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Kansas Foundation for AGRICULTURE IN THE CLASSROOM
KFAC

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Course:	Biology 9-12	**Unit:**	Vertical Gardening - Agriculture Careers
Lesson Title:	Plant Selection		
Estimated Time:	2 class periods of 40 minutes		

Objectives:

1) Determine which crops best suit vertical gardens based on economic, social, and environmental factors.
2) Explain the basic plant parts, plant physiology, and life cycle.

Equipment Needed:

Electronic device to access and read or watch the news segment
Electronic device for students access and complete choice board
Electronic device or resource for students to research
Electronic device to access and edit the dictionary template

Supplies Needed:

Paper/Notebook for bell ringer and exit ticket
Paper copies of pages 53-77 of the Kansas Garden Guide (1 per student)

Accessibility Options

Students can access information visually through online videos with subtitles and auto-translations.
Utilize Speech-to-Text and text-to-speech add-ons for reading/listening/writing support (Updated 7/17/23)

For more suggestions, please visit:
https://www.washington.edu/doit/equal-access-science-and-students-sensory-impairment

Instructor Directions &	Procedures

Estimated Time	
Day 1 40 minute period	Go over the background of growth and structure Do vocab and life cycle
Day 2 40 minute period	Propagate seeds and allow time for germination and initial growth

No.	9-12 Next Generation Science Standards		
HS-LS 1-2	Structure and Function: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.		
	Disciplinary Core Ideas	Science and Engineering Practices	Cross-Cutting Concepts
	LS1.A: Structure and Function	Developing and using models	System and System Models Structure and Function

No.	9-12 National Agriculture Literacy Outcomes
T1. 9-12 f&h	f. Evaluate the various definitions of “sustainable agriculture,” considering population growth, carbon footprint, environmental systems, land and water resources, and economics h. Understand the natural cycles that govern the flow of nutrients as well as the way various nutrients (organic and inorganic) move through and affect farming and natural systems
T2. 9-12 b&d	b. Compare similarities and differences between organic and inorganic nutrients (i.e., fertilizer) on plant growth and development; determine how their the application affects plant and animal life d. Evaluate evidence for differing points of view on topics related to agricultural production, processing, and marketing (e.g., grazing, genetic variation, and crop production; use of fertilizers and pesticides; open space; farmland preservation; animal welfare practices, world hunger)

T4. 9-12 d&f T5. 9-12 e	d. Evaluate the benefits and concerns related to the application of technology to Agricultural systems (e.g., biotechnology) f. Predict the types of careers and skills agricultural scientists will need in the future to support agricultural production and meet the needs of a growing population e. Discuss how agricultural practices have increased agricultural productivity and have impacted (pro and con) the development of the global economy, population, and sustainability

Supporting Resources
Graphic organizer for easily analyzing data
The Journey 2050 introductory video describes social, economic, and environmental considerations

Vocabulary	
Monocot	“Monocotyledon” is a chiefly herbaceous plant having an embryo with a single cotyledon
Dicot	“Dicotyledons” are flowering plants or angiosperms in which the seeds typically contain two embryonic leaves or cotyledons
Cotyledon	a type of leaf that is part of the developing plant inside a seed and either stores food or grows from the seed to produce food
Hydroponics	a technique of growing plants using a water-based nutrient rather than soil

Careers Mentioned	
Plant scientist	Studied crops and developed ways to improve their quantity and quality
Plant psychologist	Studies of how plants function may specialize in the physical, chemical, or biological function of particular plants.
Weed Scientists	Play an important role in managing vegetation. This includes identifying weeds and learning how to combat them or determining how herbicides interact with plants, offering suggestions on weed control methods to landowners.
Botanist	Studies plants and their environment, such as algae, fungi, lichens, mosses, ferns, and flowering plants. They may specialize in the

	identification and classification of plants.
Plant Geneticist	Research to understand, improve, or create new varieties of plants or crops.
Soil Scientist	Study soil characteristics, map soil types, investigate responses of soils under certain conditions, chemical composition, structure, and properties of soil, and the chemical processes and transformations they undergo.

Day 1

Essential question: What crops can we successfully grow in our vertical garden?

1) Bellringer: Describe the first vertical hydroponic farm in Kansas. What materials do they need, and what plants are they growing?
(Students can watch the 2-minute news segment (English subtitles available) or skim the article.)
(5 minutes)

2) In research teams of 2-3 members, have students collaborate to answer the following questions:
(30 minutes)

Questions to Explore:

1) What types of food are needed in our community? (Who will eat them?)
2) What types of plants would grow well in vertical farming?
3) What are their physical space requirements?
4) What parts of the plant are you harvesting?
5) What are the differences between the root systems?

Students will use resources from the choice board to answer these questions.

Personal Dictionary vocabulary resource: Monocot, dicot, perennial, annual, fibrous root system, tap root system. Students can customize this template. You can instruct your students to identify the part of speech (noun, verb, adjective, etc.) to clarify how the term is used.

