Designing the Perfect Plant

Activities to Investigate Plant Ecology

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Plant ecology is an important subject that often receives little attention in middle school, as more time during science classes is devoted to plant biology. Plant ecology can be thought of as the study of the distribution of plants in the environment and the interactions of the plants with biotic (living) and abiotic (nonliving) things in that environment (Gurevitch, Scheiner, and Fox 2002). We have developed a series of activities, including a card game—Designing the Perfect Plant—to introduce students to plant ecology and the ecological tradeoffs associated with different types of plants and plant attributes. The activities also introduce students to general ecological concepts such as biodiversity, environmental disturbance, habitat, competition, and predation.

Through these activities, students will learn that, despite the title of the game, there is no perfect plant. The definition of success for any plant species is its ability to reproduce and assure long-term survival. The astoundingly large number of plant species on Earth—

FIGURE 1 Plant trait advantages and disadvantages

Category	Trait	Advantage
Growth form	Grass	Many species are fairly drought tolerant. Survive grazing and fire well. Wind pollinated, so don't need insects.
	Forb	Often good colonizing species that reproduce rapidly when resources are available.
	Tree/shrub	Tall, so shades out competitors. Long lived, so produces lots of seeds over lifetime.
Life history (trees and shrubs must be perennial)	Annual	Life cycle completed in one season. Don't have to survive winter, so most energy goes into producing seeds.
	Perennial	Has existing structure, so doesn't have to use lots of energy to grow new plant each year, allowing for quicker growth and seed production in spring.
Life strategy (if stress tolerator, must choose among ability to tolerate heat, cold, drought, or flood)	Competitor	Competes well with other plants for resources and may be able to dominate in an area for many years.
	Stress tolerator	Can still survive and reproduce in stressful settings.
	Ruderal (weed)	Colonizes newly disturbed areas well and quickly produces lots of offspring.
Leaves (applies only to trees)	Coniferous	Doesn't lose leaves in winter, so doesn't have to spend energy growing new ones in spring.
	Deciduous	Doesn't use energy to keep leaves alive during winter.
Reproduction	Sexual (seed)	Seeds can disperse. Genetic variation.
	Asexual (vegetative)	Rapid population expansion. Don't require pollinators and seed production. Growth may be stimulated by grazing or other disturbance.
Dispersal (applies only to plants with seeds)	Short distance	Seeds likely to land in good habitat.
	Long distance	Seeds colonize larger areas.
Dormancy	Seed dormancy	Seeds can survive underground until conditions are right for germination and seedling survival.
	No seed dormancy	All seeds will germinate and are thus not subject to predation.
Defenses	Has defenses	Can deter grazing or other predation.
	No defenses	Subject to grazing or other predation.

approximately 250,000 known species—is evidence that there is no one perfect plant. Rather, the abundance of plant biodiversity on Earth is possible because each species of plant has a relatively unique combination of traits that allows it to survive in a specific environment (Crawley 1997). As an example, for a specific set of environmental conditions, a grass might be better suited for survival than a shrub or tree. But what are the traits that make the grass more suited for that environment? Should it reproduce after one year and then die, or should it live longer? Should it reproduce by seed or vegetatively? If it reproduces by seed, would it be more advantageous to have seeds with short or long dispersal distances? Does it make sense for the grass to have defenses against herbivores, or can it thrive even if it is attacked by predators? Will the species be able to survive disturbances such as fire, flooding, or burrowing as well as environmental factors such as drought and extreme heat or cold? All of these issues represent tradeoffs inherent in the traits of plant species.

Disadvantage
Often not shade tolerant, so doesn't compete well with taller plants.
May not be shade tolerant, so do not compete well with taller plants.
Slow growing and takes lots of energy to build and maintain support structure (trunk).
Has to grow new plant from seed each year, so seed production is delayed. May not be able to complete life cycle if conditions poor.
Has to use energy to survive through winter, so less energy devoted to seed production.
Slow growing.
Slow growing and does not compete well with other plants.
Does not compete well when other plants are present.
Takes energy to maintain leaves in winter.
Takes energy to produce new leaves in spring.
Seedling establishment very poor in some climates.
Genetic clones, so not tolerant of ecological/environmental changes.
Seedling overcrowding may occur, so not all seedlings survive. Population does not spread quickly, and large-scale disturbance may remove entire population.
Seeds may not land in suitable habitat.
Seeds subject to predation.
Seeds may germinate when conditions are not favorable for survival.
Takes energy to produce defenses, so less energy devoted to reproduction.
Devotes more energy to reproduction and grows faster.

