University of California
Agriculture and Natural Resources

# ESTIMATING NITROGEN AVAILABILITY IN ORGANIC ANNUAL PRODUCTION:

## For N budgeting and other purposes

By Margaret Lloyd, Daniel Geisseler, Patricia Lazicki, Joji Muramoto and Richard Smith

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# DECRIPTION OF THE MANUSCRIPT, AS A WHOLE

The Organic Nitrogen Estimation document is intended to serve as an interactive guide for users to be able to understand and estimate a seasonal crop-specific organic nitrogen budget. Because the worksheet used to estimate a budget for organic production comes with many decisions that a user has to make, we have developed the flier to walk people through the factors that affect nitrogen release and how to make those decisions. The flier can be read as a standalone document to explain nitrogen release in organic production. Nonetheless it is organized to match the worksheet and the worksheet references many of the tables and figures in the flier. When completing the worksheet, users will often find that they have to do 'side calculations', in order to get the units that they use at home to match the units requested on the worksheet. Examples of common conversions are linear bed feet (or square feet) to acreage, yards to tons, and gallons to acre-inches. A conversion tool would allow quick access to these conversions to assist in the process. Completing this worksheet is a very big undertaking in time, mental energy and information needed. As such, we have developed the 'preparation' guide to layout the information that a user will need in order to complete the worksheet. This could be done in advance to sitting down to complete the worksheet and will help break up the total amount of time needed to complete the worksheet. This 'preparation' guide can also be given to users in advance to a workshop or one-on-one session in order to have them prepared with the information needed.

# DESCRIPTION OF EACH SECTION

| | Description/purpose |
|---|---|
| **Section 1.** Estimating Nitrogen Availability in Organic Vegetable Production: For N budgeting and other purposes | This is the descriptive document explaining all categories in the worksheet and how organic N budgeting works. This can also be used/read as a standalone document for those wanting to understand organic N budgeting. |
| **Section 2.** Preparing information for the nitrogen worksheet | This document is intended to serve as a ‘cheat sheet’ to let the user know information that can be collected in advance of doing an N budget to make the worksheet faster and easier to complete. It is numbered to correspond with the location in the worksheet where that information will be used. |
| **Section 3.** The Worksheet | The worksheet serves as a guide for calculations undertaken in an N budget. All tables and figures referenced in this document are referring to Section 1. |
| **Section 4.** The demo worksheet: A completed worksheet for illustrative purposes. | This is a completed worksheet to serve as an example. It includes notes for readers describing decisions made during the process. |

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# GLOSSARY

**Ammonium** is a mineral form of nitrogen that is readily plant-available.

**Crop residue** is plant material remaining after harvesting, including leaves, stalks, roots. (1)

**Cull fruits**, or **culling** is sorting produce usually done to eliminate injured, decayed, or otherwise defective produce (culls) before cooling or additional handling. (3)

**Denitrification** refers to the reduction of nitrogen oxides (usually nitrate and nitrite) to molecular nitrogen or nitrogen oxides with a lower oxidation state of nitrogen by bacterial activity (denitrification) or by chemical reactions involving nitrite (chemodenitrification). Nitrogen oxides are used by bacteria as terminal electron acceptors in place of oxygen in anaerobic or microaerophilic respiratory metabolism (SSA). Denitrification occurs when N is lost through the conversion of nitrate to gaseous forms of N, such as nitric oxide, nitrous oxide and dinitrogen gas. This occurs when the soil is saturated and the bacteria use nitrate as an oxygen source. (2)

**Immobilization** is the reverse of mineralization. All living things require N; therefore, microorganisms in the soil compete with crops for N. Immobilization refers to the process in which nitrate and ammonium are taken up by soil organisms and therefore become unavailable to crops. Incorporation of materials with a high carbon to nitrogen ratio (e.g. sawdust, straw, etc.), will increase biological activity and cause a greater demand for N, and thus result in N immobilization. Immobilization only temporarily locks up N. When the microorganisms die, the organic N contained in their cells is converted by mineralization and nitrification to plant available nitrate. (2)

**Leaching** is a pathway of N loss of a high concern to water quality. Soil particles do not retain nitrate very well because both are negatively charged. As a result, nitrate easily moves with water in the soil. The rate of leaching depends on soil drainage, rainfall, amount of nitrate present in the soil, and crop uptake. The EPA has set the maximum contaminant level for drinking water at 10 ppm N as nitrate. Well-drained soils, unexpected low crop yield high N inputs (especially outside of the growing season) and high rainfall are all conditions that increase the potential for nitrate leaching. (2)

**Nitrate** is a mineral form of N and is the most plant available form of N.

**Mineral forms** of nitrogen include ammonium ($NH_4^+$) and nitrate ($NO_3^-$).

**Mineralization** is the process by which microbes decompose organic N from manure, organic matter and crop residues to ammonium. Because it is a biological process, rates of mineralization vary with soil temperature, moisture and the amount of oxygen in the soil (aeration).(2)

**Nitrification** is the process by which microorganisms convert ammonium to nitrate to obtain energy. Nitrate is the most plant available form of N, but is also highly susceptible to leaching losses. Nitrification is most rapid when soil is warm (67-86°F), moist and well-aerated, but is virtually halted below 41°F and above 122°F. (2)

**Nitrogen fixation** refers to the conversion of atmospheric N to a plant available form. This occurs either through an industrial process, as in the production of commercial fertilizers, or a biological process, as with legumes such as alfalfa and clover. Nitrogen fixation requires energy, enzymes and minerals, so if a plant available form of N is present, the crop will use it instead of fixing it from the air. (2)

**Plant-available** refers to the forms of nitrogen—nitrate and ammonium—that are readily available for use by most plants.

**SOM—Soil organic matter** is the organic fraction of the soil exclusive of undecayed plant and animal residues. (4)


1. Environmental Indicators for Agriculture – Vol. 3: Methods and Results, OECD, 2001, glossary, pages 389-391.
2. Johnson, C., G. Albrecht, Q. Ketterings, J. Beckman, and K. Stockin. 2005. Nitrogen Basics – The Nitrogen Cycle. Cornell University Cooperative Extension. http://cceonondaga.org/resources/nitrogen-basics-the-nitrogen-cycle
3. Kitinoja, L., and A. A. Kader. 2015. Small Scale Postharvest Handling Practices: A Manual for Horticultural Crops (5thedition). University of California, Division of Agriculture and Natural Resources p. 37.
4. *Soil Science Society of America.* 2020 In Glossary of Soil Science Terms. Retrieved from https://www.soils.org/publications/soils-glossary#

# SECTION 1. ESTIMATING NITROGEN AVAILABILITY IN ORGANIC VEGETABLE PRODUCTION: FOR N BUDGETING AND OTHER PURPOSES

**Use in conjunction with the companion worksheet**

## INTRODUCTION

A crop-based nitrogen (N) budget can help estimate whether a crop's N supply is appropriate for both optimal crop production and water quality protection.

This document covers the typical sources of N in organic, annual cropping systems which includes:

- Soil organic matter
- Granular fertilizers
- Liquid fertilizers
- Crop residue (including cover crops)
- Irrigation water
- Compost
- Residual soil nitrate

While each of these sources can be a source of N, the total N in the material differs from the amount available to plants. This is especially relevant in organic systems due to the reliance on soil microorganisms to mineralize complex organic forms of N to plant available N. This document will help you estimate the amount of plant-available N from the multitude of N sources.

Soil tests are an important component to a nitrogen budget since they provide a snapshot of the N status at the time of testing. This can be used to determine whether a sidedress application is needed, cross-check N availability of an early N application over time, gain insight into the contributions of N from the soil organic matter, check for residual N after a growing season, and others purposes. This document will help you utilize soil test results for your N management.

By improving your prediction of plant available N, this will increase your ability to synchronize N supply with plant N demand, and minimize N loss to the environmental.

The goal of this worksheet is to understand how to estimate plant available N to ensure the crop demand is met and loss of N to the environment is minimized in organic vegetable production.

**Background**

**N management in organic systems is challenging because complex organic forms of N originating from compost, manures, crop residue and other organic materials need to be mineralized by microbes to mineral forms of N to become plant-available.** Because N is an essential plant nutrient and building block for plant growth and development, it is important to maintain enough available N in the soil to meet the crop's N needs during periods of rapid growth (Fig.1).

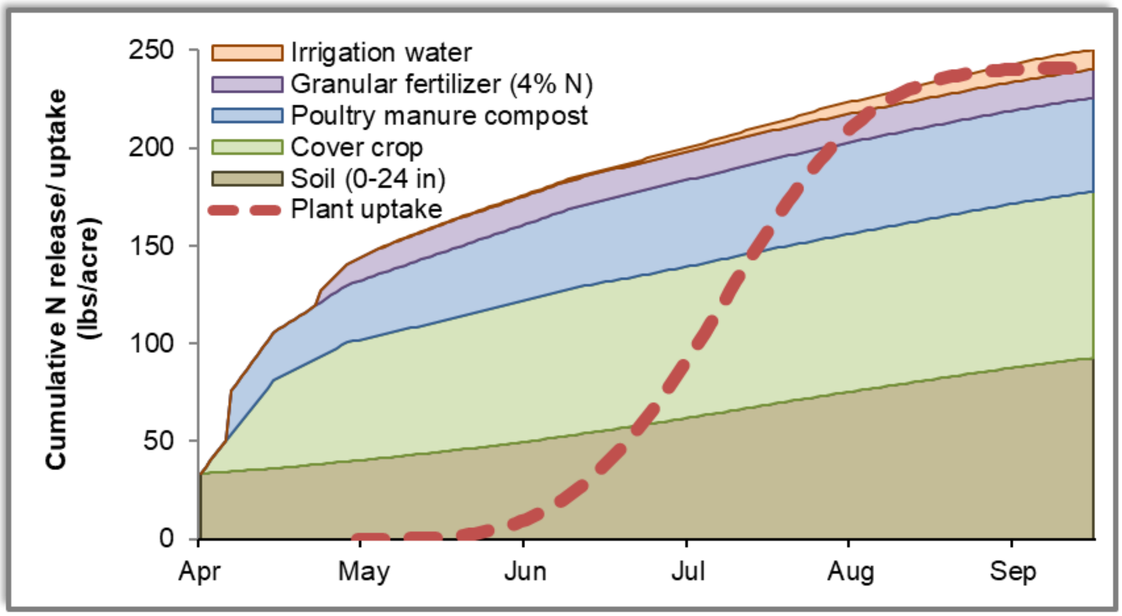


**Figure 1**: An example of N uptake and N supply in an organic tomato field. Data are based on the actual field trial in Davis, California (Crop: Fresh Market Tomato cv Brandywine). See extended captions for more details.

Why is nitrogen subject to leaching?

**Once mineralized, organic forms of N are converted to plant-available mineral forms of N: ammonium ($NH_4^+$) and nitrate ($NO_3^-$) .** Ammonium has a positive charge and is attracted to the negative charges on clay particles and soil organic matter. Ammonium is typically short-lived in the soil as microbes convert it to nitrate. Nitrate has a negative charge and is repelled by these negative charges (Figure 2), and is thus at risk for being leached below the root zone by rainwater or irrigation. To minimize nitrate leaching, irrigation needs to be carefully managed, especially with young or shallow rooted plants.

