

CHAPTER 2

THE PLANT

INTRODUCTION

*Not all crops are appropriate for hydroponics or controlled environment agriculture (CEA). The reason: ECONOMICS

*Both hydroponics and CEA (e.g., shade and greenhouses, etc.) cost money. Therefore, the crops chosen must yield a high enough monetary return to justify the expense.

You will not find growers growing wheat, sorghum, corn, etc. hydroponically.

*In North America the typical crops that are grown using hydroponics/CEA include:

TOMATOES (beefsteaks, TOV's (tomatoes on the vine) and cherry types)

COLORED BELL PEPPERS (mainly yellows or goldens, also oranges, reds)

LONG CUCUMBERS (also known as English, European, Seedless or Burpless)

LETTUCE (several crops can be grown per year in hydroponics/CEA)

SPECIALTY SALAD GREENS

MEDICINALS (especially root crops grown using "aeroponics" where the roots can be harvested without destroying the whole plant – mainly in research)

*Other crops that are grown using some form of CEA or protected agriculture include:

FOLIAGE PLANTS (usually require shade and humidity – as in the jungles from which they come)

FLORAL CROPS (including cut flowers, i.e., mums or carnations, and potted plants i.e., roses, etc.)

CERTAIN "ROW" CROPS (can be planted outside in colder climates using plastic tunnels (row covers) for protection against the cold)

* WHICH CROP TO GROW = Important decision for any grower, DEPENDS ON:
MARKET... LOCATION... EXPERIENCE...

MARKET (see also Chapter 15):

Research the region. Know if there are other growers in the area = competition.

If there are too many tomato growers... try cucumbers, peppers, basil, etc.

Know the market.

Who will you sell to: brokerage houses, grocery vs specialty stores
farmer's markets, restaurants, etc.?

Do your buyers want specific types or varieties of produce?

NOTE: Consult seed companies for suitable crops/varieties.

LOCATION (see also Chapter 11):

The selection of a crop will dictate the best location for the operation...

But, if you already have a location, that may dictate your crop.

Example: If a grower chooses tomatoes in Arizona, an optimum elevation is between 4,000 and 5,000 feet. Any lower and it is usually too hot to grow in the Summers. Any higher and it is too cold to grow in the Winters... UNLESS significant expense (\$\$) is put toward cooling or heating!

Example: If a grower has land at about 2500 feet in elevation in Arizona, a crop that can tolerate warmer temperatures than beef steak tomatoes, such as cucumbers, cherry tomatoes or basil could be selected...
Or grow different crops in Summer and Winter.

The selection of a “cultivar” or “variety” is also important.

Seed companies are always coming out with new cultivars (or varieties) to suit different climates and tastes.

With the move of many growing operations to higher light regions of the world, for better photosynthesis (i.e., Southwest USA, Mexico, Spain, Israel) AND the demand for good quality, good tasting tomatoes year around, many seed companies are introducing more HEAT TOLERANT varieties.

Example: The first tomato variety used by EuroFresh in Willcox, AZ in the early 1990's was “MATCH”, then they switched to “TRUST”. But Trust is a Dutch variety (DeRuiter Seed) with an optimum day temperature of 22C (72 F). And because their original greenhouses were passively cooled (no fan and pad/evaporative cooling), they weren't able to grow in the Summer (temperatures in Willcox can reach 33-38C (90-100F).

This was a PROBLEM for EuroFresh: From June until October of each year, when the operation was not producing tomatoes, they would lose their “shelf space” in the markets. This shelf space became increasingly difficult to regain.

Their SOLUTION: Build evaporatively cooled (fan and pad) greenhouses AND do variety trials to determine the best tomato varieties for their conditions. They even experimented with growing one variety in the Winter and another variety in the Summer.

NOW they specialize in TOV's and smaller varieties (grape, mini-plum)

EXPERIENCE:

If a grower has experience with a particular crop... stick with it.

“Grow what you know” – It is much easier to try out new varieties of tomato than to switch from, say, tomatoes to cucumbers or lettuce!

These will require different pruning techniques & even different systems.

If a grower does not have experience with a particular crop...

Work for someone who is successful with that crop to gain experience.

OR Hire someone who is experienced... an expert!

*This chapter will cover some basic information on plants (anatomy, development, physiology) and then concentrate on tomatoes with discussions of other crops (mainly fruits and vegetables) grown in hydroponics and CEA.

BASIC PLANT ANATOMY & DEVELOPMENT

*Flowering plants are composed of TWO MAJOR SYSTEMS: SHOOTS AND ROOTS.

