OAT SEED LAB: TEACHER NOTES

PURPOSE: This lab is intended as a first experience doing and reporting an investigative study scientifically. It provides a model to follow in any subsequent investigative studies, either in class or as individual projects. It would be appropriate in any secondary science classroom, but has been used regularly in a high school biology classroom. It includes specific guidelines in setting up the study, collecting the data, processing the data (graphing and calculating significant differences with a t-Test), discussing the results, reaching a conclusion, and suggesting further improvements or further studies.

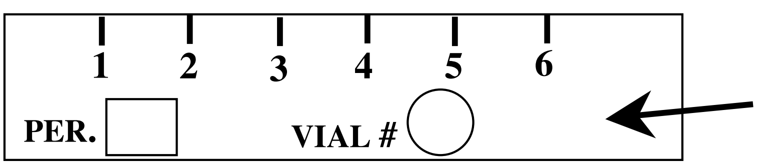
IMPLEMENTATION: This lab can be started in the first week of class as part of an extensive introduction to the nature of science. If seeds are planted on a Wednesday or Thursday, sprouting should be just about right to begin measuring on the following Monday, and continue daily measuring for at least one week (5 close data points). If growth is followed beyond the weekend, seedlings may get too long and start bending and breaking. You can try it, but be prepared for some problems.

Before students set up the lab, you may want to determine (with pre-test or other means) their ability and accuracy in measuring with metric rulers, using mm and cm dimensions, followed by any needed instruction and practice. I've often simply done my quick and practical introduction to the metric system at this point, to serve at least as a review and/or reinforcement (see **Meaningful Metrics** with **Dramatic Demos** at http://www.indiana.edu/~ensiweb/connections/metrics.con.html

MATERIALS PREPARATION:

VIALS: Obtain plastic vials equal to the number of students (one per person), plus some extras in case of problems or absences. Each vial we used was about 3 cm diam. by 8.5 cm tall. This was sufficient to hold 6 oat seeds, held at the top with a layer of wet paper towelling, and holding enough liquid to keep the seeds moist for 2-3 days. Ideally, provide wooden blocks with holes drilled in it to hold the vials needed for a group of students (table, or row). I had rows with 8 students per row, so I had a block for each row, each with 8 holes in it.(each 3.3 diam. by 2.5 cm deep). Each block has a table ID letter on it, and each hole has a vial number next to it. This makes it much easier to distribute each day. Have the shop or a parent make the blocks if you don't have the equipment to do it. Keep the blocks with vials on a north windowsill shelf or another area where all vials get about the same amount of indirect or artificial light (no direct sunlight). Each period had its own set of blocks.

TAPE: Prepare strips of 1" masking tape about 11 cm long. I have my lab assistants place lengths of tape on a glass plate already marked with marker lines 11 cm apart, and use a razor blade to cut across 5-6 strips at a swipe, then use corner of blade to begin removal of the strips. Students get their strips and lay them out like this, placing 6 numbered marks about 1.5 cm apart (location for each oat seed):



Odd numbered vials mark: "Experimental"
Even numbered vials: mark "Control"

Strip should be placed carefully (horizontally) around the vial with its top edge about 1.5 cm below the top edge of the vial. Once this is done, prepared vials (cleaned after each year) can be used year after year without adding the tape, just making sure its period number and roll number are accurate.

TOWEL: If possible, use paper towels from a folded sheet dispenser package (each 3-folded towel is about 8 cm X 24 cm. Fold this in half and tear the halves apart at the crease, forming two 8 x 12 cm pieces, enough for two vials. Roll the piece around your finger and insert into vial so that the top edge is about even with the top of the vial, and the downward fold faces out to the vial (so roots won't grow into the fold).

PREPARING TEST SOLUTION: If you are using VF-11 or some other "plant food," make the concentration recommended in its directions, using tap water to make the solution. If you are using salt (NaCl), try 0.1% solutions by weight (1g/liter of tap water), or 1% solutions (10g/liter tap water), and place into labeled capped bottles to be placed at sinks convenient for students to pour into vials. Clean, empty drinking water bottles (re-labeled) would work for this. Be sure that all bottles contain the same concentration of solution (for the experimental variable).

PROCEDURES:

SEEDS and PLANTING: Oat seeds (*Avena sativa*) can be ordered from most any biological supply house. Have students select 6 seeds randomly (perhaps avoiding obviously damaged or tiny ones). Notice that one end is pointy and the other is fuzzy, and also that one side is grooved while the opposite side is smooth. For consistency, they should all be inserted with the pointy end down and the grooved side toward the plastic vial, between the moistened paper towel and plastic vial, just above its position marked on the tape. This is most easily done by first running a little water into the vial, rolling it around to get the towel wet, then pouring out the water. Using closed forceps, nudge the towel away from the vial at the #1 position, making a little pocket there. Then grasp the seed so the pointy end points away from your hand, with the groove up, and insert between towel and side of vial. Remove forceps leaving seed with fuzzy end up about even with top edge of vial. Repeat for each seed. After "planting," it helps if the damp paper towel is pressed gently around each seed to help maintain its vertical position. This high position in the vial assures that each seed will get some air and not be surrounded by water. Sufficient water is wicked up to the seed by the towel.