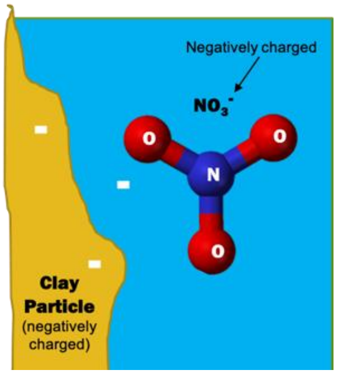


**Figure 2**: Sketch of a negatively charged nitrate molecule and a negatively charged clay particle.

<u>The role of microbes in nitrogen availability and 'tying up' nitrogen.</u>

**Amending the soil with organic forms of N stimulates microbial activity by providing C and N, both essential for microbial metabolism.** Carbon (C) is the primary energy source for microbial metabolic processes. To use C, microbes require N. "Feeding the soil" organic forms of N stimulates microbial activity and population booms because the microbes can now breakdown carbon sources in the soil. With this activity, there is also rapid turnover of microbes as well as organic matter decomposition, which become the two main sources of nitrate N release, available for plant use. As such, with each application of organic forms of N, only a portion of it becomes available to plants in the short term. Materials with a higher C:N ratio (e.g. > 24:1) require additional N to facilitate microbial breakdown. This additional N is taken from the pool of plant-available forms of N in the soil. Because this reduces the amount of N available to plants, it is sometimes referred to as "tying up N". As microbial populations grow and become more active, they can cycle both C and N in the soil matrix, releasing N in previously bound organic forms to forms readily taken up by plants. With each application of organic forms of N, only a portion of it becomes available to plants in the short term. **The unmineralized organic N becomes part of the soil organic matter pool of N, available in the future as the material is subject to mineralization processes (Figure 3).**

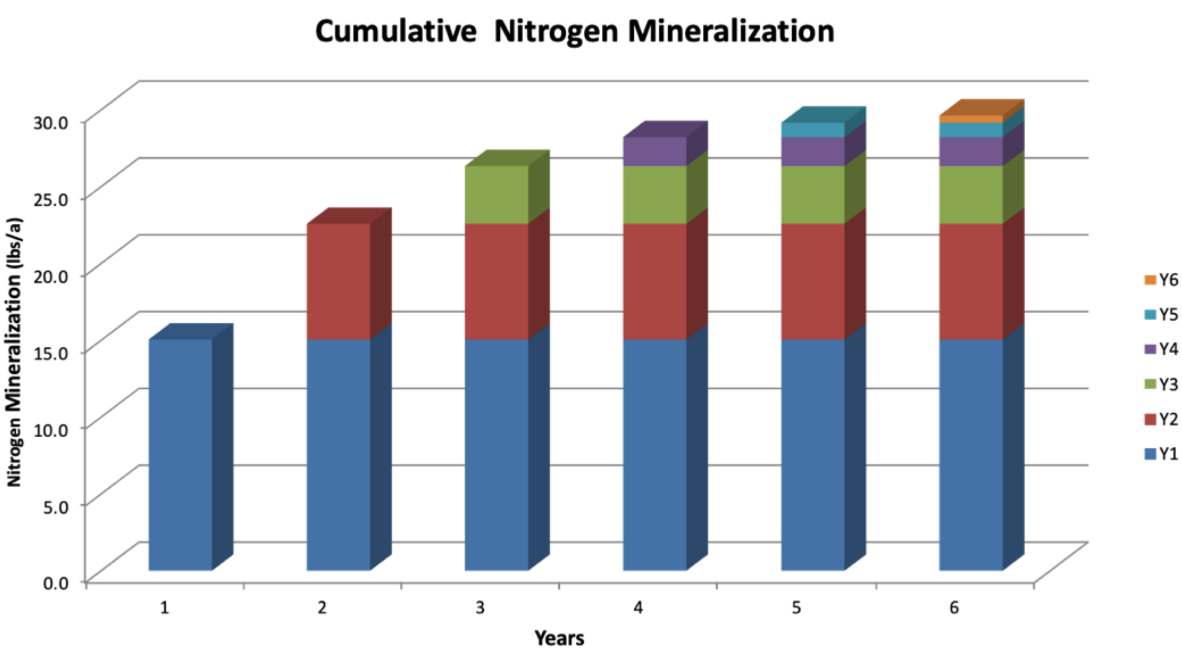


**Figure 3**. A model of available mineral N increasing and approaching a steady state after about 4 years, when receiving continual application of the same amount of organic N (43 lb N/A) from a manure (Crohn, 2004).

# PART 1. CROP N DEMAND

**Summary**

- Establish your target N need based on crop uptake demand
- Winter grown crops generally use less N than summer grown crops
- Uptake numbers are best used as a starting point, not an absolute

### A. Crop N Uptake: Establishing your target need

**Crop N demand and yield are very closely linked.** The crop N demand includes N requirements to produce the plant material, harvested crop and cull produce, and is a good starting point for estimating how much N the crop needs. The predicted yield is useful in tailoring the total crop N demand to your operation and calculating N removed from the field with harvested fruit (Table 1). When reviewing crop N demand estimates, consider how the location, production method (organic or conventional), yield and other factors associated with the information may differ from your conditions and expected yield, and adjust accordingly. Most data will be based on yields achieved when grown on commercial-scale, conventional production under optimal conditions. A few reputable sources that publish this type of information are land grant universities, cooperative extension, and commodity groups.

**Time of year and soil properties must be considered.** Crops that can be grown in both winter and summer usually take up less N in a winter planting. In Table 1, where crop N uptake ranges are given, the lower end of the range is appropriate for a winter production season for non-coastal climates. Soil texture influences water movement which influences nitrate movement. In contrast to clay soils which hold water more tightly, leaching of residual nitrate is more pronounced on sandy soils. On a sandy soil following a wet winter it is often necessary to apply more fertilizer N to make up for the loss of residual soil N than after a dry winter.

**Because plants do not capture all N applied, the amount of total fertilizer N needed for optimal crop growth is often more than actual crop uptake.** Two reasons for the imperfect match between N applied and N uptake are inefficiencies in irrigation management and variability in the field. Conversely, following a crop that leaves high levels of residual soil N in the soil (e.g. from crop residue, such as broccoli or alfalfa), the amount of fertilizer N needed for optimal growth may be *less* than the total crop uptake because mineralization of N from crop residues can supply a significant portion of crop needs. To address this aspect, soil testing would provide guidance on 'current status' of available soil N. Depending on the levels of residual soil nitrate in the soil, the quantity of N needed to be added by the grower can be adjusted. While these inefficiencies can be minimized with good management, they cannot be eliminated. This means that uptake numbers are best used as a starting point, not a prescription.

**Table 1:** Estimates of N uptake by major California crops

| Crop | Example yield (tons/acre) | Total crop N uptake (lb N/ton yield) | Total crop N uptake (lb N/acre) | N in harvest (lb N/ton yield) |
|---|---|---|---|---|
| Lettuce | 20 | 8 | 160 | 3 |
| Tomato (fresh-market) | 30 | 8 | 240 | 4 |
| Tomato (processing) | 50 | 5 | 250 | 3 |
| Sweet potato | 20 | 5 | 100 | 5 |
| Broccoli | 10 | 35 | 350 | 11 |
| Carrot | 20 | 10 | 200 | 3 |
| Melon | 20 | 7 | 140 | 4 |
| Potato | 25 | 11 | 275 | 6 |
| Strawberry | 40 | 5 | 200 | 3 |
| Spinach | 15 | 8 | 105 | 5 |

*Source: Lettuce: Bottoms et al., 2012; Hartz et al., 2017. Tomato (fresh-market): Lazicki et al., 2019. Tomato (processing): Hartz and Bottoms, 2012. Sweet potato: Weir and Stoddard, 2001. Broccoli: Hartz et al., 2017. Carrot: Lazicki and Geisseler, 2016. Melon: Contreras et al., 2011; Soto-Ortiz et al., 2008. Potato: Wilson et al., 2012. Strawberry: Bottoms et al., 2013. Spinach: Heinrich et al., 2013.*

# PART 2. N SUPPLY: BASELINE

### B. Available N from Soil Organic Matter

The amount of N released from the soil organic matter (SOM) depends on:

- the amount of SOM
- soil temperature
- soil moisture
- soil texture

A common rule of thumb is that about 1-3% of the total nitrogen in SOM becomes available annually

**Long-term additions of cover crops, manures and compost all increase SOM,** thereby increasing the amount of N which will become available from the soil.

**Under warm, moist conditions, more available N is released from the soil (and amendments) than when it is cool or dry**. For irrigated California crops, more N will be available in summer than winter. This means a crop planted in warm weather will be able to meet more of its N needs from N released from SOM than a crop planted in cooler weather.

**Soil texture** also influences N mineralization from SOM because higher clay content soils typically have higher SOM and higher N mineralization rates as compared with those with lower clay content, such as sandy and loamy soils (Colman, 2013).

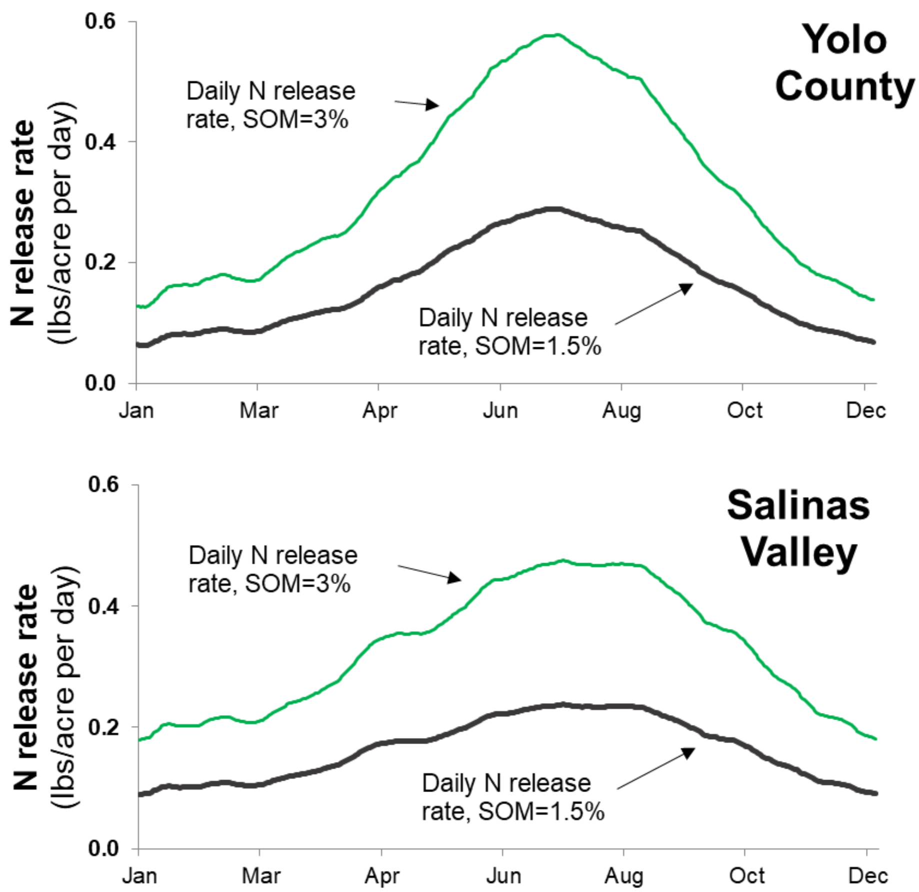


**Figure 4:** Modeled daily N release from SOM in the top foot of soils from Yolo County and the Salinas Valley, with high and low SOM contents, assuming that 2% of the soil N is mineralized annually. In this example, 60 and 120 lb N/acre were mineralized from the 1.5% and 3% SOM soil, respectively. Average soil temp May through September for Yolo County (hot, inland Sacramento Valley) are 72 °F and Salinas Valley (moderate, central coast) are 68°F. See extended captions for more details.

**Example. How much N would become available from SOM mineralization in an acre?**

Assume 2% SOM mineralization, a soil with 2% organic matter, a bulk density of 1.45 g/cm$^3$ and at a depth of 7”:

$2.85 \times 10^6$ lb soil/acre x 0.02 (% organic matter) x 0.07 (% N) x 0.02 (% mineralized) =

72 lb N/acre becomes available from SOM mineralization

| | Central Coast | | Sacramento Valley | | Imperial Valley | |
|---|---|---|---|---|---|---|
| SOM | 1.5% | 3.0% | 1.5% | 3.0% | 0.75% | 1.5% |
| | lb N per acre per month (top 12 ") | | | | | |
| January | 3 | 6 | 2 | 5 | 2 | 3 |
| February | 3 | 6 | 2 | 5 | 2 | 3 |
| March | 4 | 7 | 3 | 6 | 2 | 5 |
| April | 5 | 9 | 4 | 8 | 3 | 6 |
| May | 6 | 11 | 6 | 11 | 4 | 8 |
| June | 6 | 12 | 7 | 14 | 5 | 10 |
| July | 7 | 14 | 9 | 17 | 6 | 12 |
| August | 7 | 15 | 8 | 17 | 6 | 13 |
| September | 7 | 13 | 7 | 14 | 5 | 10 |
| October | 6 | 11 | 5 | 11 | 4 | 8 |
| November | 4 | 8 | 3 | 7 | 3 | 5 |
| December | 3 | 6 | 2 | 5 | 2 | 4 |

*Table 2. Estimates of N mineralization (lb N/acre/month) from high and low soil organic matter (SOM) soils in different climate regions of California, assuming that 2% of the soil N is mineralized annually in the top 12”. See extended captions for more details. Imperial valley extends from the Salton Sea to Mexico and is a hot desert climate with <3 inches annual precipitation. Sacramento Valley is the northern end of the Central Valley with +/- 20 inches annual precipitation. Central Coast lies from Ventura to Santa Cruz counties and is known for a mild coastal climate with +/- 10 inches annual precipitation.*

## C. Crop Residue: Available N from Cover Crops and Post-Harvest Residue

### C1. Available N from Crop Residue

The amount of N made available from crop residues depends on:

- Biomass of the residues

- N content of the residues
- C:N ratio
- Soil moisture
- Whether residues are left on the surface or incorporated.

