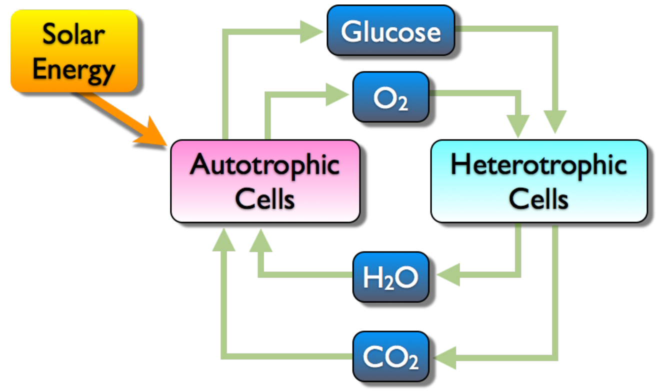
PART 2: The Needs of Plants

Section A: Energy in the Biosphere



The vast majority of energy that enters the biosphere is initially absorbed by autotrophs. Autotrophic organisms are producers that create organic compounds (carbohydrates) and oxygen gas (O_2) from simple molecules (carbon dioxide, CO_2, and water, H_2O) through the process of photosynthesis. This is known as "fixing carbon." The autotrophs then use these molecules to produce energy, proteins, lipids, and complex carbohydrates. Heterotrophs, or consumers, are unable to "fix carbon" from the atmosphere, so they must rely on autotrophs to provide organic carbon that is necessary for growth.

Plants absorb light primarily through photosynthetic pigments such as chlorophyll, which are contained in organelles called chloroplasts. This light energy drives the photosynthetic process, which removes CO_2 from the atmosphere to combine with H_2O to produce glucose ($C_6H_{12}O_6$) and O_2.

$$6\,CO_2 + \,6\,H_2O \xrightarrow{sunlight} C_6H_{12}O_6 + 6\,O_2$$

The products of photosynthesis, $C_6H_{12}O_6$ and O_2, are also used to produce energy in the process of cellular respiration. This energy is then used to process other organic compounds such as cellulose (used for support), lipids (waxes and oils), and amino acids (building blocks of proteins). O_2 is released into the atmosphere during photosynthesis. Plants also emit CO_2 during cellular respiration. They produce less CO_2than they absorb and are therefore carbon sinks. Cellular respiration, as illustrated in the equation below, shows $C_6H_{12}O_6$ being oxidized by the cells to produce CO_2, H_2O and chemical energy. This energy is stored in the molecule adenosine triphosphate (ATP).

$$6\,C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6H_2O + energy$$

Autotrophs are critical for the survival of heterotrophs that exist further up the trophic pyramid. Humans rely on autotrophs to capture the sun's energy to produce the necessary building blocks for growth.

Reading Questions

1. Support the claim that plants are 'carbon sinks.'

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Section B: The Cycling of Matter

Understanding the relationship between abiotic and biotic components in the environment is critical when making informed decisions about issues that surround agriculture. Abiotic components are used to build biotic components within the biosphere due to the role that autotrophs play to fix carbon in the biosphere.

The majority of nutrients are assimilated into a plant through its root system. The rate of nutrient absorption is a direct result of the soil's pH. The pH of the soil determines whether or not a nutrient is dissolved in water and therefore available to the plant for uptake by its roots. Most nutrients can easily dissolve when the pH of the soil solution ranges from 6.0 to 7.5 as indicated with the graphic to the right.

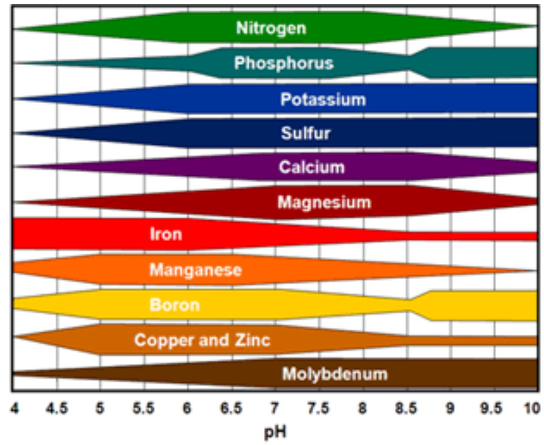


Image from Crop Insights: Soil Sampling and Test Interpretation https://www.pioneer.com/ May 25, 2015

Carbon, the most important building material in a plant, is primarily removed from the atmosphere instead of the soil. Both corn and soybean use atmospheric carbon, CO_2, to grow and develop. Soybean, a C3 plant, creates a 3- carbon compound during photosynthesis, whereas corn, a C4 plant, makes a 4-carbon compound during photosynthesis. A 4C plant is more efficient at photosynthesis than a C3 plant because they use less water per weight of biomass produced and can tolerate greater water and temperature stress than C3 plants. However, in terms of ground use, C3 crops can produce some of the highest amounts of edible calories and protein per acre: for example, corn kernels are 75% starch whereas soybean is 60% oil and protein. Consequently, more photosynthetic activity is required to make oil and protein compounds than to make the same weight in starch.[1]

