

Estimating Nitrogen Mineralization in Organic Potato Production

D.M. Sullivan, J.P.G. McQueen, and D.A. Horneck

EM 8949-E
January 2008

This bulletin is one of a series on organic potato production developed by “OSPUD.” OSPUD is a collaboration among Oregon State University personnel and 11 farmers operating diversified organic vegetable farms. The purpose of OSPUD is to improve potato quality and profitability through a participatory learning process and on-farm, farmer-directed research. The first 2 years of OSPUD were supported by Western SARE Grant SW05-091. For more information on OSPUD, visit ospud.org.

Potatoes require adequate nitrogen to produce quality tubers and high yields. Organic farming practices are designed to build soil nutrient levels gradually. In organic systems, nitrogen (N) enters the soil in the form of crop residue and amendments (e.g., manures, composts, and specialty products).

Much of the N added to the soil is held in organic forms not immediately available for crop uptake. A soil with 3 percent organic matter in the top foot contains about 5,000 lb N per acre. However, only a small fraction of soil organic N is released in plant-available forms each year through a process called **mineralization**.

This publication describes a “crop N uptake” method for estimating N mineralization from soil organic matter.

Crop N uptake is a site-specific indicator of N that is “available” to the crop. The crop N uptake measurement integrates many factors that affect the quantity of N provided by mineralization, such as soil organic matter percentage, management, cropping history, previous soil amendments, and biological activity.

In organic cropping systems, crop N uptake data is one of the best tools for determining appropriate rates of current-season N inputs. You can use your data about soil N mineralization, together with other site-specific information, to customize your N management program.

Unfortunately, crop N uptake data must be collected and processed during a busy part of the year. The increase in potato yield and quality, combined with reduced N input costs, often makes it profitable to contract with a consultant to perform and interpret the measurements.

This publication also summarizes crop N uptake measurements from six Oregon organic farms. These measurements demonstrate the importance of soil N mineralization in supplying plant-available N to organic potatoes.



Lane Selman, Oregon State University

What is mineralization?

Decomposition of soil organic matter into plant-available N is called **mineralization**. A simple way to think about mineralization is:

Mineralization process =



The quantity and timing of soil N mineralization depend mainly on:

- ▶ Organic matter content of the soil
- ▶ Soil temperature
- ▶ Soil moisture
- ▶ Crop rotation

Mineralization occurs most rapidly in soils that are warm and moist and have high organic matter content. N mineralization is increased when high-N crop residues (legumes) are tilled into the soil.

Using N mineralization data to fine-tune N management

This publication is a guide to estimating the quantity of soil N mineralization under site-specific conditions. Below is an example of how you can use mineralization data to fine-tune N management.

Example

You want to supply 200 lb plant-available N/acre for the potato crop. Soil N mineralization supplies 150 lb N/acre (as determined by the “crop N uptake” method described in this publication). You need to supply approximately 50 lb available N from a rapidly available N source.

$\text{Crop need (200 lb/acre)} - \text{N mineralized (150 lb/acre)} = \text{Rapidly available N needed (50 lb/acre)}$

Once you have estimated how much rapidly available N is needed, you can use the “Organic Fertilizer Calculator” (see “For more information,” page 7) to compare the per-pound cost of available N in different organic amendments. The Calculator estimates plant-available N at 4 and 10 weeks after amendment application. The Calculator does not estimate changes in long-term soil N mineralization rates resulting from many years of amendment application.

Mineralization, the “black box” in fertilizer rate calculations

The amount of plant-available nitrogen present in a spring soil sample usually is only a small fraction (less than 10 percent) of the available N needed by a potato crop. Much more N is mineralized from soil organic matter during the growing season.