*THE SHOOTS:

- *Grow up in response to gravity AND will grow toward a light source.
- *Bear the leaves, flowers and fruit.
- *The leaves usually contain pigments and are the sites of photosynthesis.
- *The leaves also contain stomata, pores in the leaf through which water exits and through which gas exchange occurs (carbon dioxide in and oxygen out).
- *Leaves attach to the stem = NODE; the stem in between nodes = INTERNODE
- *Flowers or clusters of flowers are usually produced at regular intervals.

*THE ROOTS:

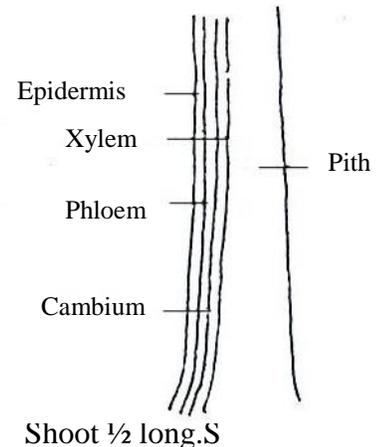
- *Grow down in response to gravity and grow in response to moisture.
- *Act to anchor the plant in the growing medium.
- *Absorb water, mineral nutrients and oxygen.
- *Classified as tap or fibrous. Submerged roots may not develop root hairs.
- *Storage organs (carbohydrates, etc.); site of synthesis alkaloids, hormones, etc.)

*SHOOTS AND ROOTS: CONNECTED BY VASCULAR TISSUE

The XYLEM (dead) carries water and mineral nutrients from the roots to the leaves, flowers and fruits.

The PHLOEM (alive) mainly carries photosynthates, the products of photosynthesis, from the leaves (the “source” of photosynthesis) to various “sinks” (apical meristem, fruit, roots, etc.)

The CAMBIUM separates the xylem and phloem. It is the growing layer that produces new xylem to the inside and new phloem to the outside of the stem.



*THE LEAVES: THE PRIMARY SITE OF PHOTOSYNTHESIS

(though any green tissue is usually photosynthetic).

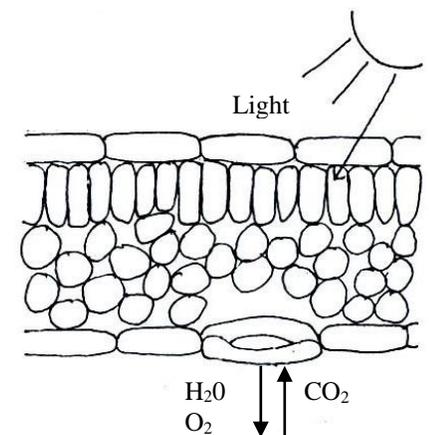
Tomato leaf (C3): covered on both sides by the EPIDERMIS.

The epidermis is covered by a waxy CUTICLE.

Interior to the epidermis on the upper side are the PALISADE PARENCHYMA cells contain chloroplasts where photosynthesis takes place.

Interior to the epidermis on the lower side are the SPONGY MESOPHYLL cells. These create air spaces for gas exchange.

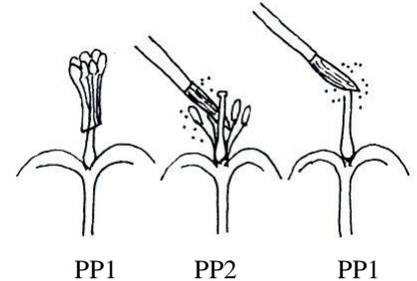
Mainly on the lower leaf surface are pairs of cells, called GUARD CELLS, that form openings, STOMATA, through which gas exchange takes place.



***MAINTAINING OR CREATING DIFFERENT VARIETIES:**

1. HEIRLOOM VARIETIES: These are “open pollinated” and will grow “true to type” from seed for generation to generation (oldest method to improve plants). A grower saves seeds from plants with desirable traits (i.e., firm or odd shape or color fruit), plants them, grows the plants, again saves the tomatoes with the desirable traits and uses the seeds in these fruits to plant the next crop. Examples include Green Zebra, Brandywine, Yellow Pear and Ox Heart.

2. F₁ HYBRIDS: In recent years these have been created by breeding techniques. The male parts (ANTHERS) from parent plant one (PP1) are removed leaving the female parts. Pollen from parent plant two (PP2) is transferred to the female portion (STIGMA) of parent plant one. The flower on parent plant one, now pollinated, will develop into a fruit which will contain the F₁ seeds. These seeds are collected, dried, packaged and sold to the grower as a particular variety.



The grower plants seeds, grows plants, harvests fruits. However, seeds from these fruits WILL NOT produce the same variety as was obtained from the initial cross.

