Plant Growth: Effects of Fertilizer, Drought, & Density

SC Academic Standards: 4.L.5A; 5.L.4A; 6.L.5B; 7.L.3A; 7.EC.5A-B; H.B.3A; H.B.2D; H.B.6A-D

NGSS DCI: 4-LS1.A; 5-LS1.C; 5-LS2.A; 5-ESS3.C; MS-LS1-C; MS-PS3.D; MS-LS2.A; MS-LS2.C; HS-LS1.B-C; HS-LS2 A-C

Science and Engineering Practices: S.1A.1; S.1A.2; S.1A.3; S.1A.4; S.1A.5; S.1A.7; S.1A.8

Crosscutting Concepts: Patterns, Cause and Effect: Mechanism and Explanation; Structure and Function; Energy and Matter: Flows, Cycles, Conservation, and Systems Models, Stability and Change.

Focus Question(s): What factors affect how well a plant grows? How does addition of fertilizer, amount of fertilizer, type of fertilizer, drought, and seed density affect plant growth?

Background: Plants belong to the Domain Eukarya, and the Kingdom Plantae. Plants include mosses and ferns (the more primitive plant groups) and the Gymnosperms and Angiosperms (more advanced plants which make seeds and have vascular tissue). The flowering plants (Angiosperms: Division Anthophyta) are particularly diverse with over 275,000 species which are divided into 2 classes, the **monocotyledons** (monocots) and the **eudicotyledons** (dicots).

Flowering plants (and gymnosperms, but not ferns or mosses) come from **seeds**. Each seed contains a tiny plant embryo waiting for the right conditions to **germinate**, or start to grow. Seeds wait to germinate until three needs are met: water, correct temperature (warmth), and a good location (such as in soil). During its early stages of growth, the seedling relies upon the food supplies stored with it in the seed until it is large enough for its own leaves to begin making food through photosynthesis – so it doesn't necessarily need the sun right away, though it will eventually. The seedling's roots start growing first, from the radicle of the seed, and push down into the soil to anchor the new plant and to absorb water and minerals from the soil. And its stem, with new leaves, pushes up toward the light. The germination stage ends when a shoot emerges from the soil. But the plant is not done growing. It's just started. Plants need water, warmth, nutrients from the soil, and light to continue to grow. Water is obtained from the soil, through the roots, and contains many dissolved nutrients. Light comes from the sun and is absorbed by chlorophyll in the leaves (and green stems). Oxygen is generally absorbed via the roots from the soil as well, but CO_2 is absorbed (and excess oxygen released) from the leaves, through small pores called stomata.

The flowering plant's body is thus: roots are generally belowground (and thus protected from evaporative forces of the sun) and so do not have a cuticle, or waxy covering. **Roots** are mainly used to absorb water and dissolved nutrients from the soil, and to anchor the plant in place / lend to stability. The **shoots** (stems and leaves) are used for photosynthesis and are covered by a waxy **cuticle** which helps to prevent excessive water loss via evaporation, which, in a plant, is called **transpiration**. However, this protective cuticle can limit gas exchange (and plants need to take in CO_2 from the air and respire O_2 out. So, the cuticle has tiny cells called guard cells that together in pairs can create an opening between them – and when open, gases can be exchanged (CO_2 in, O_2 out). The opening is called a stomate (**stomata**, pl.) and is generally found on the underside of the leaf, where humidity is generally greater than the topside of the leaf, and so transpiration slower (the smaller the gradient between inside leaf humidity (near 100%) and outside leaf (air) humidity, the slower the rate of transpiration. And hot sun (top of the leaf) increases that gradient, while the shady humid underside decreases the gradient). It is a fine line between needing CO_2 for photosynthesis and needing to conserve water.

The leaves are where the plants absorb the suns energy to carry on **photosynthesis**. The green light is the *least* useful so the plant reflects that light away and absorbs the red and blue light energy. Because plants reflect green light, they appear (look) green. But in autumn, as plants are preparing to drop their leaves, they reabsorb their colored pigments, including chlorophyll, before leaves drop. When chlorophyll is reabsorbed first, the other colorful pigments (like lycopene (red) and carotene (orange), are visible. Also through the leaves, via pores called stomata, the plants absorb and release oxygen and carbon dioxide.

