A large proportion of the observations compiled for this analysis are from Canada. None are from California. It is not possible to determine how well these values represent straw from California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Anderson and Hoffman, 2006 | Wisconsin | | | | 3 |
| Horton, 1978 | Canada | 1 | 1977 | 1 | 1 |
| Horton and Seacy, 1979 | Canada | 1 | 1978 | 1 | 3 |
| Kernan et al., 1979 | Canada | 4 | 1975/76 | 2 | 20 |
| Mathison et al., 1999 | Canada | 4 | 1994/95 | 2 | 195 |
| McCartney et al., 2006 | Canada | | 1974-94 | | 748 |
| **Overall** | | | | | **970** |

*Summary statistics of barley straw N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Anderson and Hoffman, 2006 | 12.3 | 4.8 | 6.8 - 15.5 | 39.2 |
| Horton, 1978 | 10.8 | | | |
| Horton and Seacy, 1979 | 10.9 | 4.8 | 7.9 - 16.5 | 44.3 |
| Kernan et al., 1979 | 13.8 | 1.4 | 11.8 - 15.2 | 10.0 |
| Mathison, 1999 | 12.4 | 3.0 | 9.9 - 16.9 | 24.5 |
| McCartney et al., 2006 | 16.3 | 5.3 | | 32.2 |
| **Overall** | **15.4** | **4.83** | **6.8 - 16.9** | **31.3** |

## Variability

As is the case with other types of straw, the N concentration in barley straw is highly variable. In their variety trial, Mathison et al. (1999) found that the differences between locations were largest, with barley type and year also significantly contributing to the overall variability. Another important factor not investigated in the studies included in this report is N fertilization level and N availability.

In a study carried out in the UK, Murozuka et al. (2014) found that the N concentration in wheat straw increased linearly from 5.6 to 12.5 lbs/ton (0.32% to 0.71% in the dry matter) when the N application rate increased from 43 to 257 lbs/acre. A linear increase from 13.4-24.1 lbs N/ton was also observed in rice straw when N fertilization was increased stepwise from 0 to 214 lbs/acre (Nori et al., 2008). The effect of N fertilization on straw N concentration is especially pronounced at high levels, while low N application rates ranging from 0 to 57 lbs/acre have been found to result in only a minor increase in durum wheat straw N concentration (Tolera et al., 2007).

## Discussion

Samples should be collected from Central Valley fields to determine whether the value in this report is a good estimate for the Central Valley. Compared to other commodities, the N concentration in straw varies considerably. Therefore, for a robust average, a large number of samples need to be analyzed. Despite the uncertainty in the value presented here, it is important to note that the amount of N removed with straw is small compared to the N removed with grain. Assuming a harvest index of 0.5 (which means that 50% of the aboveground biomass is in the grains), only about 25% of the total N in the aboveground biomass of barley is in the straw and stubble.

## References


Anderson, T., Hoffman, P., 2006. Nutrient Composition of Straw Used in Dairy Cattle Diets. Focus on Forage 8(1), 1-3. Available online at: http://fyi.uwex.edu/forage/files/2014/01/StrawFOF.pdf

Horton, G.M.J. 1978. The intake and digestibility of ammoniated cereal straws by cattle. Canadian Journal of Animal Science 58, 471-478.

Horton G.M.J. , Steacy, G.M., 1979. Effect of anhydrous ammonia treatment on the intake and digestibility of cereal straws by steers. Journal of Animal Science 48, 1239-1249.

Kernan, J.A., Crowle, W.L., Spurr, D.T. Coxworth, E.C., 1979. Straw quality of cereal cultivars before and after treatment with anhydrous ammonia. Canadian Journal of Animal Science 59, 511-517.

Mathison, G.W., Soofi-Siawash, R., Okine, E.K., Helm, J., Juskiw, P., 1999. Factors influencing composition and ruminal degradability of barley straw. Canadian Journal of Animal Science 79, 343–351.

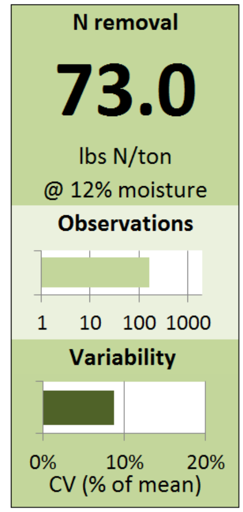
McCartney, D. H., Block, H. C., Dubeski, P. L. and Ohama, A. J. 2006. Review: The composition and availability of straw and chaff from small grain cereals for beef cattle in western Canada. Canadian Journal of Animal Science 86, 443–455.

Murozuka, E., Laursen, K.H., Lindedam, J., Shield, I.F., Bruun, S., Magid, J., Møller, I.S., Schjoerring, J.K., 2014. Nitrogen fertilization affects silicon concentration, cell wall composition and biofuel potential of wheat straw. Biomass and Bioenergy 64, 291.

Nori, H., Halim, R.A., Ramlan, M.F., 2008. Effect of nitrogen fertilization management practice on the yield and straw nutritional quality of commercial rice varieties. Malaysian Journal of Mathematical Sciences 2, 61-71.

Tolera, A., Tsegaye, B., Berg, T., 2008. Effects of variety, cropping year, location and fertilizer application on nutritive value of durum wheat straw. Journal of Animal Physiology and Animal Nutrition 92, 121–130.

# Beans dry, Blackeye (Cowpea)




## Data sources

The USDA Food Composition Database reports an average protein content based on 147 observations and thus has the most influence of any study on the calculated average value. In addition, data from two studies carried out in South Africa and Australia and one value from the NRCS Crop Nutrient Tool were included. The values included here are for mature dry beans. Nitrogen in the pods and foliage are not included. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

About 90% of the values contributing to the average N concentration came from the USDA Nutrient Database. The values are similar to the one reported in the NRCS Crop Nutrient Tool, which is derived from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" (Howard et al., 1962).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Muchow et al., 1993 | Australia | 2 | 1989-90 | 2 | 4 |
| Sebetha et al., 2015 | South Africa | 3 | 2012-13 | 2 | 12 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 147 |
| **Overall** | | | | | **164** |

*Summary statistics of blackeye bean N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Muchow et al., 1993 | 73.2 | 6.3 | 67.6 - 80.6 | 8.6 |
| Sebetha et al., 2015 | 64.1 | 4.7 | 56.3 - 70.7 | 7.3 |
| NRCS Crop Nutrient Tool | 72.8 | | | |
| USDA Food Composition Database | 73.7 | 7.8 | | 10.6 |
| **Overall** | **73.0** | **7.6** | **56.3 - 80.6** | **10.4** |

## Variability

The range of values reported is relatively small. However, no range of the values included in the USDA database is available. With a CV of 6.3% of the mean, the variability of the N concentration reported in the studies and databases included is also relatively small. Sebetha et al. (2005) found that site and year had a stronger effect on bean protein content than N application level.

## Discussion

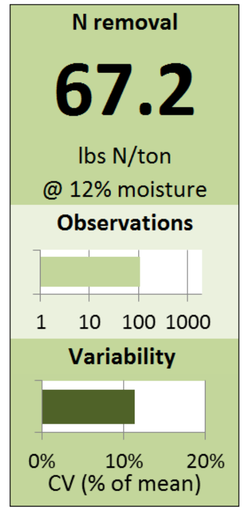
With no recent values from California available, it is not possible to determine whether the observations included in this report are a good estimate of the N concentration in blackeye beans harvested in the Central Valley. A more robust estimate based on a representative sample from the Central Valley is needed.

## References


Muchow, R.C., Robertson, M.J. Pengelly, B.C., 1993. Accumulation and partitioning of biomass and nitrogen by soybean, mungbean and cowpea under contrasting environmental conditions. Field Crops Research 33, 13-36.

Sebetha, E.T., Modi, A.T. Owoeye, L.G., 2015. Cowpea crude protein as affected by cropping system, site and nitrogen fertilization. Journal of Agricultural Science 7, 224-234.

# Beans dry, Garbanzo (Chickpea)




## Data sources

The USDA Food Composition Database contains protein concentrations from garbanzo beans harvested between 2011 and 2012 in the Northern U.S. (Idaho, Montana, North and South Dakota, as well as Washington), compiled by the Northern Pulse Growers Association (http://northernpulse.com/) for the annual Pulse Quality Survey. With 54 observations, this dataset contributes 50% of the observations in our analysis. The other half is from six studies carried out all over the world. The values included here are for mature dry beans. Nitrogen in the pods and foliage are not included. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Lee et al., 2011 | Yolo, CA | 1 | 2006 | 1 | 2 |
| Ayaz et al., 2010 | New Zealand | 1 | 1998-2000 | 2 | 2 |
| Kurdali et al., 1996 | Syria | 1 | 1994 | 1 | 1 |
| López-Bellido et al., 2004 | Spain | 1 | 1996-2001 | 4 | 32 |
| Soltani et al., 2006 | Iran | 1 | 2004 | 1 | 3 |
| Elias and Herridge, 2014 | Australia | 13 | 2006-07 | 2 | 14 |
| USDA Food Composition Database | Northern U.S. | | | | 54 |
| **Overall** | | | | | **108** |

*Summary statistics of garbanzo bean N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Lee et al., 2011 | 58.8 | 2.3 | 57.1 - 60.4 | 3.9 |
| Ayaz et al., 2010 | 49.3 | 3.5 | 46.8 - 51.7 | 7.1 |
| Kurdali et al., 1996 | 71.1 | | | |
| Lopez Bellido et al., 2004 | 67.7 | 3.8 | 63.9 - 72.1 | 5.7 |
| Soltani et al., 2006 | 73.4 | | 51.0 - 95.7 | |
| Elias and Herridge, 2014 | 65.5 | 8.2 | 51.6 - 79.2 | 12.5 |
| USDA Food Composition Database | 65.5 | 9.2 | 53.1 - 72.6 | 14.1 |
| **Overall** | **67.2** | **7.6** | **46.8 - 95.7** | **11.3** |

## Relevance

Only one study from California, contributing two observations is included in the dataset. However, in this study beans were produced under adverse conditions (severe waterlogging; Lee et al., 2011). Therefore, it is not possible to determine the degree to which the average value in the table is representative for garbanzo beans grown in the Central Valley.

## Variability

The variability within individual studies is relatively small. However, across all studies, the range of values reported is relatively large. In a study carried out over two years at 7 sites, both year and site contributed to the variability (Elias and Herridge, 2014). A study carried out in Spain found little effect of N fertilization levels, ranging from 0 to 130 lbs/acre on bean protein content (López-Bellido et al., 2004).

## Discussion

With the data available it is not possible to determine whether the observations included in this report are a good estimate of the N concentration in garbanzo beans harvested in the Central Valley. Only one study from California, which was conducted under atypical conditions, is included here. Therefore, a more robust estimate based on a representative sample from the Central Valley is needed.

## References

Ayaz, S., McKenzie, B.A., Hill, G.D. McNeil, D.L., 2004. Nitrogen distribution in four grain legumes. Journal of Agricultural Science 142, 309–317.

Elias, N.V., Herridge, D.F., 2014.Crop-available water and agronomic management, rather than nitrogen supply, primarily determine grain yield of commercial chickpea in northern New South Wales. Crop & Pasture Science, 65, 442–452.

Kurdali, F., 1996. Nitrogen and phosphorus assimilation, mobilization and partitioning in rainfed chickpea (*Cicer arietinum* L.). Field Crops Research 47, 81-92.

Lee, J., Six, J., van Kessel, C., 2011. Dinitrogen fixation by winter chickpea across scales in waterlogged soil in a Mediterranean climate. Journal of Agronomy & Crop Science 197, 135-145.

López-Bellido, R.J., López-Bellido, L., Castillo, J.E., López-Bellido, F.J., 2004. Chickpea response to tillage and soil residual nitrogen in a continuous rotation with wheat II. Soil nitrate, N uptake and influence on wheat yield. Field Crops Research 88, 201–210.

Soltani, A., Robertson, M.J., Manschadi, A.M., 2006. Modeling chickpea growth and development: Nitrogen accumulation and use. Field Crops Research 99, 24–34.

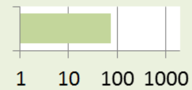
# Beans dry, Lima

N removal

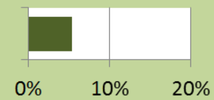
**72.3**

lbs N/ton
@ 12% moisture

**Observations**




**Variability**




## Data sources

The USDA Food Composition Database reports average protein concentration of raw mature lima bean seeds based on 49 samples entered into the database before 1986. A value for lima beans is also included in the NRCS Crop Nutrient Tool, most likely taken from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" (Howard et al., 1962). In addition, two studies carried out in Egypt and Syria contributed a total of 25 observations and one value from Peter Robinson was included. The values included here are for mature dry beans. Nitrogen in the pods and foliage are not included. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

While beans sold in the U.S. contribute two thirds of the samples included in this analysis, only two samples are known to be from California (Robinson, 2011, NRCS Crop Nutrient Tool). However, as most U.S lima beans are grown in California and imports are small (USDA ERS), the USDA Food Composition Database most likely includes many samples from California. Therefore, the value in the table may be reasonable estimate of N in lima beans harvested in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Robinson, 2011 | California | 1 | 1997/2011 | 1 | 1 |
| El Sheikh et al., 2012 | Egypt | 1 | 2008/09 | 2 | 24 |
| USDA Food Composition Database | | | | | 49 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **75** |

*Summary statistics of lima bean N removal data.*

| Source | Summary (lbs N/ton @ 12% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Robinson, 2011 | 65.3 | | | |
| El Sheikh et al., 2012 | 83.2 | 5.1 | 75.7 – 90.0 | 6.1 |
| USDA Food Composition Database | 67.3 | 3.2 | | 4.7 |
| NRCS Crop Nutrient Tool | 63.3 | | | |
| **Overall** | **72.3** | **3.90** | **63.3 – 90.0** | **5.4** |

### Variability

Bean seed N concentration does not vary much, the overall CV being 5% of the mean. However, the N concentration in the beans harvested in Egypt is about 20% higher than the values reported by Peter Robinson (2011) and in the two databases from the U.S. This may be due to different varieties or crop management.

High fertilizer N application rates moderately increase N concentrations in bean seeds. El Sheikh et al. (2012) found that the N concentration in lima bean seeds increased by 12-15% when the N application N rate was increased from 106 to 218 lbs/acre.

### Discussion

The samples collected in the U.S. have similar N concentrations, while the beans grown in Egypt and Syria have higher N concentrations. The value in the table may be reasonable estimate of N in lima beans harvested in California. However, a more robust estimate based on a representative sample from the Central Valley is needed.

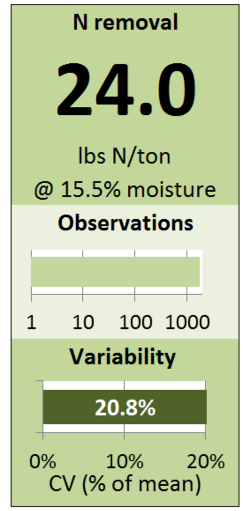
### References

El-Shaikh, K.A.A., Obiadalla-Ali, H.A., Glala, A.A.A., El-Abd, S.O., 2012. Productivity and quality of lima bean grown in sandy soil as affected by plant densities and NPK applications. Acta Horticulturae 936, 311-319.

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

USDA, ERS. Available online at: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1394

# Corn – Grain




## Data sources

Ciampitti and Vyn (2012) synthesized data from 100 published studies, MS theses and dissertations. Of these, 63 studies were from studies in the USA. The authors divided their dataset into an old and new era. A total of 1775 observations from experiments between 1991 and 2011, the new era, were included in this report. It's unlikely that studies completed in California contributed to the dataset as we could not find published California studies reporting N concentrations in corn grains.

## Relevance

The average amount of N removed with corn grain is 24 lbs/ton at a moisture content of 15.5%. For comparison, the NRCS Crop Nutrient Tool estimates the amount of N removed to be 27.8 lbs/ton. With no information available from California, it is not possible to determine the degree to which these values are representative of corn grains harvested in California.

### Variability

The analysis of the data from Ciampitti and Vyn (2012) reveals that corn grain N concentrations vary considerably. However, half the values in their study were between 21.0 and 27.2 lbs N/ton. As their dataset included values from around the world, the wide range is at least partly due to a presumably large number of varieties included, diverse cropping systems and widely differing N application rates. Within California, these factors will likely vary much less.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Site x Years |
|---|---|---|---|---|---|
| | Location | n | Years | n | n |
| Ciampitti and Vyn, 2012 | Global | | 1991-2011 | | 1775 |
| Overall | | | | | 1775 |

*Summary statistics of corn grain N removal data.*

| Source | Summary (lbs N/ton @ 15.5% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Ciampitti and Vyn, 2012 | 24.0 | 5.0 | 6.0 - 53.6 | 20.8 |
| **Overall** | **24.0** | **5.0** | **6.0 - 53.6** | **20.8** |

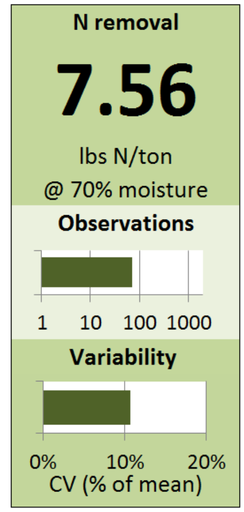
## Discussion

Corn grain samples should be collected from Central Valley fields to determine whether the value in this report is a good estimate for California. With small grains, N application rate and variety both influence grain N concentration, and concentrations can differ considerably between one year and the next. It is likely that these factors also affect corn grain N concentration. Therefore, samples should be taken from fields in the major growing areas of the Central Valley over a period of several years.

## References

Ciampitti, I.A., Vyn, T.J., 2012. Physiological perspectives of changes over time in maize yield dependency on nitrogen uptake and associated nitrogen efficiencies: A review. Field Crops Research 133, 48–67.

# Corn – Silage




## Data sources

A total of 71 observations from two 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.

*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 |
| **Overall** | | | | | **72** |

*Summary statistics of corn silage N removal data.*

| Source | Summary (lbs N/ton @ 70% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| 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 |
| **Overall** | **7.56** | **0.80** | **5.0 - 10.4** | **10.5** |

## Relevance

As the dairy farms were not selected based on their silage quality, this set of samples can be considered a very good estimate of corn silage quality in California.

## Variability

The variability of the data is intermediate with a CV of 10.6% 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 is the moisture content of the silage, since it ranged from 60 to 81% in the two datasets.

## Discussion

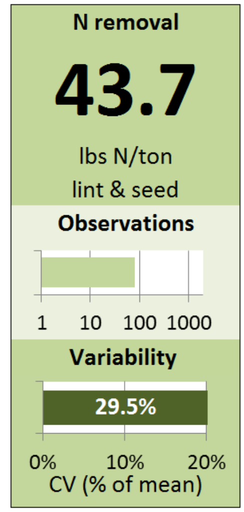
Since the samples were recently collected from dairy farms in the Central Valley, they can be considered a very good estimate of Central Valley corn silage. With a total of 71 samples, the sample size is relatively large.

## 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




## Data sources

The main source of data is from an N rate trial carried out at different locations in Fresno and Kings County between 1998 and 2000 (Fritschi et al., 2003, 2004). Both Pima and Acala cotton varieties were included. Result from three other studies, carried out in Israel, Greece and Syria were also included in this report.

## Relevance

The California study has been carried out at several locations in the main cotton growing area of the Central Valley. Its results can be considered a very 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, 2004b | California | 2 | 1998-2000 | 3 | 20 |
| Halevy et al., 1987 | Israel | 1 | 1980-85 | 5 | 25 |
| **Pima** | | | | | |
| Fritschi et al., 2003, 2004b | California | 1 | 1999-2000 | 2 | 7 |
| **Other studies** | | | | | |
| Stamatiadis et al., 2016 | Greece | 1 | 2008/09 | 2 | 18 |
| Janat, 2008 | Syria | 1 | 2011 | 1 | 10 |
| **Overall** | | | | | **80** |

*Summary statistics of cotton N removal data.*

| Source | Summary (lbs N/ton lint & seed) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| **Acala** | | | | |
| Fritschi et al., 2003, 2004b | 47.3 | 9.6 | 26.3 - 63.2 | 20.2 |
| Halevy et al., 1987 | 47.4 | 7.3 | 39.5 - 54.5 | 15.5 |
| **Pima** | | | | |
| Fritschi et al., 2003, 2004b | 33.1 | 6.9 | 23.3 - 41.0 | 20.9 |
| **Other studies** | | | | |
| Stamatiadis et al., 2016 | 44.8 | 1.7 | 43.0 - 46.4 | 3.8 |
| Janat, 2008 | 32.6 | 1.5 | 30.5 - 35.1 | 4.5 |
| **Overall** | **43.7** | **12.9** | **23.3 - 63.2** | **29.5** |

*Summary statistics of cotton N removal data expressed in lbs N/ ton of lint.*

| | Summary (lbs N/ton lint) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| **Overall** | **120** | **36.2** | **67.9 - 183.8** | **30.2** |

## Variability

Suboptimal N availability can result in lower N concentrations in cotton seeds (Halevy et al., 1976). In contrast, Fritschi et al. (2004) did not find a clear effect of N level, ranging from 0 to 200 lbs/acre in their study carried out in Fresno and Kings county. The data suggests that the N concentration in Pima cotton may be lower than that of Acala cotton. However, a paired comparison did not indicate a significant difference. With only seven observations where both types were grown in the same year at the same location, the dataset for this comparison was very small.

## Discussion

When cotton is harvested, lint and seeds are removed from the field. Across all datasets, 43.7 lbs N were removed from the field per ton of lint and seed. When yield is expressed in tons of lint, about 120 lbs are removed from the field. This conversion is based on the average gin turnout reported in these studies of 36.8%. The values reported in the California study can be considered a good estimate of N concentration in California cotton. However, given the large variability of the data, the sample size is rather small. Therefore, additional samples need to be taken over a period of several years from fields located in the main growing areas in the Central Valley to generate a robust estimate of the N removed per unit yield and provide information about the dominant factors contributing to the variability of this estimate. A larger dataset is also needed to determine whether Acala and Pima cotton truly 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.

Halvey, J. 1976. Growth rate and nutrient uptake of two cotton cultivars grown under irrigation. Agronomy Journal 68, 701-705.

Janat, M., 2008. Response of Cotton to Irrigation Methods and Nitrogen Fertilization: Yield Components, Water-Use Efficiency, Nitrogen Uptake, and Recovery, Communications in Soil Science and Plant Analysis 39, 2282-2302.

Stamatiadis, S., Tsadilas, C., Samaras, V., Schepers, J.S., Eskridge, K., 2016. Nitrogen uptake and N-use efficiency of Mediterranean cotton under varied deficit irrigation and N fertilization. European Journal of Agronomy 73, 144-151.

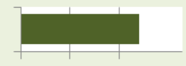
# Fescue, tall – Hay

N removal

**50.8**

lbs N/ton
@ 12% moisture

Observations




Variability


## Data sources

The data are from a UC Davis cool season grass trial carried out between fall 2005 and 2008 in Davis. The trial included 26 tall fescue varieties. Each year, the grasses were cut 3-4 times and analyzed for crude protein. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

The trial was carried out in Davis with a large number of relevant varieties over a period of three years. The trial was fertilized for maximum yield. As growers often tend to underfertilize hayfields, the average value in the table may overestimate the N concentrations found in tall fescue hay produced in the Central Valley (Putnam, personal communication).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| UC Davis Grass Cultivar Trial | | | | | |
| Cut: May 23 | Davis | 1 | 2006 | 1 | 26 |
| Cut: June 22 | Davis | 1 | 2006 | 1 | 26 |
| Cut: Aug. 28 | Davis | 1 | 2006 | 1 | 26 |
| Cut: May 15 | Davis | 1 | 2007 | 1 | 26 |
| Cut: June 22 | Davis | 1 | 2007 | 1 | 26 |
| Cut: July 30 | Davis | 1 | 2007 | 1 | 26 |
| Cut: Aug. 28 | Davis | 1 | 2007 | 1 | 26 |
| Cut: April 18 | Davis | 1 | 2008 | 1 | 26 |
| Cut: May 20 | Davis | 1 | 2008 | 1 | 26 |
| Cut: Aug. 8 | Davis | 1 | 2008 | 1 | 26 |
| **Overall** | | **1** | **2006-2008** | **3** | **260** |

## Variability

Several factors contribute to the variability of hay N concentrations, including variety, growth stage when cut, season, N fertilization level, and environmental conditions (e.g. soil type, location and weather). In the cool season grass trial, year of study (which is mainly experienced by the crop as weather variability), season when cut and variety had strong effects on N concentration in the hay. With a CV of 16.2% of the mean the variability was relatively high, especially when considering that the trial was carried out at only one location with uniform N management and likely optimal cutting stage. It can be expected that the variability among samples collected from growers' fields is much larger, especially due to the differences in N management and cutting stage.

*Summary statistics of tall fescue hay N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| UC Davis Grass Cultivar Trial | | | | |
| Cut: May 23 | 55.8 | 4.88 | 49.0 - 65.0 | 8.8 |
| Cut: June 22 | 59.6 | 4.08 | 48.7 - 67.0 | 6.9 |
| Cut: Aug. 28 | 61.8 | 4.41 | 54.6 - 70.1 | 7.1 |
| Cut: May 15 | 54.4 | 5.48 | 47.6 - 65.6 | 10.1 |
| Cut: June 22 | 43.4 | 5.78 | 33.7 - 56.3 | 13.3 |
| Cut: July 30 | 50.4 | 6.72 | 40.0 - 65.3 | 13.3 |
| Cut: Aug. 28 | 53.2 | 4.10 | 44.5 - 62.5 | 7.7 |
| Cut: April 18 | 43.4 | 2.92 | 37.2 - 47.9 | 6.7 |
| Cut: May 20 | 43.1 | 3.37 | 36.0 - 48.7 | 7.8 |
| Cut: Aug. 8 | 43.5 | 3.67 | 37.7 - 49.8 | 8.4 |
| **Overall** | **50.8** | **8.24** | **33.7 - 70.1** | **16.2** |

## Discussion

Having been fertilized for maximum yield, the trial results may somewhat overestimate the average N concentration in tall fescue hay produced in the Central Valley. The results may not fully capture the variability of hay produced in growers' fields in the Central Valley, as factors such as N application rate and growth stage when harvested vary much more in growers' fields. A relatively large number of samples would need to be collected from multiple fields across the Central Valley over a period of several years for a good assessment of the range of N concentration found in hay produced in the Central Valley.

## References

UC Davis cool season grass trial. Available online at:
http://alfalfa.ucdavis.edu/+producing/files/CoolSeasonGrassTRIAL0608.pdf

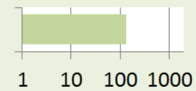
# Oat – Grain

N removal

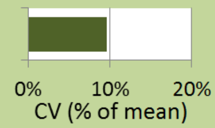
**37.7**

lbs N/ton
@ 12% moisture

**Observations**




**Variability**




## Data sources

Four studies from the U.S., Canada and Germany were included for this analysis. The total number of observations is 134, with the two studies from Pennsylvania and Canada contributing more than 90% of the observations.

## Relevance

The dataset does not include observations from California. It is therefore not possible to determine how well these values represent N concentrations in oat grains grown in the Central Valley.

## Variability

Buckley et al. (2010) conducted a study in Manitoba at two locations over two years with three varieties and four N levels. Location had by far the strongest effect on the observed differences in N concentrations, followed by N application rate. In contrast, Youngs (1972) found large differences among varieties.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Marshall and Kolb, 1986 | Pennsylvania | 2 | 1974-75 | 2 | 64 |
| Youngs, 1972 | Wisconsin | 1 | 1970 | 1 | 7 |
| Buckley et al., 2010 | Canada | 2 | 2001-02 | 2 | 60 |
| Franke et al., 1999 | Germany | 1 | 1998 | 1 | 3 |
| **Overall** | | | | | **134** |

*Summary statistics of oat grain N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Youngs, 1972 | 36.1 | 7.7 | 29.3 - 47.9 | 21.3 |
| Marshall and Kolb, 1986 | 42.0 | 3.5 | 34.6 - 50.7 | 8.3 |
| Buckley et al., 2010 | 33.2 | 3.0 | 26.5 - 38.9 | 9.0 |
| Franke et al., 1999 | 39.4 | 5.3 | 34.3 - 44.8 | 13.4 |
| **Overall** | **37.7** | **3.61** | **26.5 - 50.7** | **9.6** |

## Discussion

The values in the table may not be representative of oat grown in California. Samples need to be taken over a period of several years from fields located in the main growing areas in the Central Valley to generate a robust estimate of the N removed per unit yield and provide information about the dominant factors contributing to the variability of the estimate.

## References

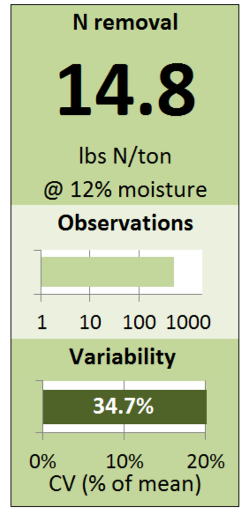
Buckley, K.E., Mohr, R.M., Therrien, M.C., 2010. Yield and quality of oat in response to varying rates of swine slurry. Canadian Journal of Plant Science 90, 645-653.

Franke, C., Dänicke, S., Kluge, H., Jeroch H., 1999. Inhaltsstoffe und Futterwert von Hafer aus dem mitteldeutschen Anbaugebiet für Broiler. Archiv für Geflügelkunde 63, 204-207.

