2017

Battleship Roots

Tallgrass Prairie Center

BATTLESHIP ROOTS

Overview
Pairs of students play a battle-ship-style game showing how roots explore the soil to obtain patchy resources.

Objectives:
Students will be able to:
- List the resources plants need from soil.
- Explain why many root systems are highly branched.
- Compare different strategies roots use for finding soil nutrients.

Subjects Covered:
Science: Life Science

Grades: 6-8

Group size: Any size; students work in pairs

Activity Time: 45 min.

Season/Location:
Any season/Indoors

Materials:
- Prairie roots specimen or image
- Printed copies of Appendix A, B and C for each pair of players
- Pencil for each player
- Optional: blue and green pencils
- Empty binders or folders that will stand up
- Calculators for determining scores

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BACKGROUND

Roots do not have senses like we do, yet they explore the soil to find resources – water and **mineral nutrients**. These resources are not evenly distributed throughout the soil. For example, soil **nitrogen** is often in forms that dissolve easily in water, dispersing it throughout the pore spaces of the soil along with water. However, **phosphorus** tends to bind tightly to clay minerals in soil and is therefore less easily dispersed throughout the soil. Water itself can be more or less available in different patches or zones within the soil.

The architecture of a plant's root system is determined partly by what kind of plant it is. For example, some prairie plants have **tap roots** that penetrate deep into the soil before branching considerably. Other prairie plant species have **fibrous root systems** that are made of numerous highly branched, fine roots. But root architecture is also quite **plastic**, meaning that it can change in response to the patchiness of nutrient availability in soil.

The plant needs its root system to gain mineral resources, but also pays an energy cost to have the roots. It takes energy to grow roots, to lubricate their passage through the soil, and to recruit partners like arbuscular mycorrhizal fungi that increase the roots' access to scarce and patchy nutrients. This energy, in the form of food molecules, comes from **photosynthesis** by the above-ground parts of the plant.

VOCABULARY

Mineral nutrients: Chemical elements that living things need
Nitrogen: Mineral nutrient used for building proteins and DNA
Phosphorus: Mineral nutrient used for building DNA
Tap root: A central, downward-growing root that produces small lateral roots
Fibrous root systems: Root systems made of many finely branched roots
Plastic: Flexible, able to change and respond
Photosynthesis: The process of using energy from the sun to transform water, carbon dioxide and minerals into sugars the cell can use as energy

TEACHER PREPARATION

- Prepare to display prairie root specimen or image of prairie roots (www.tallgrassprairiecenter.org/curriculum_images.)
- Make copies of the game charts for each pair of students.

ACTIVITY

Introducing the activity

1. Gather the group around the prairie root specimen, if available. If not, show them a poster or project a high-quality image of prairie roots. Ask them to describe what the root system looks like. Prompt with questions: Why does the root system have so many branches? Why is it so long? Are there any places where there are more branches or finer roots? Why?
2. Explain that the prairie root specimen was grown in a tube with a special growth medium and plenty of water and nutrients called N (nitrogen) and P (phosphorus). In the real prairie, water and nutrients are not always there in the right amounts throughout the soil. Roots have to explore the soil to find patches of the resources.
3. Ask students to think about where the energy to grow roots comes from. Does the energy come from water, from soil, or from the parts of the plant that grow in the sun? Remind them that all of a plant's energy comes from sugars made by photosynthesis. The resources (water, N, and P) that roots take f from the soil are materials the plant needs to keep doing photosynthesis. Growing roots takes energy, and plants have to spend that energy in ways that will get them the resources they need without costing too much!
4. If you were a root, you wouldn't have senses like sight and smell, so how would you find the resources you need from soil? Tell students they will be playing a game like Battleship in which one player is the root system of the plant and the other player is the soil.
    a. Ask students if they have ever played a game of Battleship. If not, explain how a Battleship game works or project a video showing how to play. (One example is at this link: https://www.youtube.com/watch?v=Xqrotm6VrBE)
    b. Show them how to determine the coordinates on a grid chart. Practice by pointing to different spaces on the chart and asking students for the coordinates.
    c. This game is different from Battleship in one important way: Roots grow from their tips or branch off from their sides, so you can't guess just any coordinate on the chart. You have to choose coordinates connected to your root.

Play the game!

See Rules of the Game (Appendix A)

Discussion

1. Get the winning teams to show off their root systems. Ask students to look for similarities and differences among the winning root systems. How deep did they go? How much did they branch? Where were the resources?

2. Get the lowest scoring teams to share their root systems. Emphasize that it's not really about winning but about comparing strategies. Ask students to look for patterns that could help explain why they "lost."