**Vegetable residues can provide a significant amount of biomass N.** For some crops, such as broccoli, only a small part of the N they take up is removed in the harvested, marketable part of the crop, while the rest is incorporated into the soil. Nitrogen contributions from residue can result in a return of 178-255 lb N/Ac. Review Table 3 for additional estimated crop residue N contributions.

| Crop | Example yield (tons/acre) | N in residues (% of total) | Expected residue N (lb N/ton yield) | Expected residue N (lb N/acre) |
|---|---|---|---|---|
| Lettuce | 20 | 68 | 5 | 100 |
| Tomato (fresh-market) | 30 | 56 | 4 | 130 |
| Tomato (processing) | 50 | 46 | 2 | 100 |
| Broccoli | 10 | 68 | 24 | 240 |
| Carrot | 20 | 67 | 7 | 140 |
| Melon | 20 | 40 | 3 | 60 |
| Potato | 25 | 44 | 5 | 125 |
| Strawberry | 40 | 46 | 2 | 80 |
| Spinach | 15 | 38 | 3 | 45 |

***Table 3**. Estimated N amount and availability of residues from common California crops (Central Coast of California). "N in residues" refers to the percent of the total N taken up by a plant that remains in the residue post-harvest. For example, after marketable lettuce is removed from the field, 68% of the total N taken up by the lettuce remains in the field as residue. The values in Table 3 are mostly based on studies with commercial, conventionally managed vegetables in high production areas, and so the yield values may be high compared to comparable organic production. The amount of N expected to be in the residues can be adjusted for the actual expected yield by multiplying the actual yield by the value for lb N/ton yield in column 3. (See Table 1 for references).*

**Typically, N concentration in vegetable residues varies from 2.5 to 5.0%** which is similar to a leguminous cover crop. Cereal cover crops can have >2.5% N prior to the boot stage, but decline to below 2.0% upon entering the flowering stage.

**The lower the C:N ratio, the faster mineralization and the more N becomes available for plant uptake.** Vegetable crop residues typically have a C:N ratio below 15:1 which allows for rapid N mineralization to begin immediately following incorporation into moist soil. Residues with a C:N ratio from 15 to 20, as is common in cover crops, N mineralization will proceed more slowly. Residue with C:N ratios >20 may temporarily immobilize, "tie up", N (Figure 5). Figure 5 shows the results of an incubation with incorporated high-N, medium-N and low-N residues at optimum moisture.

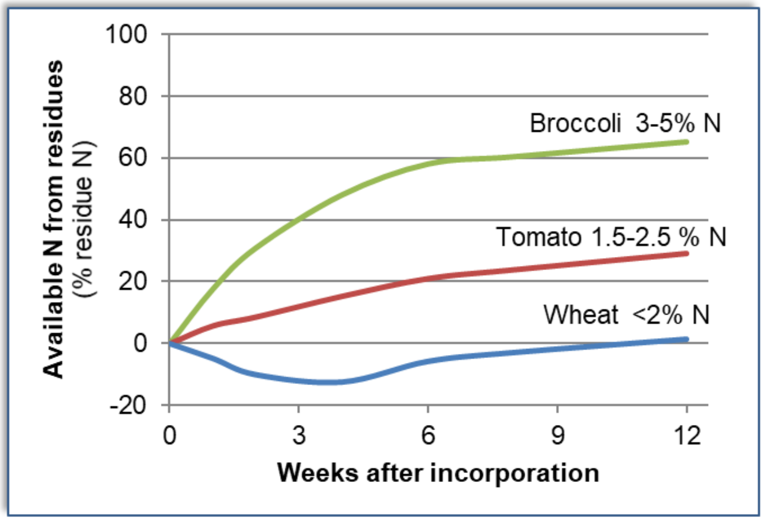


***Figure 5:*** *Examples of N release timing from high, medium, and low-N residues (Hartz, 2016). The C:N ratios average about 10:1, 20:1, and >20:1, respectively.*

**The majority of crop residue is mineralized in the first 2-4 weeks following incorporation into moist soil.** Because of this timing, nitrate made available from the mineralization processes is susceptible to loss via rain or irrigation, volatilization or denitrification during establishment of the subsequent crop. Leaching of residual soil nitrate not yet needed by a crop is one of the reasons that nitrogen budgets for first spring crops are best made using soil testing to determine what N remains at planting and/or before a rapid growth phase (see section F1).

In general the more mature a crop is (e.g. producing fruit or grain), the lower the N in the residue and the higher the C:N ratio.

**Surface-applied residues decay more slowly than incorporated residues,** since residue decomposition is a microbial process requiring contact with microbes and moisture. In addition, surface-applied residues are more vulnerable to N loss via volatilization to the atmosphere.

### C2. Available N from Cover Crops

The following aspects influence the amount of N from cover crops for subsequent vegetable crop growth.

- Biomass of cover crop
- N content of cover crop, which is higher in legumes and in younger material
- C:N ratio, which increases as material ages, lowering plant available N
- Cover crop incorporation, with those left on the surface mineralizing less N than those incorporated

**The vast majority of N in cover crop biomass is found in the above-ground plant biomass**, r**egardless of whether the N came from residual nitrate in the soil or atmospheric N fixed by bacteria in legume roots.** Often cover crop mixes include both grasses and legumes. Grasses have deep, efficient root systems and scavenge residual N from the soil profile. Legumes form a symbiotic relationship with bacteria in the soil and fix atmospheric N for their own metabolic use. This ability to extract atmospheric N means that legumes provide a net input of N to the soil when incorporated, and also typically have higher N content in their tissues. Biomass production and N content of cover crops species commonly used in vegetable production are given in Table 4.

| Cover Crop | Crop Biomass (dry) (T/A) | Tissue N Content (%) | Total N in Crop Biomass (lb/A) | Estimated N availability for next crop at 4-45% release (lb/A) |
|---|---|---|---|---|
| 'Cayuse' Oats | 4 | 1.7 | 136 | 5-61 |
| 'Merced' Rye | 3.6 | 1.9 | 137 | 5-62 |
| Mustard[1] | 3 | 2.6 | 156 | 6-70 |
| Bell Bean | 3 | 2.7 | 162 | 6-73 |
| Cereal/Legume Mix[2] | 3 | 2.9 | 174 | 7-78 |
| 'Magnus' Pea | 2 | 3.6 | 144 | 6-65 |
| Purple Vetch | 2 | 3.7 | 148 | 6-67 |
| 'Lana' Woollypod Vetch | 2 | 4.7 | 188 | 8-85 |

1 –50:50 mix of *Sinapis alba* and *Brassica Juncea;* 2 – Oats, bell beans, peas and vetch

***Table 4****: Measurements of cover crop biomass production and nitrogen content in the above-ground biomass (Central Coast of California). Measurements were taken 'at maturity' typically in March. Data represents a summary of 5+ years of cover crop field evaluations. The amount of cover crop N that is made available for vegetable crop growth varies widely, and estimates vary from 4-35% (Jackson, 2001). (Brennan et al., 2012a and 2012b; Smith, 2012).*

**Generally, cover crop age and N content drive N availability: the younger the crop and higher the N content of that species, the higher the N availability following incorporation.** Legumes and mustards have higher N contents in their tissue (e.g. >2%) that allows for more rapid N mineralization. The N content of cereals can be >2% when they are juvenile (e.g. prior to flowering), but significantly declines as they mature. As a result, the amount of N that is mineralized from cereal cover crop biomass can be less than legumes. For most crops, peak total N content occurs at peak flower, when the biomass is high and N remains in the tissue prior to being used for seed production.

Cover crop mixes with a higher proportion of legumes, particularly when terminated before flowering will release more of their N than later terminated cover crops and grass-heavy mixes.

Oregon State University has developed a calculator for estimating cover crop N contributions, available online at: https://extension.oregonstate.edu/organic-fertilizer-cover-crop-calculators. The calculator requires sampling small representative areas, recording the total fresh weight, and sending in a subsample to a lab for analysis. Since the calculator uses location-specific climate and moisture conditions, value should only be taken as broad estimates.

**The amount of cover crop N that is made available for vegetable crop growth varies widely, and estimates vary from 4-35% (Jackson, 2001).** Unmineralized N from cover crops contributes to the total N in the soil organic matter and long-term soil fertility.

**Soil testing for residual nitrate will measure N from cover crop mineralization and might be a tool to understand the contribution of N from cover crops.** Refer to Part 4 for more guidance on soil testing.

### D. Irrigation Water

#### 1. Sampling water for testing

**Where nitrate leaching has led to elevated nitrogen in well/groundwater, a considerable amount of $NO_3$ may be applied to the crop in irrigation water.** This can be seen in Figure 6, derived from field trials with drip-irrigated lettuce in Salinas, showing the relationship between N concentration in the irrigation water and available N, at irrigation rates ranging from 4-10 acre inches (Smith et al., unpublished data from 2016). Data points represent different fields. Be sure to include the nitrate from irrigation water in your budget. Also, keep in mind that the time of irrigation will be the time of that nitrate application, and how this corresponds to crop demand and release of N from other sources.

More information on the fertilizer value of irrigation water $NO_3$ can be found here: http://calag.ucanr.edu/archive/?type=pdf&article=ca.2017a0010

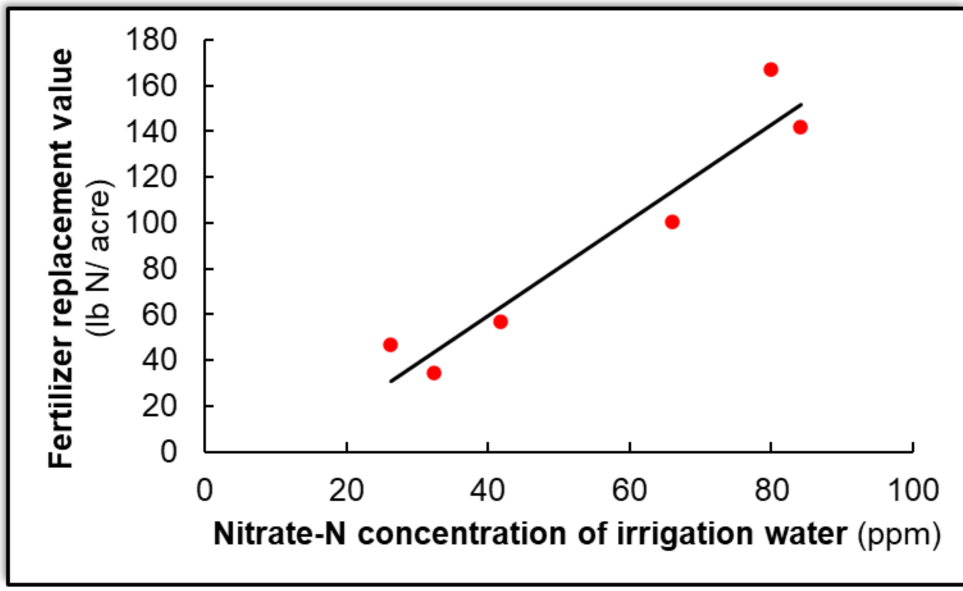


**Figure 6**. The relationship between nitrate-N concentration in irrigation water and its contribution to N

# PART 3. N SUPPLY: SEASONAL INPUTS

### E. Available N from Organic Amendments

Composts, manures, and granular and liquid organic fertilizers are all applied to supplement soil N. The N availability from these materials differs widely. Figure 7 shows how quickly N became available from different amendment types when they were mixed with organically-managed field soil and incubated for 84 days in warm and moist soil (73°F and 60% water holding capacity). A negative value indicates N immobilization. In other words, N is “tied up” so it is plant unavailable. Actual N release rates in the field will depend on soil moisture and temperature but will follow a similar pattern.

| Material | Typical %N | Typical C:N ratio | N available after 12 weeks | Releases in: |
|---|---|---|---|---|
| Municipal yard trimmings composts | 0.5 - 2 | 13 - 20 | -3% - 4% | Years |
| Poultry manure composts | 2 - 5 | 6 - 8 | 30 - 35% | Weeks-months |
| Granular fertilizers (except guano) | 2 - 7 | 5 - 7 | 38 - 60% | Days-weeks |
| Blood & feather meal | 13 - 15 | 3 - 4 | 65 - 70% | Days |
| Liquid fertilizers | 2 - 4* | 4 - 6 | 50-100% | Days |
| Guano | 12 - 13 | 3 - 4 | 80-90% | Days |

***Table 5:*** *Potential N availability from different types of organic amendments under warm, moist conditions. Negative numbers mean the compost tied up soil N (Lazicki et al., 2020). All %N numbers for solid amendments are on a dry weight basis. *Liquid %N is reported on a fresh weight basis, and so isn’t a good indicator of the release rate (see Figure 7).*

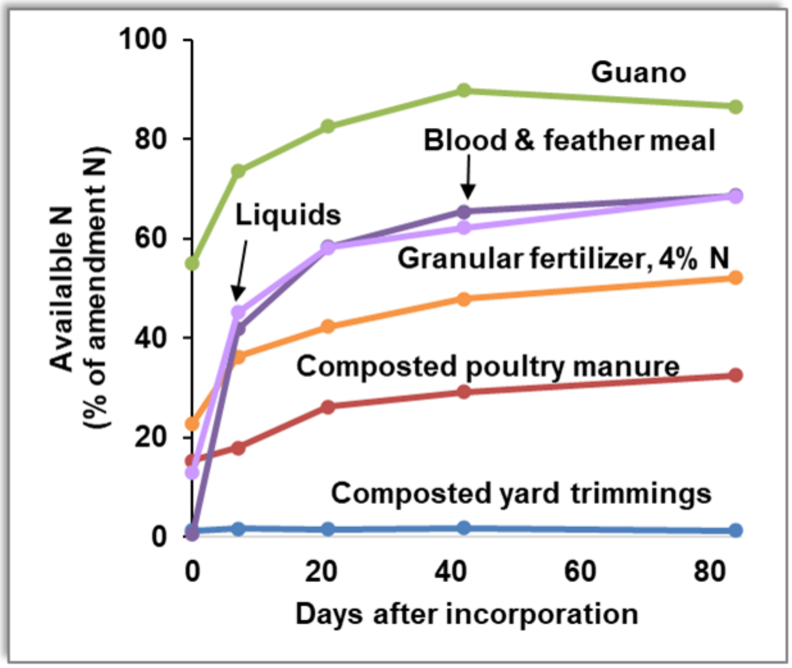


***Figure 7:*** *Predicted N release curves from different amendment types under warm, moist conditions (Lazicki et al., 2020).*

**The carbon to nitrogen (C:N) ratio of an amendment is a good predictor of how quickly its N is released** (Figure 8). The lower the C:N ratio in the material, the more quickly N will be released. As the C:N ratio exceeds 15:1, available soil N moves closer to 0 due to temporarily "tying up" N and should not be applied too close to planting.