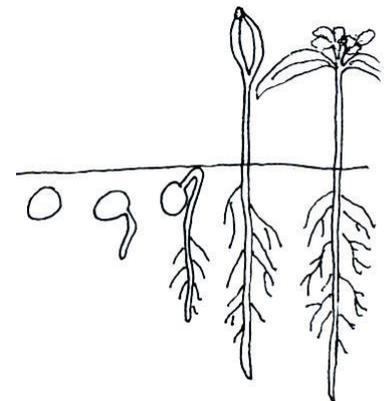
3. GENETIC ENGINEERING: Conferring specific traits by transferring genetic material from one plant, organism, etc., to another plant, organism, etc. **Examples** include the conferring of:

- 1) Insect resistance to field crops (corn, cotton, potatoes) by introducing the gene for an insect toxin found in Bacillus thuringiensis.
- 2) Herbicide resistance (Round Up, 2-4-D, etc.) to field crops (soybeans, corn, wheat) - allows the field to be planted and then, when the protected crop emerges, along with the unprotected and unwanted weeds, the herbicide will kill the weeds but not the crop.

NOTE: This seed is a little more expensive. However, the farmer does not have to spend time, fuel or money spraying for certain pests or cultivating or weeding).

*** “DICOT” SEED GERMINATION:**

- *Seeds vary in size from tiny lettuce (1-2mm) to medium tomato & pepper seeds (3-5 mm) to large cucumber (~1cm).
- *The small white root (RADICLE) emerges and pushes down (due to gravity) into the growing media.
- *The initial stem (HYPOCOTYL) emerges and grows upward (toward the light) in a whitish hook-like form (PLUMULAR HOOK).
- *When the plumular hook reaches the media surface (and light) it straightens and turns green (chlorophyll produced).
- *The first seed leaves (COTYLEDONS) are pulled out of the seed coat (TESTA), expand and turn green.



*PLANT ARCHITECTURE: Plants are divided into two types based on growth habit:

1. INDETERMINANT (typically used in greenhouse cultivation)

Vining types with an apical (top) meristem (growing point) that continues to produce a main stem, leaves and flowers (or clusters for tomatoes but singly at the nodes for peppers & cucumbers).

Plants are hung from high wires in the greenhouse to better utilizing the vertical space that the grower paid for by building a greenhouse.

of Heads: tomatoes are trained to 1 (or 2 if grafted) heads,

peppers are trained to 2-4 heads and cucumbers to 1-2 heads.

Theoretically, all indeterminate plants are perennials. Commercially, tomatoes/peppers are grown 10-12 months; cucumbers 4-5 months.

2. DETERMINANT (typically used in field cultivation)

Bush types where the plant terminates in a flower; suckers are left on.

Theoretically, all determinant plants are annuals or may be grown as annuals (continued growth usually also restricted by climate).

BASIC PLANT PHYSIOLOGY

*WATER (H₂O) MOVEMENT (TRANSLOCATION) THROUGH THE PLANT:

*Water is crucial and used in almost every metabolic process. Plants also use water to move minerals up from the soil, and to move the products of photosynthesis from the leaves (SOURCES) to fruit, roots, etc. (SINKS)

*Water translocation into and through plants is believed to be passive – requiring no metabolic energy.

*BULK FLOW: Movement of water due to an external force (gravity, pressure)

Ex: Water movement upward through the xylem due to “root pressure”.

*DIFFUSION: Movement of molecules from high to low concentration.

Ex: Movement of perfume molecules from an open bottle outward.

Ex: Movement of water molecules out of the stomates (transpiration).

*OSMOSIS: Movement of water molecules through a semi-permeable membrane from high to low concentration.

Example: Plants maintain high salt levels in their root cells that make the relative concentration of water lower inside and therefore water tends to move IN (from high/outside to low/inside concentration).

Problem: If too many salts are added to the solution around the roots, the resulting lower concentration of water outside will draw the water out of the roots, leading to wilt and ultimate plant death. Therefore, it is critical to have the proper nutrient concentrations in the solution (see Chapter 10).

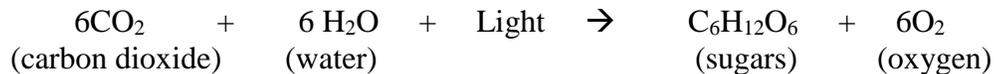
*NOTE: Just inside the ROOT is a specialized cell layer, the ENDODERMIS. The radial and transverse walls of these cells are impregnated with hydrophobic suberin (Casparian band) which forces water and solutes to pass into the endodermal cells. Water moves through the membrane via osmosis. However, the solutes (i.e., mineral nutrients) must move either by simple diffusion passively, by facilitated diffusion (via channels or carrier proteins) or by active transport (requiring carriers and metabolic energy).