The other main part of most land plants are their stems which elevate the leaves and transport food, water and dissolved nutrients up and down the plant. Plants have a vascular system, just like animals, and can move sugars, water, etc throughout their bodies. There are two main types of plant veins: the **xylem** moves the dissolved and water and the **phloem** moves the sugars (food). These veins stretch from the roots through the stem and leaves. Water is able to move up the xylem through a process called capillary action. Capillary action occurs when the forces of cohesion and adhesion combine in such a way that they overcome the downward force of gravity, and cause water to move upward through the thin tubes. Water cohesion is the force of attraction between water molecules (hydrogen bonds!) so that they stick together, while adhesion is the tendency of water molecules to stick to other substances.

Unlike animals (humans included!), plants can create their own food. Plants are able to capture the sun's energy and use it to help create sugars which then basically drive the production of all the things that we get from plants (like lipids, starch, vitamins, etc). This process is called photosynthesis. The simple equation

$$\text{Light Energy} + 6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

describes how plants take carbon dioxide and water and with the sun's energy convert these molecules to sugars, water and oxygen. The photosynthetic process occurs in the chloroplasts of plant leaves. **Chloroplasts** are organelles that contain the pigments (specifically and most importantly chlorophyll (among others)). The cholorphyll and the chloroplast membrane are part of the electron transport chain which can capture light energy, transform it to ATP (just like the mitochondria does in cell respiration in plants and animals), and then uses the ATP to convert inorganic carbon (CO_2) into organic carbon (sugar). Organic forms of carbon are amazing energy storage molecules.

Plants (and photosynthetic bacteria (cyanobacteria) and photosynthetic protists (such as some diatoms, dinoflagellates) do photosynthesis during the daytime while it's light, which uses carbon dioxide and produces oxygen. During the day and night plants take in oxygen and release carbon dioxide through cellular respiration (just like animals!) which occurs in the mitochondria.

Cellular respiration is the process where animals (like humans!) and plants break down the sugars created by photosynthesis back into energy. The chemical equation for respiration is basically the opposite of photosynthesis:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{36-38 ATP Energy.}$$

Plants carry on respiration in all their living cells except those actively carrying on photosynthesis. If respiration stops in a cell that cell will die. If enough cells can't get food, oxygen, or water, respiration stops and the whole plant can die.

What do plants need for growth? Sun, Nutrients, Water, Oxygen, Carbon Dioxide, and Chlorophyll. The sun provides warmth and energy for plants to survive. Plants use the sun's energy to makes their own food energy in their leaves. Not enough sun will slow down a plant's growth and even kill it. Too much sun can be a problem too, if the plant transpires too much or the soil dries out too quickly. Even though a plant can make its own food, it still needs access to sunlight, water, and nutrients – this means that plants will compete for space: space for their roots to spread out and absorb water / nutrients, and space for their leaves to access sunlight. In a dense forest, any new space opening up (when a tree falls down for example) has many small plants growing rapidly upwards towards the sun. In areas where water is low in supply, many plants coexist by partitioning the underground space: some plants have a long deep root and can access deeper water; other plants have shallow roots and still others have roots with lengths between the two. This is an example of niche partitioning.

Carbon Dioxide is the carbon source which plants use to make sugar (an organic, or carbon based, molecule). While there is plenty of CO_2 in the atmosphere so that plants don't need to compete for it, climate change, caused in part by increasing levels of CO_2 into the atmosphere, can affect plants. More CO_2 should mean more plant growth, right? Well, some plants do show this, in greenhouse experiments. But plants don't live on CO_2 alone, and with increased growth rates they will need more water and organic matter (and climate change predicts both less rainfall in a lot of agricultural areas and monsoon type rainfall in others, where the rainfall isn't help in the soil but – because of the heavy intense nature of a monsoon – it floods and washes away and erodes what farmland is present. Research also suggests that some plants have decreased photosynthetic rates when CO_2 levels are too high, and some crops, like wheat, show reduced nutritional quality when CO_2 levels are high, while other crops show increased susceptibility to insect pests. Climate Change is complex.)