The quantity of rapidly available N (from broiler litter, fish fertilizer, or other high-N specialty products) needed to support potato growth and development depends on the amount of N supplied by mineralization:

Crop need – N mineralized = Rapidly available N needed

Unfortunately, growers can’t accurately estimate N mineralization amounts by soil testing. Laboratories can determine soil organic N and can measure plant-available nitrogen (nitrate + ammonium-N) present in soil at the time of sampling, but they can’t predict how much of the organic N will mineralize during the growing season.

“Rules of thumb” often are used to estimate typical amounts of N supplied by mineralization. Some documents estimate that 2 percent of soil N is mineralized each year to plant-available forms. So, for a typical western Oregon soil with 5,000 lb organic N per acre (3 percent organic matter, 0- to 12-inch depth), the quantity of plant-available N from mineralization would be approximately 100 lb N/acre ($5,000 \times 0.02 = 100$). However, N mineralization often varies substantially from “rule of thumb” estimates.

Method: Measuring crop N uptake from a “zero N” plot

This method uses the crop as an indicator of N mineralized from soil organic matter. Potato plants can take up small or large quantities of mineralized N, depending on site-specific soil conditions.

This method has four main parts:

1. Planning a zero-N plot
2. Collecting plant samples
3. Laboratory analysis of samples
4. Calculating crop N uptake

Planning a zero-N plot

Location

Mark out an area in this year's potato field that can be kept free of current-season fertilization. To better represent the field, you can create more than one zero-N plot in the same field. The zero-N plot(s) should be located in areas that are typical for the field, e.g., not in wet or low-fertility areas.

Plot size

The plot should be at least four rows wide. The outer two rows act as “guard” rows to protect against accidental fertilizer application. Row length should be at least 25 feet, but a longer plot will give you more opportunity to collect representative plant samples.

Plot management

Cultural practices such as planting, cultivation, and irrigation should be the same as the rest of the field. Take care not to apply any dry or liquid fertilizers to this area during the season.

Farming system effects

The zero-N plot reflects N mineralized for a particular crop rotation. Plant-available nitrogen supplied by recent incorporation of crop residues, winter cover crops, or composts will contribute to potato crop N uptake.

Nitrogen supplied by irrigation water will also be utilized by the crop. Test irrigation water to determine nitrate-N content. To determine the amount of N supplied by an acre-inch of water, multiply the water N analysis (mg N/liter or ppm) by 0.227. For example, 1 acre-inch of water containing 10 ppm N supplies 2.3 lb N ($10 \text{ ppm} \times 0.227 = 2.3 \text{ lb N}$).

Collecting plant samples

When to collect samples

Vine + tuber samples can be taken at various times during the season to determine the rate of crop N uptake (see Figure 3, page 7).

The most important time for sample collection is near the end of the growing season, since this measurement reflects total N uptake for the season. Take this end-of-season “harvest sample” before vines start to drop leaves. The best time for this measurement is just before vine kill. Vines should be green at the time of sampling so that you can evaluate the balance of N in vines and tubers.

Sample collection method

Collect three adjacent plants from a section of row that represents typical in-row plant spacing (Figures 1 and 2). Sampling more than one row section can help verify your measurement. We recommend that you keep plant samples from each row section separate.

1. Select row section(s) from within the zero-N plot.
2. Sample three adjacent plants from each row section.

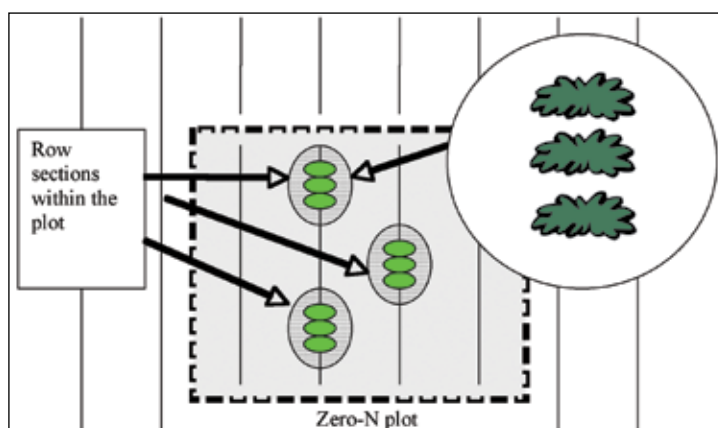


Figure 1. Recommended plant sampling method. Harvest three adjacent healthy plants from three sections of row within the plot.