ADDING WATER: In the control vial, students fill with tap water to a level about even with the top of the tape (below the seeds). In the experimental vial, students pour the "test" solution from the supply bottles provided at the sinks, same level as the control. They should then place each vial in its assigned hole in the block, and take the block to the area designated by the teacher, where it gets diffuse light (not direct sunlight). It would probably be good idea to reverse the position of the block each day so that the amount of light received by each vial averages out to be about the same over the week or so of growing.

MEASURING: See the "Instructions for Collecting and Processing Data" handout sheet for measuring details. As soon as seedlings begin to show above the vial rims (about 4-5 days after planting), they should begin measuring. Remind them that they should use their metric ruler the same way as their partner, so that the experimental and control seedlings in a given pair of vials will be measured the same way. Also, be sure that students measure and record the lengths of their partners' vials if their partners are absent, and measure both vials for any nearby team where both partners are absent. Keep measuring every school day (takes about 5 minutes each day) until they're so tall that many are bending over.

CLEANUP: On last measurement day, each student pours out the liquids into the sink, then removes the seedlings and paper towels together into a wastebasket (not the sink!) Rinse the vials and place upside down in wire or plastic baskets to drain and dry.

PROCESSING DATA: Students are asked why it's ok to ignore those plants that clearly did not grow at all, or lagged way behind the majority of plants. If they don't come up with anything, give some hints so they come to recognize that they are testing the effect of some variable (the fertilizer or other variable) on the relative *amount of growth* of the seedlings, not whether they germinate (start growing) or not. Also, they should realize that one or two extremely short seedlings, or non-germination, could be due to seed damage or natural poor health. In either case, it would be misleading to include these with the data for the majority of seedlings, and this justifies the discounting of the few not growing well.

CLASS DISCUUSSION: Have teams share results with the class, discuss possible reasons for different conclusions, perhaps reach a class consensus.

ALTERNATIVE STUDIES

Since we may be heading into a time when more and more coastlines may be inundated with seawater, it could be informative to see how oat seeds respond to salty water (see “Preparing Solutions” above).

Try comparing different brands of “plant foods,” with one or two teams (or periods) doing a different brand from other teams (or periods). Or try single components of “plant foods” to see which, if any, influence seedling growth. Ask the question: “Does it stimulate growth, inhibit growth, or have no significant effect on growth?” Consider nitrates, phosphates, or potassium compounds

Ask the question “Why do the seedlings bend toward the window?” See if students can come up with some hypotheses (e.g., “growing toward light” or “growing toward the cooler air next to the window” or “growing away from the students (or teacher, or noise in the room, etc.).” Then see if they can come up with an experimental design to clearly test their hypothesis. The challenge: does the design allow for only one variable? And what, specifically, do they predict to happen if their hypothesis is correct, and if it is wrong? [See the Sample of Research Report part II-B: Predictions].

Consider weighing all the seedlings in each vial separately (blotted equally), listing the weight (“biomass”) from each team for the experimental group, and for the control group, separately. Do a t-Test analysis of those data to see how it compares with the analysis of lengths.

More Questions: Where does elongation occur: tip end, middle, or at the base of the shoot (near the seed)? Clue: Oats are a kind of grass, and when you mow the lawn, what part are you cutting off? Why do you need to mow it weekly (what happens between cuttings)? How can you test your hypothesis? See if students can come up with a process of putting 2 little ink dots 1 mm apart at tip end, middle, and near seed, and predicting which set of dots will move apart. Also, which part of the cotyledon is sensitive to light, and causes the cotyledon to lean toward light? Is this a *bending* process, or a *growing* process? Where does the bend occur? (Charles Darwin was the first to try this).

What is the effect of darkness (or light) on seed growth? Possible **hypotheses**? (light stimulates seed growth, or light inhibits seed growth.) **Test**? (grow 1 batch of seeds in the dark, e.g., inside a cardboard shoebox), and one batch in a clear plastic shoebox, both side-by-side in the light...same temperature, etc.). **Prediction**? (If light stimulates growth, then seedlings in the clear box will grow taller/faster; otherwise, they will all grow the same, or those in the dark box will grow taller/faster.

What is the effect of acid rain on seed germination? UV light on seed germination? Heat/cold on seed germination? High CO_2 levels on seed germination? Will large seeds grow taller/faster than tiny seeds?

Have a contest: which team/class can grow the tallest seedlings? Winners get wrinkled peas (tell them “very special: doubly homozygous recessive!”} Also good for birthday gifts! Or conception day gifts for those with summer birthdays!!

Compare growth with husks on, to growth without husks (do this before “planting”). Also, compare growth with the “groove” toward the vial vs groove away from the vial. Compare growth when planted upside down (fuzzy end down) vs right side up (fuzzy end up).

ALTERNATIVE CONTAINERS, SEEDS: Try using the cut-off bottoms of 1/2 liter drinking water bottles (or similar sized plastic bottles, preferably with uncorrugated lower sides). Line the inner wall with heavy absorbent paper, e.g., paper towel, supported by wads of paper towels inside. Holds more seeds. For other **seeds**, try cucumber and mustard. They’re dicots, but grow fairly straight and fast. Can also measure tap root, or number of branches in shoot.