Seeds to Seeds

A Scientific Investigation

National Science Education Standards

All students should develop

- **Abilities necessary to do scientific inquiry**
- **Understandings about scientific inquiry**

This exciting, meaningful activity is paramount for students to realize how very powerful scientific inquiry is in regard to its implications to everyday life. Students will plant winter wheat, harvest the wheat, compare harvest yields for three "treatment" plots, and draw conclusions based upon the results.

Harvest season for winter wheat varies according to location. Some schools and school systems have year-round schedules and, regardless of the time of the harvest season, the same students who plant the wheat will harvest it, will determine harvest yields, and will draw conclusions about the effects of fertilizer on the growth of wheat. In some areas, the harvest season for winter wheat is early enough that students will harvest the wheat before the scheduled summer break – even in schools with traditional school calendars. (This is true for parts of the southern U.S., including Georgia where this lesson was field tested.) In situations where the students will not be present when the wheat is ready to harvest, it is suggested that teachers seek volunteers to cut and bag the wheat and when students return to school the following term, they will complete the activity. (Volunteers could include master gardeners, PTA groups, science clubs, and members of community, civic, and service clubs.) After the students have returned to school, the students who have now progressed to the next grade level, along with "new" students, will determine the harvest yields and draw conclusions about the effects of fertilizer on the growth of wheat. The lesson is written such that students who harvest the wheat do not have to be the ones who planted the wheat.

In addition to implementation in the regular classroom, this lesson is a fun and educational experience for students participating in extracurricular science clubs, homeschool study groups, 4-H programs, and enrichment and remedial programs.

Background Information

Essential Plant Nutrient

Seventeen chemical elements are known to be essential for plant growth. An element is considered essential if it is necessary for the plant to complete its life cycle, including vegetative and reproductive phases, and no other element can substitute for it completely. Essential nutrients are divided into main groups: non-mineral and mineral.

Non-mineral nutrients are carbon (C), hydrogen (H), and oxygen (O). Those nutrients are found in the atmosphere and water. They are used in photosynthesis.

Products of photosynthesis account for most of the increase in plant growth. Insufficient carbon dioxide, water, or light will reduce growth. However the amount of water used in photosynthesis is so small that plants will show moisture stress before water is low enough to affect photosynthesis rate.

The 14 mineral nutrients – those coming from the soil – are divided into three groups: primary secondary, and micronutrients. **See chart below.**

The primary nutrients usually become deficient in the soil first, because plants use relatively large amounts. The secondary nutrients and micronutrients are usually deficient less often. Although smaller amounts are usually used, they are just as important as the primary nutrients. Plants must have all of the secondary nutrients and micronutrients when and where they need them in meeting the nutritional needs of plants.

Lack of Nutrients

What happens if crops and food plants don't get the correct balance of needed nutrients at the right time? Various negative effects can include poor growth, yield losses, inferior quality harvests, poor nutritional value, and diminished storage and shelf life, and greater disease and insect damage. Components of crop products that may suffer include contents of protein, carbohydrates, vitamins, and other nutritive factors.

A few examples of how various deficiencies of nutrients can affect some fruits, vegetables, and other crops are described in "Plants Need Proper Nutrition" (see page 68) and included on the CD *It's All about the Food.*

Replenishing Nutrients

The nutrients removed in harvested crops are replaced from minerals in the soil and as soil organic matter decomposes and breaks down. However, there is only a limited supply of organic matter in soil. It must be replenished from decomposing plant residues, but building organic matter takes years and soil minerals are often very low.

Most of the nutrients exported from the field in food products cannot easily be recycled, so fertilizers are needed to replace the nutrients that are mined from the soil by crop growth. They help produce higher crop yields, and higher yields mean more plant residues to rebuild soil organic matter.