> The C:N ratio of an amendment is a good predictor of how quickly its N is released (Figure 8). The lower the ratio, the more quickly N will be released.

- Low C:N ratio materials like guano, feather meal and fish emulsion released much of their N in the first week, and almost all their N within three weeks. This quality makes them good sidedress materials or to remediate known N-deficiency.
- Poultry manure composts and granular fertilizers contributed some available N as soon as they are applied, but released their N more slowly. When applied in/near moisture under warm conditions, they will release more quickly, though still over weeks, not days.
- High C:N materials like plant-based, yard trimmings composts released almost no N. They provide C which supports microbial communities and over time improves soil physical structure, but provide little N for the current crop. Long term soil fertility may be improved.
- When C:N ratio is unavailable, the total N concentration is closely related to availability. Generally, as total N increases, availability of N increases, forming a similar curve to Figure 8.

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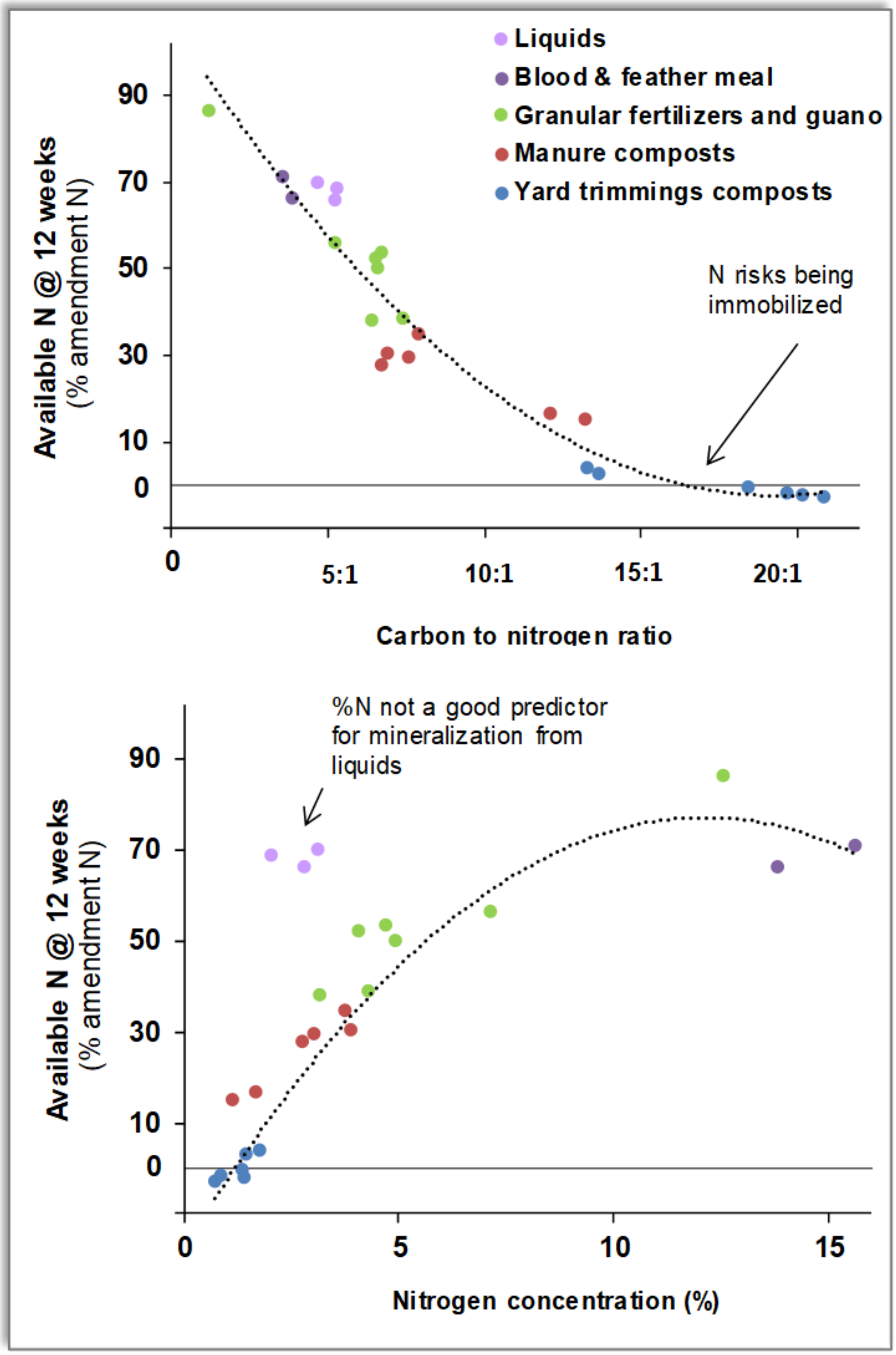



***Figure 8**: Relationship between potentially available N and amendment carbon to nitrogen ratio (Lazicki et al., 2020).*

**Plant-based liquid fertilizers ranged from 48% to 92% N availability whereas manure-based liquid fertilizers (typically fish) ranged from 83% to 99% N availability after 4 weeks (Hartz et al., 2010; Lazicki et al., 2020)**.Organic liquid fertilizers are suspensions and often includes particulate matter with which 8-21% of total N content is associated. Without proper filtration these materials increase the risk of clogging drip emitters. If they are injected before the filter, a significant amount of the N can be removed from the suspension (Hartz et al., 2010). Regular backflushing may be required to maintain system flow. New technology in liquid organic fertilizer is now providing materials in which N is thoroughly dissolved and does not have the issues just discussed. Coupled with the high cost of unit N in a liquid product, liquid fertilizers are often viewed as an easy way to supplement in-season fertility, but too expensive to provide the bulk of the crop's N demand.

**In all cases, amendment N release is slower in cool weather or dry conditions as microbial activity is decreased.** Crops planted in cold temperatures may benefit from starter fertilizers that contain some available N initially—those with a higher amount at day 0 and a steep initial curve (Figure 7). For example, manure-based composts have roughly 15% of their total N available at initial application, whereas granular fertilizers started with an average of about 22% (Figure 7).

# PART 4. SOIL AND TISSUE TESTING FOR VERIFICATION AND MONITORING

> Nitrogen is a very dynamic nutrient. It's constantly being released from organic forms, taken up by plants and soil organisms, leached downwards in water or volatilized into the atmosphere. Appropriate soil sampling method and timing is critical for N budgeting.

The objective of soil nitrate-N sampling is to capture the amount of soil N that will be available for crop uptake in the current season. Nitrogen is a very dynamic nutrient. It's constantly being released from organic forms, taken up by plants and soil organisms, leached downwards in water or volatilized into the atmosphere. Therefore, the results from a soil nitrate test are only relevant for that moment in time. A fall soil nitrate test will <u>not</u> show how much N will be available for plant uptake the following spring. Soil tests can be sent to a lab for analyses for $25-$50 per sample, or conducted in the field using nitrate test strips, which provide an estimate for roughly $1 per sample.

### F. Ways to use a soil test:

**Testing can verify that applied amendments are releasing N at the anticipated rate.** Because many organic fertilizers require microbial activity to mineralize and release N in plant available forms, there is a lag in the time between application and availability. As discussed above, we can make rough estimates of the amount of N that will become available from mineralization of SOM, crop residue, compost and soil amendments. And we can consider the factors that influence the rate of mineralization, namely soil moisture, soil temperature, C:N ratio, and total N%. However, for more refined management objectives, soil nitrate tests offer a snapshot of what is currently available to support plant growth by measuring plant available N in the rootzone. For example, Figure 9 shows modeled N available from the top foot of soil and 2 tons/acre of poultry manure compost for a tomato crop in Yolo County. The soil test in mid-June measured 20 ppm $NO_3$-N which is equivalent to approximately 75 lb/acre of available N in the top 12" of soil. Figure 9 can help you anticipate N availability during the growth period of a crop.

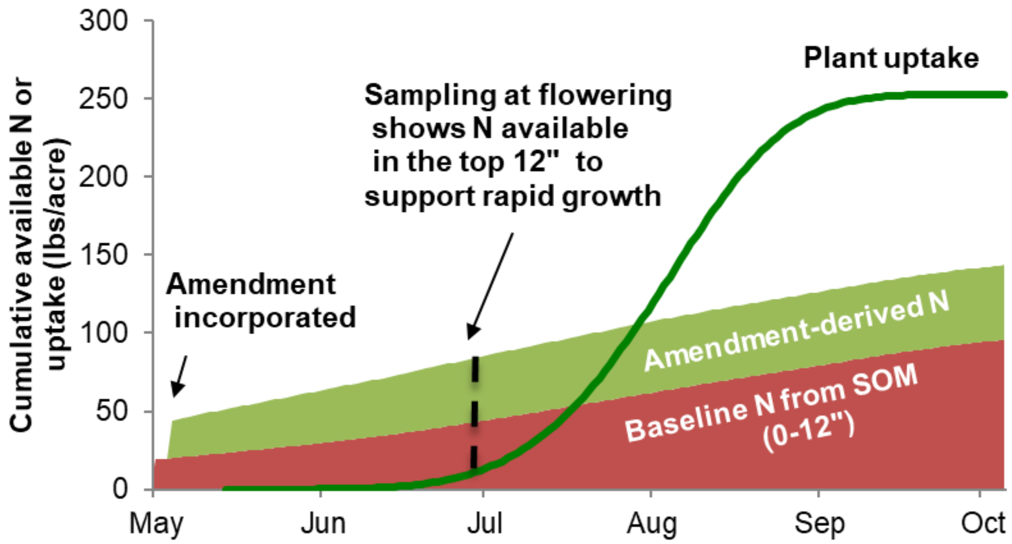



***Figure 9:*** *Example of how an early season soil nitrate test can be used to assess the N available for rapid growth*

1. **Testing can provide a guide to how much fertilizer is needed for the crop assuming irrigation does not leach it before crop uptake occurs**. When taken prior to a fertilization event, results will indicate if there is sufficient residual soil nitrate to provide for the crop or if additional fertilizer is needed to achieve desired crop yield. Soil amendments and soil organic matter continue to release N over the season and can provide for the N needs of the crop (Figure 9). Residual soil nitrates provide for the needs of the crop during the rapid uptake phase of the crop cycle.

**When to Sample:**

**Sampling for soil nitrate-N is intended to capture what is available for crop uptake in season**. The sample timing will vary depending on the crop. Here are example scenarios of the use of preplant and pre-sidedress soil tests to help make decisions on whether additional fertilizer is needed.

For processing tomatoes, a soil nitrate test early in the crop cycle can indicate whether an in-season sidedress as late as 5-6 weeks after transplanting may increase fruit yield (Bottoms et al., 2012). A yield response of furrow-irrigated tomatoes was unlikely when the pre-sidedress nitrate-N concentration in the top 2 feet of the profile was above 16 ppm (Bustamente and Hartz, 2015; Krusekopf et al., 2002).

For a 50-65 day lettuce crop, a soil sample can be taken following establishing the crop. A test value of 20-25 ppm $NO_3$-N or above indicates that there is adequate residual soil nitrate to provide the crop needs for a period of 10-14 days (Breschini and Hartz, 2002).

Fast growing 30-day crops such as spinach require that soil tests be taken prior to planting. There is not sufficient time in the crop cycle to test later given the lag time in the release of N from organic fertilizer and the rapid growth rate of the crop. Testing soil N immediately prior to planting ensures that residual N is credited in the N application budget, and that the crop is optimally fertilized.