3) Exit ticket: What are 3 things you learned, 2 skills you practiced, and 1 question you have about your work today? (5 minutes)

Day 2

Essential Question: What crops can we successfully grow in our vertical garden?

1)Bellringer: What are 2-3 crops you think would grow well in our vertical garden? Why? (5 minutes)

2) Students work in research teams to create a plant profile card using information from pages 53-77 of the Kansas Garden Guide. Students can make these on Google Slides or on poster paper to share with the class. (20 minutes)

(Mention CRAP test resources if students are not evaluating the reliability of their sources)
Each profile card must include:

a) Plant name
b) Picture of a mature plant
c) Type of plant (monocot, dicot, annual, perennial, etc.)
d) Root structure
e) Days until harvest

f) Yield
g) Height

3) Each group posts their poster/shares their slide with the class. Every team needs to choose 2 plants they feel are best suited for their vertical garden and give 3 reasons why they made these choices. If time allows, they can share their reasoning with the class. (10-15 minutes)

Main topics teachers should know:

Each plant has a first leaf or set of leaves that emerge from a seed during germination. It provides nutrients for the seedling until the true leaves grow and the plant can photosynthesize on its own. A plant can either have one cotyledon or two cotyledons which are the first leaves or the first pair of leaves that images from a seed when it germinates. Monocots are flowing plants and have one cotyledon. They usually have narrow leaves with parallel veins, are often grass-like plants, and are in multiples of three. Monocots usually have fibrous root systems that consist of many small, thin roots spreading out from the base of the plant. This helps them absorb water and nutrients efficiently, which can be advantageous in hydroponic or aeroponic systems where nutrient delivery is carefully managed. A dicot has two cotyledons and usually has broadleaves with branching veins with their flower parts are often in fours or fives. Dicots often have tap roots, a single thick root that grows deep into the soil with smaller secondary roots branching off. This can be considered in vertical gardening, as plants with extensive tap roots may require deeper growing containers or a medium that allows for root expansion.

There are different classifications based on the length of the plant life cycle. Annual plants complete their entire life cycle, from seed to seed, in one growing season. They grow quickly, produce flowers and fruit, and then die. Many vertical farms prefer growing annuals because they have shorter growing cycles, allowing for quick harvest and more crop rotations within the year. Perennials live for more than two years, continuing to grow and produce flowers and fruits across multiple seasons. While they may require more initial care, they can provide continuous harvests over time, making them suitable for longer-term vertical farming setups.

Stems support the plant and act as a conduit, transporting water, nutrients, and food between the roots and leaves. They also hold the leaves, flowers, and fruits, positioning them for maximum sunlight exposure and pollination. There are two types of stems, the first being Herbaceous stems that are soft, green, and flexible. They are often found in annual plants. The second type of stem is woody stems that are hard and rigid and provide long-term support for trees and shrubs.

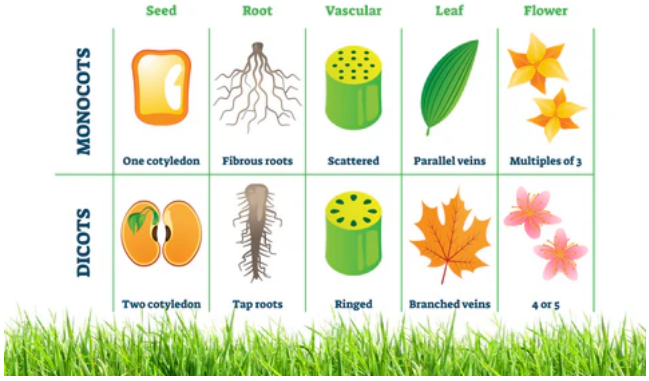
The leaves are the main site of photosynthesis, the process by which plants convert sunlight, carbon dioxide, and water into food or glucose and oxygen for the plant. They are also involved in transpiration, where water vapor exits the plant, helping to cool it and draw water from the roots. Leaves typically have a blade and a petiole, which connects the leaf to the stem. The surface of leaves may have stomata, tiny openings that allow for gas exchange.

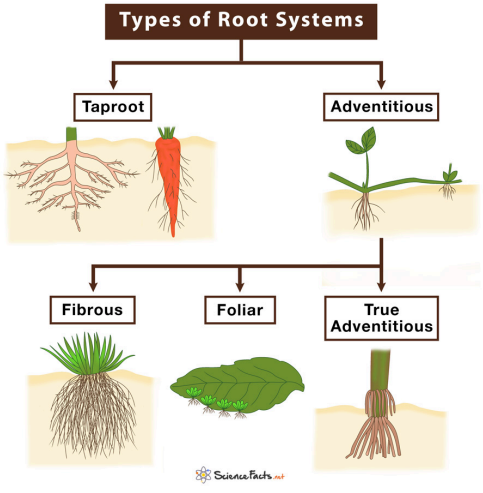
Plant physiology involves understanding how plants grow, absorb nutrients, and convert light into energy through photosynthesis. Vertical farming often relies on controlled environment agriculture systems, which means adjusting light, water, and nutrients to optimize growth. The vertical arrangement of crops can influence light exposure, air circulation, and nutrient uptake. Therefore, plants that thrive in environments with consistent, direct light are well suited for vertical gardens. Plants that grow in compact or stacked systems without interfering with neighboring plants are often chosen for vertical setups.

