Nitrogen Dynamics
Feeding the Crops that Feed Us

Overview

All plants require nitrogen in relatively large amounts and nitrogen is the most commonly limiting nutrient in agriculture. Consequences of insufficient nitrogen in a crop include slow growth, small plant size, pale and yellowish coloration, and reduced yields. Farmers typically add substantial quantities of nitrogen to fields in order to produce higher yields; this sometimes leads to negative environmental impacts.

We can measure soil nitrate levels to estimate whether there is sufficient nitrate in the soil for good crop growth. This activity allows students to measure the amount of nitrate present in the soil in different areas of the farm and determine whether the amount present is insufficient, sufficient or excessive for optimum crop growth. In this activity the students also explore how environmental and management factors can impact nitrogen dynamics. Students will be able to assess how much nitrogen is available for peak crop production and think about which farming practices might mitigate possible negative environmental consequences when supplying nitrogen to crops.

Resource References

The California Nitrogen Assessment, Agricultural Sustainability Institute- UC Davis
http://asi.ucdavis.edu/research/nitrogen

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Introduction

Nitrogen is an essential nutrient for crops, and productive crops need relatively large amounts of nitrogen. Consequences of insufficient nitrogen in a crop include slow growth, small plant size, pale and yellowish coloration, and reduced yields. Because of its critical role in high-yielding crop production, farmers in the U.S. typically add 100 – 250 lbs of nitrogen per acre per cropping cycle.

Most of the earth's nitrogen is in the form of a gas that is abundant in the atmosphere. However, plants cannot absorb this nitrogen unless it is first converted into a mineral form. This process is called nitrogen fixation and it can occur in the various places, most notably in the roots of certain plants, such as beans and peas, and in fertilizer factories. There are several forms of mineral nitrogen. We are particularly interested in nitrates (NO_3), because nitrates are the main form of nitrogen used by most crops.

We can measure soil nitrate levels to estimate whether there is sufficient nitrate in the soil for good crop growth. For most vegetable crops, soils with "Nitrate Nitrogen" (NO_3-N) concentrations of 10 ppm or less have limited N availability and insufficient nitrogen will likely result in decreased crop productivity. Soils with levels greater than 20 ppm NO_3-N generally have sufficient nitrogen to provide the crop with all of the nitrogen it needs for several weeks without additional N fertilization. Crops grown in soils with between 10 and 20 ppm NO_3-N might respond to fertilization, but not as dramatically as those grown in soils with less than 10 ppm NO_3-N. Because low soil nitrate levels can lead to decreased yields, many farmers try to ensure that there is sufficient nitrate in the soil (e.g. 20 ppm Nitrate-N, or more) to satisfy crop demand during the season.

Nitrogen Losses

Unfortunately, the nitrate form of nitrogen can also escape from farming systems and lead to water and air pollution. When soil nitrate concentrations are high, there is more nitrogen that can potentially be lost from the system. However, many factors besides nitrate concentrations in the soil solution influence whether nitrates are lost from the system and, if so, how much is lost and how quickly. The main processes by which nitrates are lost from the system, and the factors that contribute to those losses, include:

- Nitrate leaching: can occur when water carrying nitrate moves through the soil, past the crop root zone and into deeper layers below the soil. Such water often ends up in ground water. Thus, high irrigation or rainfall rates in excess to a crop's water needs can often leach nitrates into ground water. If high nitrate ground water is used for drinking water, it can cause health problems.

- Runoff: can occur when rainfall (or irrigation) rates exceed a soil's capacity to absorb water. The excess water flows from geographically higher areas to lower ones and often ends up in surface waters such as rivers and lakes. This excess water can contain nitrates and other pollutants that can negative impacts on water quality aquatic organisms.

- Denitrification: is the conversion by certain soil microbes (under anaerobic conditions) of nitrate to various N-containing gases. These gases volatilize from the soil into the atmosphere. One of these gases, nitrous oxide, is a potent and important greenhouse gas. High moisture contents in soils (e.g., saturated or waterlogged situations) lead to anaerobic conditions, thus excess soil water tends to lead to denitrification.

Thus, nitrogen poses significant challenges for managing cropping systems to be both productive and sustainable because nitrate is the predominant form of nitrogen that is absorbed by crops and it is also the form that is most likely to lead to pollution of air and water. Adding to this challenge is the complexity of soil nitrogen dynamics and the fact that the amount of nitrate in the soil often varies substantially over the course of a season (or even a few weeks). Therefore, understanding what controls and changes nitrate concentrations in soils is important to sustainable nitrogen management.