Plants need certain amounts of nutrients to flourish. Proteins are made of different amino acids combined in certain orders that create specific polypeptides. Most of these nutrient needs are the same from plant to plant, but there are exceptions, which lead to different uptake needs by each plant. The result is that nutrients are depleted in the soil. Listed below are the requirements of both corn and soybeans. They are listed as a percent, or in parts per million (ppm) based upon whether they are a macronutrient (%), or a micronutrient (ppm).

Nutrient Element	Unit	Sufficient
Nitrogen (N)	%	2.90-3.50
Phosphorus (P)	%	0.30-0.50
Potassium (K)	%	1.91-2.50
Calcium (Ca)	%	0.21-1.00
Magnesium (Mg)	%	0.16-0.60
Sulfur (S)	%	0.16-0.50
Manganese (Mn)	ppm	20-150
Iron (Fe)	ppm	21-250
Boron (B)	ppm	4-25
Copper (Cu)	ppm	6-20
Zinc (Zn)	ppm	20-70

Table 1: Nutrient Sufficiency Ranges for Corn

Source: Bulletin 827: Corn, Soybean, Wheat and Alfalfa Field Guide. The Ohio State University Extension, College of Food, Agricultural, And Environmental Sciences. 2014 p65

Nutrient Element	Unit	Sufficient
Nitrogen (N)	%	4.25-5.50
Phosphorus (P)	%	0.30-0.50
Potassium (K)	%	2.01-2.50
Calcium (Ca)	%	0.36-2.00
Magnesium (Mg)	%	0.26-1.00
Sulfur (S)	%	0.21-0.40
Manganese (Mn)	ppm	21-100
Iron (Fe)	ppm	51-350
Boron (B)	ppm	21-55
Copper (Cu)	ppm	10-30
Zinc (Zn)	ppm	21-50
Molybedenum (Mo)	ppm	1.0-5.0

Table 2: Nutrient Sufficiency Ranges for Soybean

Source: Bulletin 827: Corn, Soybean, Wheat and Alfalfa Field Guide. The Ohio State University Extension, College of Food, Agricultural, And Environmental Sciences. 2014 p116

[1] Iowa State University, University Extension. Soybean Growth and Development (December 2009) PM 1945. p 22.

Reading Questions

1. Explain why understanding pH is so important when it comes to the uptake of nutrients in a plant.

2. Why is carbon an exception when it comes to nutrient uptake?

3. Describe the difference between a C3 and C4 plant.

Section C: Understanding Stages of Growth

Factors Affecting Plant Growth:
- planting date
- seeding rate
- hybrid selection
- tillage
- fertilization
- pest control

The primary row crops that are planted in Ohio are corn (monocot) and soybean (dicot). The uniqueness of the plants requires farmers to evaluate many parameters in order to make the correct crop nutrient choice for their farm operation. It is important to understand the stages of growth and development, which are expressed differently in corn (determinate) and soybean (indeterminate). The other factor that has to be kept in mind is the weather, including both temperature and precipitation. In addition, there is the potential of the production environment that needs to be considered.

Corn and soybean are both angiosperms. Angiosperms are a classification of flowering plants that include all of the necessary parts for reproduction. Those parts are the pistil (stigma, style, ovary and ovule) and stamen (anther and filament).

In plant reproduction, the anther will split and release the pollen (pollen is a haploid microspore, or a microgametophyte). Pollination then occurs as the pollen is transferred to the pistil through either wind or animal. Several steps occur that result in fertilization; but for our purposes, it occurs when the male gamete from the pollen joins with the female gamete from the ovary concluding in a zygote (seed).

Corn

Corn growth is determined by 1) Growing Degree Units (GDUs), or heat units, 2) soil moisture, and 3) nutrient availability in the production environment. Growing Degree Unit accumulation triggers tasseling (VT), or the beginning of the reproductive stage for corn.

Corn has both the male and female reproductive parts on the same plant. The tassels form anthers that hang off of them, releasing pollen to come into contact with the individual silks of the corn ear. In an ear of corn, every potential kernel develops its own silk to be fertilized. In corn, the vegetative state stops after the reproductive state occurs. This means that the ear of corn will develop, but the plant does not grow taller after tasseling has occurred.