Figure 2. Vines, tubers, and roots harvested from one section of row (three adjacent plants) at midseason. (Photo: John McQueen, Oregon State University)

Tuber subsampling

If you deliver all harvested tubers to the lab, you can ignore these instructions. If you subsample tubers, you will need to calculate harvested tuber dry weight, using the instructions below.

The tuber subsample should reflect typical tuber size and should contain at least six tubers. At the time of subsampling, record data on:

- ▶ Harvested tuber weight (all tubers from three adjacent plants)
- ▶ Subsampled tuber weight (the tubers sent to the lab for drying, grinding, and N analysis)

Ask the laboratory to provide you with tuber dry weight for the subsample.

To determine harvested tuber dry weight, use the following equation:

Harvested tuber dry weight = $A \times B \div C$
where:

A = harvested tuber fresh weight (all tubers harvested)

B = subsample dry weight (obtained from lab)

C = subsample fresh weight (measured before shipment)

Example

You harvested 3,000 g of tubers (6.6 lb) from a section of row (three plants). You selected six tubers to send to the lab (tuber subsample). At the time of shipment, the six fresh tubers weighed 1,200 g. The lab oven-dried the tubers, and the dry weight for the six-tuber subsample was 150 g.

Calculate harvested tuber dry weight for three-plant sample:

$3,000 \text{ g (fresh weight of tubers harvested)} \times 150 \text{ g (subsample dry weight)} \div 1,200 \text{ g (subsample fresh weight)} = 375 \text{ g total harvested tuber dry weight}$

Calculate tuber dry weight per plant:

$375 \text{ g (harvested tuber dry weight)} \div 3 \text{ plants} = 125 \text{ g tuber dry weight per plant}$. Enter this value in Line 2 of the worksheet on page 5.

3. Cut off and discard the roots at the soil line. (Roots represent a small portion of crop N uptake and are not included in the uptake measurement.)
4. For each row section, place tubers and vines in the same bag.

Some laboratories may be willing to collect plant samples from your field, or they may work with crop consultants who collect samples.

Laboratory analysis of samples

Working with the laboratory

Always contact the laboratory before sending samples. Labs need to be prepared to collect additional data beyond that normally collected for plant tissue samples. N uptake analysis is a custom procedure, so labs will charge more than for standard plant samples.

The first step in the analysis (drying vines and tubers) requires a lot of space in laboratory drying ovens. Make sure the lab has sufficient oven capacity to process your samples.

It is best to measure N uptake separately for vines and tubers. If you follow the recommended field sampling method (Figure 1), you will submit six samples (three tuber samples and three vine samples) at each sampling date. To facilitate communication with the laboratory, we have included an example worksheet (pages 5–6), showing data needs and calculation method for estimating crop N uptake.

Sample handling, processing, and analysis

The simplest approach is to deliver whole plants to the lab the same day they are sampled, and let the lab perform all sample handling and data collection. If you choose this method, a simple sampling method is to put plants from each row section (vines + tubers from three plants) in a separate 30-gallon plastic garbage bag. Keep the bag(s) out of the sun. Refrigerate the bagged plants if you cannot deliver them to the lab immediately.

If you cannot deliver samples the same day:

1. Separate the vines and tubers.
2. Put vines in paper bags so they do not mold. Submit the entire vine to the lab.
3. Put tubers in separate bags. If sending all of the tubers is too expensive, you can send a tuber subsample, but you will need to collect additional data. See “Tuber subsampling” (sidebar at left).
4. Ship samples via overnight mail and make sure they arrive between Monday and Thursday.

