Instructions: Soil Nitrate Quick Test for the Estimation of Nitrate-Nitrogen in 0-12" of Soil

Last revision: October, 2019

Overview: *This test produces an estimate of the concentration of nitrate-nitrogen (NO_3-N) in soil by: 1) combining a 3:1 ratio of slightly salty water to soil; 2) shaking vigorously for 3 minutes; 3) dipping an indicator pad into the mixed solution; and 4) using the resulting color on the pad to determine the soil nitrate-N concentration.*

A) Soil Sampling:

Materials Needed:

1) 5 gallon bucket or another suitable receptacle for holding/carrying several pounds of soil
2) Spade, auger, corer or another suitable tool for removing soil from the field at a known depth

Key Considerations:

1) Pay attention to sampling depth. Soil nitrate concentrations can vary by depth. The calibrations, conversions and interpretations discussed here refer to samples taken from the top 0 to 12 inches of soil depth.
2) Take a representative sample from your field. Your measurement will only be informative if your sample represents the area you are trying to manage. If not familiar with the principles of representative soil sampling, learn more about sampling for the determination of soil nitrate here: https://apps1.cdfa.ca.gov/fertilizerresearch/docs/Soil_Sampling_Nitrate.pdf.
3) Take a representative sub-sample from your bucket. Just as with your field-based sample, the soil that you remove from your bucket for the quick test should represent the average soil in the bucket. So, once you have collected a number of soil samples from throughout your field, break larger clods into smaller clods (the smaller the better but 1/2" in diameter or smaller is a good target) and thoroughly mix the contents of the bucket. In addition, when removing the soil samples that you will use in the test, remove many small portions of soil from different parts of the bucket (aim for 10-20) rather than taking a few large portions. Also, avoid adding anything except soil (e.g. rocks, debris).

B) Conducting the Soil Nitrate Quick Test:

Materials Needed:

1) Nitrate test strips. These strips indicate the nitrate concentrations in a solution through a visual comparison of the strip to a color ramp with pre-defined nitrate values associated with different colors (bottle of 50 test strips).
2) Cylindrical bottle with a cap. Although the volume and specific type of bottle are flexible, we have found that a cylindrical, 500 ml bottle works well for this test (pack of 12 bottles).
3) Purified or Distilled Water (1 gallon). Water from wells can contain nitrate-N. Using purified or distilled water ensures that the nitrate-N you measure is from the soil.
4) Calcium chloride (aka Pickle Crisp); 1 tsp per gallon of purified or distilled water. This salt helps disperse the soil and put the nitrate into solution so that it can be readily measured.
5) Nitrate reference solution. This is a liquid with a known concentration of nitrate-N. It is useful for ensuring that the test strips in your bottle are working properly (they have an expiration date). It also helps you to calibrate your eye to the color ramp on the bottle. A 10 ppm concentration solution is recommended (500 ml bottle of 10 ppm solution).

Preparing Materials:

1) *Because the calibrations assume a 3:1 ratio of liquid to soil, this step is very important!* Mark the 500 ml bottle to indicate a 3:1 ratio of liquid to soil. To do this, first measure 300 ml of water using a volumetric device like a measuring cup. If you don't have a volumetric measuring device, you can also weigh 300 g of water on a kitchen scale. Place the bottle on a level surface and pour the 300 ml volume in the bottle. On the side of the bottle, mark the upper level of the water. Remove the water. Repeat the same steps using 400 ml of water. Now you will have two lines on the side of your bottle. The lower line is the "3" and the upper line is the "1" in your 3:1 ratio. Although slightly less precise, if your bottle is cylindrical in shape, you can also measure the locations for your 3:1 ratio. For example, measure 3 inches from the bottom of the bottle to the lower line and 4 inches from the bottom of the bottle to the top line.
2) Add 1 tsp of calcium chloride (Pickle Crisp) to 1 gallon of purified or distilled water. Shake until granules dissolve. This will be your mixing solution.