Marshall, H.G. and Kolb, F.L., 1986. Relationships among grain quality indicators in oats. Crop Science 26, 800-804.

Youngs, V.L., 1972. Protein distribution in the oat kernel. Cereal Chemistry 49, 407-411.

# Oat – Straw




## Data sources

Datasets from California, Wisconsin and Canada were included, with more than 98% of the 526 observations being from Canada. All datasets reported crude protein content of oat straw in order to assess the nutritive value of straw as an animal feed. For this report, the N concentrations were calculated by dividing crude protein values by 6.25. The reports did not include information that would allow analysis of the effects of crop management on crude protein.

## Relevance

With no information available on crop management and only two observations from California, it is not possible to determine the degree to which these values represent oat straw produced in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Robinson, 2011 | California | 2 | 1997-2011 | | 2 |
| Anderson and Hoffman, 2006 | Wisconsin | | | | 9 |
| Horton, 1978 | Canada | | 1977 | 1 | 1 |
| Horton and Seacy, 1979 | Canada | | 1978 | 1 | 3 |
| Kernan et al., 1979 | Canada | 4 | 1975/76 | 2 | 12 |
| McCartney et al., 2006 | Canada | | 1974-94 | | 499 |
| **Overall** | | | | | **526** |

*Summary statistics of oat straw N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Robinson, 2011 | 15.2 | 11.2 | 7.3 - 23.1 | 73.3 |
| Anderson and Hoffman, 2006 | 13.5 | 4.3 | 7.0 – 20.0 | 31.6 |
| Horton, 1978 | 6.1 | | | |
| Horton and Seacy, 1979 | 7.3 | 0.6 | 6.7 - 7.7 | 7.8 |
| Kernan et al., 1979 | 10.9 | 0.6 | 10.4 - 11.5 | 5.4 |
| McCartney et al., 2006 | 15.0 | 5.2 | | |
| **Overall** | **14.8** | **5.2** | **6.1 - 23.1** | **34.7** |

## Variability

As is the case with other types of straw, the N concentration in oat straw is highly variable. Horton and Seacy (1979) and Kernan et al. (1979) found differences between oat varieties. A dominant factor contributing to the variability is N fertilization level and overall N availability. See **barley straw** for a more detailed discussion about the effects of N availability on straw N content.

## Discussion

Samples should be collected from Central Valley fields to determine whether the average value of this analysis is a good estimate for California. Compared to other commodities, the N concentration in straw varies considerably. Therefore, for a robust average, a large number of samples need to be analyzed. Despite the uncertainty in the value presented here, it is important to note that the amount of N removed with straw is small compared to the N removed with grain. Assuming a harvest index of 0.5 (which means that 50% of the aboveground biomass is in the grains), only about 20% of the total N in the aboveground biomass of oat is in the straw and stubble.

## References


Anderson, T., Hoffman, P., 2006. Nutrient Composition of Straw Used in Dairy Cattle Diets. Focus on Forage 8(1), 1-3. Available online at: http://fyi.uwex.edu/forage/files/2014/01/StrawFOF.pdf

Horton, G.M.J. 1978. The intake and digestibility of ammoniated cereal straws by cattle. Canadian Journal of Animal Science 58, 471-478.

Horton G.M.J. , Steacy, G.M., 1979. Effect of anhydrous ammonia treatment on the intake and digestibility of cereal straws by steers. Journal of Animal Science 48, 1239-1249.

Kernan, J.A., Crowle, W.L., Spurr, D.T. Coxworth, E.C., 1979. Straw quality of cereal cultivars before and after treatment with anhydrous ammonia. Canadian Journal of Animal Science 59, 511-517.

McCartney, D. H., Block, H. C., Dubeski, P. L. and Ohama, A. J. 2006. Review: The composition and availability of straw and chaff from small grain cereals for beef cattle in western Canada. Canadian Journal of Animal Science 86, 443–455.

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

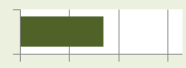
# Oat – Hay

N removal

**21.7**

lbs N/ton
@ 12% moisture

**Observations**




**Variability**


## Data sources

Values from two sources were included in the report. From 1997 to 2011, Peter Robinson, Cooperative Extension Specialist for Dairy Nutrition and Management at UC Davis, collected samples from commercial dairy farms (Robinson, 2011). Second, a UC Davis variety trial was carried out in 1999 at three sites in Yolo and Kings County (Qualset et al., 2012). At each site, 13 to 14 new and traditional varieties were grown and harvested at two to three different stages, ranging from Feekes stage 10.4 to 10.9 (heading ¾ complete to kernels watery ripe). Both reports contained values for crude protein in the dry matter. For this report, the N concentrations were calculated by dividing crude protein values by 6.25. The statistical analyses in this report were performed on the average crude protein contents of the different harvest stages.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Qualset et al., 2012 | California | 2 | 1999 | 1 | 40 |
| Robinson, 2011 | California | | 1997-2011 | | 9 |
| **Overall** | | | | | **49** |

*Summary statistics of oat hay N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Qualset et al., 2012 | 22.2 | 4.1 | 16.3 - 29.3 | 18.4 |
| Robinson, 2011 | 19.3 | 3.3 | 14.6 - 25.6 | 17.0 |
| **Overall** | **21.7** | **4.0** | **14.6 - 29.3** | **18.2** |

## Relevance

The dataset includes values from different locations in California and relevant varieties. Therefore, the average N concentration of the dataset in the table can be considered a good estimate of N concentrations found in oat hay produced in the Central Valley, as varieties and crop management are likely similar across the valley.

## Variability

The variability within each of the two datasets is relatively large. Several factors contribute to the variability of hay N contents, including variety, growth stage and season when cut, N fertilization level, and environmental conditions (e.g. soil type, location and weather). In the UC variety trial, the N concentration dropped by 25-30% between stage 10.4 and 10.9, indicating that the growth stage at which hay is harvested has a large impact on N concentration (Qualset et al., 2012).

## Discussion

The two datasets combined provide a good estimate of the average N concentration in oat hay produced in the Central Valley. To improve the estimate, a relatively large number of samples would need to be collected from different fields across the Central Valley over a period of several years.

## 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

Qualset C.O., Zwer P.K., Federizzi L., Heaton J., Vogt H.E., Jackson L.F., Putnam D., 2012. Enhancing diversity and productivity of the California oat crop: eight new varieties. Agronomy Progress Report No. 305. Available online at: http://oatnews.org/oatnews_pdfs/2016etc/EightOats_and_cover_PltSciences_Aug202015.pdf

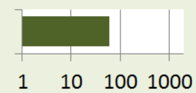
# Orchard Grass – Hay

N removal

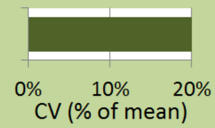
**54.5**

lbs N/ton
@ 12% moisture

**Observations**




**Variability**




### Data sources

The data is from a UC Davis cool season grass trial carried out between fall 2005 and 2008 in Davis. The trial included 6 orchard grass varieties. Each year, the grasses were cut 3-4 times and analyzed for crude protein. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

### Relevance

The trial was carried out in Davis with a large number of relevant varieties over a period of three years. The trial was fertilized for maximum yield. As growers often tend to underfertilize hayfields, the average value in the table may overestimate the N concentrations found in tall fescue hay produced in the Central Valley (Putnam, personal communication).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| UC Davis Grass Cultivar Trial | | | | | |
| Cut: May 23 | Davis | 1 | 2006 | 1 | 6 |
| Cut: June 22 | Davis | 1 | 2006 | 1 | 6 |
| Cut: Aug. 28 | Davis | 1 | 2006 | 1 | 6 |
| Cut: May 15 | Davis | 1 | 2007 | 1 | 6 |
| Cut: June 22 | Davis | 1 | 2007 | 1 | 6 |
| Cut: July 30 | Davis | 1 | 2007 | 1 | 6 |
| Cut: Aug. 28 | Davis | 1 | 2007 | 1 | 6 |
| Cut: April 18 | Davis | 1 | 2008 | 1 | 6 |
| Cut: May 20 | Davis | 1 | 2008 | 1 | 6 |
| Cut: Aug. 8 | Davis | 1 | 2008 | 1 | 6 |
| **Overall** | | **1** | **2006-2008** | **3** | **60** |

### Variability

Several factors contribute to the variability of hay N concentrations, including variety, growth stage when cut, season, N fertilization level, and environmental conditions (e.g. soil type, location and weather). In the cool season grass trial, year of study (which is mainly experienced by the crop as weather variability), season when cut and variety had strong effects on N concentration in the hay. With a CV of 20% of the mean the variability was relatively high, especially when considering that the trial was carried out at only one location with uniform N management and likely was cut at the optimal stage. It can be expected that the variability among samples collected from growers' fields is much larger, especially due to the differences in N management and cutting stage.

*Summary statistics of orchard grass hay N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| UC Davis Grass Cultivar Trial | | | | |
| Cut: May 23 | 65.7 | 4.86 | 58.9 - 70.1 | 7.4 |
| Cut: June 22 | 66.7 | 5.69 | 60.5 - 73.8 | 8.5 |
| Cut: Aug. 28 | 72.0 | 3.76 | 65.6 - 76.3 | 5.2 |
| Cut: May 15 | 54.6 | 6.24 | 50.1 - 67.0 | 11.4 |
| Cut: June 22 | 43.4 | 4.24 | 39.7 - 49.6 | 9.8 |
| Cut: July 30 | 48.4 | 6.83 | 42.0 - 61.4 | 14.1 |
| Cut: Aug. 28 | 52.6 | 6.14 | 46.2 - 60.5 | 11.7 |
| Cut: April 18 | 53.4 | 2.67 | 48.7 - 56.6 | 5.0 |
| Cut: May 20 | 42.7 | 3.27 | 38.0 - 47.9 | 7.7 |
| Cut: Aug. 8 | 45.4 | 2.59 | 41.7 - 48.7 | 5.7 |
| **Overall** | **54.5** | **10.88** | **38.0 - 76.3** | **20.0** |

## Discussion

Having been fertilized for maximum yield, the trial results may somewhat overestimate the average N concentration in orchard grass hay produced in the Central Valley. The results may not fully capture the variability of hay produced in growers' fields in the Central Valley, as factors such as N application rate and growth stage when harvested vary much more in growers' fields. A relatively large number of samples would need to be collected from a large number of fields across the Central Valley over a period of several years for a good assessment of the range of N concentrations found in hay produced in the Central Valley.

## References

UC Davis cool season grass trial. Available online at: http://alfalfa.ucdavis.edu/+producing/files/CoolSeasonGrassTRIAL0608.pdf

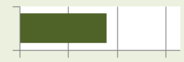
# Perennial Ryegrass – Hay

N removal

**54.9**

lbs N/ton
@ 12% moisture

**Observations**




**Variability**


## Data sources

The data is from a UC Davis cool season grass trial carried out between fall 2005 and 2008 in Davis. The trial included 6 perennial ryegrass varieties. Each year, the grasses were cut 3-4 times and analyzed for crude protein. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

The trial was carried out in Davis with a large number of relevant varieties over a period of three years. The trial was fertilized for maximum yield. As growers often tend to underfertilize hayfields, the average value in the table may overestimate the N concentrations found in tall fescue hay produced in the Central Valley (Putnam, personal communication).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| UC Davis Grass Cultivar Trial | | | | | |
| Cut: May 23 | Davis | 1 | 2006 | 1 | 6 |
| Cut: June 22 | Davis | 1 | 2006 | 1 | 6 |
| Cut: Aug. 28 | Davis | 1 | 2006 | 1 | 6 |
| Cut: May 15 | Davis | 1 | 2007 | 1 | 6 |
| Cut: June 22 | Davis | 1 | 2007 | 1 | 6 |
| Cut: July 30 | Davis | 1 | 2007 | 1 | 6 |
| Cut: Aug. 28 | Davis | 1 | 2007 | 1 | 6 |
| Cut: April 18 | Davis | 1 | 2008 | 1 | 6 |
| Cut: May 20 | Davis | 1 | 2008 | 1 | 6 |
| Cut: Aug. 8 | Davis | 1 | 2008 | 1 | 6 |
| **Overall** | | **1** | **2006-2008** | **3** | **60** |

## Variability

Several factors contribute to the variability of hay N concentrations, including variety, growth stage when cut, season, N fertilization level, and environmental conditions (e.g. soil type, location and weather). In the cool season grass trial, year of study (which is mainly experienced by the crop as weather variability), season when cut and variety had strong effects on N concentration in the hay. With a CV of 16.2% of the mean the variability was relatively high, especially when considering that the trial was carried out at only one location with uniform N management and likely optimal cutting stage. It can be expected that the variability among samples collected from growers' fields is much larger, especially due to the differences in N management and cutting stage.

*Summary statistics of perennial ryegrass hay N removal data.*

| Source | Summary (lbs/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| UC Davis Grass Cultivar Trial | | | | |
| Cut: May 23 | 63.3 | 5.02 | 58.0 - 71.8 | 7.9 |
| Cut: June 22 | 60.3 | 2.87 | 56.9 - 65.0 | 4.8 |
| Cut: Aug. 28 | 71.8 | 4.35 | 64.8 - 75.8 | 6.1 |
| Cut: May 15 | 53.7 | 3.59 | 49.6 - 58.9 | 6.7 |
| Cut: June 22 | 43.1 | 4.44 | 36.2 - 48.2 | 10.3 |
| Cut: July 30 | 52.5 | 7.13 | 46.5 - 63.9 | 13.6 |
| Cut: Aug. 28 | 54.4 | 4.72 | 46.5 - 60.8 | 8.7 |
| Cut: April 18 | 51.2 | 4.47 | 43.9 - 55.5 | 8.7 |
| Cut: May 20 | 45.6 | 2.28 | 42.5 - 49.6 | 5.0 |
| Cut: Aug. 8 | 53.3 | 7.52 | 38.9 - 60.5 | 14.1 |
| **Overall** | **54.9** | **9.21** | **36.2 - 75.8** | **16.8** |

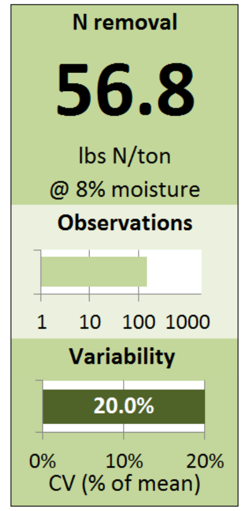
## Discussion

Having been fertilized for maximum yield, the trial results may somewhat overestimate the average N concentration in tall perennial ryegrass hay produced in the Central Valley. The results may not fully capture the variability of hay produced in growers' fields in the Central Valley, as factors such as N application rate and growth stage when harvested vary much more in growers' fields. A relatively large number of samples would need to be collected from a large number of fields across the Central Valley over a period of several years for a good assessment of the range of N concentration found in hay produced in the Central Valley.

## References


UC Davis cool season grass trial. Available online at: http://alfalfa.ucdavis.edu/+producing/files/CoolSeasonGrassTRIAL0608.pdf

# Safflower




## Data sources

Seven studies reporting N in safflower seeds were identified and included. One study from California, carried out at UC Davis, was included. Nitrogen removal data for this study was obtained directly from the lead author. Two studies were carried out in Montana, two in Greece and one in Iran. A study comparing the seed composition of different varieties was also included (Guggolz et al., 1968). While the authors are from California, the origin of the seeds is not clear. One value from the NRCS Crop Nutrient Tool was also included for a total of 149 observations.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Cavero et al., 1999 | California | 1 | 1994-95 | 2 | 12 |
| Haby et al., 1982 | Montana | 2 | 1977-78 | 2 | 24 |
| Lenssen et al., 2007 | Montana | 1 | 2000-03 | 4 | 8 |
| Guggolz et al., 1968 | | | 1967 | | 48 |
| Koutroubas et al, 2004 | Greece | 1 | 1998-99 | 2 | 20 |
| Dordas and Sioulas, 2009 | Greece | 1 | 2004-05 | 2 | 12 |
| Shahrokhnia and Sepaskhah, 2016 | Iran | 1 | 2013-14 | 2 | 24 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **149** |

*Summary statistics of safflower N removal data.*

| Source | Summary (lbs N/ton at 8% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Cavero et al., 1999 | 48.8 | 7.1 | 34.8 - 58.6 | 14.6 |
| Haby et al., 1982 | 63.1 | 7.2 | 48.9 - 71.2 | 11.4 |
| Lenssen et al., 2007 | 59.5 | 2.9 | 57.0 - 63.7 | 4.9 |
| Guggolz et al., 1968 | 54.9 | 6.4 | 45.3 - 66.2 | 11.6 |
| Koutroubas et al, 2004 | 77.2 | 25.5 | 47.2 - 109.3 | 33.0 |
| Dordas and Sioulas, 2009 | 40.6 | 6.1 | 33.8 - 45.7 | 15.1 |
| Shahrokhnia and Sepaskhah, 2016 | 49.0 | 6.1 | 36.6 - 59.4 | 12.5 |
| NRCS Crop Nutrient Tool | 49.2 | | | |
| **Overall** | **56.8** | **11.4** | **33.8 - 109.3** | **20.0** |

## Relevance

One study from California, carried out at one site, was included. The N concentration in this study was lower than the average across all studies included in this analysis. Therefore, the average value reported here may not be representative of N concentrations in safflower seeds from California.

## Variability

The variability within and among studies was uncharacteristically large for a crop where only seeds are harvested. Year of harvest has a very strong effect on N concentration in safflower seeds. Increasing N application rates also tends to result in higher N concentrations in the seeds (Haby et al., 1982; Dordas and Sioulas, 2009; Shahrokhnia and Sepaskhah, 2016). Differences among varieties were also observed (Guggolz et al., 1968; Koutroubas et al, 2004).

## Discussion

The N concentration in safflower seeds can vary considerably. With only one study available from California, it is not possible to determine how well these values represent safflower N removal from California. Samples should be collected from Central Valley fields to determine whether the value in this report is a good estimate for safflower harvested in the Central Valley. For a robust estimate, samples need to be taken over a period of several years.

## 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.

Dordas, C.A., Sioulas, C., 2009. Dry matter and nitrogen accumulation, partitioning, and retranslocation in safflower (*Carthamus tinctorius* L.) as affected by nitrogen fertilization. Field Crops Research 110, 35-43.

Guggolz, J., Rubis, D.D., Herring, V.V., Palter, R., Kohler, G.O., 1968. Composition of several types of safflower seed. Journal of the American Oil Chemists Society 45, 689-693.

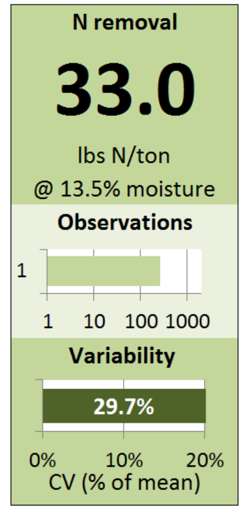
Haby, V.A., Black, A.L., Bergman, J.W., Larson, R.A., 1982. Nitrogen fertilizer requirements of irrigated safflower in the northern Great Plains. Agronomy Journal 74, 331-335.

Koutroubas, S.D., Papakosta, D.K., Doitsinis, A., 2004. Cultivar and seasonal effects on the contribution of pre-anthesis assimilates to safflower yield. Field Crops Research 90, 263–274.

Lenssen, A.W., Waddell, J.T., Johnson, G.D., Carlson, G.R., 2007. Diversified cropping systems in semiarid Montana: Nitrogen use during drought. Soil & Tillage Research 94, 362–375.

Shahrokhnia, M.H., Sepaskhah, A.R., 2016. Effects of irrigation strategies, planting methods and nitrogen fertilization on yield, water and nitrogen efficiencies of safflower. Agricultural Water Management 172, 18-30.

# Sorghum – Grain




## Data sources

No published studies from California reporting N concentration in sorghum grain were available. Ciampitti and Vara Prasad (2016) synthesized data from 13 published studies, MS theses and dissertations. Of these, 8 studies were from trials in the U.S., namely from Kansas, Nebraska and Texas. The dataset included a total of 256 observations.

## Relevance

The average amount of N removed is 33 lbs/ton at a moisture content of 13.5%. For comparison, the NRCS Crop Nutrient Tool estimates the amount of N removed to be 32.3 lbs/ton. With no information being available from California, it is not possible to determine the degree to which these values are representative of sorghum grains harvested in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Ciampitti and Vara Prasad, 2016 | Global | | 1965-2017 | | 256 |
| Overall | | | | | 256 |

*Summary statistics of sorghum grain N removal data.*

| Source | Summary (lbs N/ton @ 13.5% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Ciampitti and Vara Prasad, 2016 | 33.0 | 9.80 | 10.4 - 74.0 | 29.7 |
| **Overall** | **33.0** | **9.80** | **10.4 - 74.0** | **29.7** |

### Variability

The analysis of the data from Ciampitti and Vara Prasard (2016) reveals that sorghum grain concentrations can vary considerably with the highest value being more than seven times the lowest value and the CV of the dataset being 29.7% of the mean. However, half the values in their study were between 25.0 and 38.4 lbs N/ton.

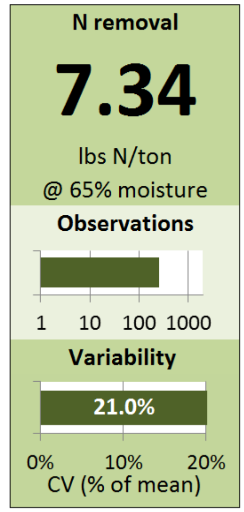
## Discussion

The N concentration in sorghum grain can vary considerably. With no recent data available from California, it is not possible to determine how well these values are a good estimate of sorghum N removal from California. Samples should be collected from Central Valley fields to determine whether the value in this report is a good estimate for sorghum grains harvested in the Central Valley. For a robust estimate, samples need to be taken over a period of several years.

## 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.

# Sorghum – Silage




## Data sources

The data included in this report are from a variety trial conducted at two locations in Fresno County over three years. A large number of varieties were included. With no information available about the most widely used sorghum varieties in California, the entire dataset from the trial was used in this report. As protein content was reported, it was divided by 6.25 to calculate N values for this report.

## Relevance

The trial was carried out at two locations in the Central Valley with a large number of varieties over a period of three years. The average N concentration can be considered a good estimate of N concentrations found in sorghum silage produced in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Dahlberg et al., 2015 | Fresno | 2 | 2015 | 1 | 72 |
| Dahlberg et al., 2014 | Fresno | 2 | 2014 | 1 | 84 |
| Dahlberg et al., 2013 | Fresno | 2 | 2013 | 1 | 104 |
| **Overall** | | | | | **260** |

*Summary statistics of sorghum silage N removal data.*

| Source | Summary (lbs N/ton @ 65% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Dahlberg et al., 2015 | 8.08 | 1.37 | 6.0 - 11.9 | 16.9 |
| Dahlberg et al., 2014 | 6.93 | 1.61 | 3.9 - 10.0 | 23.2 |
| Dahlberg et al., 2013 | 7.16 | 1.46 | 4.5 - 9.5 | 20.3 |
| **Overall** | **7.34** | **1.55** | **3.9 - 11.9** | **21.0** |

## Variability

With the large number of varieties included, it's not surprising that the factor variety contributed more to the overall variability than year of study. Other factors that may contribute to the variability of silage N concentrations include growth stage when cut and N fertilization level. In the trials included here, these factors most likely varied less than they do among growers' fields, thus underestimating the overall variability in sorghum silage N concentration.

## Discussion

The trial provides a good estimate of the average N concentration in sorghum silage produced in the Central Valley. The results may not capture the variability of hay produced in growers' fields in the Central Valley, as factors such as N application rate and growth stage when harvested vary much more in growers' fields. A relatively large number of samples would need to be collected from fields across the Central Valley over a period of several years for a robust estimate of the range of N concentrations in sorghum silage produced in the Central Valley.

## References


Dahlberg, J., Hutmacher, B., Wright, S., 2013. 2013 Field demonstrations of sorghum forages for the California dairy industry. Available online at: http://sorghum.ucanr.edu/data/files/Final%202013%20Kearney%20and%20Westside%20Forage%20Sorghum%20Silage%20Trials.pdf

Dahlberg, J., Hutmacher, B., Wright, S., 2014. 2014 Field demonstrations of sorghum forages for the California dairy industry. Available online at: http://sorghum.ucanr.edu/data/files/2014%20Kearney%20and%20Westside%20Forage%20Sorghum%20Silage%20Trials.pdf

Dahlberg, J., Hutmacher, B., Wright, S., 2015. 2015 Field demonstrations of sorghum forages for the California dairy industry. Available online at: http://sorghum.ucanr.edu/data/files/Final%202015%20Kearney%20and%20Westside%20Forage%20Sorghum%20Silage%20Trials.pdf

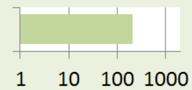
# Sunflower

N removal

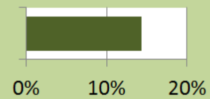
**54.1**

lbs N/ton
@ 8% moisture

**Observations**




**Variability**




## Data sources

The dataset consists of ten studies and the NRCS Crop Nutrient Tool for a total of 208 observations. Roughly half of the observations were from the U.S, but none from California. Most studies compared different fertilizer application rates.

## Relevance

With no data available from California, it is not possible to determine how well these values represent sunflower N removal from California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Deibert and Utter, 1989 | North Dakota | 1 | 1985-86 | 2 | 8 |
| Narem, 1982 | South Dakota | 11 | 1980-81 | 2 | 55 |
| Mathers and Stewart, 1982 | Texas | 1 | 1975-76 | 2 | 30 |
| Robinson, 1973 | Minnesota | 1 | 1970-71 | 2 | 2 |
| Steer et al., 1986 | Australia | 2 | 1981-82 | 2 | 17 |
| Blamey and Chapman, 1981 | South Africa | 1 | 1975-77 | 4 | 16 |
| Adrianasolo et al., 2016 | France | 1 | 2011-12 | 2 | 16 |
| Scheiner et al., 2002 | Argentina | 2 | 1996 | 1 | 24 |
| Özer et al., 2004 | Turkey | 1 | 1998-99 | 2 | 20 |
| Gholamhoseini et al., 2013 | Iran | 1 | 1996-97 | 2 | 18 |
| NRCS Crop Nutrient Tool | | | | | 2 |
| **Overall** | | | | | **208** |

*Summary statistics of sunflower N removal data.*

| Source | Summary (lbs N/ton @ 8% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Deibert and Utter, 1989 | 56.1 | 3.11 | 53.4 - 60.7 | 5.5 |
| Narem, 1982 | 51.7 | 4.54 | 35.9 - 60.4 | 8.8 |
| Mathers and Stewart, 1982 | 60.5 | 8.78 | 44.2 - 69.9 | 14.5 |
| Robinson, 1973 | 47.5 | | | |
| Steer et al., 1986 | 50.7 | 12.90 | 32.8 - 67.9 | 25.4 |
| Blamey and Chapman, 1981 | 45.2 | 5.39 | 33.0 - 53.9 | 11.9 |
| Adrianasolo et al., 2016 | 46.2 | 5.83 | 42.1 - 50.3 | 12.6 |
| Scheiner et al., 2002 | 61.9 | 5.01 | 57.1 - 69.5 | 8.1 |
| Özer et al., 2004 | 56.7 | 2.04 | 54.7 - 59.9 | 3.6 |
| Gholamhoseini et al., 2013 | 55.6 | 5.42 | 46.7 - 65.3 | 9.7 |
| NRCS Crop Nutrient Tool | 56.3 | 1.79 | 55.1 - 57.6 | 3.2 |
| **Overall** | **54.1** | **7.76** | **32.8 - 69.9** | **14.3** |

## Variability

The variability within and among studies was relatively small. Year of harvest had a strong effect in several studies (Blamey and Chapman, 1981; Deibert and Utter, 1989; Gholamhoseini et al., 2013; Adrianasolo et al., 2016). Nitrogen application rates also affected N concentrations in sunflower seeds, especially at low rates (Mathers and Stewart, 1982; Narem, 1982; Scheiner et al., 2002; Özer et al. 2004). In contrast, applications that exceeded the optimal rate generally had little effect on yield and only moderately increased seed N concentration.

## Discussion

The term "seed" is not used in a consistent manner. While some studies clearly report achene yield (hulls plus kernels or seeds), others reported 'seed' yield and N concentrations in 'seeds', which may refer either to the achene or to the kernel alone. The descriptions of the methods do not suggest that kernels and hulls were separated and it is likely that the authors reporting 'seed' yield were actually measuring achene yield. Thus, we assumed that the authors in all studies determined yield and N concentration of the achenes.

Due to this uncertainty and the fact that no values were found from California, samples should be collected from Central Valley fields over a period of several years for a robust estimate of the amount of N removed from fields with sunflower seeds and hulls.

## References


Deibert, E.J., Utter, R.A., 1989. Sunflower growth and nutrient uptake: Response to tillage system, hybrid maturity and weed control method. Soil Science Society of America Journal 53, 133-138.

Andrianasolo, F.N., Champolivier, L., Debaeke, P., Maury, P., 2016. Source and sink indicators for determining nitrogen, plant density and genotype effects on oil and protein contents in sunflower achenes. Field Crops Research 192, 33-41.

Blamey, F.P.C., Chapman, J., 1981. Protein, oil, and energy yields of sunflower as affected by N and P fertilization. Agronomy Journal 73, 584-587.

Gholamhoseini, M., Ghalavand, A., Dolatabadian, A., Jamshidi, E., Khodaei-Joghan, A., 2013. Effects of arbuscular mycorrhizal inoculation on growth, yield, nutrient uptake and irrigation water productivity of sunflowers grown under drought stress. Agricultural Water Management 117, 106-114.

