USDA NRCS
Natural Resources Conservation Service

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SOIL BIOLOGY CLASSROOM ACTIVITIES

For more soil biology information see The Soil Biology Web Page (from the NRCS Soil Quality Institute) at http://soils.usda.gov/sqi.

Soil Biology Classroom Activity #1
EARTHWORM FARM

DESCRIPTION

Set up an earthworm farm and watch how earthworms bury surface residue and mix soil.

LESSON

Earthworms are significant for mixing soil, increasing decomposition of plant material, and improving water infiltration and water holding capacity.

BACKGROUND

Some earthworms are native to the US, but many species, including *Lumbricus terrestris* (the night crawler), were introduced from Europe. Most prefer well-aerated, moist soil. Earthworms are uncommon in arid areas, and sandy soil. Ultraviolet light (sunlight) will kill earthworms.

Earthworms ingest soil and organic matter, get their nutrition from the microorganisms living in the organic matter, and then egest "casts" – a mixture of soil and organic matter. Where earthworms are common, much of the soil has passed through the guts of an earthworm.

The mechanical action of tillage kills some worms, but more importantly, tillage removes the surface residue that earthworms need for food and protection from desiccation and predation. Earthworms especially like fungi, which thrive in minimally-tilled soil.

Lumbricus terrestris has many common names including night crawler, dew worm, and angleworm. They are one of several species (called "anecic") that form deep, relatively permanent burrows. In contrast, "endogeic" species meander around in the upper soil, filling their channels with casts as they go. Both types are important for mixing soil and improving soil structure.

Bacteria and fungi decompose organic matter. Worms encourage decomposition by shredding plant residue and mixing it with soil, microbes, and water.

Earthworms change the physical structure of the soil in ways that improve the rooting environment for plants and increase the amount of water held by soil. They create burrows that speed the movement of water into and through the soil and provide nutrient-lined channels for root growth. They create casts that become stable soil aggregates.

TIME AND MATERIALS

- one dozen night crawlers
- one or two dishpans, or deeper containers.
- soil to fill the container(s).
- dry plant material
- Allow at least one week for surface residue to disappear and worm casts to appear. Allow several weeks or preferably months to observe soil mixing.

PROCEDURE: Earthworms bury plant litter

1) Get a dozen night crawlers. Buy them from a bait shop, or collect them from dark-colored, moist soil.

2) Fill one or two dishpans with soil. Use two pans if you would like to set up an experiment in which one pan has earthworms and the other is a control. However, for demonstration purposes, a single container works fine. Fill the pan(s) with any medium-textured soil. Do not use peat, and do not use soil with much sand—it is abrasive to worms. The soil should be kept moist, but not soggy. Moisten the soil slowly, if needed. You may punch a drain hole in the pan to insure that no water sits at the bottom.

3) Place 6-12 earthworms on the surface of one pan.

4) Sprinkle plant material on the surface. Use dry leaves, grass clippings, or residue from a farm field. Make a single thin layer leaving some soil visible. If you use two pans, be sure both have the same type and amount of material.

5) Make daily observations for at least a week. Look for burrow openings, casts, and the disappearance of plant material.

Earthworm farm (cont.)

VARIATION: Earthworms mix soil

1) Acquire a clear container(s). Build one or two plexi-glass containers 2-3 ft. tall, 1-2 ft. wide, and 2-4 inches from front-to-back. (As in the first procedure, the second container is optional, but can be used as a "control".) Drill drain holes in the bottom. A fish tank works, but be careful that water does not collect in the bottom, and remember that the amount of soil will be extremely heavy. A two liter bottle with the top cut off may work, but it may be more difficult to keep the worms alive.

2) Find soil of two different colors. As mentioned above, avoid sand and peat. Fill the container(s) with 1"-2" layers of alternating soil colors. A sand or clay layer could be added to see how worms respond to barriers.

3) Add earthworms and plant material as in steps 3 and 4 above. Add more plant material as it is consumed.

4) Observe. If you use two containers, the one without earthworms can be used for comparison as worms change the other. If you use one container, take pictures periodically, or mark the location of the original layers. You can keep the system going, and watch increasing amounts of soil mixing over months or years. If the worms die, remove them if possible and add new ones.

HINTS

Do not overload the system by using too many earthworms, too much surface residue, or too much water. You are not making a compost pile; you are imitating a farm field or forest floor.

Be sure the worms get plenty of darkness every day so they can work at the surface. If the container has clear sides, keep it covered most of the time to prevent algae growth. The sides can be uncovered briefly each day, or for a whole day occasionally.

A sick worm can infect and kill the whole batch. Avoid this by removing dead worms quickly (if possible), and by starting with healthy worms. They should be plump, quick-moving, and show no physical damage.