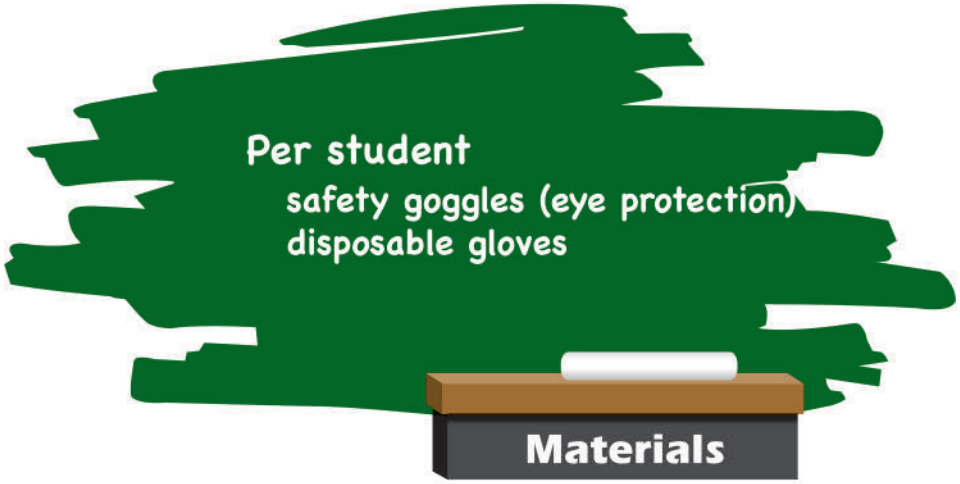
Farmers could not produce enough food to feed the world if they did not use mineral fertilizers. Fertilizer accounts for an estimated 40% to 60% of crop yields in North America and even more in some developing areas of the world.

Adjusting Soil pH

Soil pH is an important characteristic defining relative acidity or alkalinity. Many factors influence soil pH, including parent materials, the amount of precipitation, native vegetation, crops grown, soil depth, and nitrogen fertilization. When soil pH is too low (acidity is too high), various detrimental effects may hinder plant growth and damage root systems. Desirable pH levels vary – some crops thrive in more acid conditions. Limestone can be used to eliminate soil acidity. Sulfur is commonly added to soils where the pH is too high for optimal plant growth.

Primary Nutrients	Micronutrients
Nitrogen (N)	Boron (B)
Phosphorus (P)	Chloride (Cl)
Potassium (K)	Copper (Cu)
	Iron (Fe)
Secondary Nutrients	Manganese (Mn)
Calcium (Ca)	Molybdenum (Mo)
Magnesium (Mg)	Nickel (Ni)
Sulfur (S)	Zinc (Zn)

Lab Activity



Per class

surveyor's tape
stakes (for marking the plots)
hammers
rakes
meter sticks
metric rulers
twine (for marking the rows)
hand spades
wheat seeds
permanent markers
"yard sale" type signs that can be used for labeling the plots
landscape timbers (if necessary)
spreader (optional)
fertilizer
lime or sulfur (if necessary)

Teacher Preparation (2 to 3 weeks before beginning the unit)

A. Contact your local Cooperative Extension Office for information about purchasing wheat seeds, planting and harvesting wheat in your area, and determining the recommended amount of fertilizer (and, if appropriate, lime or sulfur for adjusting soil pH) for growing wheat on your site. Each state has an office at a land-grant university; also, in most states there is a network of regional offices. The Cooperative Extension office serving a given area (county or region) can be found on the USDA's website: http://www.csrees.usda.gov/Extension/. (If soil samples will be taken and sent for testing, allow 7 to 10 days to get the results – in Georgia, where this lesson was field tested, the University of Georgia (UGA) College of Agricultural and Environmental Sciences soil test kit costs $15.) Also, help can be acquired by contacting local feed and seed stores, contacting local master gardeners, and searching the internet.

B. Select the area where 3 winter wheat plots (3 m x 3m) will be established. Each of the three sites will be 3 m x 3 m, will need to be within close proximity of one another and, if possible, will need to be near a water source. Further, the terrain of the plots should be level and each plot should receive full sun throughout the day. Mark the 3 m x 3 m area plots with stakes and surveyor's tape. Ask a parent volunteer, master gardener, or, if feasible, school custodian to clear the area where the three plots will be located and, if necessary, to till the soil. If soil samples will be taken and sent for testing, acquire a soil test kit and follow the directions precisely.

C. Purchase wheat seeds, fertilizer, and, if necessary, lime or sulfur. To Plot C the recommended amount of fertilizer will be applied; to Plot B one-half the recommended amount of fertilizer will be applied; and to Plot A no fertilizer will be applied. The same amount of lime or sulfur for adjusting the pH will be applied to each plot. Refer to Part A (above) for sources of help in determining the amount of wheat seeds to purchase and the amounts of fertilizer and lime or sulfur to purchase.

Note 1: One of the teachers, who participated in field testing this lesson, took the recommendations (based on soil test results) received from the UGA College of Agricultural and Environmental Science to a local feed and seed store. From the size specification of the plots, information regarding what the students would be doing, and the recommendations derived from the soil analysis, personnel at the feed and seed store determined (1) how much fertilizer and lime needed to be applied to a plot (3 m x 3 m) which would receive the recommended amount of fertilizer and lime, (2) how much fertilizer and lime needed to be applied to a plot (3 m x 3 m) which would receive the recommended amount of lime and one-half the recommended amount of fertilizer, and (3) how much lime needed to be applied to a third plot (3 m x 3 m) which would receive the recommended amount of lime and would receive no fertilizer. (All 3 plots received the same amount of lime.)