Mathers, A.C., Stewart, B.A., 1982. Sunflower nutrient uptake, growth, and yield as affected by nitrogen or manure, and plant population. Agronomy Journal 74, 911-915.

Narem, R.A., 1982. Nitrogen fertility requirements, dry matter production and nutrient uptake of the sunflower. MS thesis, South Dakota State University.

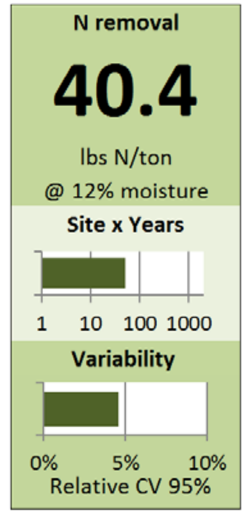
Özer, H., Polat, T., Öztürk, E., 2004. Response of irrigated sunflower (*Helianthus annuus* L.) hybrids to nitrogen fertilization: Growth, yield and yield components. Plant, Soil & Environment 50, 205-211.

Robinson, R.G., 1973. Elemental composition and response to nitrogen of sunflower and corn. Agronomy Journal 65, 318-320.

Scheiner, J.D., Gutiérrez-Boem, F.H., Lavado, R.S., 2002. Sunflower nitrogen requirement and $^{15}N$ fertilizer recovery in Western Pampas, Argentina. European Journal of Agronomy 17, 73-79.

Steer, B.T., Coaldrake, P.D., Pearson, C.J., Canty, C.P., 1986. Effects of nitrogen supply and population density on plant development and yield components of irrigated sunflower *(Helianthus annuus* L.). Field Crops Research 13, 99-115.

# Triticale - Grain




## Data sources

Between 2005 and 2012, UCCE Yolo County Field Crops Farm Advisor Kent Brittan and collaborators carried out trials with different triticale varieties at four locations in the southern Sacramento Valley (Brittan, 2011 and 2012). The trials produced a total of 51 observations. Grains were analyzed for protein content. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

The trials included data from several years, varieties and locations. Even though no locations in the San Joaquin Valley are included, the dataset can be considered a good estimate of N in triticale grain from the Central Valley. Wheat variety trials have shown that even though location can have an effect on grain N concentration; it is not consistent over the years.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Brittan, 2011 and 2012 | Sacramento V. | 4 | 2005-12 | 7 | 51 |
| **Overall** | **Sacramento V.** | **4** | **2005-12** | **7** | **51** |

*Summary statistics of triticale grain N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD [1)] | Range | |
| Brittan, 2011 and 2012 | 40.4 | 5.25 | 29.5 - 50.9 | 13.0 |
| **Overall** | **40.4** | **5.25** | **29.5 - 50.9** | **13.0** |

[1)] SD based on 31 observations from 2011-12.

## Variability

Detailed data of the triticale harvested in 2011 and 2012 are available allowing for an analysis of the factors contributing most to the variability in triticale protein concentration. Most of the variability was due to year, while variety and location contributed much less to the overall variability. The N application rate differed between sites, ranging from 20 to 180 lbs N/acre, thus capturing at least part of a factor that likely has a strong effect on triticale grain N concentration and that may vary considerably among growers.

## Discussion

Even though the trial locations were limited to the southern Sacramento Valley, the results of this analysis are a good estimate of triticale grown in the Central Valley. The variety trials also captured many factors that contribute to the variability in N concentration.

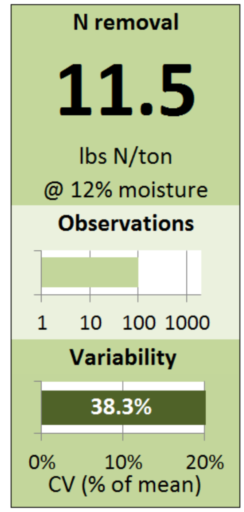
Several triticale varieties are tested each year within the UC Small Grains variety trials at several locations across the Central Valley. Crude protein contents are generally not determined for triticale. Analyzing grain samples from the variety trials would be a simple way to improve the estimate presented here.

## References


Brittan, K.L., 2011. 2011 Southern Sacramento Valley small grains research program. Available online at: http://www.californiawheat.org/uploads/resources/402/brittan-2011-southern-sacramento-valley-small-grains-research-program-report-with-tables.pdf

Brittan, K.L., 2012. 2011-12 Southern Sacramento Valley small grains research program cultivar assessment. Available online at: http://www.californiawheat.org/uploads/resources/505/11.12-brittan-full-report.pdf

# Triticale – Straw




## Data sources

Studies from around the world contributed to this analysis. The objective of these studies was to determine the nutritive value of straw and its value as a source for carbohydrates and lignin. No information on crop management was provided. All datasets reported crude protein content of triticale straw. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

A large proportion of the observations compiled for this analysis are from one study carried out in South Africa. No values are from California. Therefore, it is not possible to determine the degree to which these values represent N concentration in triticale straw from California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Pronky and Mazza, 2012 | Canada | 1 | 2010 | 1 | 1 |
| Yalchi et al., 2009, 2010 | Iran | 1 | 2007 | 1 | 2 |
| Dias-da-Silva and Guedes, 1990 | Portugal | 3 | 1988 | 1 | 8 |
| Viljoen et al., 2005 | South Africa | 10 | 2003 | 1 | 91 |
| **Overall** | | | | | **102** |

*Summary statistics of triticale straw N removal data.*

| Source | Summary (lbs N/ton @ 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Pronyk and Mazza, 2012 | 10.8 | | | |
| Yalchi et al., 2009, 2010 | 5.8 | 0.16 | 5.7 - 5.9 | 2.7 |
| Dias-da-Silva and Guedes, 1990 | 12.1 | 2.43 | 10.4 - 13.8 | 20.1 |
| Viljoen et al., 2005 | 11.6 | 4.57 | 5.5 - 29.0 | 39.3 |
| **Overall** | **11.5** | **4.42** | **5.5 - 29.0** | **38.3** |

## Variability

As is the case with other types of straw, the N concentration in oat straw is highly variable. A dominant factor contributing to the variability is N fertilization level and overall N availability. See **barley straw** for a more detailed discussion about the effects of N availability on straw N content.

## Discussion

Samples should be collected from Central Valley fields to determine whether the value in this report is a good estimate for triticale straw from California. Compared to other commodities, the N concentration in straw varies considerably. Therefore, for a robust average, a large number of samples need to be analyzed. Despite the uncertainty in the value presented here, it is important to note that the amount of N removed with straw is small compared to the N removed with grain. Assuming a harvest index of 0.5 (which means that 50% of the aboveground biomass is in the grains), only about 20% of the total N in the aboveground biomass of triticale is in the straw and stubble.

## References


Dias-da-Silva, A.A., Guedes, C.V.M., 1990. Variability in the nutritive value of straw cultivars of wheat, rye and triticale and response to urea treatment. Animal Feed Science and Technology 28, 79-89.

Pronyk, C., Mazza, G., 2012. Fractionation of triticale, wheat, barley, oats, canola, and mustard straws for the production of carbohydrates and lignins. Bioresource Technology 106, 117–124

Viljoen, M., Brand, T.S., Hoffman, L.C., 2005. Differences in the chemical composition and digestibility of cereal hay and straw produced in a Mediterranean rainfall area of South Africa. South African Journal of Plant and Soil 22, 106-109.

Yalchi, T., Seif-Davati, J., Sharifi, R.S., 2010. Chemical composition and digestibility of urea-treated triticale (x Triticosecale) straw. Journal of Food, Agriculture & Environment 8, 618-621.

Yalchi, T., Afzalzade, A., Sharifi, R.S., 2009.Effects of liquid ammonia and urea treatment on chemical compositions and *in vitro* digestibility of triticale straw. Journal of Animal and Veterinary Advances 8, 1916-1920.

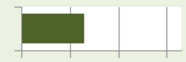
# Triticale – Silage

**N removal**

**9.03**

lbs N/ton
@ 70% moisture

**Observations**




**Variability**


## Data sources

The data included in this report are from a small grain variety trial conducted over multiple years in the Southern San Joaquin Valley by a team led by Steve Wright, UCCE Farm Advisor in Kings and Tulare Counties. Triticale was grown during the winter. Little additional information is available about crop management.

## Relevance

The trial was completed in Tulare and Kings Counties with several relevant varieties over a period of four years. Even though the trial was completed at only one site each year, the average N concentration can be considered a good estimate of N concentrations found in triticale silage produced in the Central Valley, as varieties and crop management are likely similar across the valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Wright et al., 2014 | Tulare/Kings | 1 | 2014 | 1 | 5 |
| Wright et al., 2012 | Tulare | 1 | 2011 | 1 | 4 |
| Wright et al., 2009 | Tulare | 1 | 2009 | 1 | 6 |
| Wright et al., 2009 | Tulare | 1 | 2008 | 1 | 4 |
| **Overall** | **Tulare** | | | **4** | **19** |

*Summary statistics of triticale silage N removal data.*

| Source | Summary (lbs N/ton at 70% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Wright et al., 2014 | 10.64 | 0.59 | 10.0 - 11.5 | 5.5 |
| Wright et al., 2012 | 9.62 | 0.12 | 9.5 - 9.8 | 1.3 |
| Wright et al., 2009 | 7.79 | 0.29 | 7.4 - 8.2 | 3.7 |
| Wright et al., 2009 | 8.30 | 0.24 | 8.0 - 8.5 | 2.9 |
| **Overall** | **9.03** | **1.24** | **7.4 - 11.5** | **13.7** |

## Variability

The dataset reveals that year has a large effect on the N concentration in triticale silage. Other factors that may contribute to the variability of silage N contents include growth stage when cut and N fertilization level. With the present trial, the effect of these factors may not have been fully captured.

## Discussion

The trial likely provides a good estimate of the average N concentration in triticale silage produced in the Central Valley. The results may not capture the variability of silage produced in growers' fields, as factors such as N application rate and growth stage when harvested likely vary much more among growers' fields. For a better and robust estimate, a relatively large number of samples would need to be collected from fields across the Central Valley over a period of several years.

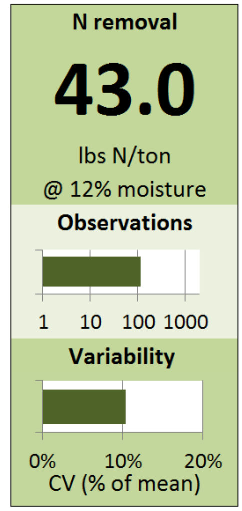
## References

Wright, S., Silva-del-Rio, N., Collar, C., Banuelos, L., 2009. Small grain silage variety study. UC ANR Small Grain News Tulare County October 2009, 11-12. Available online at: http://cetulare.ucanr.edu/newsletters/Small_Grain_News41326.pdf

Wright, S., Banuelos, L., Silva-del-Rio, N., Collar, C., Hernandez, K., Stambach, H., 2012. Small grain silage variety trial 2011. UC ANR Small Grain News Tulare County 6(3), 10. Available online at: http://cetulare.ucanr.edu/newsletters/Small_Grain_News44749.pdf

Wright, S., Banuelos, L., Souza, Collar, C., 2014. Small grain silage variety trial 2014. UC ANR Small Grain News Tulare County 10(3), 7-9. Available online at: http://cetulare.ucanr.edu/newsletters/Small_Grain_News52831.pdf

# Wheat, Common – Grain




## Data sources

The data for this report were taken from the UC wheat variety trials. These trials are carried out every year at multiple locations in California, testing current and new varieties. The results are available online at http://smallgrains.ucdavis.edu/. The variety trials report protein concentration of grains. For this report, the N concentrations were calculated by dividing crude protein values by 5.7.
For this analysis, we used the results from the years 2013-15 from the trial locations in the Central Valley. Furthermore, we only included the 6-7 wheat varieties that were planted on more than 10,000 acres in California and were grown predominantly for grain as opposed to forage varieties. Information on acreage and utilization were taken from the California Wheat Variety Survey conducted by the California Wheat Commission (available online at http://smallgrains.ucdavis.edu/).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| UC Wheat Variety Trials | Sacramento V. | 2 | 2015 | 1 | 12 |
| UC Wheat Variety Trials | Delta | 1 | 2015 | 1 | 6 |
| UC Wheat Variety Trials | San Joaquin V. | 3 | 2015 | 1 | 18 |
| UC Wheat Variety Trials | Sacramento V. | 3 | 2014 | 1 | 18 |
| UC Wheat Variety Trials | Delta | 1 | 2014 | 1 | 6 |
| UC Wheat Variety Trials | San Joaquin V. | 3 | 2014 | 1 | 18 |
| UC Wheat Variety Trials | Sacramento V. | 2 | 2013 | 1 | 14 |
| UC Wheat Variety Trials | Delta | 1 | 2013 | 1 | 7 |
| UC Wheat Variety Trials | San Joaquin V. | 2 | 2013 | 1 | 14 |
| **Overall** | | **7** | **2013-2015** | **3** | **113** |

## Relevance

The trials compare current and new varieties at multiple locations, including sites in the Sacramento Valley, the San Joaquin Valley and one site in the Delta. The results are highly representative for the Central Valley. Results from sites located outside the Central Valley were not included in the report.

## Variability

The dataset compiled for this report allows for the analysis of three sources of variability, namely location, variety and year. Of these three factors, year contributed most to the variability in grain N concentration, followed by variety. Trial location had a smaller and inconsistent effect. Nitrogen management, especially late sidedress applications, can have a considerable effect on wheat protein content (Brittan, 2012; Orloff, 2012 and 2013). Nitrogen availability and management among growers in the Central Valley is likely much more diverse than among trial sites. Therefore, the trials may underestimate the variability in protein content among samples from growers' fields.

*Summary statistics of wheat grain N removal data.*

| Source | Summary (lbs/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Variety Trial SV, 2015 | 45.5 | 4.23 | 39.7 - 52.7 | 9.3 |
| Variety Trial Delta, 2015 | 48.3 | 2.26 | 33.9 - 43.1 | 4.7 |
| Variety Trial SJV, 2015 | 45.4 | 5.63 | 39.7 - 52.7 | 12.4 |
| Variety Trial SV, 2014 | 40.2 | 3.96 | 32.1 - 49.3 | 9.8 |
| Variety Trial Delta, 2014 | 41.4 | 1.45 | 39.5 - 43.3 | 3.5 |
| Variety Trial SJV, 2014 | 40.7 | 3.33 | 33.0 - 45.9 | 8.2 |
| Variety Trial SV, 2013 | 42.8 | 2.67 | 38.7 - 48.6 | 6.2 |
| Variety Trial Delta, 2013 | 42.9 | 1.21 | 41.0 - 44.8 | 2.8 |
| Variety Trial SJV, 2013 | 43.0 | 4.82 | 36.3 - 52.4 | 11.2 |
| **Overall** | **43.0** | **4.45** | **32.1 – 52.7** | **10.3** |

## Discussion

The variety trials are an excellent and representative source for N concentrations in wheat grains harvested in the Central Valley. As they are carried out every year, the dataset can be updated periodically if desired.

Growers generally know the protein content of the wheat produced. They can therefore use this information to improve the estimate of N removed for their particular field.

## References

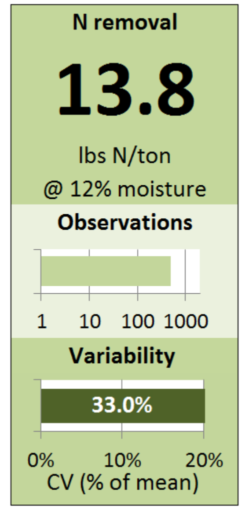

Brittan, K.L., 2012. 2011-12 Southern Sacramento Valley small grains research program. Hard red wheat protein enhancement by midseason urea application. Available online at: http://ceyolo.ucanr.edu/files/154680.pdf

Mayo P., Prato D., Fraser J., Jackson, L., Gallagher, L.W., Chicaiza, O., del Blanco, A., Maciel, F.T., Culp, D., Banuelos, G., Kirby, D., Wilson, R., Marcum, D., Marsh, B., Orloff, S., Lundy, M., Munier, D., Wright, S., Dubcovsky, J. Regional barley, common wheat and triticale, and durum wheat performance tests in California. Available online at: http://smallgrains.ucdavis.edu/

Orloff, S., 2012. Effect of nitrogen fertilization practices on spring wheat yield and protein content. 2011-12 California Wheat Commission Research Report. Available online at: http://www.californiawheat.org/uploads/resources/542/wheatcommissionfinalrptnfert12.pdf

Orloff, S., 2013. Effect of nitrogen fertilization practices on spring wheat yield and protein content. 2012-13 California Wheat Commission Research Report. Available online at: http://www.californiawheat.org/uploads/resources/643/orloff-wheatcommissionfinalrptnfert13.pdf

# Wheat – Straw




## Data sources

A total of 494 observations were included in this analysis. Most of the values were from Canada, the remainder is from studies carried out in Oregon, Washington, and Wisconsin. One dataset included three samples collected by Peter Robinson on California dairies. Several studies reported crude protein content. For this report, the N concentrations were calculated by dividing crude protein values by 6.25.

## Relevance

Only 5% of the samples were taken in California. As these samples had a considerable higher N content, the average concentration in the table may not be representative of wheat straw harvested in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Robinson, 2011 | California | 3 | 1997-2011 | | 3 |
| Church and Santos, 1981 | Oregon | 1 | 1980 | | 2 |
| Herrera-Saldana et al., 1982 | Oregon | 1 | 1979 | 1 | 1 |
| Males et al., 1982 | Washington | 1 | 1981 | 1 | 1 |
| Pritchard and Males, 1982 | Washington | 1 | 1981 | 1 | 1 |
| Sanmaneechai et al., 1984 | Washington | 1 | 1979 | 1 | 6 |
| Anderson and Hoffman, 2006 | Wisconsin | | | | 20 |
| Horton, 1978 | Canada | 1 | 1977 | 1 | 1 |
| Horton and Seacy, 1979 | Canada | 1 | 1978 | 1 | 3 |
| Kernan et al., 1979 | Canada | 4 | 1975/76 | 2 | 24 |
| McCartney et al., 2006 | Canada | | 1974-94 | | 432 |
| **Overall** | | | | | **494** |

## Variability

Compared to other commodities, the N concentrations in straw vary considerably. A major factor affecting straw N concentration is N fertilization rate and overall N availability. See **barley straw** for a more detailed discussion about the effects of N availability on straw N content.

## Discussion

The three samples from California had a higher N concentration than the other samples compiled in this report. It is therefore necessary to collect samples from Central Valley fields to determine whether the average value of 13.8 lbs N/ton is a good estimate for wheat straw from the Central Valley. Compared to other commodities, the N concentration in straw varies considerably. Therefore, for a robust average, a large number of samples need to be analyzed. Despite the uncertainty in the value presented here, it is important to note that the amount of N removed with straw is small compared to the N removed with grain. Assuming a harvest index of 0.5 (which means that 50% of the aboveground biomass is in the grains), only about one fifth of the total N in the aboveground biomass of wheat is in the straw and stubble.

*Summary statistics of wheat straw N removal data.*

| Source | Summary (lbs/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Robinson, 2011 | 22.9 | 5.6 | 18.6 - 29.3 | 24.6 |
| Church and Santos, 1981 | 9.0 | 2.4 | 7.3 - 10.7 | 26.5 |
| Herrera-Saldana et al., 1982 | 8.3 | | | |
| Males et al., 1982 | 9.6 | | | |
| Pritchard and Males, 1982 | 7.0 | | | |
| Sanmaneechai et al., 1984 | 11.1 | 3.7 | 7.2 - 17.4 | 33.7 |
| Anderson and Hoffman, 2006 | 12.8 | 3.3 | 8.2 - 19.1 | 25.7 |
| Horton, 1978 | 6.5 | | | |
| Horton and Seacy, 1979 | 7.1 | 5.1 | 6.1 - 8.6 | 72.1 |
| Kernan et al., 1979 | 10.0 | 0.8 | 9.3 - 11.0 | 7.9 |
| McCartney et al., 2006 | 14.2 | 4.7 | | |
| **Overall** | **13.8** | **4.56** | **6.1 - 29.3** | **33.0** |

## References


Anderson, T., Hoffman, P., 2006. Nutrient Composition of Straw Used in Dairy Cattle Diets. Focus on Forage 8(1), 1-3. Available online at: http://fyi.uwex.edu/forage/files/2014/01/StrawFOF.pdf

Church, D.C., Santos, A., 1981. Effect of graded levels of soybean meal and of a nonprotein nitrogen-molasses supplement on consumption and digestibility of wheat straw. Journal of Animal Science 53, 1610-1615.

Herrera-Saldana, R., Church, D.C., Kellems, R.O., 1982. The effect of ammoniation treatment on intake and nutritive value of wheat straw. Journal of Animal Science 54, 603-608.

Horton, G.M.J. 1978. The intake and digestibility of ammoniated cereal straws by cattle. Canadian Journal of Animal Science 58, 471-478.

Horton G.M.J. , Steacy, G.M., 1979. Effect of anhydrous ammonia treatment on the intake and digestibility of cereal straws by steers. Journal of Animal Science 48, 1239-1249.

Kernan, J.A., Crowle, W.L., Spurr, D.T. Coxworth, E.C., 1979. Straw quality of cereal cultivars before and after treatment with anhydrous ammonia. Canadian Journal of Animal Science 59, 511-517.

Males J.R., McReynolds W.E., Gaskins C.T., Preston, R.L., 1982. Supplementation of wheat straw diets to optimize performance of wintering beef cows. Journal of Animal Science 54, 384-390.

McCartney, D. H., Block, H. C., Dubeski, P. L. and Ohama, A. J. 2006. Review: The composition and availability of straw and chaff from small grain cereals for beef cattle in western Canada. Canadian Journal of Animal Science 86, 443–455.

Pritchard, R.H. Males, J. R., 1982. Effect of supplementation of wheat straw diets twice a day on rumen ammonia, volatile fatty acids and cow performance. Journal of Animal Science 54, 1241-1250.

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

Sanmaneechai, M., Koehler, F.E., Roberts, S., 1984. Nitrogen fertilization practices for sequential cropping of wheat, turnips, and sweet corn. Soil Science Society of America Journal 48, 81-86.

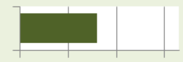
# Wheat- Silage

N removal

**10.5**

lbs N/ton
@ 70% moisture

**Observations**




**Variability**


## Data sources

The data included in this report are from a small grain variety trial conducted over multiple years in the Southern San Joaquin Valley by a team led by Steve Wright, UCCE Farm Advisor in Kings and Tulare Counties. The triticale was grown during the winter season. Little additional information is available about the crop management of the trials. In addition, samples collected by Peter Robinson, Cooperative Extension Specialist for Dairy Nutrition and Management at UC Davis, were included. These samples were taken from commercial dairy farms in California between 1997 and 2011.

## Relevance

The trial was completed in Tulare and Kings Counties with several relevant varieties over a period of four years. While the trial was completed at only one site each year, the samples collected by Robinson came from different dairy farms. Therefore, the average N concentration in the table can be considered a good estimate of N concentrations found in wheat silage produced in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Wright et al., 2014 | Tulare/Kings | 1 | 2014 | 1 | 12 |
| Wright et al., 2012 | Tulare | 1 | 2011 | 1 | 8 |
| Wright et al., 2009 | Tulare | 1 | 2009 | 1 | 4 |
| Wright et al., 2009 | Tulare | 1 | 2008 | 1 | 6 |
| Robinson, 2011 | California | | 1997-2011 | | 9 |
| **Overall** | | | | | **39** |

*Summary statistics of wheat silage N removal data.*

| Source | Summary (lbs N/ton @ 70% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Wright et al., 2014 | 12.5 | 0.75 | 11.7 - 14.5 | 6.0 |
| Wright et al., 2012 | 10.9 | 0.74 | 10.0 - 12.1 | 6.8 |
| Wright et al., 2009 | 7.9 | 0.36 | 7.4 - 8.3 | 4.6 |
| Wright et al., 2009 | 8.7 | 0.49 | 8.3 - 9.6 | 5.7 |
| Robinson, 2011 | 9.9 | 1.63 | 6.7 - 11.5 | 16.5 |
| **Overall** | **10.5** | **1.96** | **6.7 - 14.5** | **18.6** |

## Variability

Results from the variety trial reveal that year has a large effect on the N concentration in wheat silage. Other factors that may contribute to the variability of silage N contents include, growth stage when cut and N fertilization level. These factors must have contributed to the higher variability among samples collected by Robinson, hence the relatively high variability in those samples.

## Discussion

The dataset likely provides a good estimate of the average N concentration in wheat silage produced in the Central Valley. Results from the variety may not capture the variability of silage produced in growers' fields, as factors such as N application rate and growth stage when harvested likely vary much more among growers' fields. For a more robust estimate, a relatively large number of samples would need to be collected from fields across the Central Valley over a period of several years.

## 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

Wright, S., Silva del Rio, N., Collar, C., Banuelos, L., 2009. Small grain silage variety study. UC ANR Small Grain News Tulare County October 2009, 11-12. Available online at: http://cetulare.ucanr.edu/newsletters/Small_Grain_News41326.pdf

Wright, S., Banuelos, L., Silva del Rio, N., Collar, C., Hernandez, K., Stambach, H., 2012. Small grain silage variety trial 2011. UC ANR Small Grain News Tulare County 6(3), 10. Available online at:http://cetulare.ucanr.edu/newsletters/Small_Grain_News44749.pdf

Wright, S., Banuelos, L., Souza, Collar, C., 2014. Small grain silage variety trial 2014. UC ANR Small Grain News Tulare County 10(3), 7-9. Available online at: http://cetulare.ucanr.edu/newsletters/Small_Grain_News52831.pdf

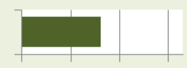
# Wheat, Durum – Grain

N removal

**42.1**

lbs N/ton
@ 12% moisture

**Observations**




**Variability**


## Data sources

The data for this report were taken from the UC wheat variety trials. These trials are carried out every year at multiple locations in California, testing current and new varieties. The results are available online at http://smallgrains.ucdavis.edu/. The variety trials report protein content of grains. For this report, the N concentrations were calculated by dividing crude protein values by 5.7.
For this analysis, we used the results from the years 2013-15 from the trial locations in the Central Valley. Only the 3-5 major varieties grown in the Sacramento and San Joaquin Valleys were included here. Information on acreage was taken from the California Wheat Variety Survey conducted by the California Wheat Commission (available online at http://smallgrains.ucdavis.edu/).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| UC Wheat Variety Trials | Sacramento V. | 1 | 2015 | 1 | 5 |
| UC Wheat Variety Trials | San Joaquin V. | 3 | 2015 | 1 | 15 |
| UC Wheat Variety Trials | Sacramento V. | 1 | 2014 | 1 | 3 |
| UC Wheat Variety Trials | San Joaquin V. | 3 | 2014 | 1 | 9 |
| UC Wheat Variety Trials | Sacramento V. | 1 | 2013 | 1 | 3 |
| UC Wheat Variety Trials | San Joaquin V. | 2 | 2013 | 1 | 6 |
| **Overall** | | **4** | **2013-2015** | **3** | **41** |

*Summary statistics of durum wheat grain N removal data.*

| Source | Summary (lbs N/ton at 12% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Variety Trial SV, 2015 | 46.7 | 1.90 | 44.4 - 48.5 | 4.1 |
| Variety Trial SJV, 2015 | 43.6 | 6.10 | 36.3 - 54.0 | 14.0 |
| Variety Trial SV, 2014 | 40.1 | 5.06 | 35.3 - 45.4 | 12.6 |
| Variety Trial SJV, 2014 | 39.5 | 4.06 | 33.7 - 44.1 | 10.3 |
| Variety Trial SV, 2013 | 35.9 | 1.89 | 33.9 - 37.7 | 5.3 |
| Variety Trial SJV, 2013 | 42.8 | 5.23 | 35.8 - 50.1 | 12.2 |
| **Overall** | **42.1** | **1.56** | **33.7 - 54.0** | **3.7** |

## Relevance

The variety trials for durum wheat are carried out annually at multiple locations, including one site in the Sacramento Valley, and 2-3 sites in the San Joaquin Valley. The results are highly representative for the Central Valley. Results from sites located outside the Central Valley were not included in this report.

## Variability

The dataset compiled for this report allows for the analysis of three sources of variability, namely location, variety and year. While protein, and thus N, contents differ between regions, no clear pattern emerges. The differences among varieties were also relatively small. The strongest effect on N content in durum wheat grains was caused by the year. Nitrogen management has a strong effect on wheat protein content. Nitrogen availability and management among growers in the Central Valley is likely much more diverse than among trial sites. Therefore, the trials may underestimate the variability in protein content among samples from growers' fields.

## Discussion

The variety trials are an excellent and representative source for N concentrations in wheat grains harvested in the Central Valley. As variety trials are carried out every year, the dataset can be updated periodically if desired.

## References

Mayo P., Prato D., Fraser J., Jackson, L., Gallagher, L.W., Chicaiza, O., del Blanco, A., Maciel, F.T., Culp, D., Banuelos, G., Kirby, D., Wilson, R., Marcum, D., Marsh, B., Orloff, S., Lundy, M., Munier, D., Wright, S., Dubcovsky, J. Regional barley, common wheat and triticale, and durum wheat performance tests in California. Available online at: http://smallgrains.ucdavis.edu/

# Asparagus

**N removal**

**5.85**

lbs N/ton
fresh weight

**Observations**


**Variability**


## Data sources

The data used for this report are from three studies from Europe and China, the USDA Food Composition Database and the NRCS Crop Nutrient Tool, which uses values from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" (Howard et al., 1962). The values in the table represent N concentrations in the harvested spears (shoots).