Soil provides a base which the roots hold on to as a plant grows bigger. It also provides plants with water and the nutrients they need to be healthy. In turn, some plants become healthy food for us. Nutrients in the soil also help plants grow strong. Some nutrients that plants need are nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. These nutrients, dissolved in water, are taken up by active transport into the root (which drives the passive osmosis of water into the root as well. Fertilizers play a key role in increasing the productivity of food crops, whether that's tomatoes in a school greenhouse or vast fields of maize. Ensuring the correct balance of minerals is crucial. If fertilizer (nutrients) inputs are too great into the soil, osmosis can actually go backwards, with water exiting the plant root and going in to the hypertonic soil, causing the plant to wilt and die.

Compacted soil (from plowing, heavy farm equipment, or overgrazing) makes it harder for plant roots to spread out. This limits their access to soil nutrients, reduces air space (important for oxygen!) and weakens the plant's hold in the ground. The more room roots have, the more soil the plant can hold in place so it doesn't wash away (erode) during a rain storm.

When they photosynthesize, plants make carbohydrates which are composed of the elements carbon (C), hydrogen (H) and oxygen (O). To convert these to proteins, the element nitrogen (N) must be added. Most plants obtain their nitrogen from the soil in the form of nitrates. Similarly, to convert carbohydrates to ATP or nucleic acids, the element phosphorous (P) must be added. This is obtained from the soil as phosphates. Potassium (K) and iron (Fe) solutions are also absorbed by plants from the soil for growth. Such substances (e.g. nitrates, phosphates, potassium salts and iron salts) are inorganic (i.e. not derived form living things) and are collectively known as mineral salts. The ones that plants need in the greatest quantities are known as the "macro-elements". Minerals are present inside N:P:K fertilizer pellets and are slowly released to the surrounding soil. Last, fertilizers come in two types: organic (stuff like compost, manure, grass clippings and /or crop residue (like corn stalks)) and inorganic (stuff you buy from the store, containing minerals like N, K, P). While both help a plant grow, organic compost in addition helps to build up the soil. Organic matter in soil acts like a sponge to not only release nutrients but to hold and store water as well.

Water comes from the sky as rain or snow and it flows on top of or through soil into lakes, rivers, and streams. Water is very important to plant growth. Water helps the plant move nutrients from the soil up through its stems and leaves. Water keeps the plant moist, flexible, and helps the plant make its own food. Too little water, as in drought conditions (especially in farmland that is not irrigated, or when irrigation supply is decreased because of the conflict between other water intensive uses such as industry) is a problem for plants. Many plants, in drought conditions, close their stomata in order to reduce transpirational water loss. Without the stomata open they can't photosynthesize. When they eventually open the stomata to obtain CO_2 the resulting transpiration can kill a plant. However, there is such a thing as over-watering your plants. A plant's roots not only need room to spread out in the soil, they also need air! If the ground is oversaturated, it has too much water and not enough air. Some plants can die if the water is not drained away soon enough.

In this lab we will discover how **amount of fertilizer and type of fertilizer** can affect plant growth; how **density** (overcrowding) can affect plant growth, and how **drought** will affect the growth of plants. We will do this by designing controlled experiments identifying the dependent, independent and controlled variables.

<u>Materials:</u> pots or planting trays (ask parents to save theirs from their gardens, or ask a garden store), composted cow manure (black cow – an "organic, rather than synthetic, fertilizer), water, 20N:20P:20K slow release pellet fertilizer, soil (plain potting soil, no miracle grow added – it is best to create your own soil blend of 1/3 sand, 1/3 vermiculite, and 1/3 peat moss), radish seeds, light source.