Performing the Extraction:

1) Fill the 500 ml bottle to the lower line with your mixing solution (1 gallon water plus 1 tsp pickle crisp).
2) Add a representative sub-sample of soil from the bucket until the liquid in the bottle reaches the upper line. Avoid adding anything except soil (e.g. rocks, debris).
3) Place the cap on the bottle and shake vigorously for 3 minutes (time yourself—it's hard work!).
4) Allow the solution to settle for 2-3 minutes.
5) While the solution is settling, test that your bottle of test strips is accurately measuring 10 ppm nitrate-N. Pour a small amount of the 10 ppm nitrate reference solution into a bottle cap. Dip a test strip into this liquid until the pad is saturated (to avoid contamination, don't dip directly into the reference solution). Note that there are two pads on the strips, and the lower pad is for the determination of nitrate-N. Allow the color to develop for 60 seconds and then compare the color on the pad to the color ramp on the side of the bottle. It should read 10 ppm.
6) Now you are ready to measure your soil solution. Using a second test strip, dip the lower pad gently into the very top of the shaken solution. You want to avoid obscuring the color on the pad with soil, so only place the tip of the pad (a quarter or less) into the liquid and allow the solution to wick up the pad until the whole pad is saturated rather than dunking the whole pad into the solution. Once saturated, allow the color on the pad to develop for 60 seconds and then compare to the color ramp on the side of the bottle to determine the nitrate-N concentration.

Interpreting Test Results:

1) Translate the quick test value to a lab value. Quick test values tend to underestimate nitrate-N concentrations compared to soil nitrate-N determined using laboratory methods, particularly for lower concentrations of nitrate-N. As a result, a correction factor is needed to translate the concentration measured on the test strip pad to a lab equivalent value. This translation will vary slightly depending on the soil type. Mineral soil types have higher bulk density than organic soil

types. This means that there are more soil particles in the same volume of a mineral soil compared to an organic soil. Because a) this test measures the amount of soil volumetrically (by displacing the liquid until the solution in the bottle reaches the higher line), and b) we add the same volume of soil regardless of the soil type, more soil particles are added from a mineral soil than an organic soil. As a result, the correction factor is smaller for a mineral soil than it is for an organic soil. Use the below chart to translate pad values to lab values. For reference: the average bulk density of the mineral soils used in this calibration is approximately 1.4 g cm^{-3}; the average bulk density of the organic soils used in this calibration is approximately 1.0 g cm^{-3}.

Mineral soil type (1.4 g cm^{-3})		Organic soil type (1.0 g cm^{-3})	
Pad value (ppm)	Lab value (ppm)	Pad value (ppm)	Lab value (ppm)
0	0	0	0
0.5	2	0.5	5
2	6	2	9
5	10	5	14
10	15	10	20
20	23	20	27
50	40	50	41

2) Understand the accuracy of the test. Based on hundreds of samples across several soil types and a wide range of nitrate-N concentrations, we have found the value on the pad to be accurate to approximately 40% of a lab-measured value. What this means in practical terms is that if you measure 20 ppm on the pad from a mineral soil, you can be confident that your sub-sample of soil would be between 14 and 32 ppm nitrate-N if it were measured in a laboratory setting.
3) What does the value mean in terms of fertilizer equivalence? For soil samples taken from 0 - 12 inches, multiply the lab equivalent value by 3 (organic soil) or 4 (mineral soil) to get an approximate fertilizer equivalence (in lb $acre^{-1}$ N). For example, a quick test pad value of 10 ppm measured on a soil sample taken from the top 12 inches in a mineral soil type would have a lab equivalence of approximately 15 ppm. This represents approximately 60 lb ac^{-1} N available in the nitrate form in the top foot of soil. Considering the accuracy of the test, this is a range of about 40 to 80 lb ac^{-1} N.
4) False positives and false negatives. The nitrate quick test is useful for providing a ballpark estimate of whether your soil nitrogen status is high, medium or low. Generally speaking, this test doesn't yield false positives. That is, if your soil sampling techniques are representative of your field conditions, high values are probably real. Whereas, medium and low values may be harder to interpret because false negatives (because the test wasn't conducted properly or your strips aren't working) are more of a possibility.
5) Final considerations. It is important to remember that this test is a snapshot in time of one important and highly plant-available form of nitrogen (nitrate-N). However, nitrogen has many forms and is very dynamic in cropping systems. So, a measurement taken at a particular moment in time may not reflect future conditions, especially if rainfall, irrigation or other environmental changes occur subsequent to the test. Nevertheless, when taken at a time when an N fertilizer application decision is being made, it can help to narrow or modify the range of rates that may be appropriate.