Sample processing and analysis at the laboratory

Below are instructions for the laboratory.

1. Oven-dry and then grind the whole vine. It is difficult to get an accurate subsample of potato vines without grinding them.
2. If desired, subsample tubers to reduce sample size. (See “Tuber subsampling,” page 4) Oven-dry the tubers.
3. Record tuber dry weight and vine dry weight.
4. Determine total N concentration in vines and tubers.
5. Summarize data. See Worksheet (Step 1, “Enter laboratory data”) for example format.

Calculating crop N uptake

Once analytical data are reported by the laboratory (Step 1 in the worksheet), use the rest of the worksheet to calculate crop N uptake.

Worksheet for calculating crop N uptake

Crop N uptake from a zero-N plot estimates the amount of plant-available N mineralized from soil organic matter. The worksheet below takes you through a step-by-step calculation of vine + tuber N uptake (pounds per acre). To use the worksheet, you will need laboratory data (Step 1) and data on plant spacing in the field (in-row and between-row spacing).

Step 1. Enter laboratory data

Line no.	Measurement	Your information	Example	Units
1	Vine dry weight (vine weight ÷ number of plants)		300 g for 3 plants = $300 \div 3 = 100$	g/plant
2	Tuber dry weight (tuber weight ÷ number of plants)		900 g for 3 plants = $900 \div 3 = 300$	g/plant
3	Vine total N		2.0	% dry weight
4	Tuber total N		0.9	% dry weight

Step 2. Calculate vine and tuber N uptake (grams per plant)

Line no.	Calculation	Your information	Example	Units
5	Vine N uptake Line 1 x (Line 3 ÷ 100)		$100 \times (2.0 \div 100) = 2.0$	g/plant
6	Tuber N uptake Line 2 x (Line 4 ÷ 100)		$300 \times (0.9 \div 100) = 2.7$	g/plant

Step 3. Calculate plant population

Line no.	Calculation	Your information	Example ^a	Units
7	Between-row spacing		36	inches
8	In-row spacing		12	inches
9	Length of row per acre $43,560 \div (\text{Line 7} \div 12)$		$43,560 \div (36 \div 12)$ $= 14,520$	ft row per acre
10	Plant population per acre $\text{Line 9} \div (\text{Line 8} \div 12)$		$14,520 \div (12 \div 12)$ $= 14,520$	plants per acre

Step 4. Calculate vine + tuber N Uptake (lb/acre)

Line no.	Calculation	Your information	Example ^a	Units
11	Vine N uptake $(\text{Line 5} \div 454) \times \text{Line 10}$		$(2.0 \div 454) \times 14,520 = 64$	lb/acre
12	Tuber N uptake $(\text{Line 6} \div 454) \times \text{Line 10}$		$(2.7 \div 454) \times 14,520 = 86$	lb/acre
13	Vine + tuber N uptake ^b $\text{Line 11} + \text{Line 12}$		$64 + 86 = 150$	lb/acre

^aUnit conversions used in Steps 3 and 4:

1 acre = 43,560 ft²

1 lb = 454 grams

1 ft = 12 inches

^bThe worksheet provides an example for a vine + tuber sample from a single section of row (three adjacent plants). If you follow the recommended plant sampling method (Figure 1), repeat the calculations for each section of row sampled. You can then calculate average crop N uptake and determine the range in N uptake values.

N mineralized at Oregon organic farms

Crop N uptake measurements can be used to adjust N fertilization rates (see box at lower left on page 2, “Using N mineralization data to fine-tune N management”). In this section, we summarize crop N uptake data from six organic farms in the OSPUD project (see “For more information”). We collected data beginning approximately at the time of tuber initiation and continuing until just before vine kill. Final tuber yields (approximately 100 days after planting) averaged about 18 ton/acre at 12 x 36 inch spacing. Soil organic matter (0 to 12 inches) was between 3 and 4 percent (average = 3.7 percent). Five farms were in the Willamette Valley, and one was in central Oregon.