The field of plant science offers numerous career paths that directly contribute to advancements in vertical farming by enhancing plant growth, yield, and resilience. Plant Scientists play a pivotal role by studying plant physiology, nutrient requirements, and environmental responses, helping to optimize crop growth in controlled environments. Plant

Physiologists focus on understanding how plants function, including processes like photosynthesis, transpiration, and nutrient absorption, which are crucial for designing efficient vertical farming systems. Weed Scientists work on identifying and managing invasive species or unwanted plants that can compete with crops for resources, ensuring that vertical farms maintain healthy and productive growth. Botanists study plant biology and diversity, aiding in the selection of plant species best suited for vertical farming, especially those with compact growth habits or high yields. Plant Geneticists are vital for developing new plant varieties with traits tailored to vertical farming, such as faster growth, disease resistance, and adaptability to low-light conditions. Finally, Soil Scientists, although traditionally associated with soil-based agriculture, contribute to vertical farming by creating or improving soil alternatives like hydroponic substrates or aeroponic nutrient solutions. These careers collectively form the backbone of research and innovation in plant sciences, ensuring vertical farming systems can sustainably meet global food demands.

  - Visible Biology Bites | Monocot vs. Dicot Plants
  - Why Vertical Farms Are Moving Beyond Leafy Greens
  - https://www.youtube.com/watch?v=bjZxB0icWQg
  - 3.3 Roots – The Science of Plants
  - Biology 2e, Plant Structure and Function, Plant Form and Physiology, Leaves | OpenEd CUNY
  - Life Cycle of a Plant | Farm Credit of the Virginias
  - Kansas Garden Guide
- Reference this document with careers related to this lesson
  - https://docs.google.com/document/d/1eK_icNtr855VQiT6S0jBFHqoptAPRQMC3VQSIYFPJ8o/edit





Suggestions for instruction:

If students have little knowledge of plant structure and function, the following lesson from National Ag in the Classroom may be used: Plant Parts and Functions

When students are analyzing what plants may work best in their vertical farming systems, make sure students understand how the size of the plant needs to match the size of the vertical gardening system. Small pots will not work with plants that have large root systems (tomatoes, potatoes, etc.) If you plan to have students plant what they choose into their vertical gardening systems, you can let them plant the plants they want even if you know they won't work well to serve as a learning experience, or you can guide them to better options through a whole class discussion about each of the crops researched by students.

What do Kansas Farmers and Ranchers Grow?

Today, Kansas is a leader in wheat, grain sorghum, and beef production. In 2017, there were 58,569 farms in Kansas, which generated more than $18.7 billion in agricultural output. Kansas is a recognized leader in crop production in the U.S. Here is how the state ranks: first in grain sorghum production, leads the nation in winter wheat production, second in sorghum for silage production, second in cropland with 29,125,505 acres, fourth in sunflower production, and hay production, seventh in corn for grain production, and tenth in soybean production. Additionally, Kansas harvested 6.5 million acres of wheat and 6 million acres of corn in 2019.

As the world population grows and the demand for animal protein increases, Kansas farmers and ranchers will play a critical role in feeding Kansas families and families worldwide. Kansas ranked third in the nation for cattle production, with approximately 6,450,000 head, and in 2019, the state produced 2.2 million head of hogs.

Kansas is quickly becoming the new dairy frontier in the United States. Kansas is the 16th-ranked for milk production and is home to 173,000 dairy cows on over 210 dairy farms. Milk processing capacity has grown significantly in recent years, with the addition of processing facilities in Rexford, Garden City, and Hughoton.

Careers:

Plant Scientist:

Description: Plant scientists play an important role in maintaining the nation's food supply by ensuring agricultural productivity and food safety. These scientists study farm crops and develop ways to improve their quantity and quality. They look for ways to improve crop yield with less labor, control pests and weeds more safely and effectively, and conserve soil and water. Some plant scientists look for ways to use agricultural products for fuel. Plant scientists study plants to help producers of food, animal feed, and fiber crops to feed a growing population and conserve natural resources. These scientists not only help increase productivity but also study ways to improve the nutritional value of crops and the quality of seed, often through biotechnology. Some plant scientists study the breeding, physiology, and management of crops and use genetic engineering to develop crops that are resistant to pests and drought. They also develop new technologies to control or eliminate pests and prevent their spread in ways appropriate to the specific environment.

Education: A bachelor's degree is the minimum requirement for plant science jobs. Students preparing for careers as plant scientists should take college courses in plant pathology, entomology, plant physiology, and biochemistry, among others. To conduct basic research or to advance to jobs directing applied research, a master's or doctoral degree is required. Advanced degree programs in plant science include classroom and fieldwork, laboratory research, and a thesis or dissertation based on independent research.