## Relevance

Only the values from the NRCS Crop Nutrient Tool are from California, but from a report published more than 50 year ago. For the USDA Food Composition Database, four samples of asparagus sold in the U.S. were analyzed. Therefore, the average value calculated here may not be representative for contemporary asparagus harvested in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Shalaby, 2004 | Germany | 2 | 2002-03 | 3 | 4 |
| Zhou et al. 2001 | China | 1 | 2000 | 2 | 3 |
| Espejo et al., 2001 | Spain | 1 | 1994-95 | 3 | 6 |
| USDA Food Composition Database | | | | | 4 |
| NRCS Crop Nutrient Tool | | | | | 2 |
| **Overall** | | | | | **19** |

*Summary of asparagus N removal data.*

| Source | Summary (lbs N/ton of fresh spears) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Shalaby, 2004 | 4.44 | 0.43 | 3.92 - 4.96 | 9.8 |
| Zhou et al. 2001 | 5.92 | 1.27 | 4.74 - 7.26 | 21.5 |
| Espejo et al., 2001 | 5.44 | 0.56 | 4.86 - 6.03 | 10.3 |
| USDA Food Composition Database | 7.04 | 0.15 | 6.85 - 7.20 | 2.1 |
| NRCS Crop Nutrient Tool | 7.48 | 1.98 | 6.08 - 8.88 | 26.5 |
| **Overall** | **5.85** | **0.82** | **3.92 - 8.88** | **14.0** |

## Variability

The variability of the datasets is intermediate, with a CV of 14% across all datasets. Shalaby (2003) found that an increased N application rate slightly, but not significantly, increased the N concentration in white asparagus spears. The N concentration has also been found to decrease from an early to a late growth stage (Zhou et al., 2001). In addition, the Crop Nutrient Tool reports a higher value for green asparagus, compared to white asparagus. It is important to note that the values reported in the NRCS and USDA databases are considerably higher than the values taken from the three studies from Europe and China. With the small dataset available, it is not possible to determine whether this is due to chance or differences in varieties, crop management and/or climatic conditions.

## Discussion

Given the low number of samples, the variable N concentrations in asparagus spears sampled in the U.S. and abroad and the fact that the values from California are based on samples taken more than 50 years ago, samples need to be collected from fields in California over a period of several years for a representative and robust estimate of N removal with asparagus.

## References

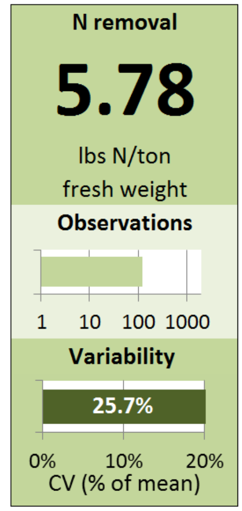
Espejo, J.A., Dobao, M.M., Tejada, M, Gonzalez, J.L., 2001. Influence of the phosphoric fertilization in the formation of dry matter and nutrients extraction in a crop of green asparagus (*Asparagus officinalis*, L.). Asparagus Research Newsletter 17, 16-48.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

Shalaby, T., 2004. Genetical and nutritional influences on the spear quality of white asparagus (*Asparagus officinalis* L.). Landbauforschung Völkenrode Sonderheft 265. Available online at: http://literatur.vti.bund.de/digbib_extern/zi032243.pdf

Zhou, Q., Zhao, L., Wang, R., Han, Y., Jing, N., 2001. The degree of growth for green spears for the harvesting and grading standards for asparagus. Asparagus Research Newsletter 17, 10-15.

# Beans, green (Snap beans)




## Data sources

The data used for this report are from a trial in Virginia, four studies from Europe and Japan, and the USDA Food Composition Database. 104 of the total 122 observations are from the USDA Database. In addition, one value from the NRCS Crop Nutrient Tool, which was taken from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" (Howard et al., 1962), was included. The values in the table represent N concentrations in the harvested pods.

## Relevance

The USDA Food Composition Database, which includes results from the analysis of green beans sold in the U.S., contributes most to the average value in the table. Only the value from the NRCS Crop Nutrient Tool is from California, but it is from a report published more than 50 year ago. With the data available, it is not possible to determine how well the average value calculated here represents N concentrations in green beans harvested in the Central Valley.

## Variability

Three studies compared different N application rates. While Segura et al. (2012) found a small increase in bean N concentration with increasing N application rates, Phillips et al. (2002) and Valdez et al. (2002) did not find a clear effect of N application rate on the N concentration in green beans. The differences among observations in the studies conducted by Varennes et al. (2002) and Martinez et al. (1998) are due to variety.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Phillips et al., 2002 | Virginia | 2 | 2000 | 1 | 3 |
| Varennes et al., 2002 | Portugal | 1 | 1997/98 | 1 | 3 |
| Martínez et al., 1998 | Spain | 3 | 1993 | 1 | 3 |
| Segura et al., 2012 | Spain | 1 | 2003/04 | 1 | 3 |
| Valdez et al., 2002 | Japan | 1 | 2000 | 1 | 5 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 104 |
| **Overall** | | | | | **122** |

*Summary of green bean N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Phillips et al., 2002 * | 4.66 | 0.18 | 4.55 - 4.98 | 3.9 |
| Varennes et al., 2002 * | 6.07 | 0.68 | 5.42 - 6.78 | 11.2 |
| Martínez et al., 1998 | 5.28 | 0.15 | 5.11 - 5.39 | 2.8 |
| Segura et al., 2012 | 4.73 | 0.36 | 4.45 - 5.14 | 7.7 |
| Valdez et al., 2002 | 5.31 | 0.22 | 4.99 - 5.52 | 4.1 |
| NRCS Crop Nutrient Tool | 7.34 | | | |
| USDA Food Composition Database | 5.86 | 1.57 | 5.82 - 7.20 | 26.7 |
| **Overall** | **5.78** | **1.49** | **4.45 - 7.20** | **25.7** |

* These studies reported N concentration in dry matter. A dry matter content of 10% was assumed based on the USDA Database.

## Discussion

Only one value in the table is from California, but the study was carried out more than 50 years ago. With 85% of the observations, the USDA Food Composition Database contributes most to the average value. To determine whether these values are a good estimate for green beans harvested in the Central Valley, some samples from the major commercial varieties need to be collected from fields in Central Valley over a period of several years.

## References


Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

Martínez, C., Ros, G, Periago, M.J., Joseüna Ortuño, J., López, G., Rincón, F., 1998. *In vitro* protein digestibility and mineral availability of green beans (*Phaseolus vulgaris* L) as influenced by variety and pod size. Journal of the Science of Food and Agriculture 77, 414-420.

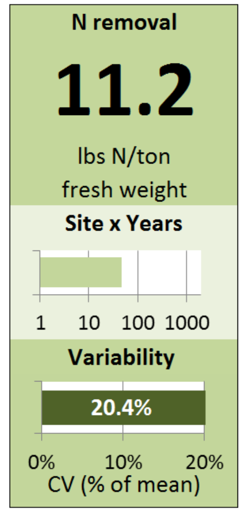
Phillips, S.B., Mullins, G.L., Donohue, S.J., 2002. Changes in snap bean yield, nutrient composition, and soil chemical characteristics when using broiler litter as fertilizer source. Journal of Plant Nutrition. 25, 1607-1620.

Segura, M.L., Contreras París, J.I., Plaza, B.M., Lao, M.T., 2012. Assessment of the nitrogen and potassium fertilizer in green bean irrigated with disinfected urban wastewater. Communications in Soil Science and Plant Analysis 43, 426-433.

Valdez, M.T., Ito, T., Shinohara, Y. Maruo, T., 2002. Effects of nutrient solution levels on the growth, yield and mineral contents in hydroponically-grown bush snap bean. Environmental Control in Biology 40, 167-175.

Varennes, A., Melo-Abreu, J.P., Ferreira, M.E., 2002. Predicting the concentration and uptake of nitrogen, phosphorus and potassium by field-grown green beans under non-limiting conditions. European Journal of Agronomy 17, 63–72.

# Broccoli




## Data sources

The dataset includes a recent study from California, carried out in 14 commercial fields in the Salinas Valley. The other studies included for this analysis were conducted in Arizona, Canada and Spain. A value from the NRCS Crop Nutrient Tool, which was taken from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" (Howard et al., 1962), was also included.

## Relevance

14 of the 46 observations are from commercial fields in the Salinas Valley. These values are about 25% lower than the average of the values reported in the other studies. The reasons for this difference are not known. Based on this and the fact that no data from the Central Valley are available, the average value in the table may not be a good estimate of the N concentration in broccoli harvested from fields in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Smith et al., 2013 | Salinas, CA | 14 | 2012-13 | 1 | 14 |
| Thompson et al., 2003 | Arizona | 1 | 2000 | 1 | 4 |
| Bakker et al., 2009a, b | Canada | 1 | 2001-02 | 2 | 8 |
| Zebarth et al., 1995 | Canada | 1 | 1990-91 | 3 | 18 |
| Rincon et al., 1999 | Spain | 1 | 1996 | 1 | 1 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **46** |

*Summary statistics of broccoli N removal data.*

| Source | Summary (lbs N/ton) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Smith et al., 2013 | 9.0 | 1.10 | 7.73 - 11.64 | 12.2 |
| Thompson et al., 2003 | 11.3 | 0.43 | 11.01 - 11.91 | 3.8 |
| Bakker et al., 2009a, b | 12.5 | 1.36 | 11.58 - 14.50 | 10.8 |
| Zebarth et al., 1995 | 12.4 | 3.25 | 7.48 - 19.01 | 26.3 |
| Rincon et al., 1999 | 10.5 | | | |
| NRCS Crop Nutrient Tool | 11.6 | | | |
| **Overall** | **11.2** | **2.28** | **7.48 - 19.01** | **20.4** |

## Variability

The variability of the data from the Salinas Valley is due to differences among commercial fields. Thompson et al. (2003) and Bakker et al. (2009 a, b) found that N application rate had little effect on the N concentration in the harvested parts of broccoli. This is in contrast to the results of Zebarth et al. (1995), who found that N concentration in broccoli increased with increasing N application rate. This study included data from three plantings over a period of 11 months. The result showed a pronounced effect of planting date on N concentration.

## Discussion

The values from the Salinas Valley are about 25% lower than the average of the values reported in the other studies. Based on this and the fact that no data from the Central Valley are available, the average value in the table may not be a good estimate of the N concentration in broccoli harvested from fields in the Central Valley. For a representative and robust estimate of N removal with broccoli in the Central Valley, samples need to be collected over a period of several years.

## References


Bakker, C.J., Swanton, C.J., McKeown, A.W., 2009a. Broccoli growth in response to increasing rates of pre-plant nitrogen. I Yield and quality. Canadian Journal of Plant Science 89, 527-537.

Bakker, C.J., Swanton, C.J., McKeown, A.W., 2009b. Broccoli growth in response to increasing rates of pre-plant nitrogen. II. Dry matter and nitrogen accumulation. Canadian Journal of Plant Science 89, 539-548.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

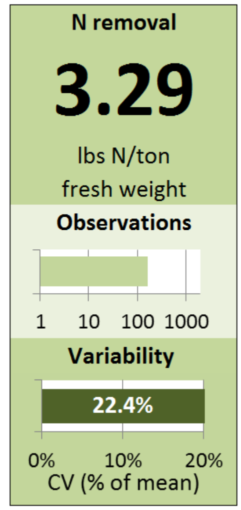
Rincon L., Saez J., Perez Crespo J.A., Gomez Lopez M.D., Pellicer C., 1999. Crecimiento y absorcion de nutrientes del brocoli. Investigación Agraria. Producción y Protección Vegetales 14, 225-236.

Smith, R., Cahn, M., Hartz, T.K., 2013. Survey of nitrogen uptake and applied irrigation water in broccoli, cauliflower and cabbage production in the Salinas Valley. CDFA-FREP Conference Proceedings 2013, 117-119. Available online at: https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/2013_Proceedings_FREP.pdf. Complemented with unpublished data.

Thompson, T.L. White, S.A., Walworth, J., Sower, G.J., 2003. Fertigation frequency of subsurface drip-irrigated broccoli. Soil Science Society of America Journal 67, 910–918.

Zebarth, B.J., Bowen, P.A., Toivonen, P.M.A., 1995. Influence of nitrogen fertilization on broccoli yield, nitrogen accumulation and apparent fertilizer-nitrogen recovery. Canadian Journal of Plant Science 75, 717-725.

# Carrots




## Data sources

The data compiled for this report are from a wide range of studies from the U.S., Canada, Poland and China. The USDA Food Composition Database contributed 19 observations. The values reported here are for carrot roots and do not include foliage. The total number of observations is 167.

## Relevance

Only the value reported in the NRCS Crop Nutrient Tool is from California, namely from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" (Howard et al., 1962). With the data available it is not possible to determine the degree to which the average value in the table is representative of the N concentration in carrots harvested in California.

## Variability

The variability in carrot N concentration is relatively large, both within and among studies, with the highest value reported being more than four times the lowest value. Nitrogen availability has a strong effect on carrot N concentration. The highest values in the dataset are from treatments with N application rates exceeding 150 lbs/acre and from carrots grown on soils with a high soil organic matter content. Large differences were also observed between years.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Makries and Warncke, 2013 | Michigan | 2 | 2001 | 2 | 20 |
| Hochmuth et al., 1999 | Florida | 1 | 1994-95 | 2 | 15 |
| Westerveld et al., 2006a, b | Ontario, Canada | 2 | 2002 | 3 | 18 |
| Caron et al., 2014 | Quebec, Canada | 1 | | 3 | 20 |
| Smolen and Sady, 2008 and 2009 | Poland | 1 | 2003-2005 | 3 | 70 |
| Chen et al., 2004 | China | 1 | 1999 | 1 | 4 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 19 |
| **Overall** | | | | | **167** |

*Summary of carrot N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Makries and Warncke, 2013 | 2.89 | 0.40 | 2.09 - 3.51 | 13.8 |
| Hochmuth et al., 1999 | 4.06 | 1.51 | 2.42 - 7.35 | 37.2 |
| Westerveld et al., 2006a, b | 4.11 | 1.61 | 1.71 - 6.95 | 39.3 |
| Caron et al., 2014 | 3.43 | 0.45 | 2.91 - 4.76 | 13.0 |
| Smolen and Sady, 2008 and 2009 | 2.94 | 0.16 | 2.68 - 3.10 | 5.5 |
| Chen et al., 2004 | 5.64 | 0.74 | 4.68 - 6.32 | 13.2 |
| NRCS Crop Nutrient Tool | 3.63 | | | |
| USDA Food Composition Database | 2.98 | 0.11 | 2.18 - 3.81 | 3.7 |
| **Overall** | **3.29** | **0.74** | **1.71 - 7.35** | **22.4** |

## Discussion

Given the variability of values reported and the absence of recent values from California, samples need to be collected from fields in California over a period of several years for a representative and robust estimate of N removal with carrots.

## References


Caron, J., Rancourt, G.T., Bélec, C., Tremblay, N., Parent, L.-É., 2014. Nitrogen budget for fertilized carrot cropping systems in Quebec organic soil. Canadian Journal of Soil Science 94, 139-148.

Chen, Q., Li, X., Horlacher, D., Liebig, H.-P., 2006. Effects of different nitrogen rates on open-field vegetable growth and nitrogen utilization in the North China Plain. Communications in Soil Science and Plant Analysis 35, 1725-1740.

Hochmuth, G.J., Brecht, J.K., Bassett, M.J., 1999. Nitrogen fertilization to maximize carrot yield and quality on a sandy soil. HortScience 34, 641-645.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

Makries, J.L., Warncke, D.D., 2013. Timing nitrogen applications for quality tops and healthy root production in carrot. Communications in Soil Science and Plant Analysis 44, 2860-2874.

Smolen, S., Sady, W., 2008. Effect of various nitrogen fertilisation and foliar nutrition regimes on carrot (*Daucus carota* L.) yield. Journal of Horticultural Science & Biotechnology 83, 427-434.

Smolen, S., Sady, W., 2009. The effect of various nitrogen fertilization and foliar nutrition regimes on the concentrations of nitrates, ammonium, dry matter and N-total in carrot (*Daucus carota* L.) roots. Scientia Horticulturae 119, 219-231.

Westerveld, S.M., McDonald, M.R., McKeown, A.W., 2006a. Carrot yield, quality, and storability in relation to preplant and residual nitrogen on mineral and organic soils. HortTechnology 16, 286-293.

Westerveld, S.M., McKeown, A.W., McDonald, M.R., 2006b. Seasonal nitrogen partitioning and nitrogen uptake of carrots as affected by nitrogen application a mineral and an organic soil. HortScience 41, 1332-1338.

# Corn, sweet

**N removal**

**7.17**

lbs N/ton
fresh weight

**Observations**


**Variability**


## Data sources

Four studies, three of them from the U.S., the other from Australia, were included in our analysis. Two of the studies investigated different N treatments (Sanmaneechai et al., 1984; Salardini et al 1992), one study compared leaching treatments (Zotarelli et al., 2008), while the fourth study was a variety trial (Heckman, 2007). No data from California was available. The N removed is for the entire ear (husk, kernel, cob and silk).

## Relevance

With no data available from California it is not possible to determine whether the values in the table are a good estimate for N concentrations in for sweet corn harvested in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Sanmaneechai et al., 1984 | Washington | 1 | 1980 | 1 | 17 |
| Zotarelli et al., 2008 | Florida | 1 | 2004-06 | 2 | 6 |
| Heckman, 2007 | New Jersey | 2 | 2003-04 | 2 | 15 |
| Salardini et al 1992 | Australia | 1 | 1988 | 1 | 12 |
| **Overall** | | | | | **50** |

*Summary statistics of sweet corn N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Sanmaneechai et al., 1984 | 9.08 | 0.74 | 7.64 - 10.60 | 8.2 |
| Zotarelli et al., 2008 | 6.78 | 1.41 | 5.18 - 9.12 | 20.8 |
| Heckman, 2007 | 6.44 | 1.17 | 4.83 - 8.40 | 18.1 |
| Salardini et al 1992 | 5.60 | 0.47 | 4.93 - 6.39 | 8.4 |
| **Overall** | **7.17** | **0.94** | **4.83 - 10.60** | **13.1** |

## Variability

The average N concentration in sweet corn ears differed considerably among studies, ranging from 5.6 to 9.1 lbs/ton. Nitrogen availability had no consistent effect on the N concentration in sweet corn ears (Sanmaneechai et al., 1984; Salardini et al 1992; Zotarelli et al., 2008). The study by Heckman (2007) showed that the N concentration can differ considerably between varieties, but also from one year to the next.

## Discussion

The value in the table may not be representative for California. Samples need to be taken over a period of several years from fields planted to different varieties to generate a robust estimate of the N removed with sweet corn in the Central Valley.

## References

Heckman, J.R., 2007. Sweet corn nutrient uptake and removal. HortTechnology 17, 82-86.

Salardini, A.A., Sparrow, A., Holloway, R.J, 1992. Sweet corn responses to basal and top-dressed rates and sources of nitrogenous fertilizers. Australian Journal of Agricultural Research 43, 171-180.

Sanmaneechai, M., Koehler, F.E., Roberts, S., 1984. Nitrogen fertilization practices for sequential cropping of wheat, turnips, and sweet corn. Soil Science Society of America Journal 48, 81-86.

Zotarelli, L., Scholberg, J.M., Dukes, M.D., Muñoz-Carpena, R. 2008. Fertilizer residence time affects nitrogen uptake efficiency and growth of sweet corn. Journal of Environmental Quality 37, 1271–1278.

# Cucumbers

N removal

**2.16**

lbs N/ton
fresh weight

**Observations**


**Variability**


## Data sources

No recent studies reporting N or protein concentration in cucumbers could be identified. The data included for this analysis are from trials in Canada and Europe, as well as from the USDA Food Composition Database and the NRCS Crop Nutrient Tool. The total number of observations is 10.

## Relevance

The research studies included in this report were published at least 40 years ago. This is also true for the value included in the NRCS Crop Nutrient Tool, which is from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" published in 1962 (Howard et al., 1962). This is the only value from California. In contrast, the values reported in the USDA Food Composition Database appear to be more recent. With the data available it is not possible to determine how well the average value represents the N concentration of cucumbers harvested in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Ward and Miller, 1970 | Canada | 1 | 1968 | 1 | 2 |
| Ward, 1967 | Canada | 1 | 1965 | 1 | 1 |
| Geissler, 1957 | Germany | 1 | 1954 | 1 | 1 |
| Davies and Kempton, 1976 | England | 1 | 1974 | 1 | 1 |
| USDA Food Composition Database | | | | | 4 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | **4** | | | **10** |

*Summary statistics of cucumber N removal data.*

| Source | Summary (lbs N/ton) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Ward and Miller, 1970 | 2.47 | 0.52 | 2.11 - 2.84 | 21.0 |
| Ward, 1967 | 2.41 | | | |
| Geissler, 1957 | 2.11 | | | |
| Davies and Kempton, 1976 | 1.60 | | | |
| USDA Food Composition Database | 2.08 | | | |
| NRCS Crop Nutrient Tool | 2.25 | | | |
| **Overall** | **2.16** | **0.38** | **1.60 - 2.84** | **17.4** |

## Variability

The variability among studies, while considerable, was not as large as might be expected for values from different countries and eras. However, none of the studies included different N fertilization levels, varieties or growth stages at harvest. Therefore, the values in the table most likely underestimate the variability of N concentrations in cucumbers.

## Discussion

Most of the values included in the table are from studies conducted more than 40 years ago. The average value reported in the table may not be representative of current varieties and management practices in California. Therefore, samples need to be collected from fields in California over a period of several years for a representative and robust estimate of N removal with cucumbers.

## References

Davies, J.N. and Kempton, R.J., 1976. Some changes in the composition of the fruit of the glasshouse cucumber (*Cucumis sativus*) during growth, maturation and senescence. Journal of the Science of Food and Agriculture 27, 413-418.

Geissler, T., 1957. Der Nährstoffentzug einer frühen Treibgurkenkultur. Archiv für Gartenbau 5, 431-466.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

Ward, G.M., 1967. Greenhouse cucumber nutrition a growth analysis study. Plant and Soil 26, 324-332.

Ward, G.M., Miller, M.J., 1970. Relationship between fruit sizes and nutrient content of greenhouse tomatoes and cucumbers. Canadian Journal of Plant Sciences 50, 451-455.

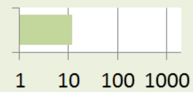
# Garlic

N removal

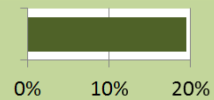
**15.1**

lbs N/ton
fresh weight

**Observations**




**Variability**




## Data sources

Few studies measuring N concentration in garlic could be identified. The studies included in the table were carried out in France, New Zealand and Ethiopia. The NRCS Crop Nutrient Tool also reports a value for garlic N removal, which was taken from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" (Howard et al., 1962). The values reported here are for the entire bulb, but do not include the leaves.

## Relevance

The one value in the table from California was published more than 50 years ago. With the data available it is not possible to determine how well the values in the table represent N concentrations in garlic harvested in California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Bertoni et al., 1992 | France | 1 | 1990 | 1 | 3 |
| Minard, 1978 | New Zealand | 1 | 1973 | 1 | 2 |
| Diriba-Shifereaw et al., 2013 | Ethiopia | 2 | 2011 | 1 | 6 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **12** |

*Summary statistics of garlic N removal data.*

| Source | Summary (lbs N/ton fresh weight) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Bertoni et al., 1992 | 13.3 | 3.44 | 9.41 - 16.03 | 26.0 |
| Minard, 1978 | 13.4 | 1.80 | 12.11 - 14.67 | 13.5 |
| Diriba-Shifereaw et al., 2013 | 15.8 | 2.91 | 12.49 - 19.45 | 18.5 |
| NRCS Crop Nutrient Tool | 20.5 | | | |
| **Overall** | **15.1** | **2.94** | **9.41 - 20.48** | **19.5** |

## Variability

The variability of the data within and among studies is relatively high. Diriba-Shifereaw et al. (2013) found that the N concentration in garlic increased by roughly 40% when the N application rate was increased from 0 to 80 lbs/acre. The effect of other factors on N concentration in garlic bulbs, e.g. variety and crop management were not investigated in the studies compiled here.

## Discussion

Few observations for garlic N concentrations were available. Only one value is from California, but the study was carried out more than 50 years ago. Therefore, for a representative and robust estimate of N removal with garlic, samples need to be collected from fields in California over a period of several years.

## References


Bertoni, G., Morard, F., Soubieille, C., Llorens, J.M., 1992. Growth and nitrogen nutrition of garlic *(Allium sativum* L.) during bulb development. *Scientia Horticulturae* 50, 187-195.

Diriba-Shiferaw G., Nigussie-Dechassa R., Kebede Woldetsadik, Getachew Tabor, Sharma, J. J., 2013. Bulb quality of garlic (*Allium sativum* L.) as influenced by the application of inorganic fertilizers. African Journal of Agricultural Research 8, 5387-5398.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

Minard, H.R.G., 1978. Effect of clove size, spacing, fertilisers, and lime on yield and nutrient content of garlic (*Allium sativum*). New Zealand Journal of Experimental Agriculture 6, 139-143.

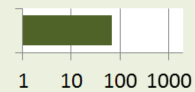
# Lettuce, Iceberg

**N removal**

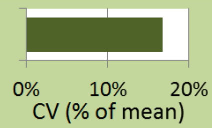
**2.63**

lbs N/ton
fresh weight

**Observations**




**Variability**




## Data sources

The majority of the data included in the table are from two recent studies carried out in commercial fields on the Central Coast. Bottoms et al. (2012) compared different irrigation and N fertilization strategies, resulting in a total of 34 observations from 15 fields. In this study, N concentrations in the aboveground biomass were determined, which includes residue (e.g. wrapper leaves) that is left in the field. Data from Breschini and Hartz (2002) suggest that the N concentration in harvested heads is about 20% lower than in the entire aboveground biomass (Hartz, personal communication). This is due to higher dry matter content and N concentration in the residue. To account for these differences, the values reported by Bottoms et al. (2012) for the aboveground biomass were reduced by 20% for this analysis.

A relatively large number of samples (n=23) has also been analyzed for the USDA Food Composition Database. Given the fact that California produces a large proportion of the iceberg lettuce consumed in the U.S., the USDA database likely includes a number of samples from lettuce grown in California. The value included in the NRCS Crop Nutrient Tool is also based on data from California; however, the report was published more than 50 years ago (Howard et al., 1962).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Bottoms et al., 2012 | Salinas, CA | 15 | 2007-10 | 3 | 34 |
| Breschini and Hartz, 2002 | Central Coast, CA | 10 | 1999 | 2 | 10 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 23 |
| **Overall** | | | | | **68** |

*Summary of iceberg lettuce N removal data.*

| Source | Summary (lbs/ton) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Bottoms et al., 2012 | 2.46 | 0.38 | 1.75 - 2.98 | 15.3 |
| Breschini and Hartz, 2002 | 2.61 | 0.49 | 1.96 - 3.60 | 18.7 |
| NRCS Crop Nutrient Tool | 2.56 | | | |
| USDA Food Composition Database | 2.88 | 0.52 | 2.02 - 4.74 | 18.1 |
| **Overall** | **2.63** | **0.44** | **1.75 - 4.74** | **16.7** |

## Relevance

Most of the data included in the table are from California, mainly from the central Coast. Even though no values are available from lettuce grown in the Central Valley, the values in the table are likely a good estimate of N concentration in Central Valley-grown lettuce, based on the assumption that crop management and varieties are similar.

## Variability

The variability of the data within datasets is relatively large. Reducing the N application rate by taking soil residual N into account had little effect on lettuce N concentration (Bottoms et al., 2012). The fact that reduced N rates had no effect on yield either suggests that in this study, N was not limiting even at the lower application rate. There was a marked difference among sites. This was also the case for Breschini and Hartz (2002).

## Discussion

The data included in the table are likely a good estimate of N concentrations in iceberg lettuce harvested in the Central Valley, even though most of the data are from the Salinas Valley. The confidence in the value could be improved by complementing the dataset with lettuce samples from Central Valley fields.

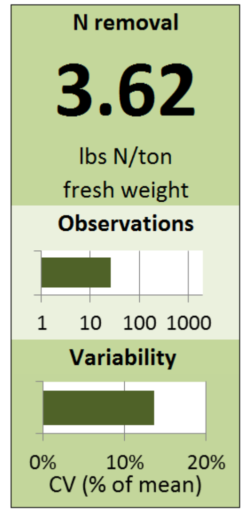
## References

Bottoms, T.G., Smith, R.F., Cahn, M.D., Hartz, T.K., 2012. Nitrogen requirements and N status determination of lettuce. HortScience 47, 1768-1774.

Breschini, S.J., Hartz, T.K., 2002. Presidedress Soil Nitrate Testing Reduces Nitrogen Fertilizer Use and Nitrate Leaching Hazard in Lettuce Production. HortScience 37, 1061–1064. Complemented with unpublished data.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

# Lettuce, Romaine




## Data sources

A large proportion of the data included in the table are from a recent study carried out in 6 commercial fields in the Salinas Valley. In each field, different irrigation and N fertilization strategies were compared, resulting in a total of 12 observations (Bottoms et al., 2012). In this study, N concentrations in the aboveground biomass were determined, which includes residue that is left in the field. Data from Breschini and Hartz (2002) suggest that the N concentration in harvested leaves is about 10% lower than in the entire aboveground biomass (Hartz, personal communication). This is due to higher dry matter content and N concentration in the residue. To account for these differences, the values reported by Bottoms et al. (2012) for the aboveground biomass were reduced by 10% for this analysis.