N available from mineralization

End-of-season crop N uptake averaged 145 lb N/acre and was at least 100 lb N/acre at each farm. A 20-ton per-acre potato crop typically takes up 200 lb N/acre when N supply is adequate, but not excessive.

Crop N uptake per day

The rate of crop N uptake during tuber growth (approximately 50 to 100 days after planting, Figure 3) averaged about 2 lb N/acre/day. This suggests that N mineralized from soil organic matter supplied much of the N needed for the potato crop. Typical N uptake rates measured by other researchers under nonlimiting N fertility conditions range from 2 to 5 lb N/acre/day.

Balance between N in vines and tubers

We found that crop N uptake could not be estimated from tuber yields, because of differences in N partitioning between vines and tubers. The amount of N found in vines at end-of-season varied substantially among farms, ranging from 22 to 111 lb N/acre. End-of-season N in tubers ranged from 40 to 70 percent of total crop N uptake.

An example of how potato plants respond to plant-available N is shown in Figure 4. Crop nitrogen uptake (vines + tubers) at Farm B was almost double that at Farm A. Tuber yields were only 20 percent higher at Farm B, demonstrating that when N is in low supply the plant compensates by moving more N to tubers. Therefore, N in both vines and tubers needs to be measured to determine end-of-season crop N uptake.

For more information

Andrews, N. and Foster, J. 2007. *Organic Fertilizer Calculator: A Tool for Comparing the Cost, Nutrient Value, and Nitrogen Availability of Organic Materials*. EM 8936-E. Oregon State University Extension Service. Corvallis, OR. <http://smallfarms.oregonstate.edu/organic-fertilizer-calculator>

OSPUD Participatory Organic Potato Project. <http://ospud.org/>

eOrganic website (under development).

Acknowledgments

The authors express appreciation for reviewer comments that strengthened the technical merit of this publication:

Craig Cogger, Washington State University-Puyallup

Dan Nelson, SoilTest Farm Consultants, Inc., Moses Lake, WA

John Hart, Oregon State University, Department of Crop and Soil Science

Nick Andrews, Oregon State University Extension Service

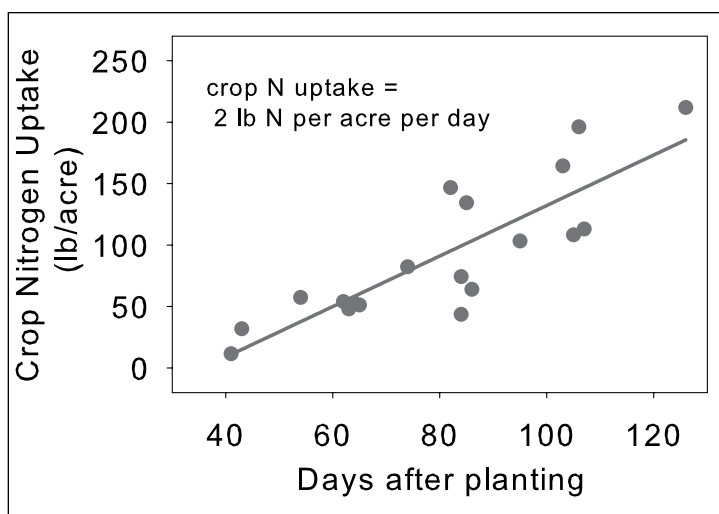


Figure 3. Crop N uptake (vines + tubers) from unfertilized on-farm plots. Data from six farms, OSPUD project. Plant population = 14,520 plants per acre (12 x 36 inch spacing). Circles are individual on-farm measurements. Plants at each farm were sampled three or four times during tuber growth. Slope of the line is the average rate of crop N uptake across farm locations.