***THREE METABOLIC PROCESSES:**

1. **TRANSPIRATION:** The evaporation of water from plants primarily through the stomata (but also through the cuticle or structures usually in woody plant bark called lenticels). Transpiration occurs via the passive process of DIFFUSION.
*Transpiration is used to move water through the plant but also used to cool the plant: As water evaporates off the leaf surface (liquid to gas) the water gains energy (heats up) and the leaf surface loses energy (cools down).
*Plants are 80-95% water and can transpire up to 98% of the water they absorb.

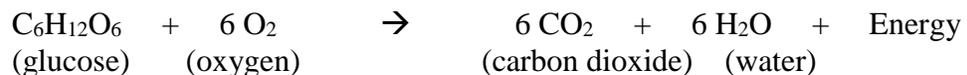
2. **PHOTOSYNTHESIS:** From the Greek, 'to synthesize using light'.
*Plants contain PIGMENTS that trap light energy = The LIGHT REACTIONS.
CHLOROPHYLLS (a and b): primary pigments.
Found in the CHLOROPLASTS (organelles in the palisade parenchyma).
Absorb mainly blue & red light; reflect much of the green/yellow/orange.
CAROTENOIDS: accessory pigments (over 600 types known). Absorb violet and blue light but reflect green, yellow, orange (like carrots) and red light.
Two kinds: CAROTENES = "hydrocarbons" (carbon + hydrogen).
XANTHOPHYLLS = hydrocarbons + oxygen.
NOTE: These pigments all reflect green, which is why plants appear green to us!
*The energy absorbed from light is used to drive The DARK REACTIONS.
CARBON DIOXIDE moves from the air into the plant through the stomata and into the chloroplasts within the palisade parenchyma cells.
Energy from light absorption is used to FIX CARBON DIOXIDE into SUGARS.
The SUGARS produced are used to produce all of the other molecules needed for life (simple and complex carbohydrates, proteins and fats).
WATER is required for the reaction. The splitting of water yields OXYGEN.
OXYGEN is then released from the plant through the stomata.

***THE OVERALL REACTION - PHOTOSYNTHESIS:**



3. **RESPIRATION:** A set of oxidation-reduction reactions producing energy.
Reactions take place in the mitochondria (organelles found in most cells).
Carbon containing COMPOUNDS are OXIDIZED to CARBON DIOXIDE.
Compounds available to be oxidized include starch, fructans, sucrose or other sugars, fats, organic acids, and even proteins.
OXYGEN (absorbed through the stomata) is REDUCED to form WATER.
NOTE: Oxygen also needs to be absorbed into the roots for respiration.

***THE OVERALL REACTION – RESPIRATION (specific for the sugar glucose):**



NOTE: **Light Compensation Point** → Rate of Photosynthesis = Rate of Respiration
~10-40 $\mu\text{mol}/\text{m}^2/\text{s}$ for most plants. Above this light level, plants grow; below, they die.

SOME BASIC BOTANY: TOMATOES

*The classification system devised by the Swedish botanist Carolus Linnaeus (1707-78):

Kingdom Division Class Order Family Genus Species

Current taxonomic research, based on genetics instead of morphological traits, is continually restructuring established classifications. Suffice it to say...

*Tomatoes belong to the

FAMILY = SOLANACEAE

This family includes peppers, potatoes, eggplant, tobacco, belladonna (deadly nightshade), datura (jimson weed), mandrake (a medicinal) and petunias.

GENUS = LYCOPERSICON

This genus is thought to have originated in the coastal strip of western South America including Ecuador, Peru and the northern portion of Chile.

SPECIES = ESCULENTUM (written: *Lycopersicon esculentum*)

This species contains plants with large fruit that grow wild or in cultivation as annuals (live only one year) or perennials (usually live two or more years).

TYPES = beefsteak, cluster (TOV), cherry, grape, cocktail, mini-plum, etc.

VARIETY = hundreds of varieties, of all types, available.

*The tomato plant:

*ROOT SYSTEM = A well-defined TAP ROOT with lateral fibrous roots.

NOTE: Tomatoes readily form ADVENTITIOUS ROOTS =
aerial roots on the stem formed in response to moisture or stress.

*SHOOT SYSTEM =

Above the two cotyledons (which are opposite on the stem), appear the first TRUE LEAVES (alternate along the stem).

The true leaves are classified as COMPOUND.