Note 2: It is recommended that the soil is tested and the results of the soil test are used to determine the recommended amount of fertilizer and pH adjustment for growing wheat; however, if a soil test is not done, soil amendment recommendations for planting wheat in specific areas can be obtained from feed and seed stores and through searching the internet. Below is an example of general recommendations; these recommendations are for growing wheat in Georgia.

	5-10-15 Fertilizer	Lime
Plot C (3 m x 3 m)	400 g (0.9 lb.)	1.6 kg (3.5 lb.)
Plot B (3 m x 3 m)	200 g (0.4 lb.)	1.6 kg (3.5 lb.)
Plot A (3 m x 3 m)	0 g	1.6 kg (3.5 lb.)

Procedure

DAY ONE

A. Discuss with the students that they are going to be involved in a scientific study in which they will compare the effects of fertilizer on winter wheat production. Three winter wheat plots will be established. Also, let the students know approximately how much time will be needed before they can harvest the wheat. If the project will extend into the following academic year, explain to students who will complete the project and, if the students who planted the wheat will not be the ones harvesting, explain how the results of the study will be communicated to the ones who planted the wheat.

B. Explain to the students that everything for the three plots will be the same other than the amount of fertilizer applied. The plots will be marked with signs – A, B, C. To Plot C the recommended amount of fertilizer will be applied; to Plot B one-half the recommended amount of fertilizer will be applied; and to Plot A no fertilizer will be applied.

C. Explain and discuss the **Background Information** for this lesson.

D. Explain to the students how the amount of fertilizer that will be applied to Plot C and to Plot B was obtained. Also, explain any pH adjustments that will be made.

DAY TWO

A. Have students take rakes, hammers, twine, stakes, spreader (if you are using one), meter sticks, surveyor's tape, lime or sulfur (if appropriate), and fertilizer to the site. Have the students rake the soil level.

B. Divide the students into groups and have them measure and mark using surveyor's tape and stakes 3 plots that are each 3 m x 3 m. Tell the students the stakes must be driven deeply into the ground.

C. Place landscape timbers (end-to-end) between plots as barriers to help prevent run-off from one plot to another, if there is a chance that run-off among plots could be a problem.

D. It is recommended that the teacher apply the soil amendments (fertilizer, lime, sulfur) to the plots; students, as well as the teacher, should wear safety goggles (eye protection) and disposable gloves. After the amendments have been broadcasted by hand or spreader (preferred), have the students rake the amendments into the soil.

E. Assign plots and specific tasks to students. Have students use twine and stakes to mark the rows in each plot; rows will be 30 cm apart. As the students work, check each plot and make sure each plot has the same number of rows. If necessary, have the students make adjustments where needed.

F. Have students return the garden supplies to the place where they are stored.

G. Have students wash hands and return to the classroom. Discuss how nutrients are replenished in the soil.

DAY THREE AND (IF NECESSARY) DAY FOUR

A. Have students take a hammer, meter sticks, metric rulers, hand spades, and wheat seeds to the plots; also, the students will take the materials for making the signs that identify the plots.

B. Explain to the students that for the purpose of this study, they will in each row plant the seeds 2 cm apart and approximately 2.5 cm deep. Students will use hand spades. Students will wear safety goggles (eye protection) and disposable gloves. Have the students begin working.

C. Assign three students to make weatherproof signs (8.5" x 11") for the plots: Plot A, Plot B, Plot C. Have students hammer each of the signs in its plot securely into the ground.

D. When students are finished, have students return the garden supplies and remaining seeds to the place where they are stored.

E. Have students return to the classroom and discuss the project's problem. Discuss what it means to make a hypothesis.

F. Have each student record the problem and his or her hypothesis on a sheet of paper. Ask students to read what they have written for the **problem** and **hypothesis.**

G. Discuss the concept **control**. Have students identify the variables in this experiment and to describe which variables are being controlled and how those variables are being controlled.

H. Tell students that nothing will be done to the plots between now and harvest unless there is a severe drought. At that time, water will be applied to each plot; the water will be measured to ensure that each plot receives the same amount. Discuss what happens if crops don't get the correct balance of needed nutrients at the right time. Have students discuss what they expect to happen during the months between now and harvest.

MONTHS LATER -- DAY ONE (preferably a Friday)

After the wheat plants have lost most of the green color in their leaves and the heads (kernels) are hard to bite, the plants are ready to be harvested.