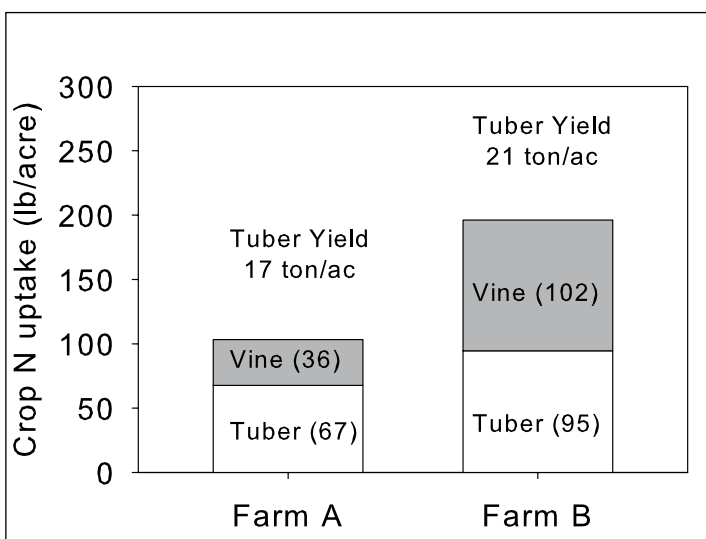


Figure 4. Balance between N present in potato vines and tubers near the time of vine kill. Two OSPUD farms, Willamette Valley, 2006. Vines at Farm A contain less N than tubers, indicating a low amount of plant-available N supplied by mineralization. Vines at Farm B contain more N than tubers, indicating a higher amount of plant-available N supplied by mineralization.

Summary

This publication describes a crop N uptake method for estimating N mineralization from soil organic matter. You can use the N mineralization estimate to adjust fertilization practices (see page 2, “Using N mineralization to fine-tune N management”). Potato plants can take up small or large quantities of mineralized N, depending on site-specific soil conditions. This method requires the establishment and maintenance of a “zero N plot” in the field.

Advantages of the method

- ▶ By being site-specific, this method integrates many factors that affect the quantity of N provided by mineralization, such as soil organic matter percentage, management, cropping history, previous soil amendments, and biological activity.
- ▶ It provides a better estimate of N mineralization than soil testing or “rule of thumb.”
- ▶ Sampling potatoes just before vine kill provides an estimate of N balance between vines and tubers. When more end-of-season N is present in vines than in tubers, plant-available N supplied by mineralization usually is in excess of crop need. (Current season N addition was not needed.)
- ▶ Sampling multiple times during the growing season (e.g., 45, 60, 75, and 90 days after planting) can provide an estimate of crop N uptake rate (see Figure 3).
- ▶ Crop N uptake measurements for potato also provide a rough indicator of N mineralized for other summer crops under similar management.
- ▶ Because zero N plot(s) are in a field managed under “normal” N management, growers can get a rough indication of crop response to current-season N addition.

Limitations of the method

- ▶ It is site-specific, so look at data from a number of fields, potato varieties, and growing seasons before implementing major N management changes.
- ▶ You must set up a zero-N plot in the field before applying any current-season N inputs. It may be difficult to maintain a zero-N plot where N is applied in irrigation water by overhead sprinklers.
- ▶ You must make arrangements with the laboratory before sampling.
- ▶ Plant sample collection, shipping, and handling is laborious.
- ▶ Calculations require both laboratory and field data (see worksheet).
- ▶ N uptake sampling and analysis is more expensive than other methods of monitoring N availability, such as soil or petiole testing.
- ▶ Late vine dieback (more than 100 days after planting) may make it difficult to obtain a sample that includes late-season crop N uptake. Sampling before vine dieback (80 to 100 days) usually underestimates total crop N uptake.

© 2008 Oregon State University

This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.

Oregon State University Extension Service offers educational programs, activities, and materials without discrimination based on age, color, disability, gender identity or expression, marital status, national origin, race, religion, sex, sexual orientation, or veteran’s status. Oregon State University Extension Service is an Equal Opportunity Employer.

Published January 2008.