An additional 12 samples were also included in the USDA Food Composition Database. Given the fact that California produces a large proportion of the romaine lettuce consumed in the U.S., the USDA database likely includes a number of samples from lettuce grown in California. The value included in the NRCS Crop Nutrient Tool is also based on data from California; however, the report was published more than 50 years ago (Howard et al., 1962).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Bottoms et al., 2012 | Salinas, CA | 6 | 2007-10 | 3 | 12 |
| Breschini and Hartz, 2002 | Central Coast, CA | 1 | 1999 | 1 | 1 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 12 |
| **Overall** | | | | | **26** |

*Summary of romaine lettuce N removal data.*

| Source | Summary (lbs/ton fresh weight) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Bottoms et al., 2012 | 3.21 | 0.51 | 2.27 - 3.90 | 15.9 |
| Breschini and Hartz, 2002 | 3.20 | | | |
| NRCS Crop Nutrient Tool | 5.12 | | | |
| USDA Food Composition Database | 3.94 | 0.48 | 3.20 - 4.70 | 12.1 |
| **Overall** | **3.62** | **0.49** | **2.27 - 5.12** | **13.7** |

## Relevance

Most of the data included in the table are from California, mainly from the central Coast. Even though no values are available from lettuce grown in the Central Valley, the values in the table are likely a good estimate of N concentration in Central Valley-grown lettuce, based on the assumption that crop management and varieties are similar.

## Variability

The variability of the data within and among datasets is relatively large. Reducing the N application rate by taking soil residual N into account had little effect on lettuce N concentration (Bottoms et al., 2012). The fact that reduced N rates had no effect on yield either suggests that in this study, N was not limiting even at the lower application rate. There was a marked difference among sites.

## Discussion

The data included in the table are likely a good estimate of N concentrations in romaine lettuce harvested in the Central Valley, even though most of the data are from the Salinas Valley. The confidence in the value could be improved by complementing the dataset with lettuce samples from Central Valley fields.

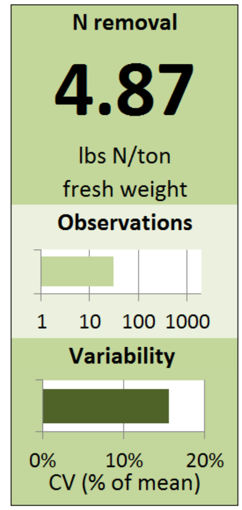
## References


Bottoms, T.G., Smith, R.F., Cahn, M.D., Hartz, T.K., 2012. Nitrogen requirements and N status determination of lettuce. HortScience 47, 1768-1774.

Breschini, S.J., Hartz, T.K., 2002. Presidedress Soil Nitrate Testing Reduces Nitrogen Fertilizer Use and Nitrate Leaching Hazard in Lettuce Production. HortScience 37, 1061–1064. Complemented with unpublished data.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

# Melon, Cantaloupe




### Data sources

Two studies from Arizona, one study from Spain and a value from the NRCS Crop Nutrient Tool were included in the dataset for a total of 31 observations. The NRCS Crop Nutrient Tool uses data from a survey on California vegetable crops published more than 50 years ago (Howard et al, 1962). The two Arizona studies only reported N concentration in the dry matter. To convert the values to N concentration in fresh melons, a dry matter content of 10% was assumed, which is the value given in the NRCS Crop Nutrient Tool.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Doerge et al., 1991 | Arizona | 1 | 1990 | 1 | 6 |
| Soto-Ortiz, 2008 | Arizona | 1 | 2003-2005 | 3 | 18 |
| Contreras et al., 2012 | Spain | 1 | 2010 | 1 | 6 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **31** |

*Summary statistics of cantaloupe melon N removal data.*

| Source | Summary (lbs/ton of fresh melons) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Doerge et al., 1991 | 3.88 | 0.87 | 2.41 - 4.91 | 22.4 |
| Soto-Ortiz, 2008 | 5.90 | 0.62 | 5.24 - 7.02 | 10.5 |
| Contreras et al., 2012 | 3.08 | 1.01 | 1.97 - 4.47 | 32.9 |
| NRCS Crop Nutrient Tool | 3.01 | | | |
| **Overall** | **4.87** | **0.76** | **1.97 - 7.02** | **15.5** |

### Relevance

Only one observation is from California. Under the assumption that the growing conditions in Arizona resemble those in California, the dataset should provide a reasonable estimate of the N concentration in Cantaloupe melons grown in California.  However, the two Arizona studies reported very different N concentrations.

### Variability

The variability within and among studies is large. Especially surprising is the difference between the two studies carried out in Arizona. In the study by Soto-Ortiz (2008), the N concentration in melons was roughly 50% higher than the N concentration reported by Doerge et al. (1991). Soto-Ortiz (2008) reported average values over the three years of the study. The variability within the dataset is due to different varieties. The variability within the study carried out by Contreras et al. (2012) is due to different N fertilization levels. In this study, the N concentration increased considerably with increasing N application rates.

## Discussion

Nitrogen concentrations in cantaloupe melons vary considerably. The available data indicate that N application rate and variety have a strong effect. Given the uncertainty about the contribution of other factors and the fact that no recent values from California are included in our dataset, samples need to be collected from fields in California over a period of several years for a more robust estimate of N removal with cantaloupe melons.

## References

Contreras, J.I., Plaza, B.M., Lao, M.T., Segura, M.L., 2012. Growth and nutritional response of melon to water quality and nitrogen potassium fertigation levels under greenhouse Mediterranean conditions. Communications in Soil Science and Plant Analysis 43, 434-444.

Doerge, T.A., Pritchard, K.H., Pier, J.W., Fernandez, P., McCreary, T.W., 1991. Nitrogen utilization efficiency in melons using soluble and slow release fertilizers. University of Arizona Vegetable Report, 41-57. Available online at: http://hdl.handle.net/10150/221437

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

Soto-Ortiz, R., 2008. Crop phenology, dry matter production, and nutrient uptake and partitioning in cantaloupe (*Cucumis melo* L.) and chile (*Capsicum annuum* L.). Dissertation. Available online at: http://hdl.handle.net/10150/194813

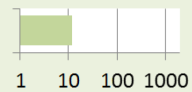
# Melon, Honeydew

**N removal**

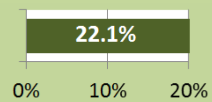
**2.95**

lbs N/ton
fresh weight

**Observations**




**Variability**




## Data sources

Little information about N removed in honeydew melons is available. The NRCS Crop Nutrient Tool contains one value based on a survey of California vegetable crops published more than 50 years ago (Howard et al., 1962). We found one study from Spain, which reported results from an N rate trial with Piel de Sapo melon, a type of melon that belongs to the honeydew group (Castellanos et al., 2012). Given the scarcity of information available, the results of this study were included here.

## Relevance

No recent values from melons harvested in California were found. It is not possible to determine whether the values reported in the table are a good estimate for honeydew melons grown in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Castellanos et al., 2012 | Spain | 1 | 2005-07 | 3 | 11 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **12** |

*Summary statistics of honeydew melon N removal data.*

| Source | Summary (lbs/ton of fresh melons) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Castellanos et al., 2012 | 2.96 | 0.63 | 1.98 - 4.25 | 21.4 |
| NRCS Crop Nutrient Tool | 2.81 | | | |
| **Overall** | **2.95** | **0.65** | **1.98 - 4.25** | **22.1** |

## Variability

The variability within the study carried out by Castellanos et al. (2012) is large. The main factor contributing to the variability is N fertilization level. Nitrogen concentration in the melons increased considerably with increasing N application rates, while the year of production had a much smaller effect. The average value from this study conducted in Spain is similar to the value reported in the NRCS Crop Nutrient Tool.

## Discussion

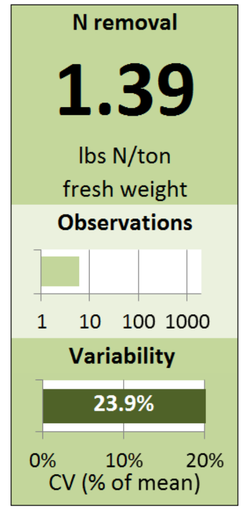
Nitrogen concentrations in honeydew melons vary considerably. The available data indicate that N application rate has a strong effect. Given uncertainty about the contribution of other factors and the fact that no recent values from California are included in our dataset, samples need to be collected from fields in California over a period of several years for a representative and robust estimate of N removal with honeydew melons.

## References


Castellanos, M.T., Cabello, M.J., Cartagena, M.C., Tarquis, A.M., Arce, A., Ribas, F., 2012. Nitrogen uptake dynamics, yield and quality as influenced by nitrogen fertilization in 'Piel de sapo' melon. Spanish Journal of Agricultural Research 10, 756-767.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

# Melon, Watermelon




## Data sources

Little information about N removed with watermelons is available. The NRCS Crop Nutrient Tool contains a value based a survey on California vegetable crops published more than 50 years ago (Howard et al., 1962). In addition, a study from Arizona was included in the dataset (Doerge et al., 1991).

## Relevance

No recent values from watermelons harvested in California were found. With the data available it is not possible to determine whether the values reported here are a good estimate for N concentrations in watermelons harvested in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Doerge et al., 1991 | Arizona | 1 | 1990 | 1 | 5 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **6** |

*Summary statistics of watermelon N removal data.*

| Source | Summary (lbs/ton fresh melons) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Doerge et al., 1991 | 1.26 | 0.17 | 0.95 - 1.40 | 13.5 |
| NRCS Crop Nutrient Tool | 2.04 | | | |
| **Overall** | **1.39** | **0.33** | **0.95 - 2.04** | **23.9** |

## Variability

Doerge et al. (1991) investigated different types of N fertilizer and times of application, while the application rate was kept constant. The treatment effect on melon N concentration was relatively small. As the effects of location, year, variety and N application rate have not been addressed in the compiled dataset, the standard deviation and CV reported in the table are of limited use.

## Discussion

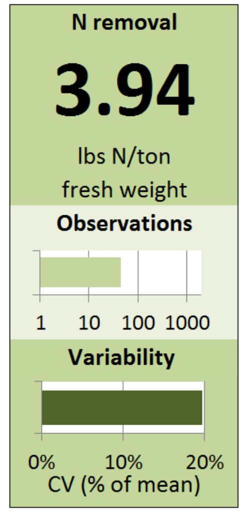
The value in the table may not be representative for watermelons grown in the Central Valley. Samples need to be taken over a period of several years from fields located in the main growing areas in the Central Valley to generate a robust estimate of the N removed per unit yield and provide information about the dominant factors contributing to the variability of the estimate.

## References


Doerge, T.A., Pritchard, K.H., Pier, J.W., Fernandez, P., McCreary, T.W., 1991. Nitrogen utilization efficiency in melons using soluble and slow release fertilizers. University of Arizona Vegetable Report, 41-57. Available online at: http://hdl.handle.net/10150/221437

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

# Onion




## Data sources

Values from three studies were included in our analysis. Zink (1966) collected samples from five fields in the Salinas Valley, while Biscaro et al. (2014) assessed aboveground biomass N uptake of fresh-market onions in Lancaster, CA from three fields in 2013 and two fields in 2014. Pradhan et al. (2015) investigated different sulfur application treatments in a study carried out in India. In addition, the NRCS Crop Nutrient Tool contributed 3 values and the USDA Food Composition Database 25 values. The NRCS Crop Nutrient Tool uses data from a survey on California vegetable crops published more than 50 years ago (Howard et al., 1962). Except for Biscaro et al. (2014), the values reported here are for the entire bulb, but do not include the leaves.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Biscaro et al., 2014 | Lancaster, CA | 5 | 2013-14 | 2 | 5 |
| Zink, 1966 | Salinas, CA | 1 | 1961 | 1 | 5 |
| Pradhan et al., 2015 | India | 1 | 2012 | 1 | 7 |
| NRCS Crop Nutrient Tool | | | | | 3 |
| USDA Food Composition Database | | | | | 25 |
| **Overall** | | | | | **45** |

*Summary statistics of onion N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Biscaro et al., 2014 | 3.42 | 0.44 | 2.97 - 3.92 | 12.9 |
| Zink, 1966 | 5.41 | 0.59 | 4.83 - 6.29 | 10.8 |
| Pradhan et al., 2015 | 4.89 | 1.15 | 3.10 - 6.16 | 23.5 |
| NRCS Crop Nutrient Tool | 3.60 | 1.74 | 1.60 - 4.80 | 48.4 |
| USDA Food Composition Database | 3.52 | 0.58 | 2.53 - 3.81 | 16.4 |
| **Overall** | **3.94** | **0.78** | **1.60 - 6.29** | **19.7** |

## Relevance

Biscaro et al. (2014) reported values of fresh-market intermediate and long-day onions varieties grown in the High Desert area of Southern California (Lancaster), where crop evapotranspiration is usually greater than other onion producing areas in California. Zink (1966) and the NRCS Crop Nutrient Tool also reported values from California. However, both datasets are more than 50 years old. In both cases, the varieties were long-day varieties. In contrast, contemporary Central Valley production is dominated by short- and intermediate-day varieties (Voss and Mayberry, 1999; Smith et al., 2011). Whether the three types differ in their N concentration cannot be determined with the data available. Therefore, it's questionable whether the values compiled for this report are a good estimate of the N concentration in onions currently harvested in the Central Valley.

## Variability

The values reported in the NRCS tool and the USDA database are much lower than the values reported in the two studies included. Part of the difference is due to different dry matter contents. While the NRCS tool and USDA database report a dry matter content of 10-14%, it ranged from 14.9 to 16.3 in the study conducted by Zinc (1966). Biscaro et al. (2014) reported dry matter content of 5-9%. The two varieties included in the NRCS Tool also differed considerably, with the N removed by Sweet Spanish and Southport onions being 4.8 and 1.6 lbs/ton, respectively.

## Discussion

The value in the table may not be representative of N concentrations in onions harvested in the Central Valley. Samples need to be taken over a period of several years from fields located in the main growing areas in the Central Valley to generate a robust estimate of the N removed per unit yield. The relevant varieties should be included in the sample. Dry matter content of the onions may have a large effect on onion N concentration and should also be investigated.

## References


Biscaro, A., Cahn, M., Smith, R., Hartz, T., 2014. Nitrogen, phosphorus and potassium uptake patterns of fresh-market onion production in southern California. American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America (ASA, CSSA, and SSSA) International Annual Meetings, Long Beach CA. Available online at: https://dl.sciencesocieties.org/publications/meetings/download/pdf/2014am/89719 Complemented with unpublished data.

Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

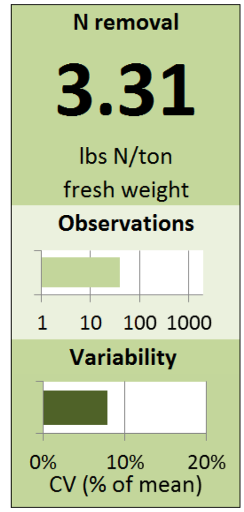
Pradhan, R., Pattnaik, A. K., Tripathy, P., Mallikarjunarao, K., Sahoo, B. B. Lenka, J., 2015. Influence of sulphur fertilization on nutrient uptake of onion (*Allium cepa* L.). Journal Crop and Weed 11, 134-138.

Smith, R., Biscaro, A., Cahn, M., Daugovish, O., Natwick, E., Nunez, J., Takele, E., Turini, T., 2011. Fresh-market bulb onion production in California. UC ANR Publication 7242. Available online at: http://anrcatalog.ucanr.edu/Details.aspx?itemNo=7242

Voss, R.E., Mayberry, K.S., 1999. Dehydrator bulb onion production in California. UC ANR Publication 7239. Available online at: http://anrcatalog.ucdavis.edu/pdf/7239.pdf

Zink, F.W., 1966. Studies on the growth rate and nutrient absorption of onion. Hilgardia 37, 203-218.

# Pepper, Bell




## Data sources

The dataset for this analysis includes four trials, one of which was carried out on the Central Coast, 20 observations from the USDA Food Composition Database and two observations from the NRCS Crop Nutrient Tool.

## Relevance

Only four observations are from a recent study carried out in California. The N concentration reported by Baameur and Smith (2012) is slightly lower than the average across all studies. However, with such a small sample size, it is not possible to determine whether the values reported in the table are a good estimate of the N concentration in bell peppers grown in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Baameur and Smith, 2012 | Central Coast, CA | 1 | 2011 | 1 | 4 |
| Russo, 1991 | Lane, OK | 1 | 1989-90 | 2 | 2 |
| Marti and Mills, 1991 | Athens, GA | 1 | 1990 | 1 | 2 |
| Haynes, 1988 | New Zealand | 1 | 1987 | 1 | 8 |
| USDA Food Composition Database | | | | | 22 |
| NRCS Crop Nutrient Tool | | | | | 2 |
| **Overall** | | | | | **40** |

*Summary statistics of bell pepper N removal data.*

| Source | Summary (lbs N/ton of fresh weight) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Baameur and Smith, 2012 | 2.59 | | | |
| Russo, 1991 | 4.74 | 0.36 | 4.48 - 4.99 | 7.6 |
| Marti and Mills, 1991 | 5.45 | 0.96 | 4.77 - 6.13 | 17.6 |
| Haynes, 1988 | 3.60 | 0.09 | 3.49 - 3.79 | 2.6 |
| USDA Food Composition Database | 3.04 | 0.21 | 2.18 - 3.33 | 7.0 |
| NRCS Crop Nutrient Tool | 2.91 | 0.50 | 2.56 - 3.27 | 17.2 |
| **Overall** | **3.31** | **0.26** | **2.18 - 6.13** | **7.9** |

## Variability

Little information about the factors affecting N concentration in bell peppers can be gained from the studies included in the table. In the study carried out by Haynes (1988), increasing the N application rate from 67 to 134 lbs/acre had little effect on the N concentration in bell pepper. As yield did not respond to

N rate either, the crop yield may not have been limited by N. Therefore, the standard deviation and CV reported in the table are of limited value.

## Discussion

The values in the table may not be representative for N concentrations in bell pepper grown in the Central Valley. Samples need to be taken over a period of several years from fields located in the main growing areas in the Central Valley to generate a robust estimate of the N removed per unit yield and provide information about the dominant factors contributing to the variability of this estimate.

## References


Baameur, A., Smith, R., 2012. Pepper N Uptake: 1st Year study Report. Available online at: http://www.calpeppers.com/page.php?s=7&c=42

Haynes, R.J., 1988. Comparison of fertigation with broadcast applications of urea-N on levels of available soil nutrients and on growth and yield of trickle-irrigated peppers. Scientia Horticulturae 35, 189-198.

Marti, H.R., Mills, H.A., 1991. Nutrient uptake and yield of sweet pepper as affected by stage of development and N form. Journal of Plant Nutrition 14, 1165-1175.

Russo, V.M., 1991. Effects of fertilizer rate, application timing and plant spacing on yield and nutrient content of bell pepper. Journal of Plant Nutrition 14, 1047-1056.

# Potato

N removal

**6.24**

lbs N/ton
fresh weight

**Observations**


**Variability**


## Data sources

Four studies from the U.S. were included in the dataset, with one of the studies being carried out in Tulelake, CA. In addition, values from the USDA Food Composition Database and the NRCS Crop Nutrient Tool were included for a total of 64 observations.

## Relevance

The dataset is based on values from the U.S. including one study from California. However, no recent values from potatoes grown in the Central Valley are included. Therefore, it is not possible to determine how well the dataset represents N concentrations in potatoes harvested in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Wilson et al., 2012 | Tulelake, CA | 1 | 2012 | 1 | 4 |
| Lauer et al., 1985 | Paterson, WA | 1 | 1980-81 | 2 | 5 |
| Waddell et al., 1999 | Staples, MN | 1 | 1994-95 | 2 | 22 |
| Curless et al., 2005 | Antigo, WI | 1 | 2000-02 | 3 | 21 |
| USDA Food Composition Database | | | | | 11 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | **4** | | | **64** |

*Summary statistics of potato N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Wilson et al., 2012 | 8.02 | 0.97 | 6.83 - 9.22 | 12.1 |
| Lauer et al., 1985 | 5.81 | 1.53 | 4.18 - 8.33 | 26.4 |
| Waddell et al., 1999 | 5.94 | 0.74 | 4.08 - 6.91 | 12.5 |
| Curless et al., 2005 | 6.37 | 0.87 | 5.19 - 8.14 | 13.6 |
| USDA Food Composition Database | 6.16 | 0.53 | 4.61 - 7.10 | 8.6 |
| NRCS Crop Nutrient Tool | 6.05 | | | |
| **Overall** | **6.24** | **0.85** | **4.08 - 9.22** | **13.6** |

## Variability

The variability among studies is relatively small. However, the average N concentration reported in the study from Tulelake is considerably higher than the average values in the other studies. With the data available it is not possible to determine whether this is also the case with potatoes grown in the Central

Valley. Several studies reported that higher application rates increase the N concentration in potato tubers (Wilson et al., 2012; Lauer et al., 1985; Curless et al. (2005). Other factors have not been investigated in the studies included here.

## Discussion

The values in the table should be complemented with analyses of potatoes grown in the Central Valley to increase the confidence in the estimate and provide information about the dominant factors that affect N concentration in potato tubers. For a robust and representative estimate of the N removed per unit yield and an assessment of the dominant factors affecting the N concentrations in potatoes, samples need to be collected from Central Valley fields planted to the major varieties over a period of several years.

## References

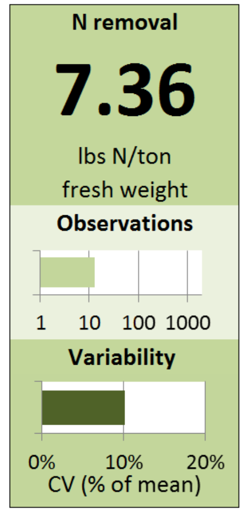
Curless, M.A., Kelling, K.A., Speth, P.E., 2004. Nitrogen and phosphorus availability from liquid dairy manure to potatoes. American Journal of Potato Research 82, 287-297.

Lauer, D.A., 1985. Nitrogen uptake patterns of potatoes with high-frequency sprinkler-applied N fertilizer. Agronomy Journal 77, 193-197.

Waddell, J. T., Gupta, S.C., Moncrief, J.F., Rosen, C.J., Steele, D.D., 1999. Irrigation and nitrogen management effects on potato yield, tuber quality, and nitrogen uptake. Agronomy Journal 91, 991–997.

Wilson, R., Kirby, D., Culp, D., Nicholson K., 2012. Classic Russet and Russet Norkotah potato yield and quality response to nitrogen fertilization. Intermountain Research & Extension Center Research Report 151. Available online at: http://ucanr.edu/sites/irecBETA/files/188015.pdf

# Pumpkin




## Data sources

Only two studies reporting N or protein concentration in pumpkin could be identified. One study was completed in Illinois the other in Brazil. A value from the NRCS Crop Nutrient Tool was also included. The total number of observations is 13.

## Relevance

Only the value in the NRCS Crop Nutrient Tool is from California. However, it is from the UC Bulletin "Nutrient composition of fresh California-grown vegetables" which was published in 1962 (Howard et al., 1962). With the data available it is not possible to determine whether the average value in the table is a good estimate of the N concentration of pumpkins harvested in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Swiader, 1985 | Illinois | 1 | 1984 | 1 | 2 |
| Santos et al., 2012 | Brazil | 1 | 2008 | 1 | 10 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **13** |

*Summary statistics of pumpkin N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Swiader, 1985 * | 4.59 | 0.45 | 4.27 - 4.91 | 9.8 |
| Santos et al., 2012 | 8.17 | 0.77 | 7.55 - 9.06 | 9.4 |
| NRCS Crop Nutrient Tool | 4.82 | | | |
| **Overall** | **7.36** | **0.74** | **4.27 - 9.06** | **10.1** |

* The study reported N concentration in dry matter. A dry matter content of 9.3% was assumed based on the NRCS Crop Nutrient Tool.

## Variability

The average N concentrations differ considerably among studies. The reasons for these large differences are not known. Increasing N application rates from 0 to 63 lbs/acre had little effect on N concentration of pumpkins (Santos et al., 2002).

## Discussion

The N concentration of pumpkins can vary considerably. The average value in this report is based on a small sample size and is likely not representative of pumpkins harvested in the Central Valley. Given the limited number of observations and the large differences among studies, samples need to be taken over a period of several years from fields located in the main growing areas in the Central Valley to generate a robust estimate of the N removed per unit yield and provide information about the dominant factors contributing to the variability of this estimate.

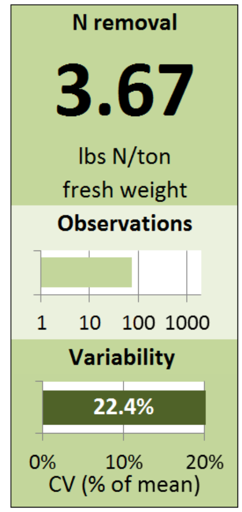
## References


Howard, F.D., MacGillivray, J.H., Yamaguchi, M., 1962. Nutrient composition of fresh California-grown vegetables. California Agricultural Experiment Station, Bulletin No. 788, California Department of Agriculture.

Santos, M.R., Sediyama, M.A.N., Moreira, M.A., Megguer, C.A., Vidigal, S.M., 2012. Rendimento, qualidade e absorção de nutrientes pelos frutos de abóbora em função de doses de biofertilizante. Horticultura Brasileira 30, 160-167.

Swiader, J.M., 1985. Seasonal growth and composition and accumulation of N-P-K in dryland and irrigated pumpkins. Journal of Plant Nutrition. 8, 909-919.

# Squash




## Data sources

The term squash is used for a number of different types, including straight neck squash, crookneck squash, zucchini, and acorn squash (*Cucurbita pepo*), butternut squash (*Cucurbita moschata*), hubbard and pink banana squash (*Cucurbita maxima*), Chinese wintermelon (*Benincasa hispida*), or balsam-pear squash (bitter melon; *Momordica charantia*).
The NRCS Crop Nutrient Tool and the USDA Food Composition Database contain data for most of these types and the value in the table is an average across all types. In contrast, the research studies included were all carried out with zucchini.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Chance et al., 1999 | Athens, GA | 1 | 1998 | 1 | 4 |
| Kolota and Slociak, 2006 | Poland | 1 | 2000-02 | 3 | 18 |
| Martinetti and Paganini, 2006 | Italy | 1 | 2003 | 1 | 5 |
| Rouphael and Colla, 2005 | Italy | 1 | 2002 | 1 | 4 |
| Rouphael and Colla, 2009 | Italy | 1 | 2008 | 1 | 4 |
| USDA Food Composition Database | | | | | 28 |
| NRCS Crop Nutrient Tool | | | | | 11 |
| **Overall** | | | | | **74** |

*Summary statistics of squash N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Chance et al., 1999 | 2.59 | 0.90 | 1.81 - 3.87 | 34.7 |
| Kolota and Slociak, 2006 | 3.94 | 0.38 | 3.43 - 4.50 | 9.7 |
| Martinetti and Paganini, 2006 | 4.39 | 0.20 | 4.19 - 4.63 | 4.5 |
| Rouphael and Colla, 2005 | 4.14 | 0.10 | 4.02 - 4.23 | 2.3 |
| Rouphael and Colla, 2009 | 3.48 | 0.51 | 2.83 - 3.95 | 14.7 |
| USDA Food Composition Database | 3.44 | 0.69 | 2.05 - 4.80 | 19.9 |
| NRCS Crop Nutrient Tool | 3.75 | 1.63 | 0.64 - 6.40 | 43.5 |
| **Overall** | **3.67** | **0.82** | **0.64 - 6.40** | **22.4** |

## Relevance

The USDA Food Composition Database contributes more than a third to the observations in the table. It includes values from squash sold in the U.S. The database reports the protein concentration of the edible part of squash. Depending on the skin thickness and the size of the seeds, this may be the entire fruit (e.g. zucchini), or only part of the fruit (e.g. Chinese wintermelon, butternut squash). Therefore, the values in the database may not always reflect the amount of N removed with harvested squash. With no recent values from squash grown in California being included in our analysis, it is not possible to determine whether the average value in the table is a good estimate of squash harvested in the Central Valley.

## Variability

The variability within the NRCS and USDA databases is due to the inclusion of different types of quash. Two studies compared different N fertilization programs. Kolota and Slociak (2006) did not find a clear trend in zucchini N concentrations with increasing N application rates ranging from 0 to 215 lbs/acre. Similarly, the N concentrations of zucchini grown with different types of fertilizers applied at 220 lbs N/acre differed little and was not consistently increased compared with an unfertilized control (Martinetti and Paganini, 2006).

## Discussion

The values in the table may not be representative of N concentrations in squash harvested in the Central Valley. Samples need to be taken over a period of several years from fields located in the Central Valley to generate a robust estimate of the N removed per unit yield. Sampling should include the major varieties and types of squash. This will help determine whether one value can be used for the different types of squash or whether different values need to be developed for individual types.

## References


Chance, W.O., Somda, Z.C., Mills, H.A., 1999. Effect of nitrogen form during the flowering period on zucchini squash growth and nutrient element uptake, Journal of Plant Nutrition, 22:3, 597-607.