Background lesson

Prior to beginning the "designing a plant" activity, some basic information on ecological tradeoffs was presented to students in the form of viewing pictures followed by a discussion. Students were shown pictures including a tree, a shrub, forb, grass, a deciduous leaf, conifer needles, small seeds, large seeds, seeds with mechanisms for long-distance dispersal, herbivores, fire, drought, snow, disturbed ground, and plant defenses such as thorns. These pictures can be obtained from various websites such as Google Images, or better yet, by taking some pictures on schoolgrounds. For each picture, students were instructed to record everything they could think of that related to plant ecology. They were told to especially think of advantages and disadvantages of each growth form or adaptation, as well as how each environmental factor shown might affect plant growth and survival. After the slide show, students presented their thoughts on the ecological significance of each picture, and we provided additional information. First,

FIGURE 2 Game cards

WEATHER Good growing conditions. All plants +5 Except: All tolerators +3 Plants with defenses +3	**WEATHER** Cold and dry spring. Deciduous trees get late start growing leaves. Deciduous trees –3	**WEATHER** Mild drought. Drought tolerators +2 Dormant seeds +2
WEATHER Extreme drought. Drought tolerators thrive. Dormant seeds survive. Drought tolerators +4 All other plants –4 Dormant seeds +3.	**WEATHER** Excess rainfall. Wet tolerators thrive. Wet tolerators +4 All other plants –4	**WEATHER** Extreme heat. Heat tolerators thrive. Heat tolerators +4 All other plants –4
WEATHER Extreme cold in fall. Cold tolerators thrive. Cold tolerators +4 All other plants –4	**WEATHER** Extreme cold in spring. Pollinators late in arriving so no seed produced by any plants. All seed producers –3	**WEATHER** Mild winter. Coniferous trees +3.
WEATHER Excellent spring weather. Deciduous trees +3	**WEATHER** Extremely cold winter. Coniferous trees –3.	
DISPERSAL Favorable winds. Long-distance-dispersal seeds blow into good habitat and they all survive. Long distance dispersal +3	**DISPERSAL** Strong winds. Long distance dispersal seeds blow into poor habitat and seeds don't survive. Long distance dispersal –2 Short distance dispersal +2	**DISPERSAL** Very calm winds. Seeds do not disperse far, so all seeds land in same area and some don't survive. Long distance dispersal –2 Short distance dispersal +2
DISPERSAL Short-distance-dispersal seeds attacked by insects. Short distance dispersal –3	**DISPERSAL** Seeds stick to animal fur and are well dispersed. Long distance dispersal +2	**DISPERSAL** Burrowing animals dig up and spread parts of vegetative plants. Vegetative reproducing plants +2

DISTURBANCE No disturbance. Trees and shrubs +4 Other non-ruderals +2 Ruderals –3	**DISTURBANCE** Burrowing. Animals dig up soil. Ruderals +4 Vegetative plants +1	**DISTURBANCE** Late spring snowstorm. Breaks branches off of deciduous trees. Deciduous trees –2
DISTURBANCE Fire. Ruderals +5 Grasses +3 Forbs +1 Trees –2	**DISTURBANCE** Flooding. Ruderals +2 All other plants –2	**DISTURBANCE** Logging. Ruderals +5 Trees –4
PREDATION/DISEASE Attack by pine beetles. Coniferous trees –3	**PREDATION/DISEASE** Attack by seed-eating insects. Seed producers –3	**PREDATION/DISEASE** Seed pathogens. Dormant seeds –3
PREDATION/DISEASE Root or stem eating insects. Perennial plants –2	**PREDATION/DISEASE** Disease. Vegetative plants –2	**PREDATION/DISEASE** Spring grazing. Grasses +2 Annuals –2
PREDATION/DISEASE Fall grazing. Plants with defenses +3 Seed producers –3	**PREDATION/DISEASE** Heavy grazing. Plants with defenses +3 Vegetative plants +3 Annuals –3	

students were told to work individually, then to bring their individual ideas to a small group. Following that, the entire class discussed some main small-group highlights. For example, we discussed ecological tradeoffs of a tree maintaining its leaves throughout the winter (a conifer has to use energy to maintain its needles, but it does not need to grow new ones in the spring) versus losing its leaves (a deciduous tree doesn't "spend" energy on leaves through the winter, but must use resources to grow new leaves each spring). Similarly, we discussed the advantages and disadvantages of plants having defenses (e.g., resources devoted to defenses such as thorns or to the development of secondary metabolites that are unpalatable cannot be used for growth and reproduction). As an additional exercise, teachers can make a writing assignment where students answer questions about ecological tradeoffs. Armed with this background, students then completed three activities in plant ecology, including:

1. designing a plant,
2. drawing the plant such that others could determine all of its characteristics, and
3. playing a card game to see which plant is "best."

At this point, students might perform a short task such as describing in writing a plant and its characteristics. Other students could then read the descriptions and tell what advantages or disadvantages that particular plant might have.