After the first 7-12 true leaves the stem forms a FLOWER CLUSTER.

Thereafter, there are typically 3 leaves between flower clusters.

There can be 2 or 4 leaves, and sometimes no leaves (= reprod).

Side shoots (SUCKERS) can grow from the axils of each leaf.

These are usually removed (pruned) to maintain a single stem.

*FLOWER is complete = PISTIL (female), STAMENS (male), petals & sepals.

Typically the tomato flower contains:

A PISTIL made up of the OVARY, STYLE and STIGMA

A ring of STAMENS = FILAMENT + ANTHERS (POLLEN)

5 yellow PETALS

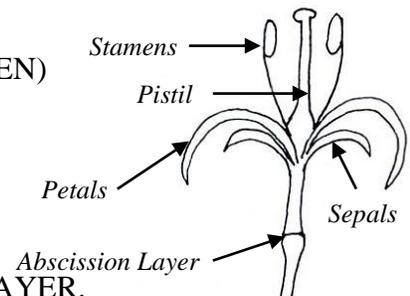
5 green SEPALS

One to many flowers are borne on the stem of the TRUSS
(or PEDUNCLE).

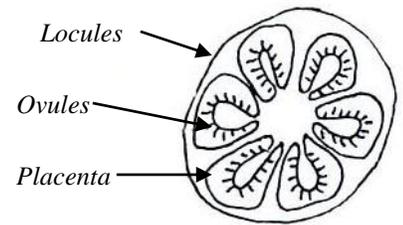
Each flower is attached to the truss by an ABSCISSION LAYER.

If the plant is stressed, flowers may be aborted at this point.

It usually takes 7-8 weeks to go from open flower/pollination to harvest.



- *FRUIT = The tomato fruit is classified as a BERRY.
The first fruit on a cluster is the KING FRUIT.
It contains two or more LOCULES (chambers) with fertilized OVULES (the seeds) embedded in a PLACENTA surrounded by a gelatin matrix.
Seeds, when removed, dried and stored cool, can show 90% germination after 10 years.



OTHER CROPS GROWN USING CEA AND/OR HYDROPONICS:

1. PEPPERS

- *Peppers are a member of the Solanaceae family (like tomatoes).
- *Scientific name: *Capsicum annuum*.
”Capsicum” comes from the Greek “kapto” meaning “to bite” referring to the pungency of many of the varieties (especially small fruited varieties).
- *This species originates in South America (also like tomatoes) and includes most of the commonly grown pepper varieties including sweet or red peppers, chilies and bells (greens, reds, oranges, yellows) including mini-bells. Pepper fruit = berry.
NOTE: The Tabasco pepper from Mexico is a separate species: *C. frutescens*.
- *Seed germination is similar to that of tomato (but seeds have a shorter shelf life).
- *Pepper plants produce SIMPLE leaves, usually 1 leaf per node, initially.
- *The plant grows as a single stem for perhaps 7-12 nodes like tomato), then branches.
- *At this first branch point a flower is produced (though sometimes 2) = CROWN FRUIT.
This should be removed to promote stronger fruit set higher on the plant.
- *The plant is trained to 2 to 4 stems and supported with vine twine to the wires.
Details for pepper plant training are given in Chapter 3.
- *At each succeeding node the stem branches and can form a flower (or even 2 or 3).
- *Flowers are complete with white petals & require pollination for fruit development, otherwise, they form a “pancake” fruit with few or no seeds inside.
- *Depending on light, plant vigor, temperature, fruit load, etc., flower removal and/or fruit pruning will be adjusted to maintain proper set/development of remaining fruit.
- *Fruit takes ~ 6 weeks to reach the mature size (skin is glossy – “MATURE GREEN”).
Colored peppers (red, orange, yellow) require another 3-6 weeks to turn color.
- *Many pepper varieties prefer cooler temperatures than tomatoes.
Yellow or gold peppers, in particular, require shading, especially in Summer.

2. CUCUMBERS

- *Cucumbers are a member of the Cucurbitaceae family which also includes melons, squashes and loofah gourd.
- *Scientific name: *Cucumis sativus*.
- *Most likely originated in India or Burma. It has been cultivated for 3000 years.
- *Seeds are large (1 cm long) and remain viable for ~4 years. If sealed in airtight containers with carbon dioxide, viability can be extended for several years.
- *The main stem grows like a vine, with laterals and tendrils.
There are several methods of training (see Chapter 3 for details).

- *At each successive node a flower is usually formed.
- *Up to a height of 80-100 cm (2.6-3.3 feet) the flowers/fruit are removed to reduce plant stress and flower abortion and to encourage full root development.
- *Cucumbers are fast growers – up to 15 cm (about 6 inches) per day.
- *Cucumber plants can prefer warmer temperatures than most tomatoes.