2. **Post-season soil tests can also be taken just after harvest to measure how much N was left over from the crop.** High postharvest $NO_3$ in the top foot of soil, may indicate overfertilization or poorly timed

application of organic sources releasing N too late in the crop production cycle. High postharvest $NO_3$ contents below the top foot or two may indicate excess irrigation, moving nitrate below the root zone. Records of soil samples taken over time can be used to fine-tune N management.

3. **Soil tests can be useful in comparing or tracking performance of fields, fertilizers, and practices and serves as a general feedback tool to your farming decisions and history.** Keeping a log will support this ability to monitor over time.

**Where to sample:**

Most vegetable crops have the majority of their root systems in the top foot (12") of soil, which is also where cover crop residues and amendments are generally placed. Therefore, soil samples are normally taken from the top foot. However, some deep-rooted crops such as broccoli and tomato can obtain a significant proportion of N from deeper depths. For these crops, the accuracy is improved by deeper sampling. Each foot should be sampled separately. When N is sampled at multiple depths, these results should be added together to present a single total amount of N available.

For postharvest tests, sampling as deeply as three feet (if possible) is informative, as a low available N in the top foot may be a result of efficient N management or of excess irrigation causing N to leach below the crop rooting zone.

If sampling in beds where amendments have been banded, the bands should be avoided and more samples should be taken to account for the possibility of hitting a band.

Proper soil sampling procedure and handling is very important to capturing the information desired. Please refer to the following resources for detailed description of how to collect a high quality soil sample.

- Taking and interpreting soil tests: http://calag.ucanr.edu/Archive/?article=ca.2016a0027
- Guidelines on soil sampling: http://geisseler.ucdavis.edu/Guidelines/Soil_Sampling_Nitrate.pdf
- How to use and interpret the nitrate quick test:
  https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=4406
  http://smallgrains.ucanr.edu/Nutrient_Management/snqt/

**Interpreting the soil test report**

**Nitrate, $NO_3$-N, is the nitrogen form used for N budgeting**. The two major forms of N which are available for plant uptake are ammonium ($NH_4^+$) and nitrate ($NO_3^-$). Under normal growing conditions, $NH_4^+$ is quickly converted to $NO_3^-$, so that almost all the plant available N will be in the form of $NO_3$-N.

**Labs normally report values as concentration, or parts per million (ppm), which is the same value as mg/kg**. The amount in lb/acre can be calculated by multiplying this number by a factor of 3-4 for every foot of soil, depending on the soil bulk density, with low values for very high organic matter or very heavy clay soils and higher values for more compacted or very sandy soils. A commonly used factor for the top 12" of agricultural soils is 3.6 assuming a soil bulk density of 1.35 $Mg/m^3$.

**Some labs report the concentration of $NO_3^-$ rather than $NO_3$-N.** When reporting in $NO_3^-$, this includes the weight of the oxygens as well as the N. Use the worksheet to convert $NO_3^-$ to $NO_3^-$-N.

**G. Ways to use a tissue test:**

**Tissue testing provides information on the current nitrogen status of the plant, but does not indicate future availability of the nutrient, as is provided by a soil test.** Typically, they are used to monitor N levels in a crop to check for sufficiency prior to or during rapid growth, or to determine deficiency based on symptoms. Tissue type used for sampling varies by crop, as do % N levels and timing. Refer to Table 5 for crop-specific guidance.

**Table 6**. Plant tissue sampling guidance for sampling method and result interpretation.

| Crop | Growth stage | Plant part to sample | Number of plants to sample | Sufficient leaf N (%) |
|---|---|---|---|---|
| **Vegetables** | | | | |
| Broccoli | First buds to heading | Recently matured leaf, typically 3-4 nodes down from the growing point | 20-60 | 3.0 - 5.0 |
| Carrot | Midgrowth (>4 inches high) | Most recently matured leaf or petiole | 20-30 | 2.1 - 3.5 |
| Cauliflower | Head initiation | Recently matured leaf, typically 3-4 nodes down from the growing point | 20 | 3.0 |
| | Preharvest | Recently matured leaf, typically 3-4 nodes down from the growing point | 20 | 3.0 |
| Celery | Mid-growth | Most recently matured leaf or petiole | 20 | 2.5 |
| | Preharvest | Most recently matured leaf or petiole | 20 | 2.0 |
| Melon | Early flower | Most recently matured leaf or petiole, typically 6th from the growing tip | 20-30 | 2.7 - 4 |
| | Early fruit set/bulking | Most recently matured leaf or petiole, typically 6th from the growing tip | 20-30 | 2.3 - 3.5 |
| | First harvest | Most recently matured leaf or petiole, typically 6th from the growing tip | 20-30 | 2.0 - 3.0 |
| Onion | Early season | Tallest leaf | 20-30 | 3.0 |
| | Midseason | Tallest leaf | 20-30 | 2.5 |
| | Late season | Tallest leaf | 20-30 | 2.0 |
| Lettuce | Early heading to pre-harvest | Youngest wrapper leaf | 20-60 | 4.3 - 5.6 |
| **Berries** | | | | |
| Strawberry | Preharvest | Young mature leaves | 30-40 | 3.1 - 3.8 |
| | Main harvest | Young mature leaves | 30-40 | 2.4 - 3.0 |

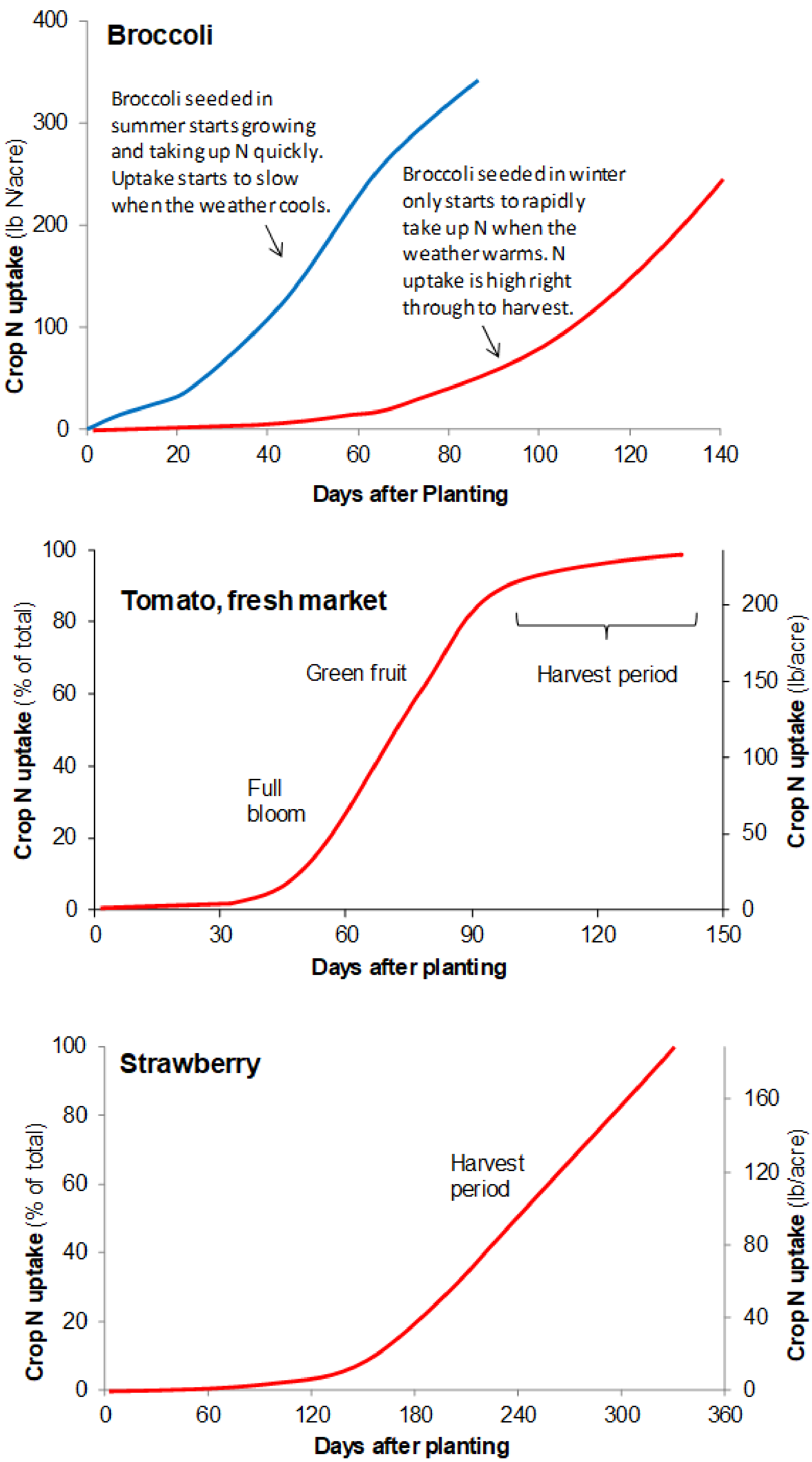
References: Broccoli, Cauliflower, Celery: Hartz, 2007; Jones, 1998. Carrot: CPHA, Jones, 1998. Melon: CPHA, Lorenz and Tyler, 1976. Onion: Maynard and Hochmuth, 2007. Lettuce: Hartz et al., 2007; Jones, 1998. Potato: Voss, 2004. Strawberries: Hartz, 2012; Ullrich et al., 1992. Tomato: Hartz, 1998.

# PART 5. TIMING N WITH CROP DEMAND

To optimize N-use efficiency it is essential to synchronize N application with periods of plant N demand.

- N uptake by crops producing fruits or seeds often follows an “S” shape, as shown for tomato in Figure 10. Uptake is slow during crop establishment, followed by rapid uptake as the crop growth accelerates, and then slows or stops late in the season when seed or fruits ripen.

- For crops where the leaves, stems or flowers are harvested during vegetative growth (broccoli, lettuce, celery), N uptake is normally rapid until harvest. This has implications for management of residual N, as crops that require high levels of N in the soil right up to harvest may be more challenging to manage in a way that minimizes residual N vulnerable to post-season leaching. Post-harvest soil testing can be an important check for residual N levels to determine whether post-harvest N management steps are needed to minimize N leaching to the environment.




Temperature matters: Crops planted in warm weather and from transplants start the rapid N uptake stage earlier than crops planted in cool weather or from seeds.

For most crops where a mature fruit or grain is harvested, such as tomato, N uptake slows during the harvest period.

Strawberries steadily take up N during harvest, unlike most crops where a mature fruit or grain is harvested.

***Figure 10:*** *Example of crop N uptake curves of different crop growth patterns. See extended captions for more details. See extended captions for more details.*

## CONCLUSION

Nitrogen availability on an organic farm is influenced by many factors, including those of farmer's work such as cropping choices, amendment applications, tillage, and those of the land such as soil type, water quality, rainfall and temperature. Consequently, it can be very challenging to achieve a real balance between N inputs and N outputs solely relying on the worksheet approach. This is largely because the amount of N mineralized from soil organic matter is likely to be highly variable among fields and cropping histories, and it can contribute a very wide range of available N. For this reason, coupling a worksheet approach with soil sampling during the growing season to determine whether nitrate in the root zone is deficient, adequate or excessive is essential.

Successfully predicting N availability from multiple, diverse sources on an organic farm is a learning process. Data like that presented in this article, repeated on-farm soil and tissue testing, N budget number crunching, record keeping, and field observations build on your ability to synthesize and refine your understanding of N mineralization in a given scenario. With dedication and time, you will hone your ability to understand and predict N release on your farm to optimize crop productivity and minimize environmental pollution.

# RESOURCES

| Resource | Description | Location |
|---|---|---|
| Soil fertility management for organic crops (UCANR publication 7249) | University of California extension guide to using organic soil fertility sources. | https://anrcatalog.ucanr.edu/pdf/7249.pdf |
| California Fertilization Guidelines: N uptake and partitioning | Estimates total N uptake amount and timing for major California Crops (annual and perennial) | http://geisseler.ucdavis.edu/Guidelines/N_Uptake.html |
| Nitrogen calculator for Central Valley Crops | Estimates total N uptake amount and timing for minor Central Valley crops (annual only) | http://geisseler.ucdavis.edu/Guidelines/N_Calculator.html |
| California Fertilization Guidelines | Estimates of N, P, and K requirements for major California crops (annual and perennial) | http://geisseler.ucdavis.edu/Guidelines/Home.html |
| Nutrient management resource links | Collection of links to a variety of tools and informational resources related to nutrient management | http://geisseler.ucdavis.edu/Guidelines/Resources_Topic.html |
| Nitrogen concentrations in harvested plant parts - A literature overview | Estimates of N removal for major California crops, gives expected ranges | http://geisseler.ucdavis.edu/Guidelines/Geisseler_Report_2016_12_02.pdf |
| NRCS nutrient removal calculator | Estimates N,P and K removal for a wide variety of temperate and tropical crops | https://plants.usda.gov/npk/main |
| UC SAREP Cover Crop Database | Contains extensive info on more than 40 different cover crop species | https://asi.ucdavis.edu/programs/ucsarep/research-initiatives/are/nutrient-mgmt/cover-crops |
| Oregon State University—organic fertilizer and cover crop calculator | Provides info about cover crops and organic fertilizers, including a free calculator to compare nutrient values and costs. | https://extension.oregonstate.edu/organic-fertilizer-cover-crop-calculators |

| | | |
|---|---|---|
| SARE Cover Crop Topic Room | Organized collection of educational materials developed out of decades of cover crop research | https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops |
| "Managing Cover Crops Profitably" (Free ebook) | Explores how and why cover crops work and provides all the information needed to build cover crops into any farming operation. | https://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition |

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**Extended captions.**

Figure 1. Citation Geisseler, Lloyd, and Lazicki (unpublished). Field studies occurred in the Sacramento Valley in a silt loam soil, with an average organic matter. Cover crop was an oat legume mix with 3% N that averaged approximately 3 T/A biomass that was incorporated 1 month before planting. Granular fertilizer was applied at 700 lb/acre. Irrigation water total estimated 3.6 acre-feet with a concentration of 1 ppm $NO_3$-N.

