GUIDE TO NITROGEN QUICK-TESTS FOR VEGETABLES WITH THE 'CARDY' NITRATE METER

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Project Leaders
Kurt Schulbach
Richard Smith
Tim Hartz
Louise Jackson

Introduction

Managing nitrogen fertility is a difficult task. Nitrogen is a very mobile and reactive element which undergoes many complex transformations and movements into and out of the soil. Nitrogen is added to the soil in many forms, most commonly as commercial fertilizers, crop residues and cover crops and manures. Nitrogen is also removed from the soil in the harvested portion of crops, by leaching and by gaseous losses to the atmosphere. In addition to these fates, nitrogen undergoes many transformations while in the soil. The most important of these are the biochemical reactions of immobilization and mineralization. Nitrogen that is immobilized is unavailable to plants either because it is held in the tissues of microorganisms or because it has been changed into complex organic forms that resist breakdown. Mineralization is the opposite process where nitrogen in these complex organic forms or in plant residue are broken down into simple molecules that can be absorbed by plants.

By far the majority of the nitrogen in the soil is in the organic form. However, only 1-4 percent of this nitrogen may be mineralized to plant available forms annually. The rate at which these complex forms are broken down into the plant available forms is constantly changing, controlled by a series of interactions of crop residues, soil, microbes, and soil moisture and temperature. When plant residues which are low in nitrogen are incorporated into the soil, it may reduce the amount of nitrogen available to the plants by immobilization by microbes. In crops such as broccoli where large amounts of relatively high nitrogen containing residues are disked under, the result can be a fairly rapid mineralization by microbes, increasing the inorganic nitrogen available. When high nitrogen containing residues are turned under, succeeding crops can draw a substantial portion of the nitrogen they need, perhaps 50% or more, from the organic matter in the soil. From an economic standpoint, it is important to take this mineralized nitrogen into account to minimize fertilizer cost and reduce the chance of excess fertilizer being leached into the groundwater.

The two forms of nitrogen that are taken up by plants are the ammonium and nitrate ions. The ammonium ion has a positive charge meaning that it is held by the soil particles and is resistant to leaching. Nitrate, on the other hand has a negative charge and moves freely in the soil solution and is readily lost by leaching. When soil organic matter is broken down it is first transformed into ammonium and later it may be transformed into nitrate. When ammonium fertilizers are applied, the ammonium is also

converted to nitrate by a process called nitrification. Since ammonium tends to be converted to nitrate in agricultural fields, soils usually contain higher levels of nitrate than ammonium.

Because of the complex nature of nitrogen in the soil, it is difficult to know how much fertilizer to apply, often resulting in under or over fertilization. The use of soil and plant tissue testing can be a valuable tool for determining the fertilizer needs and maximizing fertilizer efficiency. While plants take up nitrogen in both the ammonium and nitrate forms, nitrate is usually more abundant that ammonium so nitrogen tests measure nitrate rather than ammonium. In principle, it is a good idea to measure both forms, but that become more time-consuming. However, measuring nitrate levels in organic fields or fields fertilized with large amounts of organic material or slow release nitrogen may not work as well since the plants may take up more of their nitrogen in the ammonium form. Under conventional fertilizer practices, plants tissue contains high levels of nitrate which have been shown over many years to be a good indication of the nutrient status of the plant. However, once the nitrate reaches the leaf blades, it becomes incorporated into other compounds, and the rate of this metabolism may affect the levels of nitrate in the petioles. Therefore, environmental factors that affect plant metabolism may affect the nitrate levels in the petioles. For example, lettuce has been shown to require higher petiole nitrate levels under colder temperatures.

Quick Tests

In the past, nitrate levels in plant tissue were obtained by collecting the sample, drying it in a oven, grinding the plant material and then extracting the nitrate and determining the concentration. Another method of determining nitrate levels is to make the measurement on the sap of the plant. This method requires much less labor, and with modern technology, testing fresh sap can be done on-farm. Whether nitrogen monitoring is done by the grower, a consultant, or a fertilizer company, quick tests offer a couple of advantages over conventional laboratory testing. The quick tests are generally lower in costs than dry tissue testing, but the main advantage is that the results can be obtained quickly, often the same day as the sampling. In many cases, this rapid turnaround can be important in making fertilization decisions.

In addition to tests for plant tissue, quick tests for determining nitrate levels in the soil have also been developed. Soil quick tests are especially useful early in the season when the plants are too small to collect tissue samples.