(***Teacher's note:** Keep all the pots in the same setting to minimize any variation in temperature, lighting, pests, and other environmental factors. Even when the environmental conditions are kept as constant as possible, it is a good idea to randomize the grouping of plants rather than placing all the plants that are receiving the same treatment together in one group. This helps to further minimize the effect of any environmental differences).

(*Teacher's note: prepare germinated radish seeds by taking a cookie sheet, layering it with wet paper towel, spreading out the seeds, and covering with wet paper towel. Add more water as needed, but don't flood – just keep it moist. They should germinate in 3-5 days, so prepare these about a week in advance).)

Procedure: A. Test effects of amount of organic compost on plant growth.

1. Each group needs approximately 100 germinated radish seeds.
2. Mix your different soil types (treatments) as directed:

A: 100% compost
B: 25% soil / 75% compost
C: 50% soil / 50% compost
D: 75% soil / 25% compost
E: 100% soil / 0% compost

3. Prepare 15 pots per group (3 of each treatment). Fill each pot ¾ full with soil mixture. Wet soil until it just begins to run out bottom of pot. Label each pot with your name and treatment.
4. Plant the required number of seeds about 0.5 cm below the surface (use a pencil to make a hole, drop in, use eraser to spread soil over. Be gentle, don't break off germinating root/shoot of radish seed).
5. Every other day for 2 weeks measure the height of each plant, then combine to get an average for each treatment:
   (total height of all plants / total # plants measured)
6. Every other day also water the plants: 20 ml of water per pot.

Treatment	**# pots (6 seeds per pot)**	**# of germinated seeds: these have stems poking above soil surface**	**% seed germination ((#germinated/total # seeds in pot)*100)**	**Average height of plants in pot (mm)**
A: 100% compost	**3**	**/18**		
B: 25% soil / 75% compost	**3**	**/18**		
C: 50% soil / 50% compost	**3**	**/18**		
D: 75% soil / 25% compost	**3**	**/18**		
E: 100% soil / 0% compost	**3**	**/18**		

Table 1. Effects of amount of organic compost / organic matter on plant growth.

B. Test the amount of inorganic pellet fertilizer on plant growth.

1. Each group needs approximately 100 germinated radish seeds.

2. Prepare 15 pots per group (3 of each treatment). Fill each pot ½ full with soil mixture, and Add the required number of fertilizer pellets
3. Add about 3 cm more soil (so there will be about 2 cm between fertilizer pellet and seeds).
4. Wet soil until it just begins to run out bottom of pot. Label each pot with your name and treatment.

5. Plant the required number of seeds about 0.5 cm below the surface (use a
   a. pencil to make a hole, drop in, use eraser to spread soil over. Be gentle, don't break off germinating root/shoot of radish seed).

6. Every other day for 2 weeks measure the height of each plant, then
   a. combine to get an average for each treatment:
      (total height of all plants / total # plants measured)

7. Every other day also water the plants: 20 ml of water per pot.

Treatment	**# pots (6 seeds per pot; 1/3 peat moss, 1/3 vermiculite, 1/3 sand)**	**% seed germination ((#germinated / total # seeds in pot)*100)**	**# of germinated seeds: these have stems poking above soil surface**	**Average height of plants in pot (mm)**
A: 0 fertilizer pellets	**3**		**/18**	
B: 3 fertilizer pellets	**3**		**/18**	
C: 6 fertilizer pellets	**3**		**/18**	
D: 9 fertilizer pellets	**3**		**/18**	
E: 12 fertilizer pellets	**3**		**/18**	

Table 2. Effects of inorganic 20:20:20 N:P:K pellet fertilizer on plant growth

C. Test various regimes of watering to discover effects on plant growth

1. Each group needs approximately 80 germinated radish seeds.

2. Prepare 15 pots per group (3 of each treatment). Fill each pot ¾ full with soil mixture. Wet soil until it just begins to run out bottom of pot. Label each pot with your name and treatment.