Figure 3. These values are modeled based daily average soil temperature data for each region from 2014-2019, using parameters derived by Miller and Geisseler (2018) and an assumed N release of 2% of the soil's total organic N annually (Meisinger et al., 2008).

Figure 10. Broccoli data from a conventional field in the Salinas Valley. Yields were 28,000 and 22,000 lb/acre for summer and winter-seeded broccoli, respectively[19]. Tomato data from a fresh-market organic heirloom trial in Yolo County. Total yield was 62,000 lb/acre[18], with unpublished data. Strawberry from conventional fields in the Salinas and Pajaro valleys Yield was 72,000 lb/acre[2].

Nitrogen uptake curves for additional crops can be found here: http://geisseler.ucdavis.edu/Guidelines/N_Uptake.html

Table 2. Data were modeled using 5-year average soil temperatures for each region as described in

Figure 3. NOTE: These values represent modeled potential N availability, based on several assumptions. Actual available N will be affected by soil moisture, leaching, the quality of the organic matter, and other factors. At this point, these numbers are not yet backed by University of California research. The best way to determine the actual soil mineral N available at a given time is with a soil test.

# SECTION 2. PREPARING INFORMATION FOR THE NITROGEN WORKSHEET

In preparation to completing a nitrogen budget, some information can be collected in advance. By having this information handy, you will be able to move much more quickly through the worksheet.

Supporting documents

- Nutrient analysis from the compost supplier
- Fertilizer label(s)
- Most recent or relevant soil test results
- Most recent or relevant water test results

Background information

- Field size or area for which the budget is being developed
- Bed length and width
- Volume of application tools, ex wheel barrow, compost spreader, buckets, etc.

## PART 1. CROP N DEMAND

### A. ABOUT THE CROP FOR WHICH YOU'RE MAKING THIS BUDGET

**1.** __________ Lb N/Acre

**1. Total crop N uptake (average value or range) provided by a reliable source (e.g. Table 1).** Visit the resources to find guidance on N uptake levels for various crops.

**2.** __________ Tons/Acre

**2. Yield associated with the above N value** (**Table 1**)

**3.** __________ Tons/Acre

**3. Your predicted yield** (2000 lb = 1 Ton)

### C. COVER CROPS AND CROP RESIDUES (Tables 3-4)

**C1. Crop Residue**

**7.** __________ Tons/Acre

**7. Previous crop yield**

**Or**

**C2. Cover crops**

**11.** __________ Lb/Acre **11. Estimate legume biomass dry weight**

**12.** __________ % **12. Percent N in cover crop**

**D. IRRIGATION WATER**

**D1. Interpreting water tests**

__________ ________________ **Water test result [Test date: _____________ ]**

**Result** **Unit (ppm or mg/L, other)**

# PART 3. N SUPPLY: SEASONAL INPUTS

**E. AVAILABLE N FROM ORGANIC AMENDMENTS**

**E1. Compost**

______________**Product name**

**16.** __________ C:N ratio **16. Identify the C:N ratio of the compost** (inquire with compost supplier)

**17.** _________ % water **17. Identify the amount of water in the compost** (inquire with compost supplier)

**18.** __________ % N **18. Total N in compost** (inquire with compost supplier)

**E2. Granular Fertilizer**

______________**Product name**

**23.** _________ % N **23. Total N in product** (ex. 5-8-0 is 5% N)

**25.** _________ Lb/Acre **25. Application rate**

**E3. Liquid Fertilizer**

______________**Product name**

**28.** _________ Lb/Gal **28. Fertilizer weight** (Water is 8 Lb/Gal; many liquid fertilizers are slightly more)

**29.** _________ % N **29. Percent of N in product (3-2-2= 3% N)**

**30.** _________ Gal/Acre **30. Application rate**

## PART 4. SOIL AND TISSUE TESTING FOR VERIFICATION AND MONITORING

### F1. INTERPRETING SOIL TESTS

__________ ________________ **Soil test result [Test date: _____________ ]**

**Result** **Unit (ppm or mg/L, other)**

## SECTION 3. THE WORKSHEET

# ESTIMATING NITROGEN (N) FOR ORGANIC VEGETABLE PRODUCTION WORKSHEET

**Companion to: ESTIMATING NITROGEN AVAILABILITY IN ORGANIC VEGETABLE PRODUCTION: For N budgeting and other purposes**

This worksheet is intended to be used with the companion "Estimating Nitrogen for Organic Vegetable Production: For N budgeting and other purposes". The figure and table references can be found in section 1. This can be useful for developing a complete N budget, or for estimating and understanding plant availability of N from individual organic N sources, such as compost or cover crops.

Completing each section of this worksheet offers detailed insight into N management, offering opportunity to maximize the value of added N, and minimize the risk of over/under application. Some of the information calculated will be useful to inform other crop budgets or cropping seasons that follow similar practices or use the same products. The intent is to allow the user to best understand how applied N, in the form of amendments, irrigation water, crop residues or cover crop residue will be available to optimize crop production. As discussed in the flier that accompanies this worksheet, N in soil may change rapidly as the result of rainfall or irrigation, and predicted N release from organic materials is highly dependent upon microbial processes, which are in turn dependent upon weather, contact with soil, and other factors. Verification of predicted available N is highly recommended, using soil nitrate test strips, soil lab analyses or tissue analyses.

This worksheet focuses on plant available nitrogen from organic sources, but does not discuss the timing of the crop N demand in great detail. Understanding the timing of crop demand with the timing of plant available N is important when making fertilization decisions. Figure 10 provides a few examples of N uptake curves over time and more can be found at: http://geisseler.ucdavis.edu/Guidelines/Home.html

**This crop-based budget worksheet is for_______________**

**crop**

## PART 1. CROP N DEMAND

**A. Crop N Uptake: How much N does your crop need?** Select 1 method below to identify the N uptake demand.

**Method 1. Use N uptake suggested by a reliable source**

**1.** __________ lb N/A **1. Total crop N uptake (average value or range) provided by a reliable source (e.g. Table 1)**

5.

**Method 2. Use N uptake suggested by a reliable source and adjust based on your yield goal.**

**1.** __________ lb N/A **1. Total crop N uptake (average value or range) provided by a reliable source (e.g. Table 1)**

**2.** __________ Ton/A **2. Yield associated with the above N value** (**Table 1**)

**3.** __________ Ton/A **3. Your predicted yield** (Ton/A; 1 Ton = 2000 lb)

Then, (_______Ton/A /_______ Ton/A) x _________ lb N/A = [ ] lb N/A

3. 2. 1. 5.

**Method 3. Use your predicted yield and estimated lb N needed per ton yield**

**3.** __________ Ton/A **3. Your predicted yield** (Ton/A; 1 Ton = 2000 lb)

**4.** __________ lb N/Ton yield **4.Crop N uptake per ton of yield** (**Table 1**)

Then, __________ Ton/A x ____________lb N/T = [ ] lb N/A

3. 4. 5.

5. [ ] lb N/A **5. Total crop N uptake. Insert result from box 5. based on method used above.**

## PART 2. N SUPPLY: BASELINE

### B. Available N from Soil Organic Matter (SOM)

Estimating your SOM release is based on both the percent SOM and the history of cover cropping, compost amendments and N management. For soils with a long history of building soil organic matter through activities such as compost and cover cropping, estimate a higher N release and for those with a shorter history of soil building, estimate N release on the lower end. Similarly, higher rates of compost application and crop residue will increase SOM accumulation, whereas tillage reduces SOM. In addition, warm season production should have higher numbers than cool season production.

[ ] lb N/A **6. Estimated N from SOM** Reference Figure 4 and Table 2. A typical release rate will likely be from 50-120 lb N/acre/year in the top 1' of soil, based on roughly 2% of the total soil N becoming available.

### C. Available N from crop residue: cover crops and post-harvest residue

If a cover crop or commercial crop is incorporated no more than 6 weeks prior to planting the crop intended for this budget, the N from these residues should be accounted for. Choose from either the cover crop or crop residue options.

**C1. Available N from Previous Crop**

_______________ **Specify previous crop**

_________C:N ratio of previous crop residue at time of incorporation.

**7.** __________ Ton/A **7. Previous crop yield**

**8.** _________ lb N/Ton **8. N in crop residue (**Table 3.)

**9.** __________lb N/A **9. Estimated N in crop residue**

The amount of N expected to be in the residues can be adjusted for the actual expected yield by multiplying the actual yield by the value for lb N/ton yield.

__________ Ton/A x __________ lb N/Ton = __________ lb N/A

7. 8. 9

**10.** [ ] **lb N/A** **10. Total N from previous crop available this season**

Use a lower % N available when material is left on the surface and not incorporated, or when the soil is drier. C:N ratio is an excellent predictor of N availability. A C:N ratio greater than 20:1 will generally not release nitrogen, but rather be used to degrade the carbon, whereas 10:1 will provide intermediate rates of release.

__________ lb N/A x __________% / 100 = __________ lb N/A

9 4-45% 10

**C2. Available N from cover crops**

The amount of N a cover crop contributes depends on several factors including the species, how thick the stand is, and at what stage it is terminated. The C:N ratio is the best predictor of nitrate release rates.

_______C:N ratio of cover crop residue

__________________ **Specify cover crop type**

**11.** __________ lb/A **11. Estimate legume biomass dry weight**

Use your own information of biomass dry weight, reference UC SAREP cover crop database or use the table provided in the flier. When referencing another source providing a range, consider your own scenario regarding crop density and crop height/maturity to select a number in the range. For example, if a crop is terminated earlier, at 50% of maturity, select a number on the lower end of the range. More dense and longer production times will likely fall on the higher end of the range.

**12.** __________ % **12. Percent N in cover crop**

Use your own information from a sample sent to a lab, utilize the table in the flier, reference UC SAREP cover crop database, or find other resources.

**13.** __________ lb N/A **13. Total N from cover crop** (Reference Table 4)

__________ lb/A x __________% /100 = __________ lb N/A

11 12. 13.

**14.** __________ lb N/A **14. Total N from cover crop available this season**

It's estimated that about 4-35% of cover crop N is directly available for the next crop. Use a lower % availability when material is left on the surface, not incorporated, or when the soil is drier. Use an intermediate % for legume-cereal mixes. Use a higher % when the cover crop is terminated at optimum growth (early flower) and a lower % for more mature crops. C:N ratio is an excellent predictor of N availability. A C:N ratio greater than 20:1 will generally not release N, but rather be used to breakdown carbon, whereas 10:1 will provide intermediate rates of release.

__________ lb N/A x __________% / 100 = __________ lb N/A

13. 4-35% 14.

**D. Irrigation Water**

**D1. Sampling water for testing**

To convert $NO_3$-N concentration in the water to lb N/acre inch, $NO_3$-N concentration reported in ppm is multiplied by 0.227 and by the number of acre-inches of water applied. For example, for 1 acre-inch of water containing 10 ppm nitrate-N: (10 ppm) x (1 acre-inch) x (0.227) = 2.27 lb N are applied per acre.

**15.** ________ lb N/A **15. N contribution from irrigation water based on water test result**

[Test, result: ___________date: _____________ ]

Estimate total water use _________ acre-inches x ____________lb N/acre inch = _________ lb N

Water use NO$_3$-N in water 15.

**Conversion Tool**

Convert ppm to lb N/acre inch __________ppm x 0.227 = ___________lb N/acre inch

NO$_3$-N NO$_3$-N

## PART 3. N SUPPLY: SEASONAL INPUTS

**E. Available N from Organic Amendments**

**E1. Compost**

Most compost companies will provide an analysis of the compost material which will include the total % N and C:N ratio.

______________**Product name**

**16.** __________ C:N ratio **16. Identify the C:N ratio of the compost**

**17.** _________ % water **17. Identify the amount of water in the compost**

**18.** __________ % N **18. Total N in compost (dry weight)** (Check the report to see if the total N is given in wet or dry weight basis. 'As is' or 'fresh weight' is typically equivalent to 'wet weight'.)