Salary: A Plant Scientist in Kansas makes on average $63,268 per year, or $3,228 (5%) less than the national average annual salary of $66,496. Kansas ranks number 26 out of 50 states nationwide for Plant Scientist salaries.

Links:

https://ag.purdue.edu/department/btny/careers-in-plant-science.html#:~:text=These%20scientists%20study%20farm%20crops,use%20agricultural%20products%20for%20fuels.

https://www.ziprecruiter.com/Salaries/Plant-Scientist-Salary

Soil Scientist:

Description: Soil scientists study soil characteristics, map soil types, and investigate responses of soils under certain conditions. Soil scientists study the chemical composition, structure, and properties of soil and the chemical processes and transformations that they undergo. Some personal qualities of soil scientists include being practical; working well in a team and as an individual; being analytical; having strong communication, writing, planning, and organizing skills; and problem-solving. Soil scientists research or study soil characteristics, map soil types and investigate responses of soils to known management practices, provide advice on rural or urban land use, perform chemical analysis on micro-organism content of soil, investigate responses of specific soil types to soil management

practices, conduct experiments on farms or experimental stations to determine best soil types for different plants, and initiate and implement research and development programs for soil research.

Education: A bachelor's degree in chemistry, crop science, soil science, biology, or a related field, such as horticulture, plant physiology, or environmental science is required to become a soil scientist. There are some positions, especially those that are more research-driven, that require a master's or doctorate degree. Those degrees, along with experience, are needed for more administrative-level positions in the field.

Salary: The average Soil Scientist salary in Kansas is $73,216 as of July 25, 2023, but the range typically falls between $58,594 and $90,627.

Links:

https://www.salary.com/research/salary/benchmark/soil-scientist-salary/ks#:~:text=The%20average%20Soil%20Scientist%20salary,falls%20between%20%2458%2C594%20and%20%2490%2C627.

https://www.agcareers.com/career-profiles/soil-scientist.cfm

Plant Physiologist:

Description: A plant physiologist is a scientist who studies how plants function. These professionals may specialize in the physical, chemical, or biological functions of particular plants. Specific areas of study might include tree root structures, enzyme patterns, gene mutation, pollination, protein synthesis, genetic expression, and flower pigmentation. This field of study is a subsection of botany and may include elements of similar specializations like ecology, pathology biology, genetics, and chemistry. Plant physiologists research plant life and its functions. The goal is to add to the global collection of scientific plant knowledge. Many different areas of study might define the work of a plant physiologist, ranging from soil fertility to agricultural sustainability. Many plant physiologists work in affiliation with a university that can support them and fund their research. Professionals who work in an educational setting may also teach classes or mentor students in their labs while completing independent professional research.

Education: You're likely to need at least a master's degree to work as a plant physiologist, but if you plan to work as a researcher or teacher, a doctoral degree is often required or preferred. Some graduate programs in this area of study don't offer a master's degree option, instead proceeding directly to the doctorate.
Several undergraduate majors can prepare you for graduate study in plant physiology, including botany, biology, and agronomy programs. These majors usually include plant physiology courses, and some programs may even allow you to specialize in this area.

Salary: The estimated total pay for a Research Plant Physiologist is $88,032 per year in the United States area, with an average salary of $79,286 per year.

Link:
https://www.careerharvest.com.au/career/plant-physiologist
https://learn.org/directory/category/Biological_Sciences/Plant_Biology/Plant_Physiology.html
https://www.glassdoor.com/Salaries/plant-physiologist-salary-SRCH_KO0,18.htm

Weed Scientist:

Description: Weed scientists play an important role in managing vegetation. This may include identifying weeds and learning how to combat them or determining how herbicides interact with plants, offering suggestions on weed control methods to landowners both through chemicals, cover crops, and mechanical means, developing weed control products, recommending or selling weed control products, work to find chemical formulations that are effective in killing resistant weeds, study the environmental and human health impact of chemicals that could be used, and plant crop trials both in fields and greenhouses to use for research.

Education: To prepare for a career in weed science, you need a bachelor's degree in agronomy, biochemistry, biology, chemistry, ecology, horticulture, plant physiology, soil science, or a related field. For a research position in academia or industry, an advanced degree is typically a prerequisite.

Salary: A Weed Scientist in Kansas makes on average $62,253 per year, or $3,181 (5%) less than the national average annual salary of $65,434. Kansas ranks number 40 out of 50 states nationwide for Weed Scientist salaries.

Links:
https://www.agcareers.com/career-profiles/weed-scientist.cfm#:~:text=Weed%20scientists%20play%20an%20important,how%20herbicides%20interact%20with%20plants.

Botanist:

Description: Studies plants and their environment, such as algae, fungi, lichens, mosses, ferns, and flowering plants,--may specialize in the identification and classification of plants. Botanists have a wide range of responsibilities, which can include identifying new species of flora and fauna by studying their physical characteristics and geographic location, conducting research in fields such as ecology, genetics, evolution, conservation biology, systematics, physiology, taxonomy, and plant breeding, measuring plant growth to determine how different conditions affect growth rates, maintaining the greenhouses and laboratories where samples are stored or studied, collecting specimens of plants, algae, fungi, mosses, etc. for study and classification in herbariums or laboratories, diagnosing plant diseases and recommending appropriate treatment methods, and preparing reports and giving presentations about research findings at professional conferences.