If the wheat cannot be harvested by the students due to their being on summer break, volunteers can cut the plants and pack them in bags. (Potential volunteers include master gardeners, PTA groups, school science clubs, and members of community, civic, and service clubs.) Ensure that the volunteers know to cut the wheat at the ground and carefully to place the plants in paper bags labeled according to the treatment: A, B, C. Volunteers will need to take the wheat to a place where the wheat can be placed on newspaper to dry. After allowing several days to dry, the wheat can be returned to the labeled bags until the time the students will obtain harvest yields.

Procedure

A. Tell the students that the purpose of this experiment is to determine the effects of fertilizer on the growth of winter wheat. Explain to the students what has been accomplished and what is yet to be done. Discuss the **Background Information** of this lesson. (If the same students who planted the wheat are harvesting it, this will be a review.)

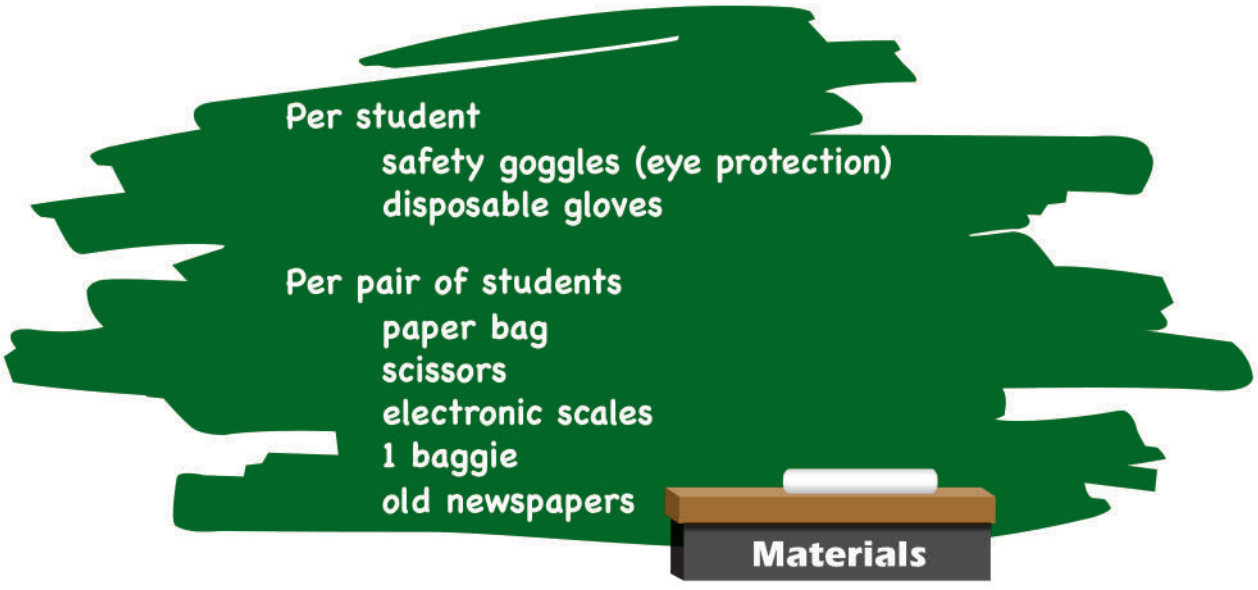
B. Tell the students that they will determine the harvest index for each of the 3 plots. Explain the steps for harvesting wheat and obtaining the harvest index. (If the wheat was cut and bagged by volunteers due to the students being on summer break, share this information with the students – letting them know that steps #1 and #2 have already been accomplished.)

1. Cut or break the stems or plants at or near the ground level.
2. Place the plants in a warm area where they can dry for 2 or 3 days. (Over the weekend is fine.)
3. Obtain the mass of the plants (leaves, stems, and heads); this is the total aboveground biomass of the plant.
4. Cut off the heads of the plants and thrash out by hand the seeds – roll the heads back and forth in your hands and let the seeds along with the chaff fall onto the table. Separate the seeds from the chaff by gently blowing on the seeds.
5. Obtain the mass of the seeds; this is the kernel or seed yield.
6. Compute the harvest index (seed yield per square meter divided by total aboveground biomass per square meter).

C. Explain the term **harvest index**. The harvest index is what is important to the farmer -- the harvest index for wheat is the ratio of the seed yield (mass of the seeds) to the total aboveground biomass (leaves, stems, heads). A big, beautiful plant with few seeds means nothing when the goal is food production. Accordingly, when more plants compared to fewer plants are required to produce a given amount of seeds, the cost to the farmer and in turn to the consumer is greater.