If your compost N is given in dry weight, adjust the amount of compost you applied 'as is' to dry weight:

**19.** __________ lb/A **19. Application rate in lb, wet weight ('as is' or 'fresh weight')**

(1 T = 2000 lb; 1 T = 2-2.5 cubic yards)

**20.** _________ lb/A **20. Application rate in lb, adjusted to dry weight**

__________ lb/A x (100-________%) / 100 = _________lb/A

19. 17. 20.

**21.** __________ lb N/A **21. Estimated total N from compost added to field**

__________% / 100 x __________ lb/A = _________ lb N/A

18 20. 21.

**22.** __________ lb N/A **22. Estimated available N from compost**

Composts are estimated to release -3 to 35% of total N in the first year (Fig. 7). Yard trimmings composts can initially tie up N whereas manure-based composts have more N available. Take a look at Figure 7 to see estimates of percent N release from composts, and Figure 8 to see the correlation between C:N ratio and available N. Place the C:N ratio of the compost used on the curve to estimate the N release percent.

__________ lb N/A x __________% / 100 = __________ lb N/A

21. -3 - 35% 22.

**E2. Granular fertilizers**

______________**Product name**

**23.** _________ % N **23. Total N in product** (ex. 5-8-0 is 5% N)

**24.** ________ lb N/lb **24. Pounds of N per pound of product**

__________% /100 = __________lb N/lb

23. 24.

**25.** _________ lb/A **25. Application rate** (1 T = 2000 lb; 1 T = 2-2.5 cubic yards)

**26.** _________ lb N/A **26. Total N applied**

__________lb N/lb x __________ lb/A = __________ lb N / A

24. 25. 26.

**27.** lb N/A **27. Total available N**

For crops grown with regular water in warm weather, granular fertilizers with a low C:N (ex. 6:1 or lower) are estimated to release 40-60% of total N in a season (See Fig. 7). Colder and/drier conditions will reduce the nitrogen release rate. Surface applied granular fertilizer releases a lower percentage of the total it contains. Granular fertilizer shanked into the soil releases a higher percent of the N it contains. Higher analysis fertilizers release a greater percentage of N than lower N (Hartz and Johnstone, 2006)

_________ lb N/A x __________% / 100 = __________ lb N/A

26. 40-60% 27.

**E3. Liquid fertilizers**

Liquid fertilizers are estimated to release 45-85% of total N in the season (Fig. 7).

_______________**Product name**

**28.** __________ lb/gal **28. Fertilizer density** Read product label to determine (Water is 8 lb/gal; Many products range from 9-10.5 lb/gal)

**29.** __________ % N **29. Percent of N in product** (ex. 3-2-2 = 3% N)

**30.** __________ gal/A **30. Application rate**

**31.** __________ lb N/A **31. Total N applied**

________ lb/Gal x ________% N x ________ gal/A / 100 = ___________ lb N/A

28. 29. 30. 31.

**32.** ______ lb N/A **32. Total available N**

_______ lb N/A x ___________% /100 = ________ lb N/A

31. 45-85% 32.

# PART 4. SOIL AND TISSUE TESTING FOR VERIFICATION AND MONITORING

**F1. Interpreting soil tests**

When using results from a soil test, consider the timing of the soil test. The results from a soil test can be used for a budget when it is taken before amendments are added and before crop residue (or cover crop) incorporation. However, if a soil test is taken after cover crop, crop residue and/or organic amendment applications are added, the soil test results will include some of the N made available from the recent activity. As such, the soil test should be fully counted towards the budget, but the crop residue and organic amendments can be reduced. Adjust accordingly. Similarly, if soil samples are more than several months old, consider what activities have occurred since then that could influence N levels (crop production, rain, amendment application, etc). To use a soil test to adjust the quantity of fertilizer applied to meet the crop needs, test for residual soil nitrate prior to a fertilization.

**33.** ______ lb N/A **33. Available N at time of soil test** [Test, result: ______date: ______ ]

**Conversion tool**

1 mg/kg = 1ppm

If soil test is in $NO_3$, convert to $NO_3$-N: __________ppm / 4.42 = ___________ppm

Result $NO_3$ — Result $NO_3$-N

If soil test is in ppm, convert: _______ppm x ____3.6__ ____ = _______lb N/A

$NO_3$-N — conversion factor for soil bulk — 14.

Labs normally report values as concentration, or "ppm". The amount in lb/acre can be calculated by multiplying this number by a factor of 3 to 4 for every 12" depth of soil, depending on the soil bulk density. Soils with very high organic matter and those with very heavy clay soils will be lower, while more compacted or very sandy soils will have higher values. A commonly used factor for the top 12" of agricultural soils is 3.6 assuming a soil bulk density of 1.35 g/cm$^3$. If a soil sample was taken to a depth of 12", use 3.6 as a conversion factor for soil bulk density. If a soil sample was taken to a depth of 6", use 1.8. For vegetables, 12" soil sampling depth is recommended for most crops in order to capture the soil where the majority of roots will grow.

* To determine the conversion factor using your soil bulk density information:

43560 ft$^2$ x 1 ft depth x 62.4 lb/ft$^3$ x ___________g/cm$^3$ = _________ /6 = ___________

Your soil bulk density. — Conversion factor for your soil bulk density

## THE BUDGET

| **PART 1. CROP N DEMAND** | lb N/ A |
|---|---|
| 5. Crop Demand | |

| **PART 2. N SUPPLY: BASELINE** | lb N/ A |
|---|---|
| 6. SOM contributions | |
| 10. Previous Crop or 14. Cover Crop | |
| 15. Irrigation Water | |
| ***TOTAL (6 + 10 or 14 + 15)*** | |
| | |
| **PART 3. N SUPPLY: SEASONAL INPUTS** | lb N/ A |
| 22. Compost | |
| 27. Granular fertilizer | |
| 32. Liquid fertilizer | |
| ***TOTAL (22 + 27 + 32)*** | |

| **Part 4. SOIL AND TISSUE TESTS** | |
|---|---|
| 33. Residual soil N (from a soil test)<br><br>Only include if soil analyses were taken prior to 'seasonal inputs' application OR reduce values for seasonal inputs | |

**AVAILABLE N GRAND TOTAL**

**Part 2 + Part 3 + Part 4 Total**

N balance ____________________ - ______________________ = ____________ lb N/Ac

Available N grand total Crop demand lb-N/ac N balance

If the N balance is positive, it suggests that the crop is likely to have enough N supply, assuming zero loss of N during the growing season. However, the larger the positive number, the more chance to lose N to the environment since crops will have a limit on N demand and irrigation will be occurring. Taking a soil sample after harvest to a depth of 2-3 feet and analyzing it for residual nitrate will allow you to determine how much N was left over and may be at risk of being leached with winter rains, unless a cover crop which can take up this N is grown during the winter.

If the N balance is negative, it suggests N supply is not adequate to meet the crop demand. Consider increasing the N supply by adding more fertilizers and re-calculate the N balance until a positive number is reached.

That being said, it can be very challenging to achieve a real balance between N inputs and N outputs solely relying on the worksheet approach. This is largely because the amount of N mineralized from soil organic matter is likely to be highly variable among fields and cropping histories, and it can contribute a very wide range of available N. For this reason, coupling a worksheet approach with soil or leaf tissue sampling during the growing season to determine whether N availability is deficient, adequate, or excessive is essential.

After a rough N budget is made, and a crop in grown with the budget in mind for a year or two, revisit the N budget worksheet to adjust numbers based on in-season soil nitrate and leaf tissue monitoring data.

## SECTION 4. THE DEMO WORKSHEET: A COMPLETED WORKSHEET FOR ILLUSTRATIVE PURPOSES.

**Companion worksheet to ESTIMATING NITROGEN AVAILABILITY IN ORGANIC VEGETABLE PRODUCTION: For N budgeting and other purposes**

This worksheet is intended to be used with the document "Estimating Nitrogen for Organic Crop Production: For N budgeting and other purposes". The figure and table references can be found in that document. It can be useful in developing a complete N budget, or for estimating and understanding plant availability of N from individual organic N sources, such as compost or cover crops.

Completing each section at least one time can be highly informative to understanding how organic sources of N that are regularly added or existing in your system, contribute to plant available N. This information is often translatable between crops or years. However, given the time it takes to fill out the worksheet, it can be challenging to routinely utilize for diverse cropping systems. In addition, there may be inaccuracies in making estimates of available N. Therefore, the accuracy of this worksheet, or of any other N budgeting approach, needs to be verified by monitoring the N status of the crop with in-season leaf or soil samples.

This worksheet focuses on plant available nitrogen from organic sources, but does not discuss the timing of the crop N demand in great detail. Understanding the timing of crop demand with the timing of plant available N is important when making fertilization decisions.

**Scenario:**

**I have been an organic farmer for 12 years in Yolo County. I grow a diverse crop mix, but fresh market tomatoes are an important one for me. My mid-season tomatoes always follow a cover crop and I typically add compost just prior to planting. Also at that time, I amend with a granular fertilizer, then during the growing season, I run a liquid fertilizer 3-5 times during rapid growth. My tomatoes are drip irrigated. I test the soil 1x per year. The tomatoes were transplanted in early May and harvest was completed by mid-September. The SOM content is 3%.**

**This crop-based budget worksheet is for_____Fresh market tomato___**

**crop**

## PART 1. CROP N DEMAND

A. **Crop N Uptake: How much N does your crop need?** Select 1 method below to identify the N uptake demand.

**Method 1. Use N uptake suggested by a reliable source**

**1.** [ 240 ] lb N/A **1. Total crop N uptake (average value or range) provided by a reliable source (e.g. Table 1)**

5.

**I chose this based on Table 1. The table says this is based on 30 Tons/Ac. I average about 29 tons, so I'll stick with this number.**

**Method 2. Use N uptake suggested by a reliable source and adjust based on your yield goal.**

**1.** __________ lb N/A **1. Total crop N uptake (average value or range) provided by a reliable source (e.g. Table 1)**

**2.** __________ Ton/A **2. Yield associated with the above N value** (**Table 1**)

**3.** __________ Ton /A **3. Your predicted yield** (1 Ton = 2000 lb)

Then, (_______Ton/A /_______ Ton/A) x _________ lb N/A = [ ] lb N/A

3. 2. 1. 5.

**Method 3. Use your predicted yield and estimated lb N needed per ton yield**

**3.** __________ Ton/A **3. Your predicted yield** (1 Ton = 2000 lb)

**4.** __________ lb N/T yield **4.Total crop N uptake** (**Table 1**)

Then, __________ Ton/A x ___________ lb N/T = [ ] lb N/A

3. 4. 5.

5. 240 lb N/A **5. Total crop N uptake. Insert result from box 5. based on method used above.**

## PART 2. N SUPPLY: BASELINE

### B. Available N from Soil Organic Matter (SOM)

6. 66 lb N/A **6. Estimated N from SOM** (Reference Figure 4 and Table 2). A typical release rate will likely be from 50-120 lb N/acre/year in the top 1' of soil, about 2% of the total soil N becomes available.

- I have been farming organically for 15 years, with annual cover cropping and compost application so the SOM and the N bank have been building on my soil for many years. So, N mineralization may be higher than in a conventional soil with the same SOM content.
- I reviewed Table 2 from early May through mid-September in the Sacramento Valley which estimated 66.
- On the other hand, I use drip irrigation which keeps a smaller soil volume moist than sprinkler or furrow irrigation. N mineralization in the dry soil will likely be lower.

### C. Available N from crop residue: cover crops and post-harvest residue

If a cover crop or commercial crop is incorporated no more than 6 weeks prior to planting the crop intended for this budget, the N from these residues should be accounted for. Choose from either the cover crop or crop residue options.

**C1. Available N from Previous Crop**

___**The residues of the previous cash crop were incorporated in fall__ Specify previous crop**

| |
|---|
| ________C:N ratio of previous crop residue at time of incorporation. |

**7.** __________ Ton/A **7. Previous crop yield**

**8.** _________ lb N/T **8. N in crop residue (**Table 3)

**9.** __________lb N/A **9. Estimated N in crop residue**

The amount of N expected to be in the residues can be adjusted for the actual expected yield by multiplying the actual yield by the value for lb N/ton yield.

__________ Tons/A x __________ lb N/ton = __________ lb N/A

7. 8. 9.

**10.** 0 **lb N/A** **10. Total N from previous crop available this season**

Use a lower % N available when material is left on the surface and not incorporated, or when the soil is drier. C:N ratio is an excellent predictor of N availability. A C:N ratio greater than 20:1 will generally not release nitrogen, but rather be used to degrade the carbon, whereas 10:1 will provide intermediate rates of release.

__________ lb N/A x __________% / 100 = __________ lb N/A

9. 4-45% 10

**C2. Available N from cover crops**

The amount of N from a cover crop contribute depends on several factors including the species, how thick the stand is, and at what stage it is terminated. The C:N ratio is the best predictor of nitrate release rates.