QUESTIONS FOR DISCUSSION

1) Which leaves will decompose faster—those buried underground by worms, or those on the surface? Why?

Buried residue decomposes faster because 1) the worms have shredded it into smaller pieces, so bacteria and fungi have more surface area to work on, and 2) most bacteria need moisture. They cannot live on the dry surface residue.

2) Earthworms do not live everywhere. What happens to surface residue where there are no worms?

Farmers do part of the work of earthworms by tilling residue into the soil. In some deciduous forests with no earthworms, residue piles up. In other places, ants, termites, beetles and other arthropods shred and bury residue.

3) Why is earthworm activity helpful?

They encourage decomposition, and therefore, the release of nutrients for use by plants and other soil organisms. They improve the stability, porosity and water holding capacity of soil. They improve water infiltration by forming deep channels and improving soil aggregation. They may improve root growth.

4) When might earthworms be undesirable?

In some places earthworms remove surface residue too quickly and leave the surface unprotected from rain and wind. Some forest seeds need a thick layer of plant litter to germinate and begin growing.

EARTHWORM INTERNET RESOURCES

A commercial site targeted at K-8 students and teachers:
yucky.kids.discovery.com (click on Worm World)

Two sites full of earthworm facts:
res.agr.ca/lond/pmrc/faq/earthwor.html
solum.soils.umn.edu/research/ars/mn_worm.htm

A worm farm variation:
res2.agr.ca/london/pmrc/faq/worm_farm.html

A commercially-made worm box:
http://www.everythingscience.net/HS-1236.html

Soil Biology Classroom Activity #2

HOW FAST DOES IT ROT?

DESCRIPTION

Compare organic matter decay in different soils.

LESSON

Decomposition is a biological process performed by living organisms. Soil and climate conditions determine biological activity and, therefore, decomposition rates.

BACKGROUND

Nutrients are continuously transformed and cycled through the environment. Decomposition by soil organisms is a critical part of these cycles. When plants and animals die, the complex compounds that make up living tissue decompose. Decomposition releases carbon dioxide and nutrients, and makes the nutrients available again to plants and other organisms.

Soil organisms also decompose would-be pollutants before they reach groundwater or surface water.

Decomposition is a stepwise process involving most soil organisms. Arthropods and earthworms shred material and mix it with soil. Then a few fungi with a particular enzyme break a specific compound into simpler parts. Then different species of fungi or bacteria can attack the newly created compounds, and so on. Each organism gets energy or nutrients from the process. Usually, but not always, compounds become simpler after each step. Some compounds cannot be broken down any further. They may combine chemically to become complex, hard-to-degrade organic compounds called humic substances. Humic substances can persist in soil for centuries and are important for improving the capacity of soil to hold nutrients and water.

Several factors affect the growth of microorganisms and therefore the rate of decomposition in soil.

Oxygen: Most microbes require oxygen (aerobic conditions). A few are active only in anaerobic conditions. Tillage aerates the soil and temporarily increases decomposition rates. Compaction reduces the air in the soil and the space for larger organisms to move around.

Water: Soil organisms are generally more active in moist than dry soil. Soil is protected from drying out if it is covered by plant litter. However, the plant litter on the soil surface will dry out more than if it were buried.

Temperature: Bacteria are most active between 70-100°F. Dark, bare soil will warm more quickly in spring compared to light-colored soil or soil covered with plant litter.

Food: Most microbes need organic matter for energy and nutrients. Decomposition is faster when the food is high in nitrogen. (Generally, young, green plant residue has more N than brown plant litter.) Harvesting plants and roots from soil means less organic matter left to feed microbes.

pH: A pH of 6 to 8 is preferred by most bacteria. Many fungi prefer a lower pH.

> Soil can act as either a sink or a source of greenhouse gases. An estimated 30 percent of the carbon dioxide, 70 percent of the methane, and 90 percent of the nitrous oxide released to the atmosphere each year pass through the soil.

MATERIALS AND TIME

- several types of plant material
- net bags
- something to mark the bags' locations
- shovel
- Allow samples to be buried for up to 2 or 3 weeks.

PROCEDURE

1. **Collect organic material**, such as leaves, grass clippings, residue from a field, or cotton fabric. Avoid kitchen scraps which may attract animals.
2. **Divide the material into two or more identical piles.** It is important that each pile have the same kind and size of pieces, because some materials rot faster than others.
3. **Pack the residue loosely into net bags.** The purpose of the bag is to help you locate the buried residue and carry it back to the classroom. Purchase netting from fabric stores or use bags intended for washing delicate clothes. Do not use bags of tightly woven fabric. You want small (1mm) arthropods to get at the residue and help shred it.