3. Plant the required number of seeds about 0.5 cm below the surface (use a pencil to make a hole, drop in, use eraser to spread soil over. Be gentle, don't break off germinating root/shoot of radish seed).
4. Every other day for 2 weeks measure the height of each plant, then combine to get an average for each treatment: (total height of all plants / total # plants measured)

5. Every other day also water the plants according to treatment described in Table 3.

Treatment	# pots (6 seeds per pot; 1/3 peat moss, 1/3 vermiculite, 1/3 sand)	% seed germination ((#germinated / total # seeds in pot)*100)	# of germinated seeds: these have stems poking above soil surface	% seed germination ((#germinated / total # seeds in pot)*100)	Average height of plants in pot (mm)
A: 0 ml Water for 5 days, then 20 ml on day 6, then 0 ml for next 5 days, then 20 ml on day 12, then no water again	**3**		**/18**		
B: 0 ml water for 3 days, then 20 ml on day 4, then no water for three days, then 20 ml on day 8, then no water for 3 days, then 20 ml on day 12, then no water again	**3**		**/18**		
C: 0 ml water for 2 days, then 20 ml on day 3, then no water for two days, then 20 ml on day 6, then no water for 2 days, then 20 ml on day 9, then 20 ml on day 12, then no water again	**3**		**/18**		
D: Water every other day with 20 ml of water	**3**				

Table 3. Effects of drought on plant growth.

D. Test the effects of density (# seeds in a pot) on plant growth

1. Each group needs approximately 120 germinated radish seeds.

2. Prepare 15 pots per group. Fill each pot ¾ full with soil mixture. Wet soil until it just begins to run out bottom of pot. Label each pot with your name and treatment.

3. Plant the required number of seeds about 0.5 cm below the surface (use a pencil to make a hole, drop in, use eraser to spread soil over. Be gentle, don't break off germinating root/shoot of radish seed).

4. Every other day for 2 weeks measure the height of each plant, then combine to get an average.

5. Every other day also water the plants: 20 ml of water per pot.

Treatment	# pots (1/3 peat moss, 1/3 vermiculite, 1/3 sand mixture)	# of germinated seeds: these have stems poking above soil surface	% seed germination ((#germinated / total # seeds in pot)*100)	Average height of plants in pot (mm)
A: 5 seeds	3	/5		
B: 10 seeds	3	/10		
C: 15 seeds	3	/15		
D: 20 seeds	3	/20		
E: 25 seeds	3	/25		

Table 4. Effects of pot overcrowding (density) on plant growth.

Data Analysis:

1. Graph germination rates and plant growth over time for the different treatments. Also, determine the mean number of seeds germinated and mean size or mass of the plants at the end of the experiment. Compare average germination rates, plant growth, and health for the different experimental treatments. Based on your experiments, what was the optimal potting mix, or density, or watering regime, for plant germination? For plant growth?
    a. # Germinated Seeds can go on Y, Treatment on X
    b. Average Height (mm) on Y, Treatment on X
    c. Average Height (mm) on Y, Time (days) on X (with key for treatment type)
2. Some things may have gone wrong in your experiments. For example, you may have over-watered your plants, causing them all to die from fungal infection regardless of the treatment. Or you may have taken measurements only on plant height, and later decided that measuring the number of leaves and length of the main stem would have given better information. These types of problems are normal and can be used as a basis for redesigning the experiment. How might you change your experimental design if you were to carry out another set of growth experiments?

3. You may not find any differences between the treatments. Or, you may discover that the plants grown without compost did best. If this is the case, it may be difficult to determine whether the compost had no effect, or you did something wrong. The tendency is to assume the compost really has an effect and to attribute insignificant or negative results to experimental mistakes. However, the interpretation of results should not be biased by your predictions or preconceived ideas about the way experiments will turn out. Often unexpected results lead to important insights and questions. Maybe your compost is of poor quality, or maybe the plant species you chose grows well in poor soils. Explore all the possibilities for explaining your results with an open mind, through discussions and new experiments. Many large seeds (like beans) grow equally well in early stages because of the food contained in their cotyledons – so amount of fertilizer or compost early on doesn't make a difference. You can try different types of seeds, like grass (small) vs. radish vs. bean (large).