The difference between nitrate and **nitrate-N**

One of the most difficult parts of fresh sap testing is the confusion between the two values; nitrate and **nitrate-N**. Nitrate (NO_3), contains both nitrogen and oxygen. The term **nitrate-N** refers only to the nitrogen portion of the nitrate molecule. The nitrate molecule contains 1 nitrogen atom and 3 oxygen atoms. Nitrogen has an atomic weight of 14 and oxygen has a weight of 16, so the weight of the nitrate molecule is 62 (14 + (16 x 3)). The percentage of nitrogen (N) in the in the nitrate molecule (NO_3) is 14/62 or

22.6%. It is often necessary to convert values between nitrate and **nitrate-N**. The conversion can be accomplished by the following formulas.

PPM NO3 x .226 = PPM **NO3-N**
PPM **NO3-N** x 4.43 = PPM NO3

In most agricultural uses, the term **nitrate-N** is usually used. However, many instruments used to measure nitrate give readings in nitrate that should be converted to nitrate-N for comparison to most published crop sufficiency values.

Fresh Sap Nitrate Testing

The easiest way to measure nitrate in fresh sap is with a specific-ion electrode meter. One such meter called the Cardy meter is readily available, but other meters could also be used. The usefulness of fresh sap analysis is strengthened where it is used on a regular basis, with good record keeping; the trend of nitrate concentration can be followed over the season. Not only does this provide insight on the nitrogen dynamics of the crop, it also allows one to pinpoint a suspect value which needs retesting. It should be emphasized that, despite careful attention to these rules, fresh sap analysis with the Cardy meter does not have the accuracy of conventional laboratory analysis of dry tissue.

Use of the Cardy Meter

Although it can be used in the field, the Cardy meter is better suited to use indoors. It is sensitive to temperature changes, so frequent recalibration is necessary through the day if used in the field. Also, readings tend to drift for the first few minutes after it is turned on. From the standpoint of accuracy and efficiency, it is better to collect a number of petiole samples and bring them to a central location indoors for analysis.

Calibration

The Cardy Meter should be calibrated using the “two point” method described in the instructions each day that it is used.

1. Turn on the power.

2. Open the sensor cover, and wipe the sensor pad clean with a piece of tissue moistened with deionized water, then blot the sensor pad dry with a piece of dry tissue.

3. Place a piece of sampling sheet onto the sensor pad and drip 2-3 drops of the standard (STD) solution on it. After the readout has stabilized, adjust the STD dial so that the display reads 20 x 100 (2000).

4. After cleaning the sensor according to step 2, Place a piece of sampling sheet onto the sensor pad and drip 2-3 drops of the SLOPE solution onto the pad. After the readout has stabilized, adjust the SLOPE with the small screwdriver provided until the display reads 15 x 10 (150).

5. After cleaning with deionized water, measure the standard STD solution again. Repeat the calibration procedure until the meter reads accurately at both calibration points.

Some calibration solutions may be listed as nitrate on the label and some may be listed as **nitrate-N**. If nitrate calibration solution are used, the field data will have to be converted into **nitrate-N** values. This can be accomplished by multiplying the readings from the field samples by .226, or by calibrating the meter to give readings directly as **nitrate-N**. Calibrating the meter to read as **nitrate-N** can be accomplished by converting the calibration solutions to **nitrate-N** and adjusting the meter accordingly. For example, if the "standard" solution is 2000 ppm nitrate and the "slope" solution is 150 ppm nitrate convert the values to **nitrate-N** as follows:

2000 ppm nitrate x .226 = 450 ppm **nitrate-N**
150 ppm nitrate x .226 = 34 ppm **nitrate-N**

To calibrate the meter in **Nitrate-N** place a drop of the 2000 ppm nitrate solution on the sensor pad and adjust the reading until it reads 450 instead of 2000. Do the same with the other calibration solution.

Care of the Cardy Meter

While rinsing the meter between determinations do not allow water to get into the crack between the sensor and the main body of the instrument. The water will get onto the metal connections and cause the instrument to give erratic and false readings.

If the Cardy meter will not be used for a few weeks or more, it is best to place a seal (provided with the meter over the sensor so that the sensor does not dry out between uses.

When to Read

The Cardy electrode takes at least 20 seconds to stabilize each time a new sample is analyzed. Make it a rule to take readings at a standard time (perhaps 30 seconds) after putting each sample on the electrode.

Sample Collection

As a general rule twenty petioles from different plants throughout a management unit are required for a representative sample. Where there are obvious or suspected differences in fertility within a field, separate samples should be collected and analyzed.

It is usually best to take at least two separate samples from a field. By comparing the results from two separate samples, it is much easier to identify data that may be out of range, and the field can be re-sampled.

The general rule when sampling crops for nitrate testing is to take the most recently fully expanded mature leaf. There are exceptions however, for example, with onions, the roots are used to determine nitrate levels.