Education: Botanists need a bachelor's degree to get hired. A bachelor's degree in botany or biology is the most common degree for botanists, but they can also earn a degree in horticulture or agriculture.
Many botanists choose to pursue a master's or doctoral degree to increase their earning potential and qualify for more senior-level positions. A master's degree takes two years to complete and a doctoral degree takes four years. Courses in these programs include advanced biology, ecology, genetics, and plant physiology.

Salary: As of Aug 7, 2023, the average annual pay for a Botanist in Kansas is $50,705 a year. Kansas ranks number 41 out of 50 states nationwide for Botanist salaries.

Links:
https://www.purdue.edu/science/careers/what_can_i_do_with_a_major/Career%20Pages/botanist.html

https://www.ziprecruiter.com/Salaries/Botanist-Salary--in-Kansas

Plant Geneticist:

Description: Plant geneticists research to understand, improve, or create new varieties of plants or crops. Looking at a plant's DNA, they can examine ways to improve the shape, size, production level, pesticide, and disease tolerance. A plant geneticist may create budgets for research projects and potentially seek funding, cross-breed plants to breed new subjects for trials, record data on plants in trials, identify genes that are responsible for certain plant features and functions, tend to trials grown in greenhouses and fields, maintain thorough records of research conducted, look for ways to genetically engineer crops productively, and supervise the work of field and laboratory workers.

Education: A bachelor's degree in biology, botany, or biochemistry is required. Depending upon the employer and nature of the job, a master's degree or doctorate (especially if doing research or teaching) may be required.

Salary: A Plant Geneticist in Kansas makes on average $80,709 per year, or $4,106 (5%) less than the national average annual salary of $84,815. Kansas ranks number 41 out of 50 states nationwide for Plant Geneticist salaries.

Links:
https://www.agcareers.com/career-profiles/plant-geneticist.cfm#:~:text=Plant%20geneticist%20conduct%20research%20to,level%2C%20pesticide%20and%20disease%20tolerance.

Take a look at the Career Glossary to find other related careers!

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Soil Scientist. AgCareers. (2024b). https://www.agcareers.com/career-profiles/soil-scientist.cfm

Weed Scientist. AgCareers. (n.d.). https://www.agcareers.com/career-profiles/weed-scientist.cfm#:~:text=Weed%20scientists%20play%20an%20important,how%20herbicides%20interact%20with%20plants

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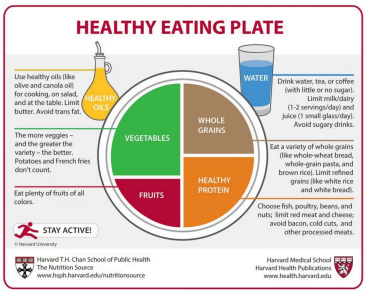
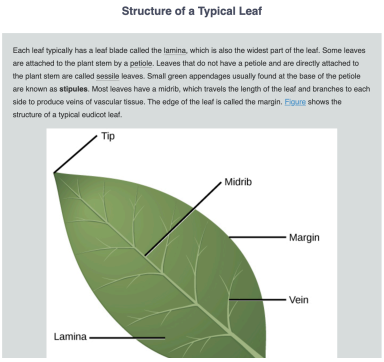
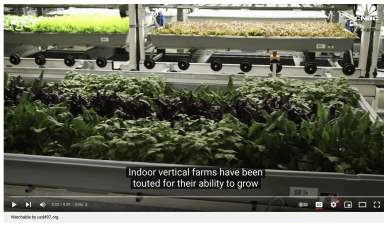
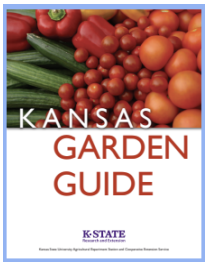
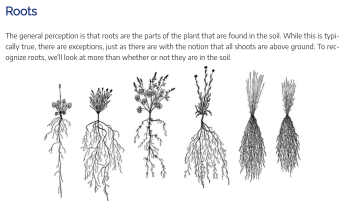
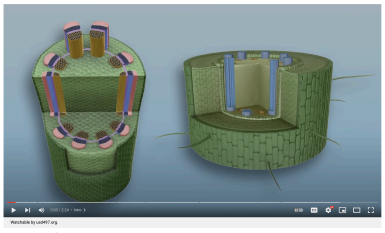
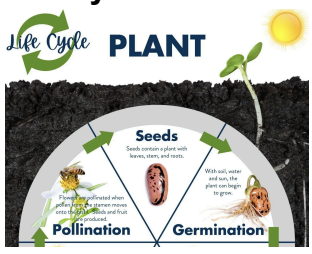
ZipRecruiter. (2024b). Salary: Plant Scientist. https://www.ziprecruiter.com/Salaries/Plant-Scientist-Salary

What plants do we need to grow? Choice Board

Background information: You will need to make a claim and give evidence to support why certain plants would be good choices to grow in a vertical garden. Use the choices below to build your background knowledge and answer the discussion questions on page 2.. Click on the images to access the websites. You can also find a list of websites on page 3.