4. You may also wish to provide students with a Raw Data table (Table 5) – you will want one for each treatment (for example, for the density experiment, you need 5 tables: one for 5 seeds, one for 10 seeds, and so on).

Day	# germinated seeds in pot	% seed germination ((#germinated / total # seeds in pot)*100)	Height of each plant (mm)	Average Height (mm)
1				
3				
5				
7				
9				
11				
13				
15				

Table 5. Raw Data for Plant Experiment, Treatment = ______________________________

<u>Extensions:</u> Many large seeds (like beans) grow equally well in early stages because of the food contained in their cotyledons – so amount of fertilizer or compost early on doesn't make a difference. You can try different types of seeds, like grass (small) vs. radish vs. bean (large). The larger seeds have more stored food in cotyledon and can grow larger. For a longer period of time in the dark. You can also have students decide what to test – there are so many possibilities: color of light, addition of various salt levels (mimicking hurricane / salt intrusion), pH (mimicking acid rain), light versus dark, etc. Last, growing radishes with different amounts of fertilizer lets you graph your data in a unique way: a **radogram**. Make a bar graph with amount of fertilizer on the X and then slice the 6 radishes horizontally through the middle, to get a circle about 3 mm thick. Stack the 6 radish slices from each treatment up to form the bar for the graph.

For younger kids, just grow a pre-soaked bean seed between a clear plastic cup and paper towel (so, seed is pressed on the wet paper towel, and towel/seed pressed against the inside of the plastic cup, seed facing out so it is visible). Try putting the seed in different orientations (germinating roots come out of the seed's radicle and will grow down, even if radicle points up). Then, every day, measure the length of the roots and shoots. Graph length versus time (day).

Reflection Questions:

- **What do plants need to grow?** (Sunlight, water, soil, nutrients, CO_2, O_2)

- **How does density affect plant growth? Why?** (as density increases each plant should show reduced growth because they are competing for a limited amount of food (nutrients) and water and light (in other words, for example the amount of water remains constant, or controlled, and with more plants, each plant gets less).

- **How does amount of fertilizer affect plant growth?** (more fertilizer generally increases plant growth; however, there is such a thing as too much – overfertilizing sometimes creates a hypertonic soil and water will move via osmosis out of the plant root and into the soil, causing the plant to wilt).

- **How does drought affect plant growth?** (plant growth is reduced).

- **Why did we do 3 pots for each treatment (replication)?** (the more times we do an experiment, and the more times we get the same answer, the greater confidence we have in our result –the more confident we are that our result is correct, that out hypothesis is supported).

Models and Explanations: In this lab we explored the effects of drought (water restrictions), overcrowding (space), and fertilizer (nutrients) on plant growth.
A student who demonstrates understanding of these concepts can justify the design of his/her scientific experiment, identify independent, dependent, and controlled variables, and explain how overcrowding, amount of water, and amount of fertilizer will affect the growth, in height, of radish seedlings. **Further, the student will be able to explain if and why** his / her data supports his/ her hypothesis. **The student should be able to explain that** plants need nutrients,

light, space, and water to survive, and that there are optimum levels of these requirements. Sometimes too much water, or nutrients, or sunlight can be bad, and thus cause a decreased growth rate. Too much water can decrease air spaces, and oxygen to roots. Too many nutrients can cause water to move by osmosis back out of the plant and into the soil, causing the plant to wilt. Sometimes plants that are too crowded together compete for resources and so each plant gets less than optimal amounts of light, water, or nutrients, negatively affecting their growth. **This student would also be able to extrapolate and describe** how plants (radish or otherwise) might react to different amounts of sunlight/shade, or carbon dioxide, acid rain, or color of light.

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<u>**Student Worksheet:**</u>

In this lab we will discover how amount of fertilizer can affect plant growth; how density (overcrowding) can affect plant growth, and how drought will affect the growth of plants. We will do this by designing controlled experiments where we can identify the dependent, independent and controlled variables.

