Activity:

Soil biology and microorganism activity

Life in the soil.

Five things are necessary for all living organisms to survive and grow: water, energy (electron donor), electron acceptor (oxygen for aerobic organisms), carbon source, essential elements (nutrients) and growth factors (things they cannot make, like some amino acids). Plants capture energy from light; humans obtain energy and carbon from the food they eat.

Microorganisms – microbes – are microscopic organisms that cannot be seen with the human eye. Even these organisms come in a variety of sizes, including bacteria, actinomycetes, algae, fungi, protozoa, and amoebae, among many others. In soils with no limiting factors, there are more microbes in a handful of soil than there are people on the planet. But not all soil organisms are microscopic, including earthworms and larger nematodes.

Microorganisms do not "eat" as humans do, but most also get energy and carbon during decomposition of their "food" - the organic materials in the soil, including dead plant and animal parts, plant exudates (organic compounds that leak from plant roots), and organic matter (partially decomposed products). As they decompose these organic materials, just as when you digest food, electrons (energy) are released as the bonds between carbon molecules are broken. Microbes use about 25% of the carbon for growth and reproduction and release about 75% into the soil as carbon dioxide.

A lack of, or imbalance among, any of those five necessities will affect the amount of biological activity in soil. Further, soil properties such as texture, pH and temperature affect the availability of the essential elements, which affects the number and type of organisms present, as do management practices. Bacteria are more common in semiarid region soils than fungi. The primary limiting factor to biological activity in the semiarid Western and Southern Great Plains is lack of water. Many of you have probably seen two- to three-year old residue on the surface of a no-till field because there is not enough biological activity to decompose them.

- Water stress decreases respiration and there is no biological activity in dry soils. Microbes in arid and semiarid regions can enter an inactive mode and exist until favorable conditions return.
- Too much water – even from too much irrigation - decreases oxygen availability, slows biological activity and favors anaerobic organisms that use other elements for electron acceptors such as iron, manganese, nitrogen and sulfur sequentially as oxygen becomes more limiting. Reduced sulfur compounds in anaerobic soils are responsible for the "rotten egg" odor.
- Fine-textured soils often have more organic carbon and microbial activity than coarse-textured soils.
- Darker soils generally have more organic matter (humus) – food – and have more biological activity than light-colored soils.
- Salinity decreases microorganism activity.
- There is little biological activity when soil temperatures are below 40 °F or above 100 °F.
- Some agronomic practices have more dramatic effects on biological activity; for example, anhydrous ammonia kills all organisms, including plant roots, in the zone of the injected ammonia, and the affected zone is larger in drier soils.
- Tillage initially increases microbial activity in moist soils, but in the long-term decreases the food supply (organic carbon), dries the soil, decreases biological activity and destroys earthworm burrows. I have only seen earthworms in no-till fields in the semiarid Western and Southern Great Plains.
- Cover crops generally increase the diversity, number, and activity of microbes.

This qualitative experiment demonstrates the relative amount of microorganism activity in the soil. Water and a food source (sugar) are added to the soil to jump start the biological activity. A balloon is placed on the bottle to collect the carbon dioxide released as the organisms decompose the food. Different soils, temperatures, amount and types of food sources (ease of decomposition) can be used to observe their effects on organism activity – the amount and rate of decomposition. More decomposition releases more carbon dioxide, resulting in a larger balloon. The decomposition rate will slow when the sugar is gone and microbes begin to decompose native organic compounds in the soil.

Materials:

Clear 12- to 16-oz glass bottles, such as soft drink bottles (larger bottles = more soil = more organisms = more potential activity). Soft plastic water bottles expand more easily than balloons, so the balloons will not inflate.

Small balloons (≤ 15 cm, 6-in) that will fit over the mouth of the bottle

Energy source – sugar or others

Soils

- Collect about two cups of soil from land you own or manage, ideally from native range and two management practices/crops, for example, dryland production during fallow and growing crop, irrigated crop, intensive vs limited tillage, rotations with and without cover crops.
- For each sample, record
    - Use a smartphone to find soil map unit using SoilWeb and location (GPS coordinates or physical location using address or directions)
    - As much as is known about past management such as cropping history/rotation, tillage system, irrigation
    - Conditions at time of sampling – date, fallow or growing crop, soil moisture status

Method:

1. Select soils/management combinations to test. Break larger aggregates (clods, clumps) into pieces about 3 to 6 mm (1/8 to ¼ inch) diameter.
2. Mix 15 ml (1 Tbsp) sugar in about 500 to 750 ml soil (2 to 3 cups) soil, depending upon the size of the bottle. Be careful not to compact wet soils.
3. Add soil to the bottle a bit at a time and gently tap the sides between each addition until the bottle is a little more than ¾ full.
4. Moisture:
    a. If you can form a ball that stays together, the soil is approximately at field capacity and needs no more water.
    b. If the soil is drier than field capacity, tilt the bottle and add 25 ml (about 2 Tbsp) water slowly, allowing it to run down the side of the bottle to the bottom. The water should soak upward into the soil by capillarity.
    c. If no water is pooled in the bottom of the bottle, immediately tilt and rotate the bottle about ¼ turn and slowly add another 25 ml water.
    d. Otherwise, wait about 5 minutes and if no water is in the bottom, repeat the process.
    e. Repeat until the soil is moist throughout and air pockets are visible in larger pores along the sides of the bottle. Be careful not to add too much water.
5. Depending upon the size of the bottle and initial soil water content, more than 100 ml may be required.