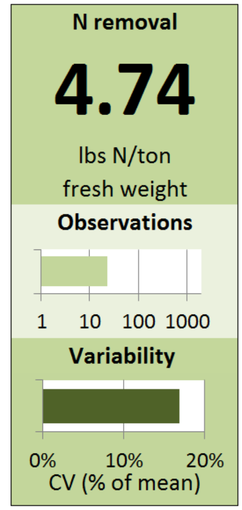
Kolota, E., Slociak, A., 2006. Nitrogen fertilization of zucchini harvested at different stages of fruit development. Acta Horticulturae 700, 121.124.

Martinetti, L., Paganini, F., 2006. Effect of organic and mineral fertilisation on yield and quality of zucchini. Acta Horticulturae 700, 125-128.

Rouphael, Y., Colla, G., 2005. Growth, yield, fruit quality and nutrient uptake of hydroponically cultivated zucchini squash as affected by irrigation systems and growing seasons. Scientia Horticulturae 105, 177–195.

Rouphael, Y., Colla, G., 2009. The influence of drip irrigation or subirrigation on zucchini squash grown in closed-loop substrate culture with high and low nutrient solution concentrations. HORTSCIENCE 44, 306–311.

# Sweet potato




## Data sources

Three studies carried out in Merced County and one study from Virginia were included in this analysis. In addition, values from the USDA Food Composition Database and the NRCS Crop Nutrient Tool were included, for a total of 23 observations.

## Relevance

The three studies from California were carried out in Merced County, where most of the sweet potatoes grown in California are produced. The average N concentration in these studies is slightly higher than the average across all datasets included in this report. Therefore, the average value provides a good estimate of N concentrations in sweet potatoes harvested in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Stoddard, 2015 | Delhi, CA | 1 | 2014 | 1 | 4 |
| Stoddard, 2009 | Livingston, CA | 1 | 2009 | 1 | 2 |
| Weir and Stoddard, 2001 | Atwater, CA | 1 | 2001 | 1 | 4 |
| Phillips et al., 2005 | Painter, VA | 1 | 2000 | 1 | 8 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 4 |
| **Overall** | | | | | **23** |

*Summary statistics of sweet potato N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Stoddard, 2015 | 4.92 | 0.48 | 4.48 - 5.57 | 9.8 |
| Stoddard, 2009 | 5.34 | 0.16 | 5.23 - 5.45 | 3.0 |
| Weir and Stoddard, 2001 | 4.67 | 1.19 | 3.50 - 6.28 | 25.5 |
| Phillips et al., 2005 | 4.28 | 0.69 | 3.43 - 5.43 | 16.0 |
| NRCS Crop Nutrient Tool | 5.66 | | | |
| USDA Food Composition Database | 5.02 | 0.93 | 4.38 - 6.37 | 16.4 |
| **Overall** | **4.74** | **0.80** | **3.43 - 6.37** | **16.8** |

## Variability

Compared with other crops, the variability of the N concentration in sweet potato tubers across studies is intermediate. Two N rate trials (Weir and Stoddard, 2001; Philips et al., 2005) found that increasing N application rates led to higher N concentrations in sweet potato tubers. Year of harvest also affected N concentration in sweet potatoes (Philips et al., 2005).

## Discussion

The value is a good estimate for N removed with sweet potatoes from Central Valley fields. Complementing the dataset with samples taken from additional fields in the Central Valley would result in a more robust estimate. Samples should be taken over a period of several years and include the major varieties.

## References


Philips, S.B., Warren, J.G., Mullins, G.L., 2005. Nitrogen rate and application timing affect 'Beauregard' sweetpotato yield and quality. HortScience 40, 214-217.

Stoddard, C.S., 2015. Phosphorous and boron fertilizer impacts on sweetpotato production and long-term storage. FREP Final Report. Available online at: https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/completedprojects/13-0266-SA_Stoddard.pdf

Stoddard, S., 2009. Sweetpotato fertilizer study 2008-09. Sweetpotato Research Progress Report 2009, 23-34. Available online at: http://cemerced.ucanr.edu/files/40704.pdf

Weir, B., Stoddard, S., 2001. Drip irrigated fertilizer trial. Sweetpotato research trials. 2001 Research Progress Report, 35-39. Available online at: http://cemerced.ucanr.edu/files/40391.pdf

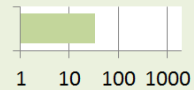
# Tomato, fresh market

N removal

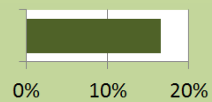
**2.61**

lbs N/ton
fresh weight

**Observations**




**Variability**




## Data sources

Little information is available on the N concentration in fresh-market tomatoes. Two studies, one from Florida and the second from Poland, were included in this analysis, together with values from the USDA Food Composition Database and the NRCS Crop Nutrient Tool for a total of 34 observations.

## Relevance

The majority of the observations are from tomatoes harvested or sold in the U.S. However, no recent values from fresh market tomatoes grown in California are included. Therefore, it is not possible to determine the degree to which the dataset is representative of tomatoes harvested in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Ozores-Hampton et al., 2015 | Florida | 1 | 2006 | 1 | 4 |
| Kleiber, 2014 | Poland | 1 | 2008-2012 | 5 | 10 |
| USDA Food Composition Database | | | | | 19 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **34** |

*Summary statistics of fresh market tomato N removal data.*

| Source | Summary (lbs/ton of fresh weight) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Ozores-Hampton et al., 2015 | 2.47 | 0.20 | 2.26 - 2.64 | 8.0 |
| Kleiber, 2014 | 2.23 | 0.12 | 2.15 - 2.31 | 5.2 |
| USDA Food Composition Database | 2.82 | 0.54 | 1.89 - 3.39 | 19.3 |
| NRCS Crop Nutrient Tool | 3.07 | | | |
| **Overall** | **2.61** | **0.43** | **1.89 - 3.39** | **16.5** |

## Variability

Ozores-Hampton et al. (2015) found that the N concentration in tomatoes increased considerably with higher N application rates. In contrast, the difference between summer and winter was small. The variability in the study by Kleiber (2014) is mainly caused by differences between the two varieties included in their study. The authors only reported values averaged over the five seasons of the study. Therefore, it is not possible to determine the effect of year on tomato N concentration. Furthermore, the standard deviation and CV reported for this study underestimate the variability in the dataset.

## Discussion

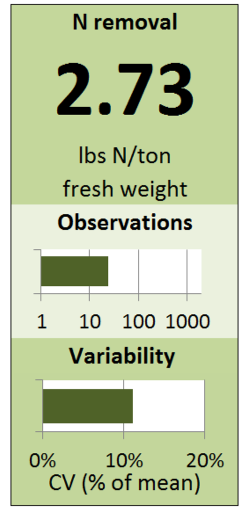
The values in the table may not be representative of N concentrations in fresh market tomatoes harvested in the Central Valley. Samples need to be taken over a period of several years from fields located in the Central Valley to generate a robust estimate of the N removed per unit yield.

## References

Kleiber, T., 2014. Changes of nutrient contents in tomato fruits under the influence of increasing intensity of manganese nutrition. Ecological Chemistry and Engineering S 21, 297-307.

Ozores-Hampton, M., Di Gioia, F., Sato, S., Simonne, E., Morgan, K., 2015. Effects of nitrogen rates on nitrogen, phosphorus, and potassium partitioning, accumulation, and use efficiency in seepage-irrigated fresh market tomatoes. HortScience 50, 1636-1643.

# Tomato, processing




## Data sources

Three studies were included for this analysis. They were all carried out recently in commercial fields across the Central Valley. The total number of observations is 24, with each observation representing a different commercial field.

## Relevance

All three studies report recent data from commercial fields at different locations in the Central Valley. The average value can be considered a very good estimate for processing tomatoes harvested in the Central Valley.

## Variability

While the variability within the studies is intermediate, it is relatively large across studies. Each observation in the dataset represents a commercial field, meaning the overall variability is due to crop management, varieties and differences in environmental conditions. Therefore, the average value as well as the variability of the data can be considered a very good estimate for the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Site x Years |
|---|---|---|---|---|---|
| | 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 |
| **Overall** | | | | | **24** |

*Summary statistics of processing tomato N removal data.*

| Source | Summary (lbs N/ton fresh weight) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| 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 |
| **Overall** | **2.73** | **0.30** | **1.9 - 3.6** | **11.1** |

## Discussion

The data included in the table can be considered a very good estimate for processing tomatoes harvested in California. With 24 observations, the sample size is relatively small. Given the variability of the data, collecting and including additional samples would improve the confidence in the estimate.

## 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

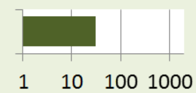
# Almonds

N removal

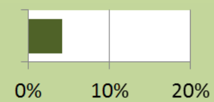
**136**

lbs N/ton of kernels

**Observations**




**Variability**




## Data sources

The data included in this report are from a recent study carried out by Patrick Brown, Professor at UC Davis, and his team. The study was carried out over a period of five years. Most of the observations are from an orchard in Kern County, but data were also collected from four other orchards in Stanislaus, Madera and Colusa Counties. The values in the table refer to N removed with hulls, shells and kernels per ton of marketable kernels. The values in the table are from two publications which contained only part of the entire dataset. Based on the complete dataset from 2008-11, Dr. Brown and his team recommend using a value of 136 lbs N/ton of kernels (68 lbs/1000 lbs of kernels; Saa Silva et al., 2012).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| **Variety: Nonpareil** | | | | | |
| Brown et al., 2012; Brown, 2013 | California | 1 | 2008 | 1 | 4 |
| Brown et al., 2012; Brown, 2013 | California | 4 | 2009 | 1 | 7 |
| Brown et al., 2012; Brown, 2013 | California | 5 | 2010 | 1 | 8 |
| Brown et al., 2012; Brown, 2013 | California | 1 | 2011 | 1 | 4 |
| Brown et al., 2012; Brown, 2013 | California | 1 | 2012 | 1 | 4 |
| **Variety: Monterey** | | | | | |
| Brown et al., 2012 | California | 1 | 2011 | 1 | 4 |
| **Overall** | | **5** | | **5** | **31** |

*Summary statistics of almond N removal data.*

| Source | Summary (lbs/ton of kernels) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| **Variety: Nonpareil** | | | | |
| Brown et al., 2012; Brown, 2013 | 120 | 6.0 | 112 - 126 | 5.0 |
| Brown et al., 2012; Brown, 2013 | 120 | 10.2 | 106 - 138 | 8.4 |
| Brown et al., 2012; Brown, 2013 | 127 | 17.8 | 102 - 152 | 14.1 |
| Brown et al., 2012; Brown, 2013 | 134 | 19.1 | 108 - 150 | 14.3 |
| Brown et al., 2012; Brown, 2013 | 157 | 32.3 | 108 - 174 | 20.7 |
| **Variety: Monterey** | | | | |
| Brown et al., 2012 | 124 | 11.2 | 110 - 134 | 9.0 |
| **Overall** | **136** | **5.6** | **102 - 174** | **4.1** |

## Relevance

The values in the table are from a recent study carried out in different orchards in the Central Valley over a period of 5 years. The value can therefore be considered a good estimate of N removed with almonds.

### Variability

The amount of N removed per ton of harvested kernels increased considerably with increasing N application rate. The year also had a strong effect on the N removed at harvest. With the exception of four observations, the data is based on 'Nonpareil' almonds, which is the major variety in California. In 2011, the average N concentration in Monterey almonds tended to be lower compared with 'Nonpareil'; however, with the data available it is not possible to determine how strongly the N concentration differs with variety.

### Discussion

The value is a good estimate for N removed from almond orchards in the Central Valley. Complementing the dataset with samples from different varieties and orchards from across the Central Valley would result in a more robust estimate.

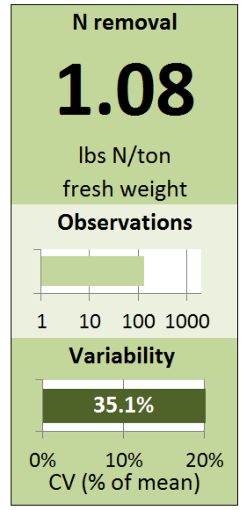
### References


Brown, P., 2013. Development of a nutrient budget approach and optimization of fertilizer management in almond. Research report submitted to the Almond Board of California.

Brown, P., Saa, S., Muhammad, S., 2012. Development of leaf sampling and interpretation methods for almond and development of a nutrient budget approach to fertilizer management in almond. Research report submitted to the Almond Board of California.

Saa Silva, S., Muhammad, S., Sanden, B., Laca, E., Brown, P., 2012. Almond early-season sampling and in-season nitrogen maximizes productivity, minimizes loss. Available online at: http://www.almonds.com/sites/default/files/content/attachments/almond_early-season_sampling_and_in-season_nitrogen_application_maximizes_productivity_minimizes_loss.pdf

# Apples




## Data sources

Several studies from around the world were included in the dataset. Only one observation is from California. The USDA Food Composition Database reports a protein content of raw apples of 0.26% of the fresh weight, which is equivalent to 0.0416% N. The values in the USDA database are for the edible part of food. These values were multiplied by a factor of 1.11 based on the following data: For 'Cox's Orange' apples, Wilkinson and Perring (1956) reported that the seeds and stems account for 0.3 and 0.13% of the fresh weight, respectively. The same study reported N concentrations in the fresh weight of flesh, seeds and stems of 0.075, 2.67 and 0.54%, respectively.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Weinbaum et al., 1992 | California | 1 | | | 1 |
| Atucha et al., 2011a, b | New York | 1 | 2007 | | 4 |
| Greenham, 1980 | England | 1 | | | 3 |
| Campeanu et al., 2009 | Romania | 1 | 2007 | | 10 |
| Palmer and Dryden, 2006 | New Zealand | 7 | 1999-2001 | 3 | 84 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 29 |
| **Overall** | | | | | **132** |

*Summary statistics of apple N removal data.*

| Source | Summary (lbs/ton of apples) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Weinbaum et al., 1992 | 1.00 | | | |
| Atucha et al., 2011a, b | 2.89 | 0.12 | 2.71 - 3.00 | 4.3 |
| Greenham, 1980 | 2.29 | 0.64 | 1.48 - 3.23 | 27.9 |
| Campeanu et al., 2009 | 1.95 | 0.69 | 1.08 - 3.23 | 35.3 |
| Palmer and Dryden, 2006 | 0.90 | 0.25 | 0.78 - 1.26 | 28.3 |
| NRCS Crop Nutrient Tool | 1.23 | | | |
| USDA Food Composition Database * | 0.92 | 0.36 | 0.60 - 2.01 | |
| **Overall** | **1.08** | **0.38** | **0.60 - 3.23** | **35.1** |

* To account for seeds and stems, the N removed was increased by 11% (see text for more detail).

## Relevance

Most of the values in the table are from a study carried out in New Zealand and the UDSA database. The average values of these two sources are lower than the average values for the other sources included. With the data available it is not possible to determine how well the average value across all data sources represents N concentrations in apples from the Central Valley.

## Variability

The N concentration in apples varies considerably within individual datasets and among datasets. The variability in the datasets of Palmer and Dryden (2006) and Campeanu et al. (2009) is due to differences between varieties. No information about the effects of N application rate and the differences from one year to another is available from these studies.

## Discussion

With little information from California and large differences in N concentrations within and among studies, the average value in the table is only a rough estimate. Samples of apples grown in the Central Valley need to be taken and analyzed. For a robust estimate of the amount of N removed, samples need to be taken from different orchards planted to the major varieties over a period of several years.

## References


Atucha, A., Merwin, I.A., Brown, M.G., 2011. Long-term effects of four groundcover management systems in an apple orchard. HortScience 46, 1176–1183.

Atucha, A., Merwin, I.A., Purohit, C.K., Brown, M.G., 2011. Nitrogen dynamics and nutrient budgets in four groundcover management systems. HortScience 46, 1184–1193.

Campeanu, G., Neata, G., Darjanschi, G., 2009. Chemical composition of the fruits of several apple cultivars growth as biological crop. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 37, 161-164.

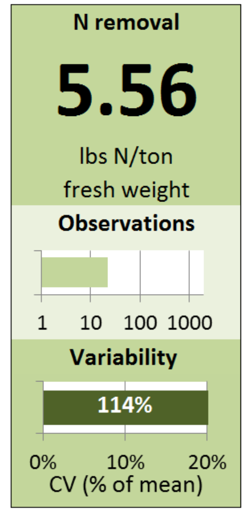
Greenham, D.W.P., 1980. Nutrient cycling: The estimation of orchard nutrient uptake. Acta Horticulturae 92, 345-352.

Palmer, J.W., Dryden, G., 2006. Fruit mineral removal rates from New Zealand apple (*Malus domestica*) orchards in the Nelson region. New Zealand Journal of Crop and Horticultural Science 34, 27–32.

Wilkinson, B.G., Perring, M.A., 1965. The mineral composition of apples III - The composition of seeds and stems. Journal of Science in Food and Agriculture 16, 438-441.

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

# Apricots




## Data sources

One value from the Central Valley for 'Tilton' apricots was included for our analysis. No other studies reporting the N removed with whole apricots could be identified. We also included the value reported in the NRCS Crop Nutrient Tool. The USDA Food Composition Database reports protein concentration in the edible part of the fruit. To account for the N in the pit (stone) this value was multiplied by 1.26. This factor is based on the following assumptions: The edible part has a dry matter content of 13.65 (USDA Food Composition Database). The pit accounts for 7.1% of the fresh weight and has an N concentration in the dry matter of 1.302% (Kamel and Kakuda, 1992). The pit is composed of the kernel and shell. The kernel accounts for 31.5% of the pits' fresh weight and has a moisture content of 40.1% (Kamel and Kakuda, 1992). The remaining 68.5% is shell with a moisture content of 10.9% (Canellas et al., 1992).

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Weinbaum et al., 1992 | California | | | | 1 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 20 |
| **Overall** | | | | | **22** |

*Summary statistics of apricot N removal data.*

| Source | Summary (lbs/ton fresh fruits) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Weinbaum et al., 1992 | 5.00 | | | |
| NRCS Crop Nutrient Tool | 4.48 | | | |
| USDA Food Composition Database * | 5.64 | 6.35 | | 114 |
| **Overall** | **5.56** | **6.35** | **4.48 - 5.64** | **114** |

* The USDA database reports protein (N x 6.25) in the edible part of the fruit. The value was increased by 26% to account for the pit (see text for more detail).

## Relevance

The N concentration reported here was estimated based on one observation from California and on the analysis of the edible part of apricots and information from different studies about N in pits. The value reported here should be considered a rough estimate of the N concentration in apricots.

## Variability

The data available does not allow for an analysis of the factors affecting N concentrations in apricots. The data reported in the USDA database are highly variable. The N removed with whole apricots may vary even more, as fruit size (which affects the ratio between pit and flesh) also influences the N concentration of whole fruits (see **prunes** for more detail).

## Discussion

The data reported here is only a rough estimate. Samples of apricots grown in the Central Valley need to be taken and analyzed. For a robust estimate of the amount of N removed, samples need to be taken from different orchards over a period of several years and include the major varieties. Fruit size and yield should also be measured in order to determine their effect on N concentration in apricots.

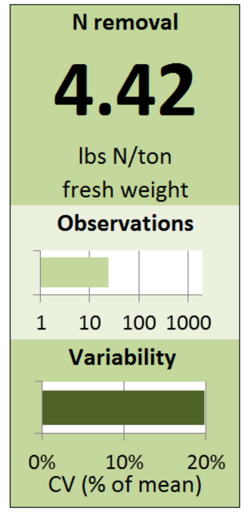
## References


Cañellas, J., Femenia, A., Rossello, C., Soler, L., 1992. Chemical composition of the shell of apricot seeds. Journal of the Science of Food & Agriculture 59, 269-271.

Kamel, B.S., Kakuda, Y., 1992. Characterization of the seed oil and meal from apricot, cherry, nectarine, peach and plum. Journal of the American Oil Chemists' Society, 69,492-494.

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

# Cherries




## Data sources

Only three studies reporting protein or N concentration in whole cherries were available. For our analysis we also included the value reported in the NRCS Crop Nutrient Tool. The USDA Food Composition Database and Neilson et al. (2007) report protein concentration in the edible part of the fruit. To account for the N in the pit (stone) this value was multiplied by 1.29. This factor is based on the following assumptions: The edible portion has a dry matter content of 17.75% (USDA Food Composition Database). The pit accounts for 6.3% of the fresh weight and has an N concentration in the dry matter of 1.17% (Kamel and Kakuda, 1992). The pit is composed of the kernel and shell. The kernel accounts for 26.6% of the pit fresh weight and has a moisture content of 38.8% (Kamel and Kakuda, 1992). The remaining 73.4% of the pit fresh weight is shell with a moisture content of 10.9% (Canellas et al., 1992; the value is for apricot shells).

## Relevance

The N concentration reported here was estimated based one observation from California and different studies, some of which reported protein in the edible part of apricots. These values needed to be converted to N in whole fruits based on information from different studies about N in pits. The value from California for 'Bing' cherries is relatively low when compared with the average values from other studies. With the data available it is not possible to determine how well the average value across all data sources represents N concentrations in cherries harvested in the Central Valley.

## Variability

Increasing N application rates can increase N concentration in cherries considerably (Fallahi et al., 1993; Neilson et al., 2007). The study by Neilson et al. (2007) was carried out over two seasons. The N concentrations in the cherries differed significantly from one year to the next. Overall, the values within individual datasets and across datasets are quite variable. The N removed with cherries may vary even more, as fruit size (the ratio between pit and flesh) also affects the N concentration in entire fruits (see **prunes** for more detail).

## Discussion

The data reported here is only a rough estimate. Samples of cherries grown in the Central Valley need to be taken and analyzed. For a robust estimate of the amount of N removed, samples need to be taken from different orchards over a period of several years and include the major varieties. Fruit size and yield should also be measured in order to determine their effect on N concentration in cherries.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Weinbaum et al., 1992 | California | | | | 1 |
| Neilson et al., 2007 | Canada | 1 | | 2 | 6 |
| San Martino et al., 2010 | Argentina | 1 | | 1 | 1 |
| Fallahi et al., 1993 | Washington | 1 | | 1 | 7 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| USDA Food Composition Database | | | | | 8 |
| **Overall** | | | | | **24** |

*Summary statistics of cherry N removal data.*

| Source | Summary (lbs/ton fresh fruits) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Weinbaum et al., 1992 | 2.70 | | | |
| Neilson et al., 2007 * | 3.83 | 0.63 | 2.89 - 4.75 | 16.4 |
| San Martino et al., 2010 | 3.13 | | | |
| Fallahi et al., 1993 ** | 5.45 | 1.03 | 3.84 - 6.67 | 18.9 |
| NRCS Crop Nutrient Tool | 4.00 | | | |
| USDA Food Composition Database * | 4.38 | 0.88 | 3.89 - 4.96 | 20.0 |
| **Overall** | **4.42** | **0.87** | **2.70 – 6.67** | **19.8** |

* The database reports N in edible part of the fruit. The value was increased by 29% to account for the pit (see text for detail).

** Dry weight was converted to fresh weight using a dry matter content of 18.62% (based on NRCS Crop Nutrient Tool).

## References


Cañellas, J., Femenia, A., Rossello, C., Soler, L., 1992. Chemical composition of the shell of apricot seeds. Journal of the Science of Food & Agriculture 59, 269-271.

Fallahi, E., Righetti, T.L., Proebsting, E.L., 1993. Pruning and nitrogen effects on elemental partitioning and fruit maturity in 'Bing' sweet cherry. Journal of Plant Nutrition 16, 753-763.

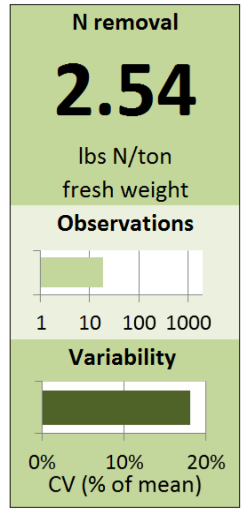
Kamel, B.S., Kakuda, Y., 1992. Characterization of the seed oil and meal from apricot, cherry, nectarine, peach and plum. Journal of the American Oil Chemists' Society, 69,492-494.

Neilsen, G., Kappel, F., Neilsen, D., 2007. Fertigation and crop load affect yield, nutrition, and fruit quality of 'Lapins' sweet cherry on Gisela 5 rootstock. HortScience 42, 1456-1462.

San-Martino, L., Sozzi, G.O., San-Martino, S., Lavado, R.S., 2010. Isotopically-labelled nitrogen uptake and partitioning in sweet cherry as influenced by timing of fertilizer application. Scientia Horticulturae 126, 42-49.

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

# Figs




## Data sources

Two studies focusing on figs as animal feeds reported protein contents. In addition, 16 values for protein content of raw figs from the USDA Food Composition Database were included. For this report, the N concentrations were calculated by dividing crude protein values by 6.25. The database reports values for the edible portion of foods. We assume here that this includes the entire fig. A value from the NRCS Crop Nutrient Tool was also included.

## Relevance

With the small dataset and no values from figs harvested in California, it cannot be determined how well the average value in the table represents figs from California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Wenninger and Shiley, 2000 | Washington | 1 | 1998 | 1 | 1 |
| Es-Shobaki et al., 2010 | Egypt | 1 | 2009 | 1 | 1 |
| USDA Food Composition Database | | | | | 16 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **19** |

*Summary statistics of fig N removal data.*

| Source | Summary (lbs/ton fresh figs) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Wenninger and Shiley, 2000 | 4.21 | | | |
| Es-Shobaki et al., 2010 | 3.20 | | | |
| USDA Food Composition Database | 2.40 | 0.36 | | 14.9 |
| NRCS Crop Nutrient Tool | 2.40 | | | |
| **Overall** | **2.54** | **0.46** | **2.40 - 4.21** | **18.1** |

## Variability

The values from the different sources differ considerably. The N concentrations of the samples analyzed for the USDA database are also variable. The factors contributing to these differences cannot be analyzed with the data available.

## Discussion

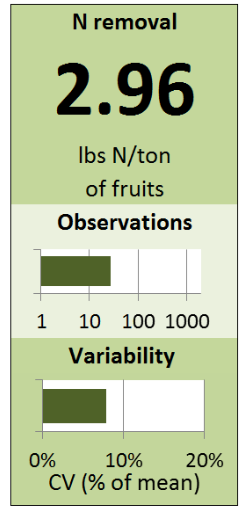
Few observations of N concentrations in figs were available, and their reported values varied widely. The average value in the table may not be representative of figs harvested in the Central Valley. Samples of figs from the Central Valley need to be collected and analyzed. For a robust estimate of the N concentration, samples need to be taken from different orchards over a period of several years and include the major varieties.

## References

El-Shobaki, F.A., El-Bahay, A.M., Esmail, R.S.A., Abd El Megeid, A.A., Esmail, N.S., 2010. Effect of figs fruit (*Ficus Carica* L.) and its leaves on hyperglycemia in alloxan diabetic rats. World Journal of Dairy & Food Sciences 5, 47-57.

Wenninger, P.S., Shipley, L.A., 2000. Harvesting, rumination, digestion, and passage of fruit and leaf diets by a small ruminant, the blue duiker. Oecologia 123, 466-474.

# Grapefruits




## Data sources

Two studies were included in this report. One study, contributing 24 of the 27 observations was carried out in California. The other was from Brazil. In both studies, orchards planted to 'Marsh' grapefruits were investigated. One value from the NRCS Crop Nutrient Tool was also included.

## Relevance

The study by Embleton and Jones (1974) was carried out in a 'Marsh' grapefruit orchard located in Indio (Riverside County) over six years between 1950 and 1974. It may provide a reasonable estimate of current N concentrations in grapefruits from California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Embleton and Jones, 1974 | California | 1 | 1950-74 | 6 | 24 |
| Bataglia et al., 1977 | Brazil | 1 | 1976 | 1 | 1 |
| NRCS Crop Nutrient Tool | California | | | 1 | 2 |
| **Overall** | | | | | **27** |

*Summary statistics of grapefruit N removal data.*

| Source | Summary (lbs/ton of fruits) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Embleton and Jones, 1974 | 3.02 | 0.15 | 2.90 - 3.24 | 5.1 |
| Bataglia et al., 1977 | 3.05 | | | |
| NRCS Crop Nutrient Tool | 2.21 | 0.86 | 1.60 - 2.82 | 38.9 |
| **Overall** | **2.96** | **0.23** | **1.60 - 3.24** | **7.8** |

## Variability

The N concentration in grapefruits increased with increasing N application rates (Embleton and Jones, 1974). Information about other factors potentially affecting grapefruit N concentration is not available from the data sources included here.

## Discussion

The dataset is a reasonable estimate of N removed with grapefruits. However, the samples for both studies were collected more than 40 years ago and the sample size is relatively small. For a more robust estimate of the amount of N currently removed from grapefruit orchards, the dataset needs to be complemented with samples from different orchards in the Central Valley planted to different varieties, collected over a period of several years.

## References

Bataglia, O.C., Rodriguez, O., Hiroce, R., Gallo, J.R., Furlani, P.R., Furlani, A.M.C., 1977. Composição mineral de frutos cítricos na colheita. Bragantia 36, 215-221.

Embleton, T.W., Jones, W.W., 1974. Foliar-applied nitrogen for citrus fertilization. Journal of Environmental Quality 3, 388-391.

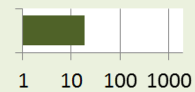
# Grapes, Raisins

N removal

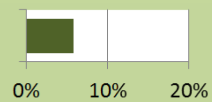
**10.1**

lbs N/ton
@ 15% moisture

**Observations**




**Variability**



CV (% of mean)

## Data sources

With one exception, the studies included for this analysis were conducted in California. All studies were done in vineyards planted to 'Thompson Seedless' grapes. The same dataset was used to determine the N removed with both table grapes and raisins. The only difference between the analyses for raisins and table grapes is the moisture content. Table grapes have a moisture content of roughly 81%, while raisins have a remaining moisture content of 15% (USDA Food Composition Database).