3. What were the best strategies? How would you define "best?" Get students to think in terms of getting the most resources for the lowest cost in root growth.
4. Would the winning strategies work well under all conditions? How could we use the game to show what happens when soil is too dry or too wet? What if the soil is very poor in nutrients? What if there were multiple root systems competing for the same resources? Why is it important for root systems to be "plastic," able to respond to changing conditions?
5. If some strategies worked better in the game, why don't all plant species in a prairie have the same root architecture?
6. Prairie roots stay alive in the soil for many years, so they do not have to start from scratch every year. How would the game have to change to better show how prairie roots explore the soil for resources?
7. In the game, the resources were captured by the roots. What happened to them after they were captured? Would the resources be used up over time? How could they be replaced or "recycled?"

ASSESSMENTS

a. Some or all of the last five discussion questions could be used as a part of a written assessment or reflection on learning.

EXTENSIONS

1. Play the game with more than one root player per soil player. Root players then compete for water and nutrients, because the same resource cannot be used more than once.
2. Soil players create new soil charts to show different distributions of resources in soil or special conditions (examples: drought, fertilizer added to top of soil), trade charts with other teams and play the game again.
3. Students choose prairie plant species to research and gather information about the architecture of their root systems. They work together to develop an explanation for the diversity of prairie root system architecture they observe. The class creates a website to share their work online.

RESOURCES

- McNear Jr., D.H. The Rhizosphere – Roots, Soil, and Everything In Between. Nature Education Knowledge 4(3): 1. http://www.nature.com/scitable/knowledge/library/the-rhizosphere-roots-soil-and-67500617
- Brundrett, M. (2008) Arbuscular Mycorrhizas. Mycorrhizal Associations: The Web Resource. http://mycorrhizas.info/vam.html

STANDARDS

MS–LS2–1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS–LS1–4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
MS–LS1–5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

APPENDICES

A. Rules of the game
B. Root player materials – blank chart with coordinates, "status" chart
C. Soil player materials – blank soil chart

Rules of the Game – Battleship Roots

1. **Players and materials.** Work with a partner. If there is an odd number, two students could be the root player on one team. Each player receives a blank grid chart. (One receives a root chart; the other a soil chart.)
   a. **Soil players** – Mark your charts to show where the resources are in the soil. Hide this information behind the binder to keep it secret from the root players.
      - **Water – Mark 30 spaces on the chart with W for water or color them blue.** Water in the soil clings to soil particles and occupies pore spaces between them. Space out the W marks so that it looks like they are in the pore spaces of the soil. Water infiltrates down into the soil due to gravity. You can show this by placing more 'W's in the lower part of your chart than near the top.
      - **Nutrients – Mark 10 spaces with N for nutrients (nitrogen and phosphorus) or color them green.** Nitrogen tends to dissolve in water, so you could put some of the 'N' marks next to 'W's. The nutrients can be clumped, but place them in at least 3 different patches.
   b. **Root players –** Make a mark in one grid square in the top row to show where your root will start growing.

2. **Growing Roots**. Root growth starts from the marked square.
   a. For each move, the root player chooses a new grid square within five squares of an existing root. Place a dot in that grid square.
   b. Draw a line from the nearest root downward toward the new dot, passing through the grid squares in between. (Real roots generally follow this rule, growing downward in response to gravity.) The line can be vertical or diagonal. It can grow from the tip of the roots or branch off its side.

3. **Capturing Resources.**
   a. **Root player –** Call out the coordinates of each of the grid squares your root (line) passes through. The soil player will tell you if your root captured any water or nutrient resources.
   b. **Soil player –** Check the coordinates on the soil chart. If the root has grown into or through a resource square, cross off that square and tell the root player which kind of resource (water or nutrients) has been captured.
   c. **Root player -** Record the resources your root captured (if any) by coloring those spaces on your root map. Color water squares blue and nutrient squares green. Also place a tally mark in the status chart for each unit of water (W) or nutrients (N) the root captured.

4. **Winning!** When time is up, the winning team will have a root system that has captured the most W and N relative to the size of the root system.*
   a. Add up the Ws your root captured. Each W counts as 1 point. Record your water points on the status chart.
   b. Add up the Ns your roots captured. Each N counts as 2 points. Record your nutrient points on the status chart.
   c. In each line of your root map, use the right-hand column to record the number of grid squares that were crossed by a root. Add up the total number of squares your root system grow through and record on the status chart.
   d. Add up your W and N points then divide by the size of your root system.
   e. The team with the highest number wins! Your plant was the most successful in getting water and nutrients needed to survive and compete.

* To simplify the game for lower grades, Steps c - e can be eliminated and the winner is simply the team that captures the most W and N.

Root Player Materials

	1	2	3	4	5	6	7	8	9	10	11	12	Number of spaces used
A													
B													
C													
D													
E													
F													
G													
H													
I													
J													
K													
L													
M													
N													

Status Chart

	Tally Marks	Points
Water		**W =**
Nutrients		**N =**
Root Length		**R =**

Points: (W + N) divided by R = _____

Soil Player Materials

	1	2	3	4	5	6	7	8	9	10	11	12
A												
B												
C												
D												
E												
F												
G												
H												
I												
J												
K												
L												
M												
N												