How fast does it rot? (cont.)

4. **Choose places to compare.** Identify several soils that are managed differently. You might compare: a wooded area away from a path, compacted soil under a path, a farm field, a lawn, a garden, soggy soil, dry soil, dark-colored soil, light-colored soil, a farm field that always has bare soil between the crop plants, and a field that always has plant residue or weeds covering the soil surface. Predict which places have the most biological activity.
5. **Bury the bags a few inches down into the soil.** Be sure each bag is buried to the same depth. Mark the locations.
6. **Examine the results**. After two or three weeks dig up the bags and judge which ones are the most decayed. If there is little difference, you may need to re-bury them for another 2 weeks or longer.

Alternative procedure

MATERIALS

- 3 X 5 note cards or cotton fabric
- plastic bags
- trowel for collecting soil

PROCEDURE

1. **Collect soil samples.** Choose several different soils to compare from the list in #4 above.
   From each place, use a trowel to scrape away any surface residue and scoop soil into a labeled plastic bag.
2. **Add a note card.** In each bag of soil, bury an identical piece of note card or cotton fabric.
3. **Make your predictions.** Which soil do you think will have the most biological activity and will decompose the note card or fabric most quickly?
4. **Examine the results.** After two or three weeks look at the note cards or fabric. Which decomposed fastest?

HINTS

Practice good scientific method and change just one variable at a time. For example, if you want to study the effect of moisture, choose soils that are identical except for the moisture. If you want to study the effect of the kind of material, be sure to bury samples in identical soils that have similar moisture contents.

The optimal length of time for leaving samples in the soil varies from place to place. The first time you do this activity, allow time to learn what is best in your situation.

QUESTIONS FOR DISCUSSION

1) Where does decomposition of plant residue fit in a diagram of the food web/chain?

Only a fraction of plant matter is eaten by above-ground herbivores. Most is consumed by the decomposers underground and enters the complex network of organisms called the soil food web. Energy and nutrients return to the above-ground food web when plants grow and animals eat plants and soil organisms.

2) What characteristics of the soil will increase biological activity and therefore decomposition rates? How do we affect those characteristics in the soil?

(See Background.)

3) What characteristics of organic matter determine how fast it decays?

Compared to large pieces, small pieces have more surface area for the bacteria and fungi to attack. Low nitrogen content relative to carbon (high C:N ratio) will limit the activity of microbes. Woody materials contain lignin and other compounds that are difficult to break down.

INTERNET RESOURCES

Carbon cycle:
http://library.thinkquest.org/11226/

Nitrogen cycle:
http://clab.cecil.cc.md.us/faculty/biology/jason/nitrc.htm
http://www.bae.ncsu.edu/courses/bae578/nitrogen.html

Organic matter and decomposition:
http://www.montana.edu/wwwpb/ag/baudr150.html
http://www.agric.gov.ab.ca/agdex/500/536-1.html

Soil Biology Classroom Activity #3

WHAT LIVES IN YOUR SOIL?

DESCRIPTION OF ACTIVITY

Use two techniques to extract large and small arthropods from soil. Students may identify the organisms, estimate numbers, or compare populations in different places.

LESSON

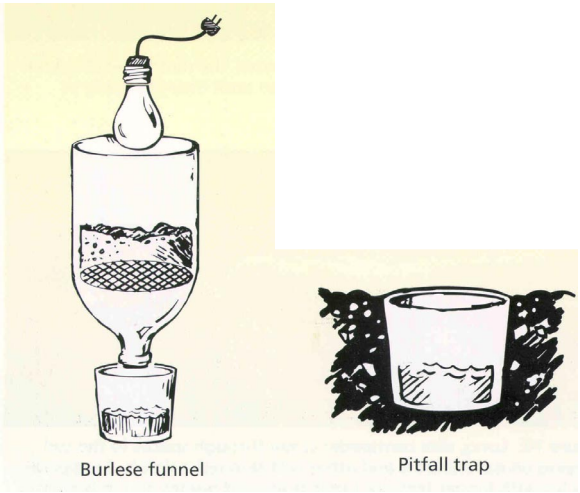
A wide variety of organisms live under our feet and perform important roles in the environment.

BACKGROUND

"Arthropods" is the name for a large group of invertebrates with jointed (arthros) legs (podos). In the soil, they may be microscopic or several inches long. They include insects (springtails, beetles, and ants); crustaceans, (sowbugs); arachnids (spiders and mites); myriapods (centipedes and millipedes); and scorpions.

Arthropods are important because they stimulate microbial activity and enhance decomposition; they help control pest populations; and they improve soil structure as they burrow through the soil or excrete fecal pellets made of soil and organic matter. Good structure is important for improving water intake, drainage, and aeration, thus protecting soil from erosion, and creating a good environment for roots.