1. Question: How does the amount of **organic** fertilizer affect plant growth?
   a. What is your hypothesis?

   b. What is your prediction?

   c. What is the independent variable?

   d. What is the dependent variable?

   e. What are the controlled variables?

Treatment	**# pots (6 seeds per pot)**	**# of germinated seeds: these have stems poking above soil surface**	**% seed germination ((#germinated / total # seeds in pot)*100)**	**Average height of plants in pot (mm)**
100% compost	**3**	**/18**		
25% soil / 75% compost	**3**	**/18**		
50% soil / 50% compost	**3**	**/18**		
75% soil / 25% compost	**3**	**/18**		
100% soil / 0% compost	**3**	**/18**		

Table 1. Effects of amount of organic compost on plant growth.

   f. What is your conclusion?

2. Question: How does the amount of **inorganic** fertilizer affect plant growth?
    a. What is your hypothesis?

    b. What is your prediction?

    c. What is the independent variable?

    d. What is the dependent variable?

    e. What are the controlled variables?

Treatment	# pots (6 seeds per pot; 1/3 peat moss, 1/3 vermiculite, 1/3 sand)	# of germinated seeds: these have stems poking above soil surface	% seed germination ((#germinated / total # seeds in pot)*100)	Average height of plants in pot (mm)
0 fertilizer pellets	**3**	**/18**		
3 fertilizer pellets	**3**	**/18**		
6 fertilizer pellets	**3**	**/18**		
9 fertilizer pellets	**3**	**/18**		
12 fertilizer pellets	**3**	**/18**		

Table 2. Effects of inorganic 20:20:20 N:P:K pellet fertilizer on plant growth

    f. What is your conclusion?

3. Question: How does drought affect plant growth?
   a. What is your hypothesis?

   b. What is your prediction?

   c. What is the independent variable?
   d. What is the dependent variable?
   e. What are the controlled variables?

Treatment	**# pots (6 seeds per pot; 1/3 peat moss, 1/3 vermiculite, 1/3 sand)**	**% seed germination ((#germinated / total # seeds in pot)*100)**	**# of germinated seeds: these have stems poking above soil surface**	**% seed germination ((#germinated / total # seeds in pot)*100)**	**Average height of plants in pot (mm)**
A: 0 ml Water for 5 days, then 20 ml on day 6, then 0 ml for next 5 days, then 20 ml on day 12, then no water again	**3**		**/18**		
B: 0 ml water for 3 days, then 20 ml on day 4, then no water for three days, then 20 ml on day 8, then no water for 3 days, then 20 ml on day 12, then no water again	**3**		**/18**		
C: 0 ml water for 2 days, then 20 ml on day 3, then no water for two days, then 20 ml on day 6, then no water for 2 days, then 20 ml on day 9, then 20 ml on day 12, then no water again	**3**		**/18**		
D: Water every other day with 20 ml of water	**3**				

Table 3. Effects of drought on plant growth.

f. What is your conclusion?

4. Question: How does the number of seeds per pot (plant density) affect plant growth?
    a. What is your hypothesis?

    b. What is your prediction?

    c. What is the independent variable?

    d. What is the dependent variable?

    e. What are the controlled variables?

Treatment	**# pots (1/3 peat moss, 1/3 vermiculite, 1/3 sand mixture)**	**# of germinated seeds: these have stems poking above soil surface**	**% seed germination ((#germinated / total # seeds in pot)*100)**	**Average height of plants in pot (mm)**
5 seeds	**3**	**/5**		
10 seeds	**3**	**/10**		
15 seeds	**3**	**/15**		
20 seeds	**3**	**/20**		
25 seeds	**3**	**/25**		

Table 4. Effects of pot overcrowding (density) on plant growth.

f. What is your conclusion?

Day	# germinated seeds in pot	% seed germination ((#germinated / total # seeds in pot)*100)	Height of each plant (mm)	Average H (mm)
1				
3				
5				
7				
9				
11				
13				
15				

Table 5. Raw Data for Treatment = ______________________________________