EXERCISES SECTION 2: THE PLANT SYSTEM

Goal

The most basic characteristic of ecological systems is a high degree of interconnectedness among the components. For example, a soil environment affects the associated plant systems and plants in turn affect the soil environment. The goal of the exercises in this section is to help farmers understand some of the most basic mechanisms in plant growth and development, and the associated needs for nutrients and energy, and how this relates to what they have already learned about soils.

19. Plant structure and function

20. Is the soil a living thing?

21. What is energy?

22. Photosynthesis

23. Principal nutrients: sources and behavior

Tips on Running the Exercises

The first exercise on plant structure and function is an active warm-up exercise, which examines the various structures in relationship to the various functions they perform in the plant. The next two exercises are easy and quick, but nonetheless important as they build on each other, and earlier exercises (e.g., atoms and molecules) to prepare the participants for doing the simulation on photosynthesis. This simulation, through drama, is fun, and also is the key for this section in that it represents the most important physiological mechanism of plants, in which energy from sunlight is captured and stored through the transformation of Carbon Dioxide and Water into sugars and starches. The last exercise introduces the principal nutrients and discusses their source or origins, and their unique functions in the plant.

EXERCISE 19. PLANT STRUCTURE AND FUNCTION

Goal

To promote discussion on general topic of plant nutrition and the structure, composition and function of each principal part of the crop plant. This can be done as a one-time exercise, or set up as a season-long monitoring.

Materials

Sharp knife or single-edged razor blade,

Hand lens

Newsprint

Colored pens

Time required

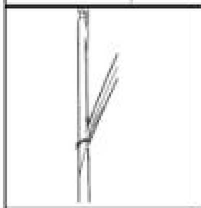
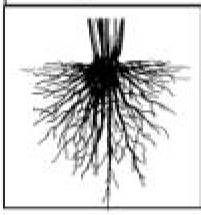
1.5 hours

Steps

Small group activity:

1. Take a mature plant and decide on what constitutes the principle sections or components of the plant (roots, stems, leaves, panicle, fruit, etc.); then cut and separate them into separate piles.
2. Discuss what the function of each part is.
3. Try and dissect or gently break apart the plant parts to see as best as possible how the plant part is formed (use hand lenses if available).
4. Rub the plant parts between your fingers and try to describe the texture and any other characteristics (soft, moist, woody, slippery, etc.).
5. Fill in the chart below.
6. Discuss the following questions.
7. Report back to the large group.

Exercises section 2. The plant system

PLANT PART	TEXTURE	FUNCTION	PROPORTION
			
			
			
			

Questions:

1. What are the relative proportions for each section (if the entire plant is 100%, then what percent is each section)?
2. What do the textures associated with each section tell you about the what the parts are made of?
3. What do the textures tell you about how rapidly the plant parts might compost or degrade when turned back into the soil?
4. Draw a representative plant to show the function of each section of the plant (feel free to use a stylized drawing, not necessarily a realistic drawing, to emphasize the function).

EXERCISE 20. IS THE SOIL A LIVING THING?

Background

This is a quick introductory exercise. The task is simply to list the basic characteristics that define living organisms, in contrast to non-living things. This exercise will help as a reference point for later discussions of the nutritional and energy needs of plants, and to be able to talk about soils as a "living thing".

Goal

To be able to list the principal characteristics that define living organisms

Time required

45 minutes

Materials

Newsprint

Tape

Pens

Steps

1. Trainer motivates the discussion by asking "is the soil a living or a dead thing?"
2. Participants contribute to make a list of characteristics that uniquely define living organisms.
3. Discussion on what characteristics of soils suggest that they are "alive".

Questions & Points to Emphasize

1. While the list may be long, the trainer should emphasize (and include, if not already listed by participants), the following:
    a. Feeding
    b. Growth
    c. Breathing (respiration)
    d. Reproduction
    e. Elimination of wastes

   f. Death

2. Which of these characteristics can be said to be true for soils? While the soil itself is a composite of both living and non-living things, it nevertheless shares several characteristics of a living entity. Principally:
   a. it breathes,
   b. it needs to be fed,
   c. it creates waste products
   d. and in many respects, it can "die" (ask the group if they know of any examples in which soils have been damaged and degraded to the point of being "dead"?)

How many living organisms in the soil?

A study done in central Europe shows just how "alive" the soil really is. The study measured the amount of living organisms in one hectare of soil, down to 20 cm in depth.

The facilitator should pose the question to the group as to how many kg of insects, worms, bacteria and fungi they believe are in a typical hectare of soil (offer the matrix below, but without the numbers). To date, most participants have seriously underestimated how much living material exists in the soil (especially bacteria and fungi!). Recall, however, this study was done in the temperate zone. Values will be different for the tropics (and depend greatly on the amount of organic matter in the soil).