To Lead This Activity You Need to Know

Facilitators of this activity need to have basic understanding of the following concepts in order to effectively lead students through this activity:

- Nitrogen fixation
- Nitrate use in agriculture
- Nitrogen dynamics and external factors that govern them (weather, time of the year, etc.)
- What causes nitrogen losses and how nitrogen losses can be minimized or prevented

Key Concepts

- The nitrogen cycle
- Use of nitrogen in agriculture
- Ways that nitrogen is lost out of the farming system

Objectives

- Increase your understanding of soil nitrogen dynamics and their practical implications
- Make and record field observations, collect samples and perform simple in-field analysis
- Analyze and interpret field data
- Develop an understanding of the relation between nutrient monitoring and nutrient management decisions and actions

Materials

- Field areas with different nitrogen and management histories (ideally, including some of the following: a recently fertilized area, an overwatered or flooded area, an recently harvested area, a fallow area, and that has had a legume cover crop)
- Containers for collecting soil (1 qt containers work well)
- 50 mL centrifuge tubes (one for every group) and a rack for holding them.
- Calcium chloride and distilled water (for CaCl solution)
- Nitrate test strips

Preparation

- Identify three areas on your farm or fields that have different nitrogen histories to use for the activity. (Examples would include somewhere overwatered, an area where cover crop has been grown, or an area where a feeder crop has been grown.)
- If you do not have centrifuge tubes, calcium chloride, or nitrate test strips, these can easily be purchased online through a basic Internet search.
- Create a (approximately 0.01M) CaCl solution by dissolving 1.5 g ofcalcium chloride in 1 liter of distilled water. A liter of CaCl solution will be sufficient to process about 30 soil samples.

Activity (45-50 minutes)

1. Introduce activity by discussing why plants need nitrogen. Go over the nitrogen cycle, explaining nitrogen fixation, and denitrification and nitrate leaching. Discuss how farmers add different forms of nitrogen to feed crops and how crops mostly take up nitrates, regardless of the form of nitrogen added.

2. Have students work individually or in pairs. Each student or pair should have one tube, a container to collect soil in, one activity sheet provided below, and a nitrate test strip. Assign each student or pair to one of the different areas with different nitrogen histories.

3. Have students start working through the instructions on the activity sheet below. Make sure that students are aware of the area's nitrogen history and what impacts that history might have on the soil's nitrate levels.

5. While the particles settle in the sample taken, discuss the ways that farming systems lose nitrogen through denitrification, leaching, and run-off. Discuss the economic and environmental consequences involved with losing this nitrogen. Discuss possible ways to mitigate these losses.

6. Have students use nitrate test strips to test their nitrate levels, record findings, and write a nitrogen management plan for their soil, as directed in the activity sheet.

8. Conclude the lesson by comparing the different nitrate levels in the different soil areas. These questions can be used to help guide the discussion:

- According to our results, what impact does flooding or excessive water have on NO_3 level in a soil? What do you think happened to the NO_3 (e.g., where did it go)?
- Which field area had the most and least amounts of nitrate nitrogen? What were their histories and how might these histories explain our results?

9. Have students share their management strategies for applying nitrogen sustainably.

Nitrogen Dynamics
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Activity Sheet

1. Describe the nitrogen history of your field or garden (has there been cover crop planted, fertilizer applied, has there been heavy rainfall or irrigation or at a low gully that gets saturated by water, etc.)

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2. Take your soil sample and prepare it for nitrate determination:

a) Label a centrifuge tube with your name and the field area name. Fill the centrifuge tube to the **30 ml level** with the .01 M $CaCl_2$ solution.

b) Take 5 random samples from you designated area, collecting subsamples from the top 8" of the soil. Place all of your subsamples in a plastic container and blend them thoroughly. This is your 'composite sample.'

c) Add a small amount of your thoroughly blended composite sample to the tube until the level of the solution rises to **40 ml**. *<u>Do not include any insects, worms, etc., and minimize the amount of visible plant residues, insects, worms, etc. in the tube</u>*. Cap tightly and shake vigorously until all clods are thoroughly dispersed.

d) Place the tube upright in the rack so that the soil particles can settle.

3. Think about how nitrogen can be lost in a farming system (e.g., denitrification, leaching, run off). Considering this, broadly estimate how much nitrate content you think your soil might have. Explain your hypothesis.

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4. Use the test strips to determine the nitrate level in the soil sample:

a) Make sure the soil particles have settled and there is a clear zone at the top of the tube. Dip a nitrate test strip into the clear zone of solution, shake off excess solution, and wait **<u>60 seconds</u>**.
b) Compare the color that has developed on the strip at the 60 second point with the color chart provided on the test strip container.
<u>You may need to estimate because your color may be between the colors on the chart.</u>

5. What is the estimated nitrate level (test strip reading) of your sample?

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6. Convert the results from your test strip reading to a NO_3-N concentration for dry soil basis**.** The nitrate test strips are calibrated in parts per million (ppm) NO_3^-. You will convert this number to ppm NO_3-N of dry soil, using the following equation and table:

a) After making your crop observations, use the test strips to determine the nitrate level in the soil sample.

b) Indicate your own Soil Nitrate-N Quick Test results below.

Field area	Test Strip Reading		Correction Factor		**NO_3-N in dry soil (ppm)**
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*[Equation: **Test Strip Reading ÷ 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

7. Now that you know the nitrate level of the soil in your plot, write up a nitrogen management plan that considers sustainable application in order to minimize environmental effects.

Consider the following in your plan:

- What time of the year would your crop of choice need nutrients?
- What weather conditions are most optimal?
- What ways can you lose nitrogen and how do you avoid them?
- What time of year would be best to apply nitrogen?
- Knowing your current nitrogen level, how much would you apply?

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