Harvard's healthy plate (Interactive) 	**Plant structures (Advanced) (video)** 	**Why vertical farms are moving beyond leaf greens (video)** 
Food Banks in our area FEEDING AMERICA®	**Plant Vocabulary** Quizlet	**Kansas Garden Guide: Root depths (Video)** 
Types of Root Systems (video) 	**Monocots vs Dicots (video)** 	**Life Cycle of a Plant** 

Discussion Questions- Identify which questions you and your partners will be responsible for answering.

1) What types of food are needed in our community? (Who will eat them?)

Source:

2) What type of plants would grow well in vertical farming?

Source:

3) What are their physical space requirements?

Source:

4) What parts of the plant are you harvesting?

Source:

5) What are the differences between the root systems?

Source:

6) What other useful information did you discover?

Source:

Choice board links

*Note: All videos have subtitles with translations available in multiple languages.

1) **Harvard's Healthy Plate**
   https://nutritionsource.hsph.harvard.edu/healthy-eating-plate/
   This site provides interactive images describing the impacts of each food group on human health. Translations are available in 25 languages.
2) **Plant structures**
   https://opened.cuny.edu/courseware/lesson/764/overview
   This website provides labeled diagrams of plant structures and functions at the macro and microscopic level. Includes a video link and interactive review questions.
3) **Why Vertical Farms are moving beyond leafy greens**
   https://www.youtube.com/watch?v=_tMVYxNRbMA
   This YouTube video (4:39) created by CNBC highlights multiple crops that a vertical farm can successfully produce.
4) **Food banks in our area**
   https://www.feedingamerica.org/hunger-in-america
   This website provides links to local food banks as well as data to explore trends in food insecurity both locally and across the country.
5) **Plant Vocabulary**
   https://quizlet.com/15506703/science-plant-vocabulary-flash-cards/?x=1jqt
   This website provides common vocabulary for plant structures and functions with audio support. Games and quizzes are available as free study resources.
6) **Kansas Garden Guide: Root Depths**
   https://www.youtube.com/watch?v=bjZxB0icWQg
   This YouTube video (1:00) provides a highlight of the rooting depths of commonly planted garden crops from the Kansas Garden Guide. A full version of the 2023 Kansas Garden Guide is available at https://bookstore.ksre.ksu.edu/pubs/kansas-garden-guide_S51.pdf (202 pages)
7) **Types of Root Systems**
   This website from the University of Minnesota provides short videos (< 2:00 in length), diagrams, and descriptions of root structures and functions.
8) **Monocots vs Dicots**
   https://www.youtube.com/watch?v=zZLTfIN106c
   This YouTube video (2:24) created by Visible Body describes the structures and functions of tissues in leafs, stems and roots with primary focus placed on xylem, phloem, and stomata.
9) **Life Cycle of a Plant**
   https://www.farmcreditofvirginias.com/blog/life-cycle-plant
   This website provides colorful infographics of the life cycle of plant (available as a pdf) and labeled diagrams of the parts of the flower and the structures involved in seed germination

Chemistry in Plant Nutrition & Growth

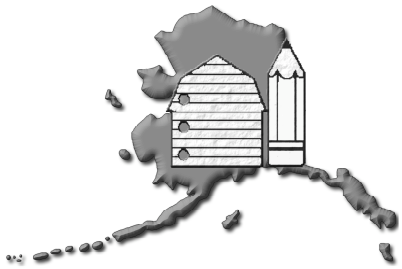
By Andrew & Erin Oxford, Bethel

Objectives
Review elements of chemistry and apply them to plant nutrition and growth in an agricultural context.

Suggested grade levels
9-12

Alaska Content Standards
Science D1,D3

Terms to Define
organic matter
fertility
radiant energy
toxicity
macronutrient
micronutrient



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A. Factors Affecting Plant Growth

Plant growth can be defined as the progressive development of the plant. Frequently, the growth term is expressed as the amount of biomass in the plant or plant part (e.g. grain in wheat). Numerous factors affect plant growth. Many of these are related to environmental factors while others are controlled by humans.