Organism	Kg / Ha x 20 cm deep
Insects	17
Worms	600
Bacteria	1,500
Fungi	3,500

EXERCISE 21. WHAT IS ENERGY?

Background

Energy is one of those ideas for which we all have a basic feeling, but may find difficulty in defining or explaining. When we think of what constitutes a living organism, one of the first characteristics we think of is that living things capture, process and store energy—yet some things that are not alive also have this capability (can you give some examples?).

Like all living organisms, plants need energy to do the work of growth and development. We can feel energy when we feel the heat from the sun. ***But only plants have developed the ability to capture, process and store energy directly from the sun***. As a result, all other life on earth depends on plants for energy—either directly (feeding on plants) or indirectly (feeding on animals that feed on plants).

Goal

This is a quick and easy exercise, probably best done as a facilitated large-group exercise/discussion. The objective is simply to get participants thinking about the diversity of forms in which energy exists, and to link the idea that food for animals originally comes from plants, and ultimately, from the sun.

Time required

30 minutes

Materials

Newsprint

Paper

Tape

Steps

1. As a large-group discussion, ask the participants to offer up a listing of different TYPES of energy, in one column, and examples of these in the next column (as below).
2. If participants have difficulty thinking of food as energy, offer some hints, such as "…if I am working all day and am tired, what do I need to increase my energy…?"
3. The facilitator should end up the discussion by tying together the idea that plants are the ONLY avenue ("open doorway") through which sunlight is captured and processed by life on earth. All sources of

FOOD (chemical energy) for animals comes originally from plants, and ultimately from the sun. ***None of the other types and sources of energy on the list relate to the process of life.***

Type of Energy	Source (example)
Solar energy	Sun
Heat energy	Fire
Kinetic energy	Wind, Water
Electrical energy	Electrical generator
Magnetic energy	Magnet
Chemical energy (inorganic)	Battery, petrolium
Chemical energy (organic)	Food

4. This is a good time to contrast short-term and long-term storage of energy in plants.
   a. Ask participants ‘if you are tired and want quick energy what do you eat? {sugar}
   b. If you need to work all day in the field, can you depend on eating just sugar? {no}
   c. What do you need to eat? {rice, or some kind of starchy food}
   d. What happens if you put a spoonful of sugar in water and stir?
   e. What happens if you put a spoonful of starch (e.g., rice grains or potato slice) in glass of water and stir?

This line of questioning should lead to an appreciation that sugar is rapidly dissolved/digested and gives quick energy, but that starch does not dissolve/digest as quickly, and therefore, while not being “quick energy”, gives a more longer lasting source of energy to the body.

5. ***SIMULATION***. Have the participants act out the difference between ***sugar*** and ***starch***:

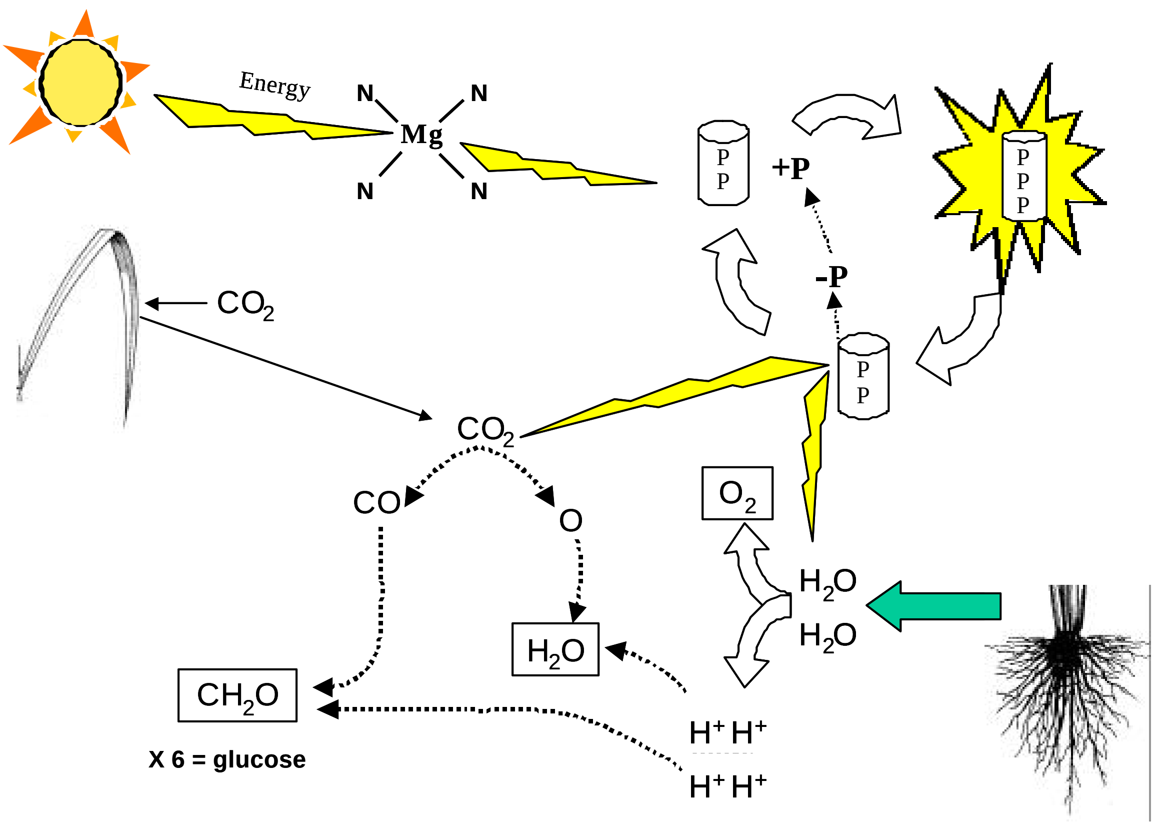
    a. Five or six individuals each represent sugar molecules. Draw a circle on the ground large enough to fit all of them and call it the "stomach". Discuss how all of them, together in the stomach are able to be digested and give up their energy at the same time.

