Soil, microbes, and plants

Focus questions	What are the relationships between soil microorganisms such as nitrogen-fixing bacteria and plants? Has the introduction of nitrogen fertilizers into soil ecosystems impacted the populations of soil microorganisms? How can we maximize corn growth while limiting fertilizer use?
Vocabulary	nitrogen, fertilizer, nitrogen-fixation, nitrogen forms (ammonium NH_4^+, ammonia NH_3, nitrite NO_2^-, nitrate NO_3^-, nitrogen gas N_2), exudate, leaching, eutrophication, yield

This investigation will ask you to evaluate the claim that **nitrogen** amendments in modern agricultural practices impact the stability of soil ecosystems. The three major nutrients found in soil are nitrogen (N), phosphorus (P), and potassium (K). Bacteria and other microorganisms in the soil allow for **nitrogen fixation** to happen (unusable atmospheric nitrogen is converted into usable nitrogen for the plant) and can increase nitrogen levels in the soil. This is an important part of the nitrogen cycle for plants and in many cases what limits the growth of producers.

Nitrogen makes up approximately 77% of our atmosphere. This form of nitrogen is of no value to plants and animals. Nitrogen gas (N_2) is captured from the air by species of bacteria and is made into **nitrates (NO_3^-).** Nitrogen then enters the food web when plants absorb those nitrates and make proteins, an essential macromolecule to animals. Consumers get the nitrogen by eating plants or other animals that contain nitrogen. They reuse the nitrogen and make their own proteins. In addition to this, nitrogen can be returned to the soil when an animal urinates or when an organism dies and decomposers go to work, in the form of **ammonia (NH_3).** Other organisms in the soil can convert ammonia into usable nitrogen compounds that will re-enter the food web. When **ammonium (NH_4^+)** is added to the soil as a fertilizer or by bacteria converting atmospheric nitrogen, it can be converted into **nitrites (NO_2^-)** and again into nitrates by different species of bacteria.

Nitrogen within a plant aids in its growth and development. Plants that lack nitrogen appear yellow, do not grow as well, and produce lower **yields.** When plants are given enough nitrogen, they are able to produce the proteins that help them to grow. One of the specific things nitrogen can do for a plant is help with the production of chlorophyll. The more chlorophyll that a plant has, the more efficient it can be in conducting photosynthesis and the more food it can make. The photosynthetic reactions occurring in their leaves are then used to produce chemicals, known as **exudate,** which they secrete through their roots. Root exudates are in the form of carbohydrates and proteins. Their presence in the soil wakes up, attracts, and grows specific beneficial bacteria and fungi that subsist on these exudates and the cellular materials sloughed off as the plant's root tips grow. These interactions between microorganisms and plants help to maintain soil structure, nutrient availability, and ecosystem stability.

Some bacteria have lessened or stopped going through nitrogen fixation altogether due to additional amounts of nitrogen added to the soil. Generally, if farmers want to get more nitrogen into the ground they need to rotate their crops. Farmers will make sure to plant crops (legumes) that will help return nitrogen levels after planting a crop that has removed a lot of nitrogen from the

soil. Farmers also can add nitrogen to the soil through the application of **fertilizers.** Farmers need to be careful to apply the correct amount of fertilizer at the appropriate time so they can maximize yields and minimize **leaching** and **eutrophication.** Runoff from agricultural fields can contain excess nutrients, not assimilated by plants, that enter into surrounding watersheds. Nitrates (NO_3^-),the most usable form of nitrogen by plants, are also the most prone to leaching (drain away from soil with percolating water) and possible eutrophication of water systems. Nitrates support freshwater eutrophication (an excessive amount of nutrients in water systems that supports algae growth), but are secondary to phosphorus, the limiting factor in freshwater algal blooms. How can the addition of nitrogen impact soil ecosystems?

Materials

- Soil
- 3 2-L bottles (cut in half) per group
- Field (dent) corn seed
- Fertilizer containing Nitrogen (Urea)
- Nitrogen fixing microbe product
- Soil nitrogen tests

Procedure

1. Evaluate the claim, evidence, and reasoning that nitrogen amendments in modern agricultural practices will impact the stability of soil ecosystems below.

Claim	**Evidence**	**Reasoning**
Nitrogen amendments in modern agricultural practices impact the stability of soil ecosystems.	• Nitrogen amendments replace nitrates (NO_3^-) that nitrifying bacteria produce in ecosystems. • Nitrates are the most usable form of nitrogen for plants.	• Nitrates are necessary for plant growth (help to produce proteins). • Nitrates in soil decrease plant production of exudates. • Fewer soil exudates attract nitrifying bacteria to the root zone in soils. • Microorganism populations are impacted due to abiotic factors in the soil ecosystem. • Soil ecosystem stability is negatively affected.

2. Research the positive and negative effects that adding nitrogen fertilizer to corn fields has on the soil ecosystem. Include your research in your experimental design below.

3. Design an experiment that will test the impact that nitrogen fertilizer has on soil microorganisms and corn growth.

4. Evaluate the empirical evidence that you collect in your investigation and compare this evidence to the claim, evidence, and reasoning above.

5. Report your conclusion to the class, utilizing your research and empirical evidence to support or refute the claim above.

Experimental design

Research the claim that nitrogen amendments in modern agricultural practices impact the stability of soil ecosystems.

Hypothesis

Make a claim that is testable and can be supported by evidence.

Materials

List the materials used in your experiment.

Procedures

Outline your experimental procedure below. Be sure to indicate your control group, independent variable, dependent variable, and experimental group.

Data

Present your data in table and graphical format.

Conclusion

Based on your findings from the lab, what conclusions can you draw? Write a conclusion to show your interpretation of the data and how it relates to the claim, evidence, and reasoning above.

Resources to help you in your investigation:

- Microbes in your soil
  ucanr.edu/sites/CalaverasCountyMasterGardeners/files/203582.pdf
- What happens to nitrogen in soils?
  agrilifeextension.tamu.edu/library/gardening/what-happens-to-nitrogen-in-soils/
- The Role of Symbiotic Nitrogen Fixation in Sustainable Production of Biofuels
  ncbi.nlm.nih.gov/pmc/articles/PMC4057678/
- Nitrogen in Plants
  cropnutrition.com/nutrient-management/nitrogen
- Types and Uses of Nitrogen Fertilizers for Crop Production
  extension.purdue.edu/extmedia/ay/ay-204.html

Rubric for self-assessment

Skill	Yes	No	Unsure
I can describe the strengths and weaknesses to be evaluated in my investigation.			
I understand that adding nitrogen fertilizer to soil ecosystems impacts the relationship between nitrogen-fixing bacteria and plants.			
I can provide evidence and reasoning to show how modern agricultural techniques have impacted the microbial populations in soil ecosystems.			