Bell bean (30%), Peas (30%), Vetch (20%), Oats (20%) **Specify cover crop type**

___12:1_____C:N ratio of cover crop residue

**11.** ____**4600**___ lb/A **11. Estimate legume biomass dry weight**

Use your own information of biomass dry weight, or reference UC SAREP cover crop database. When referencing another source providing a range, consider your own scenario regarding crop density and crop height/maturity to select a number in the range. For example, if a crop is terminated earlier, at 50% of maturity, select a number on the lower end of the range. More dense and longer production times will likely fall on the higher end of the range.

I referenced an article called "How much nitrogen is in your cover crop?" by Margaret Lloyd. I used the mix described there and planted it at 100 lb/A and waited for the first rain to germinate the seed. I terminated the cover crop in March, about a month before the sampling took place in that document, so I discounted my biomass by 1000 lb. Also, looking at the picture, my crop was not as tall as it is in the photo for field 5. Because I terminated it in March and not April, I also lowered the C:N ratio, since it was not as mature as an April cover crop.

**12.** __**3.5**_______ % **12. Percent N in cover crop**

Use your own information from a sample sent to a lab, reference UC SAREP cover crop database or find other resources.

Again, referencing the same article, it shows that this cover crop was 2.9% N. Because I terminated it a month earlier than the sample here, I would expect a higher N content, so I increased it to 3.5%.

**13.** ___161___ lb N/A **13. Total N from cover crop** (Table 4)

__4600_ lb/A x __3.5___% /100 = ___161____ lb N/A

11. 12. 13.

**14.** 32 lb N/A **14. Total N from cover crop available this season**

It's estimated that about 4-35% of cover crop N is directly available for the next crop. Use a lower % availability when material is left on the surface, not incorporated, or when the soil is drier. Use an intermediate % for legume-cereal mixes. Use a higher % when the cover crop is terminated at optimum growth (early flower) and a lower % for more mature crops. C:N ratio is an excellent predictor of N availability. A C:N ratio greater than 20:1 will generally not release N, but rather be used to degrade the carbon, whereas 10:1 will provide intermediate rates of release.

- I'm incorporating my cover crop into soil with some moisture to encourage degradation so that I can plant my tomatoes into it in early May.
- I estimated my C:N ratio at 12:1, so it's on the lower to intermediate side of release.
- I'm using a legume-cereal mix which releases at an intermediate rate, due to the higher C from cereal crops.

___161__ lb N/A x ____20___% / 100 = ____32___ lb N/A

13. 4-35% 14.

### D. Irrigation Water

#### D1. Sampling water for testing

To convert $NO_3$-N concentration in the water to lb N/acre inch, $NO_3$-N concentration reported in ppm is multiplied by 0.227 and by the number of acre-inches of water applied. For example, for 1 acre-inch of water containing 10 ppm nitrate-N: (10 ppm) x (1 acre-inch) x (0.227) = 2.27 lb N are applied per acre.

**15.** [ 55 ] lb N/A **15. N contribution from irrigation water based on water test result**

[Test date: __5/7/2018__] Test Result: ___8 ppm___________

**Conversion Tool**

Convert ppm to lb N ___8___ppm x 0.227 = ____1.816_______lb N/ acre inch

$NO_3$-N $NO_3$-N

Estimate total water use:

__30_____ acre-inches x _____1.816_______lb N/ acre inch = ___54.5___ lb N

Water use $NO_3$-N in water 15.

# PART 3. N SUPPLY: SEASONAL INPUTS

**E. Available N from Organic Amendments**

**E1. Compost**

Most compost companies will provide an analysis of the compost material which

will include the total % N and C:N ratio.

____**ABC Compost, yard trimmings compost**__**Product name**

**16.** ___**15:1**____ C:N ratio **16. Identify the C:N ratio of the compost**

**I requested a soil analysis from the company and got the C:N ratio , % N, % moisture.**

**17.** ___**35**___ % water **17. Identify the amount of water in the compost**

**18.** ____**1**____ % N **18. Total N in compost (dry weight)** (Check the report to see if the total N is given in wet or dry weight basis. 'As is' or 'fresh weight' is typically equivalent to 'wet weight'.) It was given in dry weight. 1%

If your compost N is given in dry weight, adjust the amount of compost you applied 'as is' to dry weight:

**19.** ___**20,000**___ lb/A **19. Application rate in lb, wet weight ('as is' or 'fresh weight')**

(1 T = 2000 lb; 1 T = 2-2.5 cubic yards)

I apply 10T/A, wet weight = 'as is' when it arrives at my farm. Compost leaves the supplier at the rate you ordered (ex. 10 T) and at the 'as is' weight. Even if it sits on your farm for a long time and gets very dry or very wet (from winter rain), it is still 10 T of 'as is' or wet weight compost)

**20.** ___13,000 lb/A **20. Application rate in lb, adjusted to dry weight**.

If compost N is given in wet weight (#18), do not adjust. Use the same number in 19 and 20.

__20,000_ lb/A x (100-_35__%) / 100 = __13,000__lb/A

19. 17. 20.

**21.** ___**130**___ lb N/A **21. Estimated total N from compost added to field**

____1___**%** / 100 x __13,000__ lb/A = ___130__ lb N/A

18 20. 21.

**22.** 3 lb N/A **22. Estimated available N from compost**

Composts are estimated to release -3-35% of total N in the first year (Fig. 7). Plant based composts can initially tie up N whereas manure-based composts have more N available. Take a look at Figure 7 to see estimates of percent N release from composts, and Figure 8 to see the correlation between C:N ratio and available nitrogen. Place the C:N ratio of the compost used on the curve to estimate the N release percent.

___130___ lb N/A x ___2____%_/ 100 = ___2.6____ lb N/A

21. -3-35% 22.

**Looking at Figure 8, I can see that my yard trimmings compost at 15:1 C:N ratio does not release much if any N and may actually tie it up. I'm going to say that it has a 2% release rate.**

**E2. Granular fertilizers**

______ **Pelleted chicken manure____Product name**

**23.** ____4_____ % N **23. Total N in product** (ex. 5-8-0 is 5% N)

Bag says: 4-2-2

**24.** ___0.04_ lb N/lb **24. Pounds of N per pound of product**

____4_% /100 = ____0.04__lb N/lb

23. 24.

**25.** __500_ lb/A **25. Application rate** (1 T = 2000 lb; 1 T = 2-2.5 cubic yards)

**26.** ___20__ lb N/A **26. Total N applied**

___0.04_lb N/lb x ___500__ lb/A = ___20_ lb N / A

24. 25. 26.

**27.** 10 lb N/A **27. Total available N**

For crops grown with regular water in warm weather, granular fertilizers with a low C:N (ex. 6:1 or lower) are estimated to release 40-60% of total N in a season (See Fig. 7). Colder and/drier conditions will reduce the nitrogen release rate. Surface applied granular fertilizer releases a lower percentage of the total it contains. Granular fertilizer shanked into the soil releases a higher percent of the N it contains. Higher analysis fertilizers release a greater percentage of N than lower N (Hartz and Johnstone, 2006)

____20__ lb N/A x ___50_______% / 100 = ___10__ lb N/A

26. 40-60% 27.

- These fresh market tomatoes are being grown in the summer, under irrigation so the release rate will not be limited by cool soil.

- I apply this fertilizer in a band above my drip tape so the moist soil will encourage release.
- When I look at Figure 7, I can see that a 4% granular fertilizer will release about 50% over 12 weeks, so I chose 50%.

**E3. Liquid fertilizers**

Liquid fertilizers are estimated to release 50-100% of total N in the season. (Fig. 7).

_____ **Liquid Fish Emulsion**___**Product name**

**28.** ___**9.15**__ lb/gal **28. Fertilizer density** Read product label to determine (Water is 8 lb/gal; Many products range from 9-10.5 lb/gal)

The label that I found online said it weighed 9.15 lb/gal

**29.** ___**5**___ % N **29. Percent of N in product** (ex. 3-2-2 is 3% N)

Label: 5-2-1

**30.** ___**50**___ gal/A **30. Application rate**

Over the season, I apply 50 gallons.

**31.** ___**23**___ lb N/A **31. Total N applied**

__9.15__ lb/Gal x __5___% N x _50__ gal/A / 100 = ___22.875___ lb N/A

28. 29. 30. 31.

**32.** 21 lb N/A **32. Total available N**

__23_ lb N/A x ____90___% /100 = __20.7__ lb N/A

31. 50-100% 32.

- Animal-based liquids tend to release at higher rates, so I chose an intermediate rate

# PART 4. SOIL AND TISSUE TESTING FOR VERIFICATION AND MONITORING

## F1. INTERPRETING SOIL TESTS

When using results from a soil test, consider the timing of the soil test. The results from a soil test can be used for a budget when it is taken before amendments are added and before crop residue (or cover crop) incorporation. However, if a soil test is taken after cover crop, crop residue and/or organic amendment applications are added, the soil test results will include some of the N made available from the recent activity. As such, the soil test should be fully counted towards the budget, but the N credits for crop residue and organic amendments can be reduced. Adjust accordingly. Similarly, if soil samples are more than several months old, consider what activities have occurred since then that could influence N levels (crop production, rain, amendment application, etc). To use a soil test to adjust the quantity of fertilizer applied to meet the crop needs, test for residual soil nitrate prior to a fertilization.

**14.** [ 35 * ] lb N/A **14. Available N at time of soil test** [Test date: ___2/15/2019______ ]

Test result: 55 ppm of $NO_3$

**Conversion tool**

1 mg/kg = 1ppm

If soil test is in $NO_3$, convert to $NO_3$-N: ___55____ppm / 4.42 = ___12.4____ppm

Result $NO_3$ Result $NO_3$-N

If soil test is in ppm, convert: __12.4_ppm x ____3.6______= __44.6__lb N/A

$NO_3$-N conversion factor 14.

* Because I took the soil sample in February and we had several rain events after that and I had the cover crop growing, which was likely using some of the soil nitrate, I reduced my soil nitrate.

If a soil sample was taken to a depth of 12”, use 3.6 to convert ppm to lb/A for soil bulk density. If a soil sample was taken to a depth of 6”, use a conversion factor of 1.8. For vegetables, 12” soil sampling depth is recommended for most crops in order to capture the soil where the majority of roots will grow.

## THE BUDGET

| **PART 1. CROP N DEMAND** | lb N/ A |
|---|---|
| 5. Crop Demand | 240 |

| **PART 2. N SUPPLY: BASELINE** | lb N/ A |
|---|---|
| 6. SOM contributions | 55 |
| 10. Previous Crop or 14. Cover Crop | 32 |
| 15. Irrigation Water | 55 |
| ***TOTAL (6 + 10 or 14 + 15)*** | 142 |
| **PART 3. N SUPPLY: SEASONAL INPUTS** | lb N/ A |
| 22. Compost | 3 |
| 27. Granular fertilizer | 10 |
| 32. Liquid fertilizer | 21 |
| ***TOTAL (22 + 27 + 32)*** | 34 |

| **Part 4. SOIL AND TISSUE TESTS** | |
|---|---|
| 33. Residual soil N (from a soil test)<br>Only include if soil analyses were taken prior to ‘seasonal inputs’ application OR reduce values for seasonal inputs<br>The soil test was taken before inputs and before the cover crop was mowed and incorporated, so I’m going to include all of it and all of the other inputs. | 35 |

**AVAILABLE N GRAND TOTAL**

**Part 2 + Part 3 + Part 4 Total** 211

N balance _____211_____ - _________240________ = ____-29_______ lb N/A

Available N grand total Crop demand lb-N/ac N balance

Now that I have completed this, I think that my current regime may not be supplying sufficient N to my fresh market tomatoes and the high yield that I expect. In the future, if I need more N, could consider using a higher N compost such as one with some manure in it, as a 'cheaper' way of getting a little more N into my system.

If the N balance is positive, it suggests that the crop is likely to have enough N supply, assuming zero loss of N during the growing season. However, the larger the positive number, the more chance to lose N to the environment since crops will have a limit on N demand and irrigation will be occurring. Taking a soil sample after harvest to a depth of 2-3 feet and analyzing it for residual nitrate will allow you determining how much N was left over and may be at risk of being leached with winter rains, unless a cover crop which can take up this N is grown during the winter.

If the N balance is negative, it suggests N supply is not adequate to meet the crop demand. Consider increasing the N supply by adding more fertilizers and re-calculate the N balance until a positive number is reached.

That being said, it can be very challenging to achieve a real balance between N inputs and N outputs solely relying on the worksheet approach. This is largely because the amount of N mineralized from soil organic matter is likely to be highly variable among fields and cropping histories, and it can contribute a very wide range of available N. For this reason, coupling a worksheet approach with soil or leaf tissue sampling during the growing season to determine whether N availability is deficient, adequate or excessive is essential.

After a rough N budget is calculated, and a crop in grown with the budget in mind for a year or two, revisit the N budget worksheet to adjust numbers based on in-season soil nitrate and leaf tissue monitoring data.