*The cucumber flower can display several “sex types”:

- PERFECT (bisexual or hermaphroditic): A flower with both male (stamens) and female (pistil) organs (may not have green sepals or colored petals).
- MALE (STAMINATE): A flower lacking a pistil.
- FEMALE (PISTILATE): A flower lacking the stamens.

*The cucumber plant itself can also display several “sex types”:

- MONOECIOUS: A plant with both male and female flowers.
- DIOECIOUS: Male flowers on one plant and female flowers on another.

- ANDROECIOUS: A plant with only male flowers.
- ANDROMONOECIOUS: A plant with some perfect and some male flowers.

- GYNOECIOUS: A plant with only female flowers.
- GYNOMONOECIOUS: A plant with some perfect and some female flowers.
- PREDOMINANTLY FEMALE: Mostly female but w/ some male flowers.

*NOTE: Most greenhouse cucumber varieties are usually GYNOECIOUS or, rarely, PREDOMINANTLY FEMALE. Why? If male flowers are present and pollination does occur, the result can be lumpy, oddly shaped fruit.

*Cucumbers (watermelons, etc.) can produce seedless fruit without pollination. This is called PARTHENO-CARPY (Greek for “virgin seed”)

*The cucumber fruit is considered a false berry or “PEPO”.

- It varies in size, shape and color depending on cultivar.
- The young fruit is covered with “hairs”, as is the rest of the plant.
- These hairs may get stuck on another part of the plant and cause “CROOKING” (bending) of the fruit – these should be removed.
- Greenhouse varieties have smooth, thin-skinned fruit. These tend to lose moisture quickly after picking and must be wrapped in plastic.
- The skin is not bitter (as in field cucumbers) and need not be peeled.
- Greenhouse varieties are long and thin – 25 to 50 cm.
- However, there are also “mini-cucumbers” that are much shorter.
- Greenhouse varieties are now called “LONG CUCUMBERS” but have also been called “European”, “English”, “Seedless” or “Burpless” cucumbers.
- Since most greenhouse varieties are “seedless” they will only have empty, whitish, fleshy but papery thin seed husks, which can be eaten.

3. LETTUCE

*A member of the Asteraceae (Compositae) family which also contains sunflower, purple coneflower (Echinacea), guayule, zinnia, marigold, flea bane, yarrow, edelweiss, chrysanthemum, gazania, burdock, artichoke, Transvaal daisy and dandelion.

*Scientific name: *Lactuca sativa*.

*Probably originated in Europe/Asia. First cultivated 2500 years ago as food/medicinal.

*Lettuce seeds are small, ~1mm & ~1000 seeds/gram. Good viability if kept refrigerated.

*Lettuce is an annual with milky sap, alternate leaves on a short stem that forms a rosette.

*Though lettuce is usually not “high cash value”, a hydroponic/CEA grower can produce many crops per year as opposed to 1 or 2 crops in the field.

Typically, lettuce is grown using “floating” or NFT systems (see Chapter 5).

*Different variety leaves can be green or colored, smooth or ruffled, glossy or dull.

*3 basic types of lettuce that are grown (diff. catalogues may categorize differently):

HEAD:

“CRISPHEAD” – Leaves well wrapped; firm head; crispy texture.

Iceberg, Great Lakes, Ithaca, Mesa, Mission

“BUTTERHEAD” – Outer leaves are loose; heart leaves are wrapped; and not crispy: Buttercrunch, Bibb, Boston

LEAF: Great for home hydroponics because leaves can be harvested singly.

Leaves can be green or red, variable texture and are usually higher in nutrients than Iceberg: Blackseeded Simpson, Grand Rapids, Oakleaf, Red Sails, Salad Bowl, Ibis, etc.

COS (or Romaine): Taller than all others (8-10”); upright outer leaves with inner head: Parris Island Cos, Olga, Green Towers, Little Gem (dwarf: 5-6”).

*Lettuce prefers cooler temps than tomato and is suitable for Winter growing in AZ.

*High temps can cause BOLTING (flowering) leading to BITTERNESS of the leaves.

TIP BURN is caused by calcium deficiency (via heat, high RH or reduced air circulation in the crown – anything to slow transpiration & water mov’t.)

4. SPECIALTY GREENS

*A mix of many kinds of young, tender leaves but can also contain flowers.

*Started in/around Nice, southern France as MESCLUN (French for “mix”). Includes tender early sprouts of arugula, dandelion greens, lettuces, watercress and chervil.