## Relevance

With most of the data coming from vineyards in California, the dataset provides a good estimate of N removed with raisins from California vineyards. However, it needs to be mentioned that the four studies from California were all conducted in vineyards at the Kearney Agricultural Center. With only one location, one variety ('Thompson Seedless') and a relatively small dataset, the average value in the table may not be representative of raisins produced in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Williams, 1991 | Fresno, CA | 1 | 1988/89 | 2 | 4 |
| Williams, 2015 | Fresno, CA | 1 | 1998 | 1 | 5 |
| Araujo et al., 1995 | Fresno, CA | 1 | 1985/86 | 2 | 4 |
| Williams, 1987a, b | Fresno, CA | 1 | 1983-85 | 3 | 3 |
| Alexander, 1957 | Australia | 1 | 1951-53 | 3 | 3 |
| **Overall** | | | | | **19** |

*Summary statistics of raisin N removal data.*

| Source | Summary (lbs/ton @ 15% moisture) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Williams, 1991 | 8.8 | 0.12 | 8.72 - 8.89 | 1.3 |
| Williams, 2015 | 9.7 | 0.58 | 9.06 - 10.31 | 6.0 |
| Araujo et al., 1995 | 8.6 | 1.06 | 7.88 - 9.38 | 12.3 |
| Williams, 1987a, b | 11.8 | | | |
| Alexander, 1957 | 12.5 | | | |
| **Overall** | **10.1** | **0.58** | **7.88 - 12.50** | **5.8** |

## Variability

The variability within the different studies from California was mainly due to different irrigation and fertilization treatments. With the values coming from the same or adjacent vineyards, the differences among studies can be attributed predominantly to year of harvest.

## Discussion

While the dataset may provide a good estimate of N removed with 'Thompson Seedless' grapes from California vineyards, it likely underestimates the variability of grape N concentrations in commercial vineyards as management practices likely vary more among growers.

For a more robust estimate, the dataset needs to be complemented with samples from different vineyards in the Central Valley collected over a period of several years.

## References


Alexander, D.M., 1957. Seasonal fluctuations in the nitrogen content of the sultana vine. Australian Journal of Agricultural Research 8, 162-178.

Araujo, F., Williams, L.E., Matthews, M.A., 1995. A comparative study of young 'Thompson Seedless' grapevines (*Vitis vinifera* L.) under drip and furrow irrigation. II. Growth, water use efficiency and nitrogen partitioning. Scientia Horticulturae 60, 251-265.

Williams, L.E., 1987a. Growth of 'Thompson Seedless' grapevines. I. Leaf area development and dry weight distribution. Journal of the American Society for Horticultural Science 112, 325-330.

Williams, L.E., 1987b. Growth of 'Thompson Seedless' grapevines: II. Nitrogen distribution. Journal of the American Society for Horticultural Science 112, 330-333.

Williams, L.E., 1991.Vine nitrogen requirements – Utilization of N sources from soils, fertilizers, and reserves. Proceedings of the International Symposium on Nitrogen in Grapes and Wine, 62-66.

Williams, L.E., 2015. Recovery of $^{15}$N-labeled fertilizer by Thompson Seedless grapevines: Effects of N fertilizer type and irrigation method. American Journal of Enology and Viticulture 66, 509-517.

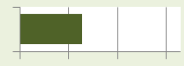
# Grapes, Table

N removal

**2.26**

lbs N/ton of grapes

**Observations**




**Variability**


## Data sources

With one exception, the studies included for this analysis were conducted in California. All studies were done in vineyards planted to 'Thompson Seedless' grapes. The same dataset was used to determine the N removed with both table grapes and raisins. The only difference between the analyses for raisins and table grapes is the moisture content. Table grapes have a moisture content of roughly 81%, while raisins have a remaining moisture content of 15% (USDA Food Composition Database).

## Relevance

With most of the data coming from vineyards in California, the dataset provides a good estimate of N removed with table grapes from California vineyards. However, it needs to be mentioned that the four studies from California were all conducted in vineyards at the Kearney Agricultural Center. With only one location, one variety ('Thompson Seedless') and a relatively small dataset, the average value in the table may not be representative of table grapes produced in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Williams, 2001 | Fresno, CA | 1 | 1988/89 | 2 | 4 |
| Williams, 2015 | Fresno, CA | 1 | 1998 | 1 | 5 |
| Araujo et al., 1995 | Fresno, CA | 1 | 1985/86 | 2 | 4 |
| Williams, 1987a, b | Fresno, CA | 1 | 1983-85 | 3 | 3 |
| Alexander, 1958 | Australia | 1 | 1951-53 | 3 | 3 |
| **Overall** | | | | | **19** |

*Summary statistics of table grape N removal data.*

| Source | Summary (lbs/ton of grapes) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Williams, 2001 * | 1.99 | 0.02 | 1.97 - 2.00 | 1.0 |
| Williams, 2015 * | 2.18 | 0.13 | 2.04 - 2.32 | 6.0 |
| Araujo et al., 1995 | 1.95 | 0.24 | 1.78 - 2.12 | 12.1 |
| Williams, 1987a, b | 2.63 | | | |
| Alexander, 1957 * | 2.81 | | | |
| **Overall** | **2.26** | **0.13** | **1.78 - 2.81** | **5.8** |

* For studies that reported N in the dry weight, a moisture content of 80.9% was assumed based on Araujo et al. (1995b) and Williams (1987a, b)

## Variability

The variability within the different studies from California was mainly due to different irrigation and fertilization treatments. With the values coming from the same or adjacent vineyards, the differences among studies can be attributed predominantly to year of harvest.

## Discussion

While the dataset may provide a good estimate of N removed with 'Thompson Seedless' grapes from California vineyards, it likely underestimates the variability of grape N concentration among growers as management practices likely vary more among growers.

For a more robust estimate, the dataset needs to be complemented with samples of the major varieties from different vineyards in the Central Valley collected over a period of several years.

## References


Alexander, D.M., 1957. Seasonal fluctuations in the nitrogen content of the sultana vine. Australian Journal of Agricultural Research 8, 162-178.

Araujo, F., Williams, L.E., Matthews, M.A., 1995. A comparative study of young ‘Thompson Seedless’ grapevines (*Vitis vinifera* L.) under drip and furrow irrigation. II. Growth, water use efficiency and nitrogen partitioning. Scientia Horticulturae 60, 251-265.

Williams, L.E., 1987a. Growth of ‘Thompson Seedless’ grapevines. I. Leaf area development and dry weight distribution. Journal of the American Society for Horticultural Science 112, 325-330.

Williams, L.E., 1987b. Growth of 'Thompson Seedless' grapevines: II. Nitrogen distribution. Journal of the American Society for Horticultural Science 112, 330-333.

Williams, L.E., 1991.Vine nitrogen requirements – Utilization of N sources from soils, fertilizers, and reserves. Proceedings of the International Symposium on Nitrogen in Grapes and Wine, 62-66.

Williams, L.E., 2015. Recovery of $^{15}N$-labeled fertilizer by Thompson Seedless grapevines: Effects of N fertilizer type and irrigation method. American Journal of Enology and Viticulture 66, 509-517.

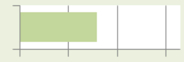
# Grapes, Wine grapes

N removal

**3.60**

lbs N/ton of grapes

**Observations**




**Variability**


## Data sources

The dataset includes values from studies from around the world. The studies were performed in vineyards with 'Cabernet sauvignon' (Williams, 1999), 'Pinot noir' (Schreiner et al., 2006, Schreiner, 2016; Wermelinger and Koblet, 1990), 'Chenin blanc' (Conradie, 1980), 'Chardonnay' (Hutton et al., 2007), 'Riesling' (Lohnertz, 1988) and 'Viosinho blanc' (Arrobas et al., 2014) grapes. Eight of the 38 observations are from a study carried out in the coastal valleys of California. Studies carried out with 'Thompson Seedless' grapes were not included in this analysis for wine grapes.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Williams, 1999 | California | 4 | 1997/98 | 2 | 8 |
| Schreiner et al., 2006 | Oregon | 1 | 2001/03 | 2 | 2 |
| Schreiner, 2016 | Oregon | 1 | 2007-08 | 2 | 2 |
| Hutton et al., 2007 | Australia | 7 | 2004-06 | 3 | 21 |
| Conradie, 1980 | South Africa | 1 | 1976 | 1 | 1 |
| Arrobas et al., 2014 | Portugal | 1 | 2012 | 1 | 1 |
| Wermelinger and Koblet, 1990 | Switzerland | 1 | 1988 | 1 | 1 |
| Lohnertz, 1988 | Germany | 1 | 1983 | 1 | 1 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **38** |

*Summary statistics of wine grape N removal data.*

| Source | Summary (lbs/ton of grapes) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Williams, 1999 | 2.61 | 0.37 | 1.96 - 3.16 | 14.1 |
| Schreiner et al., 2006 | 2.82 | 0.48 | 2.48 - 3.16 | 17.1 |
| Schreiner, 2016 | 2.32 | 0.08 | 2.26 - 2.37 | 3.4 |
| Hutton et al., 2007 | 4.26 | 0.51 | 3.50 - 5.20 | 11.9 |
| Conradie, 1980 | 2.78 | | | |
| Arrobas et al., 2014 | 2.80 | | | |
| Wermelinger and Koblet, 1990 | 4.44 | | | |
| Lohnertz, 1988 | 3.81 | | | |
| NRCS Crop Nutrient Tool | 2.25 | | | |
| **Overall** | **3.60** | **0.47** | **1.96 - 5.20** | **13.0** |

## Relevance

Only one study, contributing eight observations, is from California. With the data available, it cannot be determined the degree to which the average value in the table is representative for wine grapes from California.

The average value in the table is higher than previous estimates of N concentrations in grapes from California, which were based mainly on studies with 'Thompson Seedless' grapes. Studies with 'Thompson Seedless' grapes were not included in this analysis for wine grapes. However, they were used for the raisin and table grape datasets.

## Variability

Hutton et al. (2007) reported values from seven locations in Australia over three years. Both harvest year and location had a strong effect on the N concentration in wine grapes. This is in line with Williams (1999) who carried out a field trial for two years at four locations in the coastal valleys of California. Differences between years were also reported by the two studies from Oregon.

## Discussion

Only a few samples in the dataset were collected in California. For a robust estimate of N concentrations in wine grapes grown in the Central Valley samples from different vineyards planted to the major varieties need to be collected over a period of several years.

## References


Arrobas, M., Ferreira, I.Q., Freitas, S., Verdial, J., Rodrigues, M.A., 2014. Guidelines for fertilizer use in vineyards based on nutrient content of grapevine parts. Scientia Horticulturae 172, 191–198.

Conradie W.J., 1980. Seasonal uptake of nutrients by Chenin blanc in sand culture: I. Nitrogen. South African Journal for Enology and Viticulture, 1, 59-65.

Hutton, R., Holzapfel, B., Smith, J., Hutchinson, P., Barlow, K., Bond, W., 2007. Influence of irrigation and fertilizer management on the movement of water and nutrients within and below the rootzone of vines for sustainable grape production. Cooperative Research Centre for Viticulture Final Report. Available online at: https://www.csu.edu.au/__data/assets/pdf_file/0007/453319/KBRHJSBHReport-170907.pdf

Loehnertz, O., 1988. Nährstoffelementaufnahme von Reben in Verlauf eines Vegetationszyklus. Mitteilungen Klosterneuburg 38, 124-129.

Schreiner, R.P., Scagel, C.F., Baham, J. 2006. Nutrient uptake and distribution in a mature ‘Pinot noir’ vineyard. HortScience 41:336-345.

Schreiner, R.P., 2016. Nutrient uptake and distribution in young Pinot noir grapevines over two seasons. American Journal of Enology and Viticulture (in press).

Wermelinger, B., Koblet, W., 1990. Seasonal growth and nitrogen distribution in grapevine leaves, shoots and grapes. Vitis 29, 15-26.

Williams, L.E., 1999. Fertilizer use efficiency and influence of rootstocks on uptake and accumulation of nutrients in wine grapes grown in the coastal valleys of California. FREP final report. Available online at: https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/completedprojects/96-0399Williams.pdf

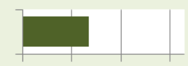
# Lemons

N removal

**2.58**

lbs N/ton of fruits

**Observations**




**Variability**


## Data sources

One study, which was carried out in California, was included in this report. No other studies were available. In addition, one value from the NRCS Crop Nutrient Tool was included.

## Relevance

The study by Embleton and Jones (1974) was carried out in 'Prior Lisbon' lemon orchards located in Santa Paula (Ventura County) over seven years between 1950 and 1974. It provides a reasonable estimate of current N concentrations in lemons from California.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Embleton and Jones, 1974 | California | 2 | 1950-74 | 7 | 21 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **22** |

*Summary statistics of lemon N removal data.*

| Source | Summary (lbs/ton of fruits) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Embleton and Jones, 1974 | 2.51 | 0.26 | 2.30 - 2.80 | 10.3 |
| NRCS Crop Nutrient Tool | 3.87 | | | |
| **Overall** | **2.58** | **0.26** | **2.30 - 3.87** | **10.0** |

## Variability

Nitrogen concentrations tended to be higher in treatments with higher N application rates and when N was applied with foliar sprays compared with ground applications. However, with only three treatments and no measure of variability for each treatment, the information available is limited. Information about other factors potentially affecting lemon N concentration is not available from the study. It is also important to note that the value in the NRCS Crop Nutrient Tool is more than 50% higher than the value reported by Embleton and Jones (1974).

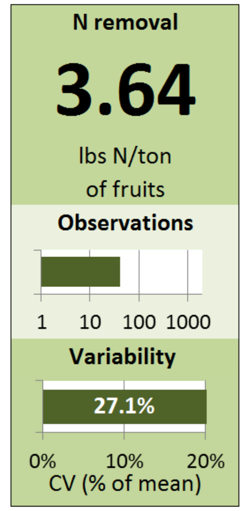
## Discussion

The dataset is a reasonable estimate of N removed with lemons. However, the samples were collected more than 40 years ago and differ considerably from the value included in the NRCS Crop Nutrient Tool. For a more robust estimate of the amount of N currently removed from lemon orchards, the dataset needs to be complemented with samples from different orchards in the Central Valley planted to different varieties, and collected over a period of several years.

## References

Embleton, T.W., Jones, W.W., 1974. Foliar-applied nitrogen for citrus fertilization. Journal of Environmental Quality 3, 388-391.

# Nectarines




## Data sources

Results from five studies and one value from the NRCS Crop Nutrient Tool were included in the dataset. Most of the observations are from an N fertilizer trial from California with 'Flavortop' and 'Fantasia' nectarines (Weinbaum et al., 1992). The same paper also included one value for 'Royal Giant' nectarines.

## Relevance

Most of the observations are from California. Weinbaum et al. (1992) reported unpublished data from an N rate trial. Except for the N application rate, no information about the trial is available. Still, the average value in the table is a reasonable estimate of N in nectarines, but should be confirmed with additional samples taken from orchards in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Weinbaum et al., 1992 | California | 2 | | 3 | 31 |
| Baldi et al., 2014a | Italy | 1 | 2011 | 1 | 1 |
| Baldi et al., 2016 | Italy | 1 | 2012 | 1 | 1 |
| Baldi et al., 2014b | Italy | 1 | 2010 | 1 | 6 |
| Krige and Stassen, 2008 | South Africa | 1 | 2004 | 1 | 1 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **41** |

*Summary statistics of nectarine N removal data.*

| Source | Summary (lbs/ton of fruits) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Weinbaum et al., 1992 | 4.05 | 1.05 | 1.94 - 5.55 | 26.1 |
| Baldi et al., 2012a * | 2.11 | | | |
| Baldi et al., 2016 * | 1.87 | | | |
| Baldi et al., 2014b * | 2.20 | 0.39 | 1.65 - 2.74 | 17.7 |
| Krige and Stassen, 2008 | 3.69 | | | |
| NRCS Crop Nutrient Tool | 3.01 | | | |
| **Overall** | **3.64** | **0.99** | **1.65 - 5.55** | **27.1** |

* For studies that reported N in the dry weight, a dry matter content of 13.7% was assumed based on the NRCS Crop Nutrient Tool

## Variability

Weinbaum et al. (1992) found increasing N concentrations in nectarines with increasing N application rates. The differences between the two varieties were also pronounced, being on average 0.86 lb/ton higher in 'Fantasia' nectarines than in 'Flavortop' nectarines. Baldi et al. (2014) also reported increased N concentrations with higher N availability. For prunes, fruit size has a significant influence on the N concentration of the fruits (see **prunes** for more detail). This is likely the case with nectarines as well.

## Discussion

The average value in the table may be a reasonable estimate for N concentrations in nectarines from the Central Valley. However, the dataset needs to be complemented with samples from different varieties and orchards from across the Central Valley taken over a period of several years. Fruit size and yield should also be measured in order to determine their effect on N concentration in nectarines.

## References


Baldi, E., Marcolini, G., Quartieri, M., Sorrenti, G., Toselli, M., 2014a. Effect of organic fertilization on nutrient concentration and accumulation in nectarine (*Prunus persica* var. *nucipersica*) trees: The effect of rate of application. Scientia Horticulturae 179, 174-179.

Baldi, E., Toselli, M., Bravo, K., Marcolini, G., Quartieri, M., Sorrenti, G., Marangoni, B., 2014b. Ten years of organic fertilization in peach: Effect on soil fertility, tree nutritional status and fruit quality. Acta Horticulturae 1018, 237-244.

Baldi, E., Marcolini, G., Quartieri, M., Sorrenti, G., Muzzi, E., Toselli, M., 2016. Organic fertilization in nectarine (*Prunus persica* var. *nucipersica*) orchard combines nutrient management and pollution impact. Nutrient Cycling in Agroecosystems 105, 39-50.

Krige, G.T., Stassen, P.J.C., 2008. Mineral nutrient distribution and requirement of pulse drip fertigated 'Donnarine' nectarine trees. Acta Horticulturae 772, 355-360.

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

# Olives

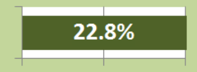
N removal

**6.28**

lbs N/ton of fresh olives

**Observations**


**Variability**




## Data sources

The current analysis was performed based on data from seven studies. One study was carried out in California, the others in Europe and Israel. The total number of observations is 29.

## Relevance

Only one study reported N concentrations in olives harvested in California (Rosecrance and Kruger, 2012). The average value reported in this study, which analyzed three oil olive varieties, is within 10% of the average value across all studies included. Therefore, the average N concentration in the table may be a reasonable estimate of N in California olives.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Rosecrance and Kruger, 2012 | California | 1 | 2010-11 | 2 | 6 |
| Rufat et al., 2016, Belguerri et al., 2016 | Spain | 1 | 2010-12 | 3 | 6 |
| Fernández-Escobar, 2015 | Spain | 1 | 1997-2003 | 7 | 6 |
| Fernández-Escobar, 2012 | Spain | 1 | 2001-06 | 6 | 6 |
| Celano et al., 1997 | Italy | 1 | 1995 | 1 | 2 |
| Rodrigues et al., 2012 | Portugal | 1 | 2010 | 1 | 1 |
| Bustan, et al., 2013 | Israel | 1 | 2007 | 1 | 2 |
| **Overall** | | | | | **29** |

*Summary statistics of olive N removal data.*

| Source | Summary (lbs/ton of fresh olives) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Rosecrance and Kruger, 2012 | 6.89 | 0.75 | 6.0 - 7.8 | 10.9 |
| Rufat et al., 2016, Belguerri et al., 2016 | 7.40 | 0.93 | 6.1 - 8.3 | 12.6 |
| Fernández-Escobar, 2015 | 5.75 | 1.90 | 4.0 - 9.7 | 33.0 |
| Fernández-Escobar, 2012 | 4.40 | 0.44 | 4.1 - 4.7 | 10.0 |
| Celano et al., 1997 | 9.17 | 2.74 | 7.2 - 11.1 | 29.9 |
| Rodrigues et al., 2012 | 4.27 | | | |
| Bustan, et al., 2013 | 6.46 | 3.10 | 4.3 - 8.6 | 48.0 |
| **Overall** | **6.28** | **1.43** | **4.0 - 11.1** | **22.8** |

## Variability

The N concentration in olives can vary considerably from one year to the next (Rosecrance and Kruger, 2012; Rufat et al., 2014; Fernandez-Escobar, 2015). Furthermore, N fertilization tends to increase the N concentration in olives. However, across multiple years, yield and N concentration don't seem to be correlated. Rosecrance and Kruger (2012) also found large differences among varieties. As olives are alternate bearing, the crop load may also have an effect on the N concentration (Bustan et al., 2013).

## Discussion

The dataset may provide a reasonable estimate of N removed with olives. However, only one study from California with six observations was included in the dataset. For a more robust estimate of the amount of N removed with olives, the dataset needs to be complemented with samples from different orchards in the Central Valley planted to different varieties, and collected over a period of several years. Table and oil olive varieties should be included.

## References


Belguerri, H., Villa, J.M., Pascual, M., Fatmi, A., Amadeu, A., Rufat J., 2016. A proposal of nitrogen balance in a very high density olive orchard. Journal of Fundamental and Applied Sciences 8, 639-654.

Bustan, A., Avni, A., Yermiyahu, U., Ben-Gal, A., Riov, J., Erel, R., Zipori, I., Dag, A., 2013. Interactions between fruit load and macroelement concentrations in fertigated olive (*Olea europaea* L.) trees under arid saline conditions. Scientia Horticulturae 152, 44-55.

Celano, G., Dichio, B., Montanaro, G., Nuzzo, V., Palese, A.M., Xiloyannis, C., 1999. Distribution of dry matter and amount of mineral elements in irrigated and non-irrigated olive trees. Acta Horticulturae 474, 381-384.

Fernández-Escobar, R., García-Novelo, J.M., Molina-Soria, C., Parra, M.A., 2012. An approach to nitrogen balance in olive orchards. Scientia Horticulturae 135:219–226.

Fernández-Escobar, R., Sánchez-Zamora, M.A., García-Novelo, J.M., Molina-Soria, C., 2015. Nutrient removal from olive trees by fruit yield and pruning. HortScience 50, 474–478.

Rodrigues, M.Â., Ferreira, I.Q., Claro, A.M., Arrobas, M., 2012. Fertilizer recommendations for olive based upon nutrients removed in crop and pruning. Scientia Horticulturae 142, 205–211

Rosecrance, R.C., Krueger, W.H., 2012. Total fruit nutrient removal calculator for olive in California. Available online at: http://www.csuchico.edu/~rrosecrance/Model/OliveCalculator/OliveCalculator.html

Rufat, J., Villar, J.M., Pascual, M., Falguera, V., Arbonés, A., 2014. Productive and vegetative response to different irrigation and fertilization strategies of an Arbequina olive orchard grown under super-intensive conditions. Agricultural Water Management 144, 33-41.

# Oranges

N removal

**2.96**

lbs N/ton of fruits

**Observations**


**Variability**


## Data sources

Most of the values in the table are from California and Florida. Studies carried out in Italy and Brazil complement the dataset. A value from the NRCS Crop Nutrient Tool is also included. Several studies, including two from California were carried out more than 40 years ago. The total number of observation is 82.

## Relevance

The study by Embleton and Jones (1974) was carried out over several years at different locations in the San Joaquin Valley and in Southern California with Valencia and Navel oranges. It provides a good estimate of N concentrations in oranges from California. These samples were taken between 1950 and 1974. However, the value from a recent study in Tulare County (Krueger and Arpaio, 2008), as well as the overall average across all studies are similar to the average reported by Embleton and Jones (1974). Based on these considerations, the average value reported in the table seems to be a reasonable estimate of N concentrations in oranges harvested from orchards in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Embleton and Jones, 1974 | California | 4 | 1950-74 | 9 | 19 |
| Labanauskas and Handy, 1972 | California | 1 | 1960-62 | 3 | 6 |
| Krueger and Arpaia, 2008 | California | 1 | 2004 | 1 | 1 |
| Alva and Parmasivam, 1998 | Florida | 1 | 1994-96 | 3 | 36 |
| Rapisarda et al., 1995 | Italy | 2 | 1990-92 | 3 | 12 |
| Roccuzzo et al., 2012 | Italy | 1 | 2010 | 1 | 1 |
| Bataglia et al., 1977 | Brazil | | 1976 | 1 | 5 |
| NRCS Crop Nutrient Tool | | | | | 2 |
| **Overall** | | | | | **82** |

## Variability

Given the fact that the studies included in the table were carried out in different countries and over a period of 60 years, the average values reported vary surprisingly little across studies. Embleton and Jones (1974) found that the N concentrations in Valencia and Navel oranges differed little (3.01 vs. 2.92 lbs/ton, respectively). They also reported increasing N concentrations in oranges with increasing N application rates. Furthermore, studies in Florida and Italy reported differences among varieties (Bataglia et al., 1977; Alva and Parmasivam, 1998). The studies included here all reported average values across years. It is therefore not possible to determine how much the N concentration in oranges varies from one year to the next.

Krueger and Arpaia (2008) analyzed the rind and juice separately. They found that 63% of the N is in the rind and 37% in the juice (Krueger, personal communication).

*Summary statistics of orange N removal data.*

| Source | Summary (lbs/ton of fruits) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Embleton and Jones, 1974 | 2.97 | 0.30 | 2.44 - 3.46 | 10.1 |
| Labanauskas and Handy, 1972 | 3.70 | 0.25 | 3.52 - 3.88 | 6.9 |
| Krueger and Arpaia, 2008 | 3.26 | | | |
| Alva and Parmasivam, 1998 | 2.70 | 0.33 | 2.35 - 3.00 | 12.2 |
| Rapisarda et al., 1995 | 2.71 | 0.36 | 2.36 - 3.19 | 13.1 |
| Roccuzzo et al., 2012 | 2.66 | | | |
| Bataglia et al., 1977 | 4.30 | 0.35 | 3.99 - 4.86 | 8.1 |
| NRCS Crop Nutrient Tool | 3.31 | 0.02 | 3.30 - 3.33 | 0.7 |
| **Overall** | **2.96** | **0.32** | **2.35 - 4.86** | **10.9** |

## Discussion

The dataset is a reasonable estimate of N removed with oranges. However, most samples from California were collected more than 40 years ago. For a more robust estimate of the amount of N removed from orange orchards, the dataset needs to be complemented with samples from different orchards in the Central Valley planted to the major varieties, collected over a period of several years.

## References


Alva, A.K., Paramasivam, S., 1998. An evaluation of nutrient removal by citrus fruits. Proceedings of the Florida State Horticultural Society 111, 126-128.

Bataglia, O.C., Rodriguez, O., Hiroce, R., Gallo, J.R., Furlani, P.R., Furlani, A.M.C., 1977. Composição mineral de frutos cítricos na colheita. Bragantia 36, 215-221.

Embleton, T.W., Jones, W.W., 1974. Foliar-applied nitrogen for citrus fertilization. Journal of Environmental Quality 3, 388-391.

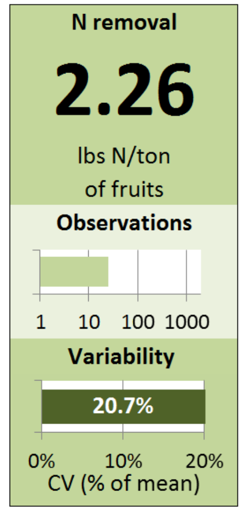
Krueger, R.R., Arpaia, M.L., 2008. Seasonal uptake of nutrients by mature field-grown 'Valencia' (*Citrus sinensis* O.) trees in California. Proceedings of the International Society of Citriculture, 588-594. Complemented with unpublished data.

Labanauskas, C.K., Handy, M.F., 1972. Nutrient removal by Valencia orange fruit from citrus orchards in California. California Agriculture 26(12), 3-4.

Rapisarda, P., Intrigliolo, F., Intelisano, S., 1995. Fruit mineral analysis of two 'Tarocco' clones of sweet orange to estimate fruit mineral removals. Acta Horticulturae 383, 125-133.

Roccuzzo, G., Zanotelli, D., Allegra, M., Giuffrida, A., Torrisi, B.F., Leonardi, A., Quiñones, A., Intrigliolo, F., Tagliavini, M., 2012. Assessing nutrient uptake by field-grown orange trees. European Journal of Agronomy 41, 73-80.

# Peaches




## Data sources

Data from six studies were included in this report. Two studies were from California, the others from Spain and Australia. The two California studies were carried out with 'O'Henry' and 'Halford' peaches. A total of 25 observations were included, of which 5 are from California.

## Relevance

The average values reported by the two California studies are within 10% of the average across all studies. Therefore, the average N concentration in the table may be a reasonable estimate of N in California peaches.

