

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
Learning target	Students will test the impact soil microorganisms have on plant growth and nutrient availability.

HS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Performance expectation HS-LS2-6	Classroom connection: Students will research claims, design an investigation, and use empirical data to construct an argument on the impact of microorganisms on nitrogen availability to plants.
--	--

Science and engineering practices

Engaging in Argument from Evidence	Classroom connection: Students will use empirical evidence to construct an argument to determine if microorganisms improve nutrient availability to plants, thereby improving plant growth.
---	--

Disciplinary core ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience	Classroom connection: Nitrogen-fixing bacteria populations change in ecosystems with fertilizer added to fields to improve plant growth.
---	---

Cross-cutting concepts

Stability and Change	Classroom connection: Students introduce nitrogen to a soil ecosystem to determine its impact on microbial populations and plant growth.
-----------------------------	---

This lesson is focused on students engaging in argument from evidence to evaluate the claim that nitrogen amendments in modern agricultural practices impact the stability of soil ecosystems.

Background

The three major nutrients found in soil are **nitrogen** (N), phosphorus (P), and potassium (K). While nitrogen makes up approximately 77% of our atmosphere, this form of nitrogen is of no value to plants and animals. Bacteria are responsible for a large part of nitrogen-fixation in soil, as Nitrogen gas (N_2) is captured from the air by species of bacteria and is made into nitrates (NO_3^-). Bacterial microorganisms in the soil allow for **nitrogen-fixation** to occur and can increase nitrogen levels in the soil.

Humans also have a large impact on the nitrogen cycle. Nitrogen within a plant aids in its growth and development, specifically in the production of chlorophyll. Plants that lack nitrogen appear yellow, do not grow as well, and produce lower yields. The more chlorophyll that a plant has, the more efficient it can be in conducting photosynthesis and the more food it can make. This increases **yield** and ultimately helps farmers to produce more food for the people throughout the world.

Generally, if farmers want to increase the levels of nitrogen in the soil they will practice crop rotation, plant legumes and/or add **fertilizer** to the soil. Fertilizers are an important aid to plant growth, but when fertilizers are applied, these bacteria may become less efficient at their jobs or stop fixing nitrogen altogether. Some nitrifying bacteria have lessened or stopped producing nitrogen forms that are usable to plants (**ammonia NH_3 , nitrites NO_2^- , nitrates NO_3^-**) due to additional amounts of nitrogen that are added to that soil.

Recently, different companies have come up with a product that might help lower fertilizer demands. They have isolated microbial strains that can be added to the soil during planting. These microbes provide enzymes to break down and convert organic matter into nutrients that are made available to the plant. This strengthens the root system, increases growth, and lowers the demands for fertilizer application by increasing the amount of nitrates taken in by a plant. This will also 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. The more farmers can minimize fertilizer usage while continuing to maximize yields for feeding the world's population, the more sustainable our environments will be.

Prior knowledge

Students will need to be familiar with the nitrogen cycle and the role nitrogen plays in plant growth. Students should be aware that bacteria in the soil help to turn atmospheric nitrogen (N_2) into a usable form for the plant, nitrate (NO_3^-).

Materials

- Soil
- 3, 2-L bottles (cut in half) per group
- Field (dent) corn seed
- Fertilizer containing nitrogen (urea)
- Nitrogen-fixing microbial soil amendment such as CisBay
- Soil nitrogen tests

Teacher preparation

This lab will take approximately 4–5 weeks to complete.

- 1 to 3 class periods should be made available to students to research the role of nitrifying bacteria within the soil ecosystem and the human impact of fertilizer into an ecosystem.
- Students will need 1 class period to design their investigation and 1 day to prepare the experiment.
- 3–4 weeks will be needed to measure plant growth and measure nitrogen levels.
- Students will collect data throughout this time and will need 1 day to report their findings back to the class.

You will need three important materials for your students to complete this investigation.

- Locate a microbial product that adds nitrogen-fixing bacteria to the soil for student use. There are several agricultural companies that provide products that maximize nitrogen availability to plants, such as CisBay.
- Purchase pelletized urea as a nitrogen source for students. You can find urea at your local garden store or farmer co-op. Urea can be used as a dry time-release fertilizer if sprinkled around the base of a plant, or as a liquid fertilizer by mixing 113 grams of urea to 1.9 liters of water resulting in a 28-0-0 solution.
- Provide soil for the experiment. Corn can be grown in soil found outside your classroom or home or in a potting soil mix. However, it is important to purchase a potting soil mix that does not already have fertilizer blended into it. Corn will grow best in a greenhouse or sunlit area that can assure that the soil will stay at or above 21° C.

Claim	Evidence	Reasoning
Nitrogen amendments in modern agricultural practices impact the stability of soil ecosystems.	<ul style="list-style-type: none">• Nitrogen amendments replace nitrates (NO_3^-) that nitrifying bacteria produce in ecosystems.• Nitrates are the most usable form of nitrogen for plants.	<ul style="list-style-type: none">• 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.

Resources

- Microbes in your soil
ucanr.edu/sites/CalaverasCountyMasterGardeners/files/203582.pdf
- What happens to nitrogen in soils?
agriflifeextension.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
croppnutrition.com/nutrient-management/nitrogen
- Types and Uses of Nitrogen Fertilizers for Crop Production
extension.purdue.edu/extmedia/ay/ay-204.html

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students are encouraged to have conversations with local individuals involved in agriculture (farmer, agronomist, hired-man, etc.). If you live in an urban environment you can have conversations with local 4-H or Soil & Water representatives in your county. Talk with them about how they assure their crops are getting the appropriate amounts of nitrogen and how to avoid some of the negative effects fertilizers might have on the ecosystem.
- **Students with special needs (language/reading/auditory/visual):** Modifications can be made in the research phase to help them better understand that nitrogen should aid in the growth of corn. There are 2 ways we could increase nitrogen uptake for corn in this lab:
 - Add nitrogen in the form of urea (as a fertilizer).
 - Add microbes to the soil to help with nitrogen fixation.
- They should design an experiment that tests the effects of nitrogen on corn growth based on this information.
- **Extra support:** youtu.be/w03i0_Yu9Xw
- **Extensions:** Challenge students to explore ways in which farmers could reduce fertilizer usage but still maximize yields. They can also discuss how maximizing yields is important for food production and financial productivity.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Identifying Explanations and the supporting claims, evidence and reasoning	Student is able to explain that interactions in ecosystems are complex but maintain consistent populations in stable ecosystems.	Student is able to identify factors that can alter the stability of ecosystems and explain how populations may be impacted by said factors.	Student is able to identify the given explanation for the soil ecosystem disturbance and cite the claim and evidence, as well as give reasoning to be evaluated.
Identifying additional evidence that is relevant to the evaluation.	Student can identify the forms of nitrogen that are important for plant growth.	Student can identify the forms of nitrogen that are important to plant growth and provide information on nitrogen amendments to the soil for corn growth in agricultural production.	Student can identify microbial applications that can aid in the conversion of nitrogen into unusable forms for corn growth and provide an explanation about how the input of nitrogen fertilizer is impacting the symbiotic relationship of nitrifying bacteria and plants.
Evaluating and critiquing	Student can produce empirical evidence to support reasoning of human impact on soil ecosystems due to nitrogen amendments in agricultural fields.	Student can evaluate how microbial products would benefit corn growth.	Student can evaluate empirical data to determine if microbial products can benefit both corn growth and microbial populations in the soil ecosystem.

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.			