Corn Vegetative and Reproductive Stages

	Stage	Common Name
Vegetative	VE	Emergence
	V1	First Leaf
	V2	Second Leaf
	V3	Third Leaf
	V(n)	n^{th} leaf
	VT	Tasseling
Reproductive	R1	Silking
	R2	Blister
	R3	Milk
	R4	Dough
	R5	Dent
	R6	Physiological Maturity

The Leaf Collar Method is employed to determine the current growth development of the corn plant. To accurately do this, the leaf collar and nodes of the plant are counted to determine leaf development. Once the plant has tasseled (VT), it changes into the reproductive stage of growth (R) when the kernel begins to develop. In most cases, the 6^{th} leaf collar (V6) is usually the first leaf to be observed on a mature corn plant.

Soybeans

Soybeans require energy, nutrients, and soil moisture just like corn, but the length of the day helps to trigger the reproductive stages of the plant. Hybrids are chosen for specific regions that capitalize on the changing day length as the summer progresses. Farmers look to have the canopy of the plants fill the space between rows in order to out compete weeds enabling the nutrients to be used solely for the yield of the plant.

Soybeans require energy, nutrients, and soil moisture just like corn, but the length of day (sunlight) helps to trigger the reproductive stages of the plant. The vegetative stage starts with the emergence (VE) and then the presence of the cotyledon (VC) and continues based on the uppermost fully developed trifoliate leaf node. To be fully developed the leaflets are completely unfolded.

Soybean Vegetative and Reproductive Stages

	Stage	Common Name
Vegetative	VE	Emergence
	VC	Unroled unifoliolate leaves
	V1	First-trifoliate
	V2	Second-trifoliate
	V3	Third-trifoliate
	V(n)	n^{th}-leaf
Reproductive	R1	Beginning Bloom
	R2	Full bloom
	R3	Beginning pod
	R4	Full pod
	R5	Beginning seed
	R6	Full seed
	R7	Beginning Maturity
	R8	Full maturity

Reading Questions

1. Why is the planting date so significant in the growth and development of corn and soybean?

2. Seeding rate addresses the amount of plants that are placed in the field. What are the benefits and drawbacks of having more seeds planted per acre?

Section D: Weather – The Uncontrollable Factor

As we have illustrated in this section, the growth and development of plants are based on: the accumulation of energy, absorption of nutrients, and the reproductive tendencies of the specific plant. All of these have to do with the evolutionary adaptations of the plant and can be supplemented directly by the farmer. In normal field conditions the one factor that cannot be managed is the weather. That is both precipitation and temperature.

Water

Water is always a concern on a field. Excess water leads to improper growing conditions and difficulty in the operation of machinery. Some fields rely on drainage ditches and culverts to drain the water and some of those ditches have been channelized. Clay tiles used to be used, but now the tile is a polyethylene product that is buried below the filed surface creates a network to remove the excess water.

Although in some cases farmers can add water to the fields, most row crops in Ohio are not irrigated. In many cases hybrid varieties address the drought tolerance of the plant. But nothing can take away the need for water at critical times of development in the plant. Too much precipitation or not enough precipitation can lead to nutrient leaching, limitation in growth and development or other detrimental soil conditions. These conditions include surface crusting, subsurface compaction, and creation of large unmanageable clods of dirt.[2]