IF THE WHEAT WAS CUT AND PLACED IN BAGS BY VOLUNTEERS, DISREGARD STEPS D, E, and F. AND PROCEED TO STEP A OF DAY TWO.

Materials For Harvesting Wheat



D. Accompany students to the plots. Assign pairs of students specific rows/plots to harvest. Have students wear eye protection and disposable gloves.

E. Distribute paper bags and have the students begin harvesting the wheat. Have students write the name of the plot (A, B, or C) on the paper bag to prevent any confusion as to which plants were harvested from which plots.

F. After students return to the classroom, have them place the plants on newspaper to dry. It is highly recommended that plants from Plot A be placed in one area of the classroom, Plot B in another area, and Plot C in a third area. Further, each of the areas needs to be labeled **A, B,** or **C**.

TWO OR THREE DAYS LATER – DAY TWO

A. Divide the class into three groups: A, B, C. (If the same students planted and harvested the wheat, these groups have already been established.) Tell students Group A will obtain the harvest yield for Plot A; Group B will obtain the harvest yield for Plot B; Group C will obtain the harvest yield for Plot C.

B. Distribute the "Data and Conclusions" sheets. Have the students record the purpose on the "Data and Conclusions" handout.

C. Review the procedure for obtaining the harvest index.

1. Determine the mass of the plants (stems, leaves, and heads). This is the total aboveground biomass.

2. Cut off the heads of the plants and thrash out by hand the seeds – roll the heads back and forth in your hands and let the seeds fall onto the table. Separate the seeds from the chaff by gently blowing on the seeds.

3. Place the seeds in a baggie and mass them to determine the seed yield.

4. Compute the harvest index (seed yield per square meter divided by the total aboveground biomass per square meter).

D. Divide each of the A, B, and C groups into subgroups. Explain to the students that the wheat will be divided among these subgroups such that each subgroup will obtain total aboveground biomass and seed yield for a portion of the plants in a given plot (A, B, or C). (In other words, each subgroup (1) will obtain the total aboveground biomass, (2) will thrash out and bag the seeds, and (3) will obtain the seed yield -- for a portion of the plants in the given plot (A, B, or C). Show students where on the "Data and Conclusions" handout this information will be recorded. After each subgroup has obtained the total aboveground biomass and seed yield for the given subgroup's portion of the plants and recorded the amounts on the "Data and Conclusions" handout, have the subgroups share their data with one another and record this data on the "Data and Conclusions" handout. Have students total and record the total aboveground biomass and seed yield of their plot (either A, B, or C).

E. Have students place the baggies with seeds in a designated place and to clean their work areas.

F. Collect the "Data and Conclusions" handouts.

DAY THREE

A. Distribute the "Data and Conclusions" handouts. Call on one student in each of the three groups to say aloud the total aboveground biomass and the seed yield for his or her plot. Have students record the data on their "Data and Conclusions" handout, as you record the data in a copy of the Data Table appearing on a display (overhead transparency, marker board, etc.) visible to the entire class.

B. Have students divide the total aboveground biomass by 9 and the seed yield by 9 for each plot. Then, divide the seed yield, which was divided by 9, by the total aboveground biomass, which was divided by 9, to obtain the harvest index. (Dividing by 9 is necessary, for the harvest index is the seed yield per square meter -- each plot was 9 square meters in size.) Tell students to record the data on their "Data

and Conclusions" handouts. Have students complete the "Data and Conclusions" handouts.

C. After students have completed the "Data and Conclusions" handouts, discuss the results and conclusions. Discuss:

   1. the differences in harvest yields among the plots;
   2. the variables that were controlled in this study;
   3. the reasons soil tests were done, if they were done;
   4. the effects of fertilizer on winter wheat production;
   5. improvements that could be made should this study be done again.

D. Collect the "Data and Conclusions" handouts.

Seeds to Seeds

Name: _____

Data and Conclusions

1. State the purpose.

_____

_____

_____

2. Compile the data for your group.

Plot ____

Total Aboveground Biomass

_____ + _____ + _____ + _____ + _____ = _____

Seed Yield

_____ + _____ + _____ + _____ + _____ = _____

3. Complete the data table.

	Plot A	Plot B	Plot C
Total Aboveground Biomass			
*Total Aboveground Biomass / 9			
Seed Yield			
*Seed Yield / 9			
Harvest Index per Square Meter (*Seed Yield / *Total Aboveground Biomass)			

4. State your conclusions.

_____

_____

_____

_____