Collect samples from healthy plants from areas in the field where the stand is uniform.

Time of Sampling

The nitrate level in the plant can vary somewhat throughout the day. Most sources would agree that the most consistent results will be obtained by collecting samples after 8 a.m., but before 2 p.m.

Sample Storage

Immediately upon collection, leaf blades should be stripped away and petioles put in plastic bags on ice in a cooler until they are analyzed; water loss can occur very rapidly in hot field conditions, leading to inaccurate readings. Once on ice, samples can be held as long as six to eight hours without appreciable change in sap nitrate readings. Always allow petioles to warm up to the temperature of the meter before analysis; once the field heat is removed, petioles in a plastic bag can be held at room temperature for one to two hours without harm. Once sap is pressed from the petioles, it should be analyzed within a few minutes.

Sap Extraction

Extracting sap from fresh tissue is not a high-tech procedure; whatever you can rig to conveniently express the juice is fine. To ensure maximum accuracy, one should collect as much sap as is reasonably possible from all petioles in the sample, and then mix the collected sap before it is analyzed. The procedures for collecting and processing fresh sap is slightly different with different crops. Some of these crop specific practices are listed in the following paragraphs.

Broccoli and Cauliflower

Collect petioles from approximately 20 leaves. As the plants mature the petioles on broccoli and cauliflower get very large. Line up the petioles on a cutting board and cut a subsample from the center of the petioles about one-quarter of inch in length. Collect the sap from all the short sections of petiole and mix it together and place a few drops of the mixture on the sensor.

Lettuce and Cabbage

Tear out the midrib from 20 leaves. The midrib on young leaves will be about 1 inch long and on more mature plants the midrib will be from 2-3 inches in length. When the plants are large, as subsample can be cut from the center of the midribs and the sap can be extracted from the subsample as with broccoli and cauliflower.

Celery

Collect petioles from approximately 20 leaves. When the plant is young, sample the whole petiole. When the leaves are large enough, take only the portion of the petiole above the first node. Later, when the leaves are very large take the section between the first and second node. Leaves that still have a light green color are too young. Line up the petioles on a cutting board and cut a subsample from the center of the petioles about one-quarter inch in length. Process the sap from the subsample.

Peppers

Pepper petioles are relatively dry and it takes a lot of petioles to collect enough sap for testing. Collect at least 50 petioles of the most recently matured leaf (ie. usually the third or fourth leaf back from the growing tip) from a representative area of the field. If the petioles are small, collect sufficient volume of petioles (ie. 1 teaspoon full) to be able to express enough sap to cover the sensor of the Cardy Meter.

Onions

Collect the root tissue from a representative sample of onion plants in a field (ie. 20-30 plants). Cut the roots from the bulbs and wash the soil off in distilled water and blot dry with a paper towel. Mix the roots thoroughly. Select a random sample of roots and squeeze the juice from the equivalent of one to two plants worth of roots into a clean cup. Pour a small amount of the sap from the cup onto the sensor of the Cardy Meter for analysis.

Sweet Corn

Collect the basal six inch piece from the main stalk of corn from a representative sample of sweet corn plants in a field (ie. 15-20). Cut a thin section from the center of each of the stalks and express the juice from these small sections for analysis. Pour a small amount of the sap from the cup onto the sensor of the Cardy Meter for analysis. Because of the destructive nature of plant tissue testing on sweet corn, soil testing is preferred for routine analysis. However, tissue testing is useful when more information on the plant nutrient status in required.

Tomatoes

Collect about 20 petioles from the most recently matured leaves. On tomatoes having compound leaves, the petiole is the whole leaf stem with all the small petioliules (and

tiny leaflets) stripped off. In normal situations the leaf petiole will be about 8 inches in length.

Watermelon and Cantaloupe

Collect about 20 petioles from representative plants beginning at the 3-4 leaf stage. Take the youngest full-sized leaf which is usually the third or fourth leaf on Cantaloupe and the fourth or fifth leaf on watermelon.

Crop nitrogen needs and fertilization

Vegetable crops differ widely in their nitrogen needs, and in the pattern of uptake over the growing season. Fruiting crops such as tomatoes require relatively little nitrogen until flowering begins, then increase their nitrogen uptake, reaching a peak during fruit set and early fruit bulking period. As fruits mature, N demand drops again. Non-fruiting crops like celery and lettuce show slow nitrogen uptake through the first half of the season, with nitrogen needs increasing rapidly as harvest approaches.