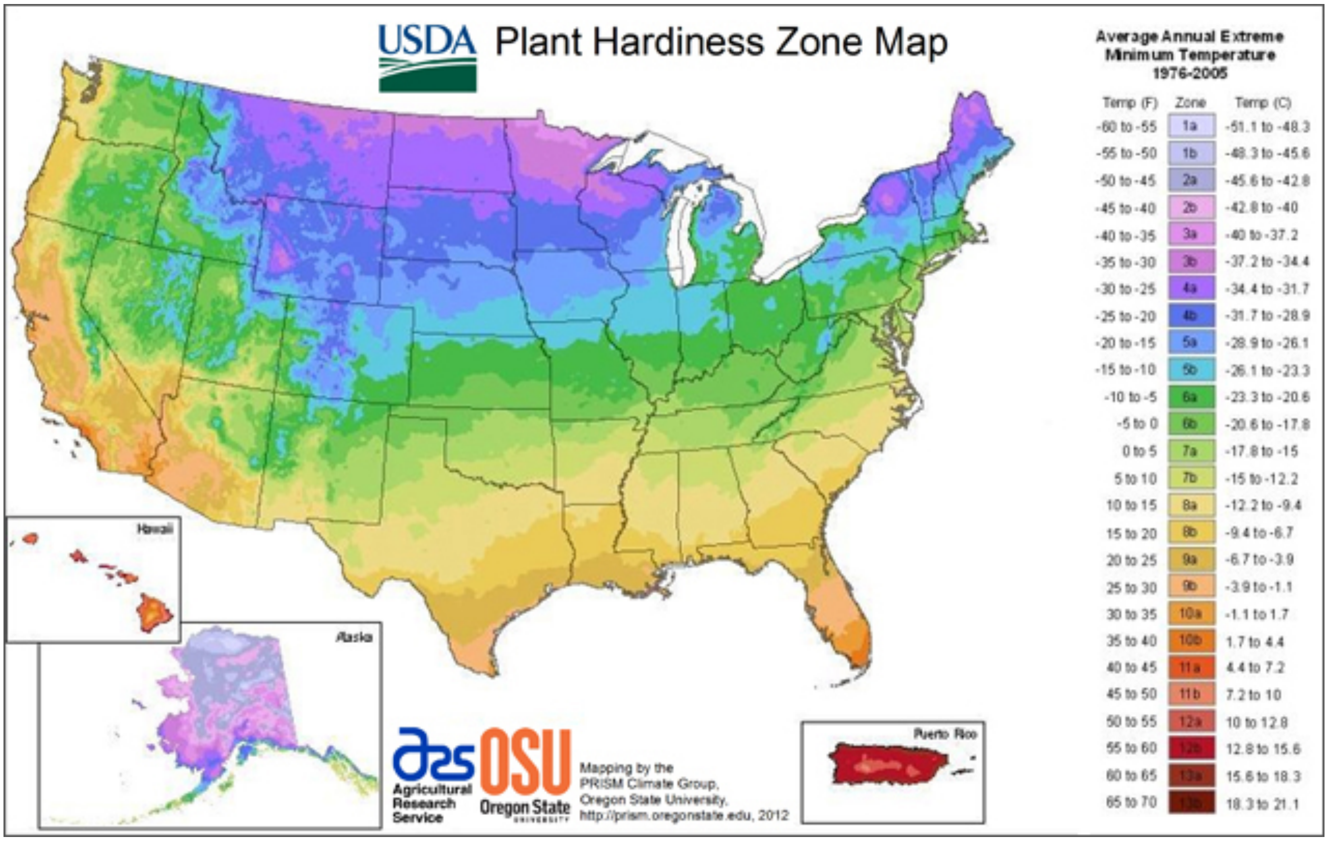
Excess water in the spring can lead to delays in preparation of the soil for the seed. Excess rain after planting and before emergence can lead to water logged fields that do not allow for proper germination. Too much water on the field after emergence can lead to the depletion of oxygen in the soil, which could lead to the death of the plant as well as increasing the odds of root disease. Too little water as the plant enters into reproduction can lead to delays in silk production in corn and the abortion of pods and flowers in soybean.

Soil moisture can be increased when farmers apply soil conservation methods that specifically address the soil's water holding capacity. Strip cropping, contour cropping, grass waterways and no-till practices all work to keep water on the field. It also might be necessary to increase drainage to maintain a balanced water budget for the field. The soil type and slope of the soil are all factors to consider when managing water.

[2] Bulletin 472, Ohio Agronomy Guide, 14th edition. (2005) The State University Extension. p 12

Temperature

Both the air and the soil temperature are factors that have to be considered when planting. Hardiness zones, based on latitude (as represented by the USDA map) help farmers determine when they will plant their crops. Seed companies design hybrids that are specific to certain zones of the country.



In the case of corn, the plants grow based on the air temperature because it is a matter of the accumulation of heat within the plant. There are several ways to determine the growth of plants but the most common is ***growing degree days*** (GDD). Corn development does not increase above 86°F, and it is nearly zero when the temperature is below 50°F. This is important to know because these become the maximum and the minimum for the equation below.

$$GDD_F = [(T_{min} + T_{max})/2] - 50$$

T_{min} = minimum daily air temperature
T_{max} = maximum daily air temperature

GDD is best used from the date of emergence (VE) and not from the date of planting. From VE to V10, a new collared leaf appears approximately every 84 GDD_F that is accumulated[3].

[3] Abendroth, Lori J. et al. Corn Growth and Development. (March 2011) Iowa State University Extension. March 2011. p 8

Soybeans, on the other hand, enter reproductive stages when the days start to get shorter. It is triggered by the lengthening of the nights and therefore does not follow the same pattern that can be established with corn in terms of GDD. GDD does help the farmer understand the amount of energy absorbed and the expected stage of growth and development. Heat stress at the R5 growth stage (beginning seed), has the greatest impact on soybean yield. During seed fill, daytime temperatures of 91 to 96°F result in fewer seeds per plant. Daytime temperatures greater than 85°F during seed fill can result in decreased soybean weight.[4]

Reading Questions

1. Identify and explain the concerns over water.

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2. Justify the use of plant hardiness zones by the USDA.

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3. What is the benefit of using 'growing degree days' as a measurement?

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[4] C.O.R.N. Newsletter 2012-23, The Ohio State University Extension. Retrieved 22 February 2015, from http://corn.osu.edu/newsletters/2012/21-22/high-temperature-effects-on-corn-and-soybean