Links to test materials:

WaterWorks Nitrate/Nitrite Nitrogen test strips (50 pack):
https://www.amazon.com/Industrial-Test-Systems-480009-WaterWorks/dp/B003R0RVLQ

United Scientific Polypropylene Wide Mouth Reagent Bottles, 500ml (12 pack):
https://www.amazon.com/United-Scientific-33309-Polypropylene-Capacity/dp/B00ES3PX6G?ref_=fsclp_pl_dp_2

Distilled Water, 1 gallon, e.g.
https://www.walmart.com/ip/Great-Value-Distilled-Water-1-Gallon/10315382

Pickle Crisp Granules 5.5 oz (Calcium Chloride):
https://www.amazon.com/Ball-1440072750-Pickle-Crisp-Granules/dp/B003IOEWL8

Nitrate Standard Solution, 10mg/L, 500ml:
https://www.hach.com/nitrate-standard-solution-10-mg-l-500-ml/product?id=7640206190

5 gallon bucket, e.g.
https://www.homedepot.com/p/The-Home-Depot-5-Gal-Homer-Bucket-05GLHD2/100087613

Related Resources:

Sampling for Soil Nitrate Determination
https://apps1.cdfa.ca.gov/fertilizerresearch/docs/Soil_Sampling_Nitrate.pdf

CDFA-FREP Nitrate Quick Test:
https://blogs.cdfa.ca.gov/FREP/index.php/nitrate-quick-test/
and
https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/NitrateQuickTestWeb.pdf

Using the Pre-Sidedressing Soil Nitrate 'Quick Test' to Guide N Fertilizer Management:
https://vric.ucdavis.edu/pdf/FERTILIZATION/fertilization&soil_Using%20the%20pre-sidedressing%20soil%20nitrate%20%E2%80%98Quick%20Test%E2%80%99%20to%20guide%20N%20fertilizer%20management.pdf

UC Salinas Valley Agriculture Blog: Details on the Nitrate Quick Test:
https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=4406

Quick Tests for Improved Precision of N Fertilization:
http://smallgrains.ucanr.edu/files/256250.pdf

Acknowledgments:
A wide range of University of California Cooperative Extension personnel have contributed to the development of this information, including: Taylor Nelsen, Konrad Mathesius, Michael Rodriguez, Jessica Schweiger, Ethan McCullough, Taylor Becker, Nicholas Clark, Sarah Light, Michelle Leinfelder-Miles, Thomas Getts, Giuliano Galdi, Jessica Henriquez, Rozana Moe, Leah Puro, Jonathan Slocum, Eric Williams, Quinn Levin, Steven Spivak, Maria Sandate-Reyes, Serena Lewin, Ryan Byrnes, Jason Tsichlis, Katherine Mulligan, Nic George, Darrin Culp, Steve Orloff, Steven Wright, Robert Hutmacher, Dinh Giang, Gabriel Rosa, and Mark Lundy. For questions regarding this information, please contact Mark Lundy (melundy@ucdavis.edu).

Digital Copy available at: http://smallgrains.ucanr.edu/Nutrient_Management/snqt/