Crops also exhibit distinct changes in nitrate levels as the crop grows. Highest values are seen during early vegetative growth, with declining nitrate concentrations thereafter. The decline is particularly steep for fruiting crops; as fruits begin to set and grow, they form a sink into which the plant pumps large amounts of nitrogen, limiting the amount of nitrate stored in leaf petioles. It is therefore important to correctly note growth stage at sampling to know what sufficiency standard to apply. The easiest method to monitor nitrate levels over time is to use a nitrate critical level graph like the ones in the appendix. It is easy to follow the current status of the crop by plotting the field test values on the graph in relation to the sufficiency levels for the particular crop and growth stage. However, if the graphs are not available the critical levels in the following table can be used.

Crop	Crop Development Stage	Fresh Petiole Sap NO3-N (ppm)
Broccoli	Mid growth	1000 - 1600
	Button formation	800 - 1200
	Preharvest	600 - 1000
Cabbage[1]	Cupping	1200 - 1500
	Early heading	1000 - 1200
	Mid heading	700 - 900
Cantaloupe	Early flower	1000 - 1200
	Fruit bulking	800 - 1000
	First harvest	700 - 800
Cauliflower	Mid growth	1000 - 1600
	Curd development	700 - 1000
	Preharvest	500 - 800
Celery	Mid growth	600 - 800
	Preharvest	400 - 600
Lettuce	Early head formation	400 - 600
	Preharvest	350 - 500
Onion[2]	Bulbs 0.5 - 1.5 inches	350 - 500
Pepper	Vegetative growth	900 - 1200
	Early flower/fruit	700 - 1000
	Fruit bulking	700 - 1000
	Preharvest	700 - 900
Sweet Corn	Entire season	600 - 700
Tomato	Vegetative growth	700 - 900
	Early flower/fruit	600 - 800
	Fruit bulking	500 - 700
	Preharvest	400 - 600
Watermelon	Early flower	900 - 1100
	Fruit bulking	700 - 900
	First harvest	500 - 700

1 - Based on one year of data
2 - Long-day type of onions

Monitoring soil nitrogen status

A simple technique for estimating soil nitrogen concentration is the 'quick-test' procedure. The procedure involves collecting a representative soil and extracting the nitrate with a known volume of an extracting solution. After the soil particles have settled out, the solution is analyzed using nitrate sensitive test strips. Since the soil and the nitrate extracting solutions are measured volumetrically, there is no need to dry or weigh soil.

SOIL NO_3-N 'QUICK-TEST' PROTOCOL

1. The soil quick test should be performed immediately before a sidedress fertilizer application. Collect a composite soil sample representative of the main root zone of the crop; blend thoroughly in a container. Don't include the top 2 inches of soil since it may be high in N but too dry for active root growth. If soil sampling is done just before a sidedress application, the nitrogen from the previous fertilizer application should have been diffused throughout the soil so the sampling location is not usually very critical. However, it is best to sample away from the fertilizer application points.

2. Fill a volumetrically marked tube or cylinder to the 30 ml level with .01M calcium chloride solution. A stock solution can be made by adding one-quarter ounce of calcium chloride to a gallon of distilled water. This will make enough solution for about 100 tests.

3. Add field moist soil to the tube until the liquid level rises to 40 ml; cap tightly and shake vigorously until soil is thoroughly dispersed. Let sit until soil particles settle out. Clods from very heavy clay soils are difficult to break down but they must be totally dissolved to get an accurate reading.

4. When solution is reasonably clear, dip a Mecrkquant nitrate test strip into the solution, shake off excess solution, and wait 60 seconds. Then compare the color on the test strip with the color chart provided.

Interpretation

The test strips are calibrated in parts per million (PPM) NO_3. The approximate conversion to PPM NO_3-N on a dry soil basis will require dividing by a correction factor based on soil texture and moisture:

Strip reading(PPM NO3) ÷ correction factor = PPM NO_3-N in dry soil

	Correction Factor	
Soil texture	Moist soil	Dry soil
sand	2.3	2.6
loam	2.0	2.4
clay	1.7	2.2

Soil less than 10 PPM NO_3-N would be considered quite low; levels above 20 PPM NO_3^--N have enough available nitrogen to meet immediate crop needs.

To minimize the variability inherent in soil sampling, run duplicate tubes for each field soil evaluated.

SUPPLY VENDORS

Cardy meter and supplies:

Spectrum Technologies 12010 S. Aero Drive Plainfield, IL 60544 (800) 248-8873	OR	J. S. Jaeger Supply Co. 9543 Roblin Court Elk Grove, CA 95758 (800) 549-9077

Nitrate Test Paper:

Ben Meadows Company 3589 Broad Street Atlanta, GA 30314 (800) 2416401	OR	Pike Agri-lab, Inc. RR 2 Box 710 Strong, Maine 04983 (207) 684-5131

Ask for: EM Quant nitrate test strips
0 - 500 Mg/liter Nitrate test range