Designing a plant

Students were instructed to design a plant, based on the plant-trait advantages and disadvantages presented in Figure 1. Students worked in groups of two, and often one student developed the characteristics and the more artistic student drew them. The goal was to make a plant that would be the most successful in the long-term survival of its species. For each category, they picked one trait (where appropriate) by circling that trait on the table. One 45-minute period was spent in making the drawings, and a second period was spent in class discussions. To assess the project, ask students to write a paragraph on the back of the design and later drawing that explains what characteristics their plant has that would allow it to survive and also what challenges their plant would face. The student paragraph should expand upon their drawing and also write the narrative in such a fashion that a reader who is unfamiliar with the work can easily understand it. You can also assess the picture itself. (Does it show special adaptations? Does it have all the necessary parts that a plant would need to survive?)

PHOTO COURTESY OF THE AUTHOR

A student points out the traits of her plant.

Drawing the plant

For this portion of the activity, students made detailed drawings of what their species would look like. Students work in teams of at least two, with an emphasis placed on having one student who enjoyed art and drawing in each group. The drawing included a representation of every trait they selected as well as the environment in which the plants lived. This act of drawing the plant characteristics allowed students to better comprehend each of them, and to recognize how the plant may fit into its environment. Drawings were then exchanged, and students attempted to deduce all of the traits of the plant they were viewing. Afterward, we discussed how each trait affected the plant's competitive ability, and the class voted on which of all the plants would be the "best." This exercise not only elaborated on the ecological tradeoffs of plant characteristics, but also reinforced the importance of detailed descriptions, which were made on the back of their drawings.

The card game

This game was designed to allow students to pit their plants against other students' plants to see which was most competitive after 10 rounds, or "generations." The game was played by dealing out four cards every generation, with each card having a set of conditions or circumstances that give or take away points from plants depending upon their traits (see Figure 2 for card suggestions and Figure 3 for instructions). The points in this game can be viewed as the number of individuals surviving in the environment. The plant with the highest point total after ten generations is the winner. There were four categories of cards—Weather, Disturbance, Predation/Disease, and Dispersal (see Figure 2). Some

FIGURE 3 Card-game directions

1. Photocopy cards (Figure 2) on heavy paper and laminate if desired. Cut the cards out.
2. Student groups are generally three to five players and each student group needs a set of cards.
3. The cards are shuffled and placed face down on the table, and the person to the left of the person shuffling turns one card face up.
4. Each student has a piece of paper to keep score based on the plant that student designed. For example, if the Weather card for "Cold and dry spring: Deciduous trees get late start in growing" (Figure 2) were turned over, then students who had designed a deciduous plant would score a –3 on their paper. The same starting player turns over another card and the individual student scoring continues. After four cards (one generation), the next student takes a turn at turning over the cards. In either 10 generations or at the end of the class period, scores are added to indicate student results.

cards, such as "good growing conditions" and "no disturbance" were repeated within the deck, as these conditions could be considered the norm for many environments. Plants with negative scores during the course of the game were considered to be trending toward extinction, but they were allowed to stay in the game, with the chance of recovering a positive score. If, however, a plant had a negative score at the end of the game, it was considered to be extinct. During play, walk around the room to monitor results and keep all groups on task.

The final assessment was a paragraph written by each student explaining how their particular plant did in the game: Was the plant successful, and how did their score reflect that? What was the most successful characteristic of their plant, and how did this come out in the game? What were the biggest challenges their plant had in the game, and why did these challenges happen? Can they name two plants in nature that have some of the same characteristics as their plant, and how did what happened in the game compare to what happens in nature?

Assessment

Students often learn vocabulary words in science without truly understanding their meanings. For example, in plant ecology, students are likely familiar with terms such as *deciduous*, *coniferous*, *dispersal*, or *vegetative growth*, but they may not be able to recognize these traits when observed in nature. The "drawing the plant" exercise necessitates that the students not only understand the meaning of these terms, but also how they fit into the overall picture of a plant as part of the environment. This exercise allows the teacher to assess students' knowledge of these aspects of plant ecology. The card-game exercise also provides a learning and assessment opportunity each time the cards are dealt. The teacher can ask students to explain why the conditions stated on the card lead to the points assigned. Again, this elucidates the ecological processes involved and allows the teacher to assess students' knowledge of these processes.

Conclusion

Perhaps the most important lesson learned from these activities, and the most frustrating for students, was that there is no one perfect plant. Throughout the course of the game, one student's plant would surge ahead in points, only to have it lose points for several successive generations because of the particular environmental and ecological conditions that occurred. This often elicited from the affected students exclamations that the game was unfair, but it offered another teaching opportunity by leading into discussions regarding the randomness of environmental processes. Overall, the activities, especially the card game, provided a fun way for students to explore plant ecology and to understand more about how plants fit into their environment. ■

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