*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 |
| El-Jendoubi et al., 2013 | Spain | 1 | 2007-10 | 3 | 9 |
| Grasa et al., 2006 | Spain | 1 | 1998 | 1 | 1 |
| Martinez, 2010 | Spain | 1 | 2006-09 | 3 | 9 |
| Huett and Stewart, 1999 | Australia | 1 | 1994 | 1 | 1 |
| **Overall** | | | | | **25** |

*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 |
| El-Jendoubi et al., 2013 | 2.60 | 0.52 | 2.30 - 3.2 | 19.9 |
| Grasa et al., 2006 | 1.66 | | | |
| Martinez, 2010 | 2.01 | 0.40 | 1.38 - 2.55 | 19.7 |
| Huett and Stewart, 1999 | 2.58 | | | |
| **Overall** | **2.26** | **0.47** | **1.38 - 3.69** | **20.7** |

## Variability

The variability within some individual studies is larger than the variability among the average values of the different studies. Niederholzer et al. (2001) found that N fertilization considerably increases the N concentration in peaches. This observation was confirmed by a study carried out in Spain (Martinez et al., 2010). In the same study, year of harvest also had a considerable effect on N concentrations in peaches. The variability reported by El-Jendoubi et al. (2013), who monitored three varieties grown in two commercial orchards, is due to variety, location, and orchard management. The authors reported average values across three study years. As is the case with prunes, fruit size likely affects the N concentration in peaches (see **prunes** for more detail).

## Discussion

The average N concentration in the table may be a reasonable estimate of N concentrations in California peaches. However, the dataset includes only a small number of observations. For a robust estimate of the amount of N removed from orchards in the Central Valley, samples need to be taken from different orchards over a period of several years and include the major varieties. Fruit size and yield should also be measured in order to determine their effect on N concentration in peaches.

## References


El-Jendoubi, H., Abadía, J., Abadía, A., 2013. Assessment of nutrient removal in bearing peach trees (*Prunus persica* L., Batsch) based on whole tree analysis. Plant and Soil 369, 421-437.

Grasa, R., Clavería, I., Paniagua, M.P., Abadía J., Abadía A., 2006. Impact of iron chlorosis on macro- and micro-nutrient budgets in peach. Acta Horticulturae 721, 99-104.

Huett, D.O., Stewart, G.R., 1999. Timing of $^{15}N$ fertiliser application, partitioning to reproductive and vegetative tissue, and nutrient removal by field-grown low-chill peaches in the subtropics. Australian Journal of Agricultural Research 50, 211-215.

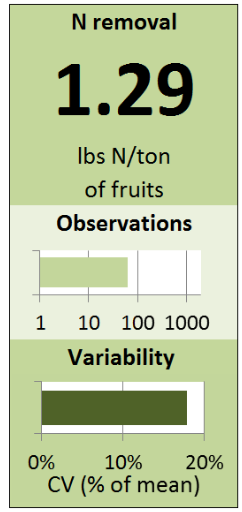
Martinez, X.D., 2010. Effects of irrigation and nitrogen application on vegetative growth, yield and fruit quality in peaches (*Prunus persica* L. Batsch cv. Andross) for processing.

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.

# Pear, European




## Data Sources

Data from five studies, the USDA Food Composition Database and the NRCS Crop Nutrient Tool were included for a total of 61 observations. Only one observation is from California. Most observations are from a study carried out in Belgium (Deckers et al. (2011) and from the USDA database. Both sources have their limitations. Deckers et al. (2011) reported N in the dry matter without reporting yield or dry matter content of the fruits. To be able to use their results for this report, we calculated N concentration in fresh fruits using a dry matter content of 16.57%, which is based on the NRCS and USDA databases. The USDA database, on the other hand, only reports protein in the edible part of pears, excluding N in seeds and stems. For apples, we multiplied the value from the USDA database by a factor of 1.11, based on a study with 'Cox's Orange' apples (Wilkinson and Perring, 1956; see **apples** for more detail). As no information about seeds and stems in pears was available, we used the same conversion factor.

## Relevance

With only one value from California and some uncertainty about the two main sources included in this report, it is not possible to determine how well the average value in the table represents N concentration in pears harvested in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Weinbaum et al., 1992 | California | | | | 1 |
| Sanchez et al., 1992 | Oregon | 1 | 1990 | 1 | 6 |
| Sanchez et al., 2002 | Italy | 1 | 1996 | 1 | 3 |
| Quartieri et al., 2002 | Italy | 1 | 1996 | 1 | 3 |
| Deckers et al., 2011 | Belgium | 1 | 2007/09 | 3 | 21 |
| USDA Food Composition Database | | | | | 29 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **64** |

## Variability

The variability within some individual studies is larger than the variability among the average values reported by different studies. Deckers et al. (2011) found a relatively small effect of harvest year on the N concentration of 'Conference' pears. Similarly, different N levels had no consistent effect on N concentrations. In two orchards in Oregon, Sanchez et al. (1992) found that the N concentration in pears was more affected by soil type of the orchards than timing of N application. No information about other factors is available from the studies in the dataset.

*Summary statistics of pear N removal data.*

| Source | Summary (lbs/ton of fruits) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Weinbaum et al., 1992 | 1.30 | | | |
| Sanchez et al., 1992 * | 1.57 | 0.16 | 1.4 - 1.8 | 10.3 |
| Sanchez et al., 2002 | 0.86 | 0.07 | 0.8 - 0.9 | 7.7 |
| Quartieri et al., 2002 * | 0.72 | 0.04 | 0.7 - 0.7 | 5.1 |
| Deckers et al., 2011 * | 1.38 | 0.12 | 1.2 - 1.6 | 8.7 |
| USDA Food Composition Database * | 1.28 | 0.31 | 0.8 - 2.1 | 23.9 |
| NRCS Crop Nutrient Tool | 1.34 | | | |
| **Overall** | **1.29** | **0.23** | **0.7 - 2.1** | **17.9** |

* Dry weight was converted to fresh weight using a dry matter content of 16.57% (based on NRCS Crop Nutrient Tool and the USDA Food Composition Database)

** Reports protein in the edible parts. To account for seeds and stems, the N removed was increased by 11% (see text for more detail).

## Discussion

With little information from California and large differences in N concentrations within and among studies, the average value in the table is only a rough estimate. Samples of pears grown in the Central Valley need to be taken and analyzed. For a robust estimate of the amount of N removed, samples need to be taken from different orchards over a period of several years and include the major varieties.

## References


Deckers, T., Verjans, W., Schoofs, H., Janssens, P., Elsen, F., 2011. Fruit quality on ‘Conference’ pear trees in Belgium. Acta Horticulturae 909, 283-294.

Quartieri, M., Millard, P., Tagliavini , M., 2002. Storage and remobilisation of nitrogen by pear (*Pyrus communis* L.) trees as affected by timing of N supply. European Journal of Agronomy 17, 105–110.

Sánchez, E.E., 2002. Nitrogen nutrition in pear orchards. Acta Horticulturae 596, 653-657.

Sánchez, E.E., Righetti, T.L., Sugar, D. Lombard, P.B., 1992. Effects of timing of nitrogen application on nitrogen partitioning between vegetative, reproductive, and structural components of mature ‘Comice’ pears. Journal of Horticultural Science 67, 51-58.

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

Wilkinson, B.G., Perring, M.A., 1965. The mineral composition of apples III - The composition of seeds and stems. Journal of Science in Food and Agriculture 16, 438-441.

# Pistachio

## Data sources

The data included in this report are from a study carried out by Patrick Brown, Professor at UC Davis, and his team in four orchards in the southern San Joaquin Valley between 2009 and 2011. The orchards were located in Kern, Madera, King and Fresno counties.

## Relevance

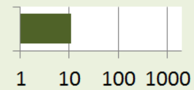
The values in the table are from a recent study carried out in different orchards in the Central Valley over a period of 3 years. The value can be considered a good estimate of N removed with California pistachios.

**N removal**

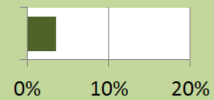
**56.1**

lbs N/ton
dry yield (CPC)

**Observations**




**Variability**




*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Siddiqui and Brown 2013 | California | 4 | 2009-11 | 3 | 11 |
| **Overall** | | **4** | | **3** | **11** |

*Summary statistics of pistachio N removal data.*

| Source | Summary (lbs/ton dry yield (CPC)) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Siddiqui and Brown 2013 | 56.1 | 1.94 | 54.1 - 57.6 | 3.5 |
| **Overall** | **56.1** | **1.94** | **54.1 - 57.6** | **3.5** |

## Variability

The variability in the dataset is due to differences between orchards. The report included average values across the years of study, so that the effect of harvest year cannot be determined. As pistachios are alternate bearing, the crop load may also have an effect on the N concentration.

## Discussion

The value is a good estimate for N removed from pistachio orchards in the Central Valley. As the dataset is relatively small, complementing it with samples from different orchards from across the Central Valley over a period of several years would result in a more robust estimate.

## References

Siddiqui, M.I., Brown, P., 2013. Pistachio early-season sampling and in-season nitrogen application maximizes productivity, minimizes loss. Available online at: http://fruitsandnuts.ucdavis.edu/files/165545.pdf

# Plums

N removal

**2.83**

lbs N/ton
of fruits

**Observations**


**Variability**


## Data sources

Data from three studies and a value from the NRCS Crop Nutrient Tool were included. Only one value is from California, while the other studies were carried out in South Africa and Bulgaria. With 11 observations, the dataset is small.

## Relevance

With only one value from California and a small dataset, it is not possible to determine how well the average value across all sources represents N concentrations in plums from the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Weinbaum et al., 1992 | California | | | | 1 |
| Woodbridge and Schutte, 2005 | South Africa | | 2001 | 1 | 3 |
| Vitanova et al., 2010 | Bulgaria | | 2004 | 1 | 6 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **11** |

*Summary statistics of plum N removal data.*

| Source | Summary (lbs/ton of fruits) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Weinbaum et al., 1992 | 2.84 | | | |
| Woodbridge and Schutte, 2005 | 2.77 | 0.28 | 2.4 - 3 | 10.3 |
| Vitanova et al., 2010 | 2.90 | 0.37 | 2.4 - 3.3 | 12.9 |
| NRCS Crop Nutrient Tool | 2.53 | | | |
| **Overall** | **2.83** | **0.32** | **2.4 - 3.3** | **11.2** |

## Variability

With the data available, little can be said about the factors affecting plum N concentrations. Woodbridge and Schutte (2005) investigated the effects of different tree densities on plum production. The variability reported by Vitanova et al. (2010) is mainly due to differences among varieties. No information about the effects of N application rate and the differences from one year to another is available from these studies. For prunes, fruit size has a significant influence on the N concentration of the fruits (see **prunes** for more detail). This is likely the case with plums as well.

## Discussion

Only one observation in the dataset was collected in California. For a robust estimate of the amount of N removed, samples need to be taken from different orchards over a period of several years and include the major varieties. Fruit size and yield should also be measured in order to determine their effect on N concentration in plums.

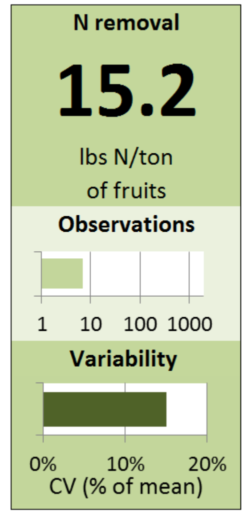
## References


Vitanova, I., Dimkova, S., Marinova, N., Ivanova, D., Kutinkova, H., 2010. Pomological and chemical characteristics of some Bulgarian plum cultivars. Acta Horticulturae 874, 317-320.

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

Wooldridge, J., Schutte, C., 2003. Effect of planting density on dry matter partitioning in young 'Laetitia' / 'Marianna' plum trees grown in lysimeter tanks. South African Journal of Plant and Soil 20, 6-10.

# Pomegranate




## Data sources

Only one study reporting N concentration of entire pomegranate fruits was available. The study was carried out in South Africa with seven different varieties.

## Relevance

With the data available, it is not possible to determine the degree to which the value in the table is representative for pomegranates harvested in the Central Valley.

## Variability

The variability in the dataset is due to different varieties. Fawole and Opara (2010) analyzed rind, mesocarp and arils separately. They found that the composition of fruits can vary considerably among varieties, with the N in arils, the edible part of the fruit, accounting for 34 to 58% of the total N. No information is available about the effect of N fertilization, fruit size and year of harvest on N concentration.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Fawole and Opara, 2012 | South Africa | 1 | 2010 | 1 | 7 |
| **Overall** | | | | | **7** |

*Summary statistics of pomegranate N removal data.*

| Source | Summary (lbs/ton of fruits) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Fawole and Opara, 2012 | 15.2 | 2.28 | 12.1 - 18.7 | 15.0 |
| **Overall** | **15.2** | **2.28** | **12.1 - 18.7** | **15.0** |

## Discussion

With the data available, it is not possible to determine how well the value in the table represens pomegranates harvested in the Central Valley. Samples of pomegranates grown in the Central Valley need to be taken and analyzed. For a robust estimate of the amount of N removed, samples need to be collected from different orchards over a period of several years and include the major varieties. Fruit size and yield should also be measured to determine its effect on N concentration in pomegranates.

## References

Fawole, O.A., Opara, U.L., 2012. Composition of trace and major minerals in different parts of pomegranate (*Punica granatum*) fruit cultivars. British Food Journal 114, 1518-1532.

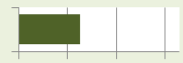
# Prunes

N removal

**11.2**

lbs N/ton
of dried fruits

**Observations**




**Variability**


## Data sources

Four studies were included in the dataset, all of them reporting values for dried plums harvested in the Sacramento Valley, where most California prunes are grown.

## Relevance

The values in the table are from studies carried out in different orchards in the Sacramento Valley. Even though the number of observations is relatively small, the average value is likely a good estimate of N removed with prunes.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Niederholzer, 2014 | California | | | | 1 |
| Brown et al., 2014 | California | 10 | 2014 | 1 | 10 |
| Southwick et al., 1996 | California | 1 | 1996 | 1 | 6 |
| Weinbaum et al, 1994 | California | 1 | 1993 | 1 | 1 |
| **Overall** | | | | | **18** |

*Summary statistics of prune N removal data.*

| Source | Summary (lbs/ton of dried fruits) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Niederholzer, 2014 | 15.0 | | 12.0 - 18.0 | |
| Brown et al., 2014 | 11.6 | 1.51 | 8.9 - 13.8 | 13.1 |
| Southwick et al., 1996 | 9.7 | 0.73 | 9.0 - 10.9 | 7.5 |
| Weinbaum et al, 1994 | 13.3 | | | |
| **Overall** | **11.2** | **1.83** | **8.9 – 18.0** | **16.3** |

## Variability

Despite the fact that the samples were taken from a relatively small geographic area, the variability among studies is relatively large. Samples taken from 10 different orchards contributed to the variability of the data observed by Brown et al. (2014). One factor with a significant influence on N concentration was fruit size, with small fruits having higher N concentrations than larger fruits. This may be due to differences in the flesh to pit ratio. Southwick et al. (1996) found that prunes with inadequate N supply tended to have lower N concentrations than prunes with sufficient N. It's important to note that the study by Southwick et al. (1996) was done with young trees, which generally produce bigger fruits. This may explain the low average N concentration reported in this study. The results may not be representative of mature trees (Niederholzer, personal communication).

## Discussion

The average value of the dataset is likely a good estimate of the N concentration in prunes from California. However, with 18 observations in total, the dataset is rather small and the variability among studies large. Increasing the number of samples included would improve the confidence in the value. When additional samples are collected, they need to be taken from different orchards over a period of several years and include the major varieties. Fruit size and yield should also be measured in order to determine their effect on N concentration in prunes.

## References

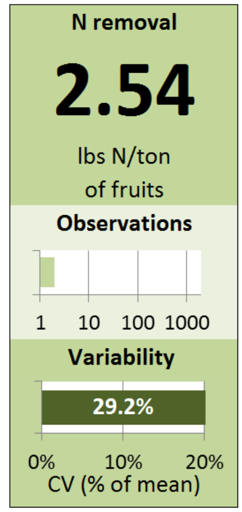

Brown, P.H. Niederholzer, F., Sepulveda R., 2014. Development of nutrient management tools for prunes. Report submitted to the California Dried Plum Board. Available online at: http://ucanr.edu/repositoryfiles/2014-41-155716.pdf

Niederholzer, F., 2014. Efficient nitrogen management in prune production. Glenn County Orchard Facts, April 2014. Available online at: http://ceglenn.ucanr.edu/newsletters/Orchard_Facts51238.pdf

Southwick, S.M., Rupert, M.E., Yeager, J.T., Weis, K.G., DeJong, T., Shackel, K., Bonin, A., 1996. Nitrogen fertigation of young prune trees and effects on horticultural performance. Report submitted to the California Dried Plum Board. Available online at: http://ucanr.edu/repositoryfiles/1996-47.pdf-78994.pdf

Weinbaum, S.A., Niederholzer, F.J.A., Ponchner, S., Rosecrance, R.C., Carlson, R.M., Whittlesey, A.C., Muraoka, T.T., 1994. Nutrient uptake by cropping and defruited field-grown 'French' prune trees. Journal of the American Society of Horticultural Science 119, 925-930.

# Tangerines




## Data sources

Only one study reporting N concentrations in tangerines could be found. In addition, a value from the NRCS Crop Nutrient Tool was included, for a total number of observations of just 2.

## Relevance

As no values from tangerines harvested in California were available, it is not possible to determine how well the values reported in the table represent tangerines grown in the Central Valley.

*Data sources and number of observations.*

| Source | Sites | | Years sampled | | Observations |
|---|---|---|---|---|---|
| | Location | n | Years | n | |
| Bataglia et al., 1977 | Brazil | 1 | 1976 | 1 | 1 |
| NRCS Crop Nutrient Tool | | | | | 1 |
| **Overall** | | | | | **2** |

*Summary statistics of tangerine N removal data.*

| Source | Summary (lbs/ton of fruits) | | | |
|---|---|---|---|---|
| | Mean | SD | Range | CV (%) |
| Bataglia et al., 1977 | 3.06 | | | |
| NRCS Crop Nutrient Tool | 2.02 | | | |
| **Overall** | **2.54** | **0.74** | **2.02 - 3.06** | **29.2** |

## Variability

The N concentrations reported in the two studies differ considerably. No information is provided to determine factors affecting N in tangerines. However, research in oranges has shown that varieties and N application rates can strongly affect N concentrations in citrus fruits (see **oranges**).

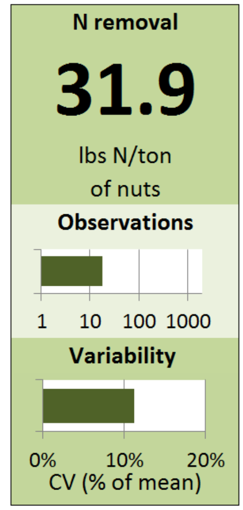
## Discussion

The average value reported in the table may not be representative for tangerines harvested in California. Therefore, samples need to be collected from different orchards in the Central Valley over a period of several years for a representative and robust estimate of N removal with tangerines. The major varieties should be included in the sample.

## References

Bataglia, O.C., Rodriguez, O., Hiroce, R., Gallo, J.R., Furlani, P.R., Furlani, A.M.C., 1977. Composição mineral de frutos cítricos na colheita. Bragantia 36, 215-221.

# Walnuts




## 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, deJong et al. (2015) determined N concentrations in 'Chandler' and 'Tulare' walnuts in three orchards in the Central Valley over a period of two years. The values reported here are for N removed with fruits (hull, shell and kernel), expressed per ton of nut yield (shell and kernel).

## Relevance

The observations in the table are from two studies carried out in the Central Valley and are likely 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 |
| DeJong et al., 2015 | Central Valley | 3 | 2013-14 | 2 | 12 |
| **Overall** | | | | | **18** |

*Summary statistics of walnut N removal data.*

| Source | Summary (lbs/ton of nuts) | | | CV (%) |
|---|---|---|---|---|
| | Mean | SD | Range | |
| Weinbaum et al., 1991 | 40.5 | 4.34 | 34.0 - 46.4 | 10.7 |
| DeJong et al., 2015 | 27.5 | 3.14 | 24.0 - 32.6 | 11.4 |
| **Overall** | **31.9** | **3.56** | **24.0 - 46.4** | **11.2** |

## Variability

In the study by deJong et al. (2015) walnut N concentration differed little between the two years investigated and between 'Hartley' and 'Tulare' walnuts. In contrast, differences between 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. Therefore the variability among growers will likely be larger.

## Discussion

The dataset is based on two studies carried out in the central Valley and can be considered a good estimate of N removed with walnuts. However, the average values of the two studies differ considerably.

For a more robust estimate of the amount of N removed from walnut orchards, the dataset is best complemented with samples from different orchards in the Central Valley planted to different varieties over a period of several years.

## 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

DeJong, T., Pope, K., Brown, P., Lampinen, B., Hopmans, J., Fulton, A., Buchner, R., Grant J., 2015. Development of a nutrient budget approach and optimization of fertilizer management in walnut. Walnut Research Reports 2015. Available online at: http://ucanr.edu/repositoryfiles/2015-231-160278.pdf

## Appendix: Acreage of crops grown in the Central Valley (San Joaquin Valley and Sacramento Valley combined).

The list is based on the USDA Agricultural Census and Survey 2012, which is currently the most recent year with a detailed list of crops (available online at: https://quickstats.nass.usda.gov/).

The percentages of each crop as well as the cumulative % are estimates of the proportion of the total acreage in the Central Valley. Non-irrigated acreage may be included for some field crops. Rice was excluded from the list. The crops included in this report are written in **bold** typeface.

### List of Central Valley crops

| # | Commodity | Acreage | % of total | Cumulative % |
|---|---|---|---|---|
| 1 | **Almonds** | 736719 | 13.15 | 13.15 |
| 2 | **Grapes** | 586993 | 10.47 | 23.62 |
| 3 | **Wheat, Winter & Spring, excl. Durum** | 552759 | 9.86 | 33.48 |
| 4 | **Hay, Alfalfa** | 498767 | 8.90 | 42.38 |
| 5 | **Corn, Silage** | 464365 | 8.29 | 50.67 |
| 6 | **Cotton** | 350765 | 6.26 | 56.93 |
| 7 | **Processing Tomatoes** | 274712 | 4.90 | 61.83 |
| 8 | **Walnuts** | 227729 | 4.06 | 65.90 |
| 9 | **Hay, Small Grain** | 226858 | 4.05 | 69.94 |
| 10 | **Corn, Grain** | 195113 | 3.48 | 73.43 |
| 11 | **Pistachios** | 175541 | 3.13 | 76.56 |
| 12 | **Haylage, excl. Alfalfa** | 169010 | 3.02 | 79.57 |
| 13 | **Oranges** | 157350 | 2.81 | 82.38 |
| 14 | **Haylage, Alfalfa** | 72795 | 1.30 | 83.68 |
| 15 | **Barley** | 65500 | 1.17 | 84.85 |
| 16 | **Hay, excl. Small Grain & Alfalfa** | 52435 | 0.94 | 85.79 |
| 17 | **Sunflower** | 46914 | 0.84 | 86.62 |
| 18 | **Peaches** | 44641 | 0.80 | 87.42 |
| 19 | **Wheat, Durum** | 42327 | 0.76 | 88.17 |
| 20 | **Sorghum, Silage** | 39252 | 0.70 | 88.88 |
| 21 | **Prunes** | 36480 | 0.65 | 89.53 |
| 22 | **Beans, Dry, excl. Lima** | 35715 | 0.64 | 90.16 |
| 23 | **Carrots** | 34280 | 0.61 | 90.78 |
| 24 | **Olives** | 32517 | 0.58 | 91.36 |
| 25 | **Pomegranates** | 28852 | 0.51 | 91.87 |
| 26 | **Tomatoes, Fresh Market** | 28671 | 0.51 | 92.38 |

**Central Valley crops (continued)**

| # | Commodity | Acreage | % of total | Cumulative % |
|---|---|---|---|---|
| **27** | **Cherries** | **28541** | **0.51** | **92.89** |
| **28** | **Potatoes** | **25799** | **0.46** | **93.35** |
| **29** | **Melons, Cantaloupe** | **25592** | **0.46** | **93.81** |
| **30** | **Onions** | **21927** | **0.39** | **94.20** |
| **31** | **Safflower** | **21723** | **0.39** | **94.59** |
| **32** | **Oats** | **21051** | **0.38** | **94.96** |
| **33** | **Tangerines** | **20386** | **0.36** | **95.33** |
| **34** | **Sweet Potatoes** | **17506** | **0.31** | **95.64** |
| **35** | **Garlic** | **17496** | **0.31** | **95.95** |
| **36** | **Plums** | **17131** | **0.31** | **96.26** |
| **37** | **Nectarines** | **16803** | **0.30** | **96.56** |
| **38** | **Sweet Corn** | **14822** | **0.26** | **96.82** |
| 39 | Grasses & Legumes Totals, Seeds * | 13683 | | |
| **40** | **Beans, Dry Lima** | **12912** | **0.23** | **97.05** |
| **41** | **Sorghum, Grain** | **12514** | **0.22** | **97.27** |
| **42** | **Triticale** | **11431** | **0.20** | **97.48** |
| **43** | **Melons, Watermelon** | **9301** | **0.17** | **97.64** |
| **44** | **Asparagus** | **7215** | **0.13** | **97.77** |
| 45 | Hay, Wild ** | 7171 | | |
| **46** | **Cucumbers** | **6908** | **0.12** | **97.90** |
| **47** | **Lemons** | **6882** | **0.12** | **98.02** |
| **48** | **Apricots** | **6850** | **0.12** | **98.14** |
| **49** | **Peppers, Bell** | **6365** | **0.11** | **98.26** |
| **50** | **Apples** | **5990** | **0.11** | **98.36** |
| **51** | **Lettuce, Head** | **5920** | **0.11** | **98.47** |
| **52** | **Pears** | **5616** | **0.10** | **98.57** |
| **53** | **Melons, Honeydew** | **5458** | **0.10** | **98.67** |
| **54** | **Broccoli** | **5121** | **0.09** | **98.76** |
| **55** | **Figs** | **4068** | **0.07** | **98.83** |
| **56** | **Pumpkins** | **4039** | **0.07** | **98.90** |
| **57** | **Squash** | **4014** | **0.07** | **98.97** |
| **58** | **Beans, Snap** | **3564** | **0.06** | **99.04** |

**Central Valley crops (continued)**

| # | Commodity | Acreage | % of total | Cumulative % |
|---|---|---|---|---|
| 59 | Vegetables, Other | 3381 | 0.06 | 99.10 |
| 60 | Blueberries | 3121 | 0.06 | 99.15 |
| 61 | Kiwifruit | 2721 | 0.05 | 99.20 |
| **62** | **Grapefruit** | **2695** | **0.05** | **99.25** |
| 63 | Persimmons | 2139 | 0.04 | 99.29 |
| 64 | Onions, Green | 1869 | 0.03 | 99.32 |
| 65 | Plum-Apricot Hybrids | 1832 | 0.03 | 99.35 |
| **66** | **Lettuce, Romaine** | **1808** | **0.03** | **99.39** |
| 67 | Beans, Green, Lima | 1655 | 0.03 | 99.42 |
| 68 | Pecans | 1298 | 0.02 | 99.44 |
| 69 | Tangelos | 1221 | 0.02 | 99.46 |
| 70 | Lettuce, Leaf | 1086 | 0.02 | 99.48 |
| 71 | Spinach | 975 | 0.02 | 99.50 |
| 72 | Eggplant | 954 | 0.02 | 99.51 |
| 73 | Cabbage | 807 | 0.01 | 99.53 |
| 74 | Strawberries | 787 | 0.01 | 99.54 |
| 75 | Peppers, Chile | 687 | 0.01 | 99.56 |
| 76 | Daikon | 594 | 0.01 | 99.57 |
| 77 | Beets | 521 | 0.01 | 99.57 |
| 78 | Brussels Sprouts | 481 | 0.01 | 99.58 |
| 79 | Tree Nuts, Other | 364 | 0.01 | 99.59 |
| 80 | Parsley | 329 | 0.01 | 99.60 |
| 81 | Wild Rice | 263 | <0.01 | 99.60 |
| 82 | Avocados | 253 | <0.01 | 99.61 |
| 83 | Radishes | 243 | <0.01 | 99.61 |
| 84 | Chestnuts | 131 | <0.01 | 99.61 |
| 85 | Blackberries | 103 | <0.01 | 99.61 |
| 86 | Greens, Kale | 98 | <0.01 | 99.62 |
| 87 | Peas, Chinese | 90 | <0.01 | 99.62 |
| 88 | Berries, Other | 89 | <0.01 | 99.62 |
| 89 | Peas, Green, excl. Southern | 83 | <0.01 | 99.62 |
| 90 | Greens, Mustard | 60 | <0.01 | 99.62 |
| 91 | Herbs | 54 | <0.01 | 99.62 |
| 92 | Okra | 53 | <0.01 | 99.62 |

**Central Valley crops (continued)**

| # | Commodity | Acreage | % of total | Cumulative % |
|---|---|---|---|---|
| 93 | Peas, Green, Southern | 44 | <0.01 | 99.62 |
| 94 | Turnips | 43 | <0.01 | 99.62 |
| 95 | Artichokes | 36 | <0.01 | 99.63 |
| 96 | Cauliflower | 32 | <0.01 | 99.63 |
| 97 | Greens, Turnip | 22 | <0.01 | 99.63 |
| 98 | Raspberries | 22 | <0.01 | 99.63 |
| 99 | Peanuts | 20 | <0.01 | 99.63 |
| 100 | Boysenberries | 19 | <0.01 | 99.63 |
| 101 | Greens, Collard | 13 | <0.01 | 99.63 |
| 102 | Celery | 6 | <0.01 | 99.63 |
| 103 | Watercress | 6 | <0.01 | 99.63 |
| 104 | Mint | 5 | <0.01 | 99.63 |
| 105 | Horseradish | 3 | <0.01 | 99.63 |
| 106 | Rhubarb | 2 | <0.01 | 99.63 |

* Not included, because category includes many different species

** Not included, because not likely to be irrigated