    b. Have the five or six individuals link hands to form a chain—this represents "starch" (present the idea that starch is just sugar linked together in long chains, with hundreds or thousands of sugars). For "digestion" to take place, the "sugar" on the end needs to be broken off first. So "digestion" takes place much more slowly, and the energy given to the stomach is much lower at any one time, but lasts much longer.

EXERCISE 22. PHOTOSYNTHESIS

Background

This exercise is an important “end point” in this early process of discussing plants and energy. It builds on the previous exercises, drawing together the ideas on how atoms are linked as molecules and modified through the use of energy. In a separate exercise participants learned of the source and method of energy capture by plants, plus the manner in which energy is stored in short-term molecules. The first part of this exercise can be done on paper or white board, but the drawings, no matter how well done, will still leave participants unclear about mechanisms. The goal of the subsequent simulation is to make clear the concepts. In this simulation participants will act out the principal mechanisms of photosynthesis.



Goal

To have participants understand and be able to describe and act out the basic mechanisms involved in photosynthesis, including energy and nutrient-related processes, inputs and outputs.

Time required

60 minutes

Materials

Paper labels with the written symbols:

SUN (1)

Mg++ (1)

P (in the shape of a battery) (1)

O (4)

H (4)

C (1)

Steps

You will need 12 participants to run the simulation

1. Individuals are chosen to represent one factor, and they each use a paper letter symbol written on it to represent the following:
    a. the sun
    b. a chlorophyll protein molecule, with Mg++ at the center
    c. a “phosphate battery”
    d. a CO_2 molecule (three participants)
    e. two H_2O molecules (six participants)

2. First, the ***“light reaction”*** takes place:
    a. the sun transfers energy to the ***chlorophyll molecule*** (the participant representing the sun hands a piece of paper or some

object that represents sunlight energy to the participant representing the chlorophyll molecule),

b. the phosphate participant (the "star" of the show) passes by the chlorophyll molecule and picks up energy (make it dramatic: before passing by he/she looks weak and slow; after being "energized" he/she looks full of energy),

c. The "charged up" P moves over to two groups of three participants each, representing two H_2O molecules. The phosphate uses his energy to break the links (linked arms are unlinked).

d. The six "H" participants stand to the side to wait for the next step,

e. For each "charge" remember that energy from the sun is transferred to the chlorophyll molecule, which is then used to "charge up" the "phosphate battery"

f. The recharged P now uses his/her energy to construct O_2 (joining the hands of the two oxygen molecules from water)

3. Next, the ***"dark reaction"*** takes place:
    a. The "phosphate battery" uses its energy to break apart CO_2 into C-O and O.
    b. The C-O pair now are hooked together (by P) with two H participants to form a sugar molecule (H-C-O-H), and
    c. the remaining O is hooked together with the two remaining H participants to form H_2O.
4. Run this simulation several times until the participants can do it smoothly. Switch roles and participants so that everyone gets a chance. Make sure everyone understands exactly what is being represented by each participant.