- Water supply- amount and distribution
- Radiant energy- quality, intensity, and duration of sunlight
- Air temperature
- Soil temperature – cool soil temperatures often limit plant growth in Alaska by slowing root growth and the recycling of plant nutrients through decomposition of soil organic matter
- Composition of the atmosphere- such as elevated CO_2 concentrations- some plants, called C_3 plants, produce higher yields with elevated CO_2 concentrations while others, called C_4 plants, do not benefit from elevated CO_2 concentrations
- Composition of the air in the soil
- Competition- from weeds, trees, other grasses or plants
- Pests- presence and absence
- Plant genotypes or varieties
- Soil Fertility- the status of a soil with respect to the ability of a soil to supply elements essential for plant growth without a toxic concentration of any element. All productive soils are fertile for the crops, plants, trees being grown, but a fertile soil may not be productive

Plant nutrition is concerned with the processes affecting the acquisition of nutrient elements by plants, the health of a plant with respect to its supply or content of essential elements, and the functions of those elements in the life of a plant

B. Essential Elements in Plant Nutrition

Definition or criteria of an essential element (Criteria proposed by Arnon and Stout in 1939)

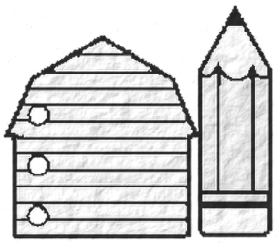
- A given plant must be unable to complete its life cycle in the absence of the mineral element(Life cycle = vegetative state, flower, produce seeds)

- The function of the element must not be replaceable by another mineral element

- The element must be directly involved in plant metabolism or a component of an essential plant constituent (e.g. Nitrogen is a constituent of proteins and chlorophyll)

There are 17 essential elements for plants. The following table lists the essential elements, their source, concentration in the plant, whether they are a macronutrient or a micronutrient, and the form of the element that can be absorbed by the plant. Beneficial nutrients are nutrients that are not needed for the plant to complete its life cycle, but may provide other benefits such as disease resistance, etc. Examples of beneficial nutrients are silicon, cobalt and sodium.

Primary Nutrients — N, P, and K- most common growth limiting nutrients-usually most deficient. Secondary Nutrients — S, Ca, Mg



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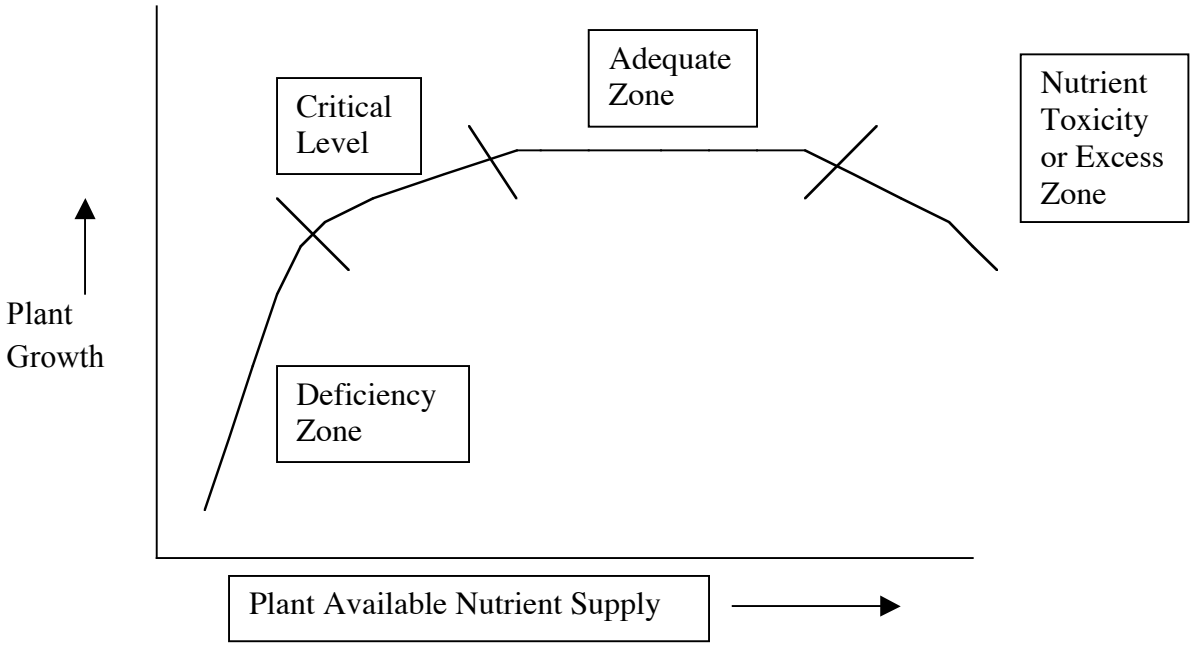
Source	Class	Element	Form Absorbed by Plant	Avg. Concentration in Plant
Non-Mineral	Macronutrients (> 1000 ppm)	Carbon (C)	CO_2	44.0 %
		Hydrogen (H)	H_2O	6.0%
		Oxygen (O)	H_2O, CO_2, O_2	44.0 %
Mineral-from soil		Nitrogen (N)	NO_3^-, NH_4^+	1.5 %
		Phosphorous (P)	$H_2PO_4^-$, HPO_4^{-2}	0.2 %
		Potassium (K)	K^+	1.0 %
		Sulfur (S)	SO_4^{-2}	0.1 %
		Calcium (Ca)	Ca^{+2}	0.5 %
		Magnesium (Mg)	Mg^{+2}	0.2 %
	Micronutrients (< 1000 ppm)	Iron (Fe)	Fe^{+3}, Fe^{+2}	100 ppm
		Manganese (Mn)	Mn^{+2}	50 ppm
		Boron (B)	H_3BO_3	20 ppm
		Zinc (Zn)	Zn^{+2}	20 ppm
		Copper (Cu)	Cu^{+2}	6 ppm
		Molybdenum (Mo)	MoO_4^{-2}	0.1 ppm
		Chlorine (Cl)	Cl^-	0.2 %
		Nickel (Ni)	Ni^+	0.5 ppm

EErin Oxford teaches at Mikelnguut Elitnaurviat Elementary in Bethel; Andrew Oxford is a district conservationist for the USDA Natural Resources Conservation Services in Bethel.