A single square yard of soil may contain 500 to 200,000 individual arthropods and tens or hundreds of different species. Most live in the top few centimeters of soil. A Berlese (pronounced "bur LAY zee") funnel can be used to collect microscopic arthropods from soil. A pitfall trap can be used to gather larger arthropods.



Berlese Funnel

MATERIALS AND TIME REQUIRED

- Trowel and plastic bags for gathering soil.
- Large funnel (2-liter bottle, or plastic milk jug)
- 2 mm mesh screening
- Jar or cup
- Preservative (ethanol or 50:50 ethanol/water mix)
- Incandescent, 60W light bulb and fixture
- Dissecting microscope
- Allow one week after set up to collect samples.

PROCEDURE

1. **Gather soil samples** Arthropods are easiest to find in soil that is rarely disturbed by tillage, not compacted by traffic, not treated with pesticides, not periodically flooded or dried out, and that has several different kinds of plants growing. Push away the surface litter and dig up about 1 liter of soil from the top few centimeters of the soil. (In another experiment, plant litter can be used in place of soil in a Berlese funnel.) Refrigerate sample if you will not use it right away.
2. **Set up the Berlese funnel.** Cut off the bottom of the bottle or milk jug to make a funnel. Cut and place the screen in the bottom of the funnel to hold the soil. It may help to tape the edges of the screen to the funnel. Half fill the funnel with soil. Set the funnel above a jar or cup with a bit of ethyl alcohol in the bottom. (Glycerol can be added to reduce evaporation.) Set up a desk lamp or hang a light bulb so the bare 60W bulb is about 4 inches over the soil.
3. **Collect the organisms**. Leave the light bulb on for 3-7 days to dry out the soil. As the soil dries, organisms will move deeper into the soil and eventually fall into the alcohol. Avoid disturbing the setup and knocking soil into the alcohol.
4. **Examine the sample**. Pour the alcohol solution into a petri dish and examine under a microscope. Put black paper and white paper behind the sample to highlight different organisms. Identify the main groups of arthropods. An identification key is at www.cals.ncsu.edu/course/ent591k/ident.html

What lives in your soil? (cont.)

Pitfall Trap

MATERIALS AND TIME REQUIRED

- a 1-to-4 cup sized container (e.g. a yogurt container)
- trowel
- preservative (optional)
- Allow one week after set up to collect samples.

PROCEDURE

1. **Set up the trap.** Choose a location that will not be disturbed for a week. Dig a hole as large as the container. Set the container into the hole so that the rim is exactly even with the soil surface. If it is a bit higher, organisms will walk around the edge and not fall in. Smooth the soil up to the rim of the container.
2. **Enhancements**. If desired, you can fashion a roof over the cup to keep out the rain and animals that might eat the arthropods. You may add a preservative (e.g. ½ of an inch of non-hazardous antifreeze or ethanol) to preserve the organisms and prevent them from eating one another.
3. **Collect the arthropods.** Leave the trap in place for one week, but check it daily, especially if you did not use a preservative.
4. **Identify the main groups of arthropods.** An identification key is available at www.cals.ncsu.edu/course/ent591k/ident.html

VARIATIONS

By searching the internet, you can find other ideas for making and using Berlese funnels and pitfall traps. (A few are listed under "Internet Resources.") Note that some of the variations are more suited for use with leaf litter than soil.

QUESTIONS FOR DISCUSSION

1) For each method, how is the sample biased? That is, which creatures will be caught and which will be missed?

The Berlese funnel captures species that are mobile and do not desiccate easily. (E.g., soft-bodied invertebrates such as larvae may be missed.). Winged critters might escape from the top of the funnel.

2) What role might each organism play in the soil environment?

3) Why do we find more arthropods in some places than others?

INTERNET RESOURCES

Another Berlese funnel description is in "Leaf Mold Community." This and other biology teaching materials by Dr. Charles Drewes are at:
www.zg.iastate.edu/~c_drewes/

"Arthropods of Pacific Northwest forests."
www.ent3.orst.edu/moldenka/

"The Ground Crew." A Berlese funnel activity, including a link to an identification key, and ways to use the data from this activity. www.cals.ncsu.edu/course/ent591k/soil.html

"Population and Community Structure." A lab activity using a pitfall trap.
cas.bellarmine.edu/tietjen/Ecology/population_and_community_structu.htm

"Schoolyard Pitfall Trap Experiment"
www.stclair.k12.il.us/services/scilit/pitfall.htm

A single spade full of rich, garden soil contains more species of organisms than can be found above ground in the entire Amazon rain forest.