6. Place the balloon over the mouth of the bottle. See Figures 1-3.
7. Ideally, keep bottles in a room at 22 to 30° C (72 to 86° F). Biological activity slows considerably below 20° C (68° F) and there is little biological activity below 5° C (41° F). If doing an experiment, temperature can be used as a variable.
8. Wait. Some balloons may fill within 2 to 4 days, others may take weeks or not fill at all. In my trials there was little evidence of respiration for 2 to 3 days, then the balloon inflated within a few hours.
9. Possible data to record: photo with date, diameter and height of balloon.

Figure 3. Loam, 4% organic matter.

Figure 2. Aerobic, both: Sand on left, loam on right.

Figure 1. Aerobic in sand (left); Anaerobic in loam (right).

Discussion:

The expansion of the balloon, if any, is proportional to the amount of biological activity - respiration - in the soil. Balloons that fill more rapidly indicate soils with a greater population of active microbes. Soil texture, initially drier soils and management conditions may require time for the microbial population to increase to a critical mass to respire enough carbon dioxide to begin filling the balloon. Direct comparisons could be difficult to interpret: a sand with a thriving microbial community might still have less microbial activity than a degraded clay loam.

Darker soils typically have more organic matter and support more microbes. Dark soils that are at field capacity when the experiment begins likely have the most active microbial community and will fill fastest.

The soil will get wetter as decomposition occurs because liquid water and carbon dioxide gas are the primary components released during decomposition and the condition may change from aerobic as happened in the loam on the right (Figure 2) to anaerobic (Figure 3).

Did your balloon get smaller or even get sucked into the bottle?

Osmosis: Some balloons may expand then decrease in size due to osmosis as carbon dioxide crosses through the balloon to achieve an equilibrium with carbon dioxide in the atmosphere.

Temperature: Gases expand as the temperature increases and condense when the temperature decreases. Moving the bottle from a warmer to colder room (or putting it in the refrigerator or freezer) will cause the gas to condense (Figure 4), possibly enough to even suck the balloon into the bottle. And placing it in the freezer may cause it to expand because water expands as it freezes and forces air out of the soil pores (Figure 5), and the process happens in reverse as the soil warms again.

Clay Robinson, PhD, CPSS, CCA, PG

Adapted from “Dr. Dirt’s K-12 Soil Science Outreach Activities and SO much more!”, DoctorDirt.org

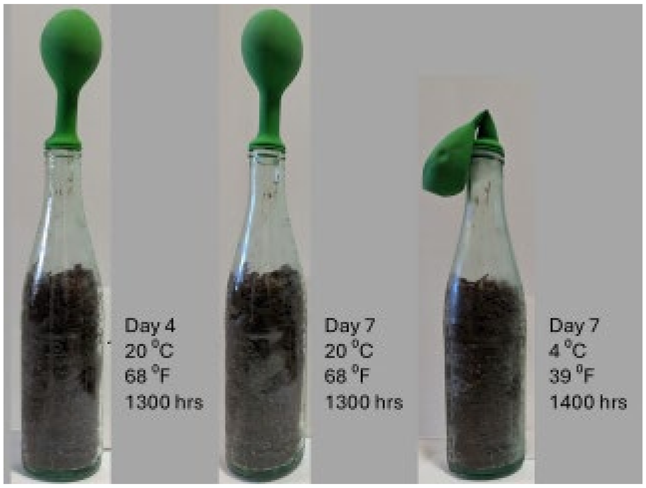

Figure 4. Temperature effects on gas, from 20 to 4 °C.

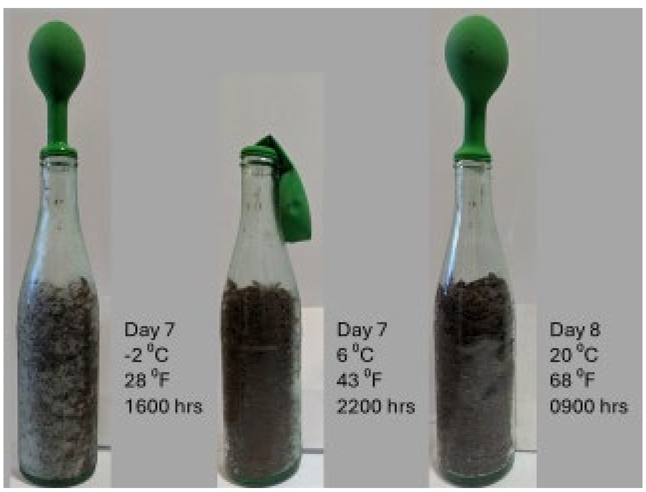

Figure 5. Temperature effects on gas, from -2 to 6 to 20 °C.

Dr. Dirt's K-12 Soil Science Outreach Activities and SO much more!
DoctorDirt.org