Questions & Points to Emphasize in Discussion

1. the energy that was originally in the form of sunlight is transformed into chemical energy, in the form of sugars and starches, through the action of the plant.
2. green plants are the ***only*** organisms that can derive energy directly from the sun (while humans are able to absorb and feel the energy of the sun, our bodies are unable to capture, process and store this energy).
3. while animals can derive food from eating other animals, ultimately all food and energy for life on earth originates from green plants, and therefore the energy from the sun. The trainer can use this as an entry point (if the topic has not already been introduced) to introduce the idea of a **FOOD WEB**, as a community of organisms in an ecosystem

that are interconnected, either directly or indirectly through interactions whereby energy and nutrients are passed from one organism to the next.

4. the metal ion **MAGNESIUM (mg++)** is responsible for the direct capture of the energy from sunlight. The mg++ is found in the center of the CHLOROPHYLL molecule, surrounded by four Nitrogen atoms. The reason a plant is green is because of the magnesium in chlorophyll. The magnesium ion, however, is unable to “hold” energy, so it must pass it on to a more permanent form—the phosphate “rechargeable battery” and ultimately sugar and starch.
5. the forms of energy storage (sugars, starches, fats and oils) and the use to which the energy is put (growth and reproduction) are fundamentally the same for both plants and animals.
6. Ultimately, the energy that comes into a system is exhausted, with the last of it being used by microorganisms that seek energy through the breakdown of organic matter. Nutrients, on the other hand, are recycled in the same system, or else move on into a different system. While molecules change form—some slowly, some quickly--the atoms are never destroyed. The atoms that make up our world are ancient, having been around for billions of years and constantly recycled in and out of countless ecosystems.
7. What happens to the plant if there is not enough P? N? Mg++?

EXERCISE 23. MACRONUTRIENT SOURCE, FUNCTION AND BEHAVIOR

Background

Nutrients have a primary location or "Primary Reservoir" where most of the nutrient is located. For Carbon, Nitrogen and Oxygen the atmosphere serves as the primary reservoir. It is interesting to think that more than 90% of the dry-weight material (meaning the plant material excluding all the water) that makes up the body of a plant comes either directly or indirectly (in the case of Nitrogen) from the atmosphere! These elements tend to move and change quickly in the soil environment (nitrogen, for example, is highly mobile and takes on many forms).

In contrast, the "soil-based" nutrient elements have their reservoir in the soil itself. These nutrients include phosphorus (P), potassium (K), sulfur (S), calcium (Ca), and most of the mineral "trace elements" or "micronutrients" (of which the plant requires only a very small amount to grow).

Goal

To understand where nutrients are stored in the environment, where they are found in the plant, what their function is in plant growth and development, and what their behavior is when in the soil environment.

Time required

60 minutes

Materials

Pens

Tape

Newsprint

Steps

This exercise is presented here as a facilitated large-group discussion. This is principally because much of the material will be new to participants, and they will therefore be more dependent on input from the trainer.

The facilitator begins by asking the group to help fill in the table below. Go over each point querying the participants for as much knowledge as they possess, then provide some input, only if the participants are unable to come up with the complete answer.

Questions & Points to Emphasize

1. N and C are "atmospheric" nutrients, while P, K and the other macro and micronutrients are almost all having their source from the soil (mineral nutrients). Recall from the simulation on photosynthesis that C comes directly into the plant through the leaves as the gas CO_2. Most nitrogen, on the other hand, is obliged to pass through microbial populations in the soil in order to be "fixed", and eventually pass on to the roots.
2. For rice, about 70% of the N is found at harvest in the panicle. For P the distribution is about 50/50 panicle/straw, while for K, 98% resides in the straw. Discuss the implications for recycling nutrients by putting straw back into the soil.
3. For behavior in the soil, discuss the implications of the fact that N is highly mobile, under several different forms, and that no "mineral" source for N exists naturally in the soil. This means that the availability of Nitrogen to the plant is highly dependent on the soil environment. This contrasts with both P and K, which are very much less mobile, and less frequently than N are limiting factors to production.
4. What other nutrients are necessary? Introduce the idea that some 20 different nutrients are required—what are some of them and how to they fit into this matrix? (see Appendix B).

Nutritional Factor	Principal Source	Function	Distribution in Plant	Behavior in soil
N	Atmosphere via soil microbes	Part of "dynamic" molecules especially proteins	Rice: 70% in grain 30% in straw	Highly mobile
P	Soil reservoir	energy transportation important part of proteins	50% grain 50% straw	Not mobile easily immobilized
K	Soil reservoir	important for fruiting, transportation of nutrients, and stem turgor	2% grain 98% straw	Not mobile
C	Atmosphere	Principal structural element: sugar, starch	55% of dry weight of plant is C	variable, depending on form
Others?				