Peter Bierman, UAF Cooperative Extension Service Land Agent in Palmer, contributed to this lesson.



Relationships between plant growth and available nutrient supply typically follow a relationship similar to that depicted above. The concept is when equal increments of a nutrient are applied to a crop, the yield response becomes smaller with each increment.
This concept is sometimes referred to as the Law of Diminishing Returns.

Plant available nutrients:
• Means a form or forms of nutrients that may be immediately absorbed by the plant roots
• The nutrients are soluble and in the soil solution
• Most of the time, only the inorganic form of the nutrient will be absorbed by the plant root. Organic forms cannot be absorbed.
• The concentration of nutrients in the soil greatly exceeds the annual uptake of the nutrients by the plants because only a portion of the nutrients are in a form that is available for plant uptake.

Plant Nutrition and Growth Problem Solutions (see problems on separate student sheet)

1. A given plant must be unable to complete its life cycle in the absence of the mineral element. The function of the element must not be replaceable by another mineral element. The element must be directly involved in plant metabolism or a component of an essential plant constituent.

2. Nutrients may not be plant available- nutrients are in an organic form which cannot be absorbed. Disease, heat stress, competition from other plants, and an inadequate supply of water are other reasons.

3. The product is worthless as a fertilizer because it does not contain any of the essential nutrients except for carbon. In particular, it does not contain the primary nutrients which most often limit plant growth if they are deficient. Three of the other elements in the product are beneficial nutrients (cobalt, sodium, and silicon) that are not needed by the plants to complete its life cycle.

micronutrients are found in plants at a concentration below 1000ppm on a dry weight basis. They are also divided by the quantity or abundance of nutrients the plant needs. Plants need more macronutrients than micronutrients.
Primary nutrients are usually limit plant growth the most and are the most deficient whereas secondary nutrients do not limit plant growth as much and are not as deficient in the soil.

5. Cations: Cu^{+2}, NH_4^+, Mn^{+2}, Ca^{+2}, K^+, Mg^{+2}, Fe^{+3}, Fe^{+2}, Zn^{+2}, Ni^+
   Anions: NO_3^-, $H_2PO_4^-$, SO_4^{-2}, Cl^-, HPO_4^{-2}, MoO_4^{-2}
   Uncharged molecule: H_3BO_3, which is boron

6. Water supply, radiant energy, air temperature, soil temperature, composition of the atmosphere, composition of the air in the soil, competition, pests, plant genotypes or varieties, soil fertility

Name _____

Plant Nutrition & Growth Problems

1. What are the three criteria that must be met for an element to be considered essential for plant growth?

2. A field site that contains a "fertile" soil, one which contains large amounts of nutrients, may not necessarily be a "productive" site, or one that can produce large plants. Why might this be the case?

3. A salesman comes to your door with a new miracle product designed (he claims) to fertilize houseplants and lawns. The product, called Miracle Ash, contains 45% carbon, 10 ppm cobalt, 1000 ppm sodium, 5 ppm silicon, and 300 ppm aluminum. Why is this product worthless as a fertilizer or plant nutrition supplement?

4. What is the basis for dividing the 17 essential plant nutrients into the two classes of macronutrients and micronutrients? What is the basis for dividing the mineral macronutrients into primary and secondary fertilizer nutrients?

5. What essential mineral nutrients are absorbed by the plant primarily as cations? As anions? What mineral nutrient is absorbed primarily as an uncharged ion pairmolecule?

6. What are some factors that affect plant growth?

C	**Currency**: ***The timeliness of the information.*** • When was the information published or posted? Revised or updated? • Does your topic require current information, or will older sources work as well?
R	***R*elevance**: ***The importance of the information for your needs.*** • Does the information relate to your topic or answer your question? • Who is the intended audience? / an appropriate level?
A	**Authority**: ***The source of the information.*** • Who is the author/publisher/source/sponsor? • What are the author's credentials or organizational affiliations? • Is the author qualified to write on the topic? / contact information?
A	**Accuracy**: ***The reliability, truthfulness and correctness of the content.*** • Where does the information come from? / supported by evidence? • Has the information been reviewed or refereed? • Does the language or tone seem unbiased and free of emotion?
P	**Purpose: *The reason the information exists.*** • What is the purpose of the information? Is it to inform, teach, sell, entertain or persuade? • Does the point of view appear objective and impartial? • Are there political, religious, institutional or personal biases?