*Most mixes today combine 8-16 different kinds of leaves and/or flowers.

Lettuces add sweet or mild flavors and tender or crunchy textures:

Butterheads like Bibb or Perella Red

Loose leaf reds and greens like Lollo Rosso, Oakleaf and Tango

Romaines like Little Gem (a dwarf)

“Greens” add spicy flavors, firmer textures and various colors and shapes:

Arugula, dandelion greens, frisee (fine curly endive), Belgian endive (inner leaves), Swiss chard, kale (red and green), mizuna, radicchio, red mustard, shiso, totsoi, watercress (anchocress, upland broadleaf or curled cress), purslane and chervil (a green or herb with a cool licorice flavor).

Flowers: the entire flower or petals may be added for color and flavor:

Bachelor’s buttons, calendulas, nasturtiums (and their leaves), marigolds, borage, lavender, pansies and violas.

*Can easily be grown in CEA/Hydroponics, however, thousands of “soil” acres are now in production. Some growers have farms in coastal areas for Spring and Summer growing and farms in the deserts of California and Arizona for Fall and Winter.

5. HERBS

*All herbs may be grown in hydroponics, are a favorite of home gardeners and include anise, basil, borage, caraway, catnip, chervil, chives, coriander, chamomile, dandelion, dill, fennel, marjoram, oregano, lavender, peppermint, rosemary, rue, sage, spearmint, savory and thyme.

*Commercial production:

Most herbs are grown in soil, and some growers are doing “organic”.

BASIL is one herb that has been grown widely in hydroponics.

MINTS are grown on a much smaller scale in hydroponics.

GINGER is being grown in Hawaii using sand culture hydroponics.

In sand, the roots retain a lighter color and are favored over the darker roots obtained when grown in soil.

MITSUBA is grown in Japan in hydroponics. It has a distinctive aromatic flavor like celery or parsley. Used in soups or eaten raw in salads.

*Herbs are perfect for hydroponics and the classroom since they are usually small.

Each student can have their own plant.

Plants grow quickly - the life cycle may be observed in one semester.

Plants may be sold fresh or dried to raise money for school activities.

6. MEDICINALS

*Plants with medicinal value have been harvested from the wild for thousands of years by herbalists and village shamans.

NOTE: Archeologists have noted that some medicinals have been harvested to extinction. Example: A plant in Roman times that was highly sought after as a means of birth control is now extinct.

NOTE: The root medicinal, Goldenseal, was almost harvested to extinction in the wild and may now, by law, only be harvested from cultivation for medicinal use.

*Herbalists and shamans, through trial and error, have learned that medicinals have their highest potency when harvested from certain soils or locations, during specific times of the year, or in association with specific environmental conditions.

*Researchers are now studying these practices to define optimum conditions for growing medicinals and for obtaining maximum medicinal efficacy.

*With Hp/CEA we can control these factors and provide an optimum environment.

Example: The root medicinal Echinacea usually takes 2-3 years to grow in soil.

However, it only takes 9 months in the greenhouse using aeroponics (see Ch. 5).

* All parts (roots, leaves, flowers, etc.) can have medicinal qualities. However, root (or rhizome) medicinals are of particular interest to greenhouse hydroponic growers and can be grown using **Aeroponics** where the roots hang down into an enclosed box and are sprayed with a complete nutrient solution. A portion of the roots could be harvested on a regular basis without destruction of the plant itself (as is the unfortunate result for soil-grown plants).

- *Aeroponics for root/rhizome medicinals offers several advantages over soil culture:
 - The plants have faster growth rates (as mentioned above for Echinacea).
 - The roots are easily accessible and can be sampled whenever needed.
 - The roots are “unadulterated”, i.e., they are pure medicinal crop roots without weed species roots being mixed in, as is possible with soil crops.
 - The plants can be grown in higher densities than in the soil.

*Root/rhizome medicinals with potential for use in hydroponics/aeroponics: 2015 retail prices from Pacific Botanicals (or Starwest Botanicals = SWB):

BLACK COHOSH – for menopause & menstrual problems		
Organic dried root cut		\$20.10 / lb
Organic powdered root		\$19.10 / lb
BURDOCK – “blood purifier”		
Organic dried root cut		\$13.70 / lb
Organic powdered root		\$13.80 / lb
ECHINACEA – immune enhancer		
Organic <i>E. angustifolia</i> dried root cut		\$27.20 / lb
Organic <i>E. purpurea</i> dried root cut		\$22.00 / lb
GINGER – treats stomach upsets, diarrhea, nausea, arthritis, colic, heart cond.		
Organic dried cut rhizome		\$11.85 / lb
Organic powdered rhizome		\$12.85 / lb
GINSENG (different species with similar efficacy) – an overall tonic		
Organic powdered root (Panax ginseng, China)		\$240.75 / lb [SWB]
Organic powdered root (P. quinquefolius, Canada)		\$192.67 / lb [SWB]
GOLDENSEAL – dries out mucous membranes/colds		
Organic dried cut rhizome	\$8/oz or	\$84 / lb
VALERIAN – a sedative in sleeping disorders		
Organic dried root cut [Pacific Botanicals]		\$18.85 / lb
Organic dried root cut [Starwest Botanicals]		\$29.42 / lb [SWB]
Organic powdered root [Starwest Botanicals]		\$31.92 / lb [SWB]

NOTE: “Organic” usually is higher priced than non-organic.
 “Imported” (depending on country of origin) can be a higher price than “USA”.
 Certain varieties/cultivars or companies can be a higher price than others.

7. BERRIES

- * Various berry species are grown in soil outdoors in areas conducive to their growth. However, they are highly seasonal crops.
- * People are trying protected or controlled environment agriculture techniques to grow berries out of season, year-around and in regions not usually conducive to berries.
- *Mexico is now growing blueberries, raspberries and blackberries out of season for fresh export to the USA using low tech, low plastic hoop houses or under bird netting (protected agriculture) but still in soil.
- *Northern USA and Canada are using greenhouses, including retractable roof types, to grow various berries. The retractable roof offers protection from inclement weather but the option to open the structure to the outdoors in good conditions.

- *New Zealand is testing greenhouses for year-around production of raspberries.
- *Dr. Kubota & Mark Kroggel (UA/CEAC) have been researching strawberries as an alternative greenhouse crop in the desert southwest USA. They optimize growing conditions (light, humidity, temperature, etc.) to produce high-flavor fruit.

REFERENCE MATERIAL:

1. **Greenhouse Crops in North America: A practical guide to stonewool culture.** 1993. D.H. Marlow. Grodania A/S, 415 Industrial Dr., Milton, Ontario, Canada, L9T 5A6.
2. **Growing Greenhouse Seedless Cucumbers in Soil and in Soilless Media.** 1994. A.P. Papadopoulos. Agriculture and Agri-Food Canada Publication 1902/E from the Communications Branch, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada, K1A 0C7. ISBN 0-662-22118-4.
3. **Growing Greenhouse Tomatoes in Soil and in Soilless Media.** 1991. A.P. Papadopoulos. Agriculture and Canada Publication 1865/E from Communications Branch, Agriculture Canada, Ottawa, Ontario, Canada, K1A 0C7. ISBN 0-662-18859-4.
4. **Hydroponic Gardening: A practical guide to growing plants without soil.** 1991. L. Dalton and R. Smith. Cobb/Horwood Publications, P.O. Box 85-055 Sunnynook, Auckland, New Zealand.
5. **Hydroponic Food Production.** 2001. H.M. Resh. Woodbridge Press Publishing Company, P.O. Box 209, Santa Barbara, CA, 93160. ISBN 0-88007-222-9
6. **Hydroponic Herb and Sprout Production: A World Review.** 1993. M.H. Jensen. In: Proceedings of the 14th Annual Conference on Hydroponics. Hydroponic Society of America, 2819 Crow Canyon Road, Suite 218, San Ramon, CA 94583.
7. **Introduction to Plant Physiology, 3rd Ed.** 2004. W.G. Hopkins and N.P. Huner. John Wiley & Sons, Inc. ISBN 0-471-38915-3
8. **Peppers as a Commercial Crop: Grower Guide No. 3 – 2nd Series.** 1995. Edited by P. Rogers. Grower Books, Nexus Media Limited, Swanley, Kent, BR8 8HY. ISBN 1-899372-03-2
9. **Personal Communication:** Dr. Anita Hayden, Native American Botanicals Corporation, P.O. Box 44287, Tucson, AZ 85733, concerning root medicinals.
10. **Plant Physiology, 3rd Edition.** 1985. F.B. Salisbury and C.W. Ross. Wadsworth Publishing Company, Belmont, CA, 94002. ISBN 0-534-04482-4.
11. **Seed Catalogs** – Various for classification and variety information.
12. **Revolution in Your Salad Bowl.** 1994. B. Reynolds-Bateson. Sunset Magazine
13. **The Cultivation of European Cucumbers in Greenhouses.** Nunhems zaden b.v. Haelen, Holland.
14. **Vascular Plant Families.** 1977. J.P. Smith. Mad River Press, Inc., Rt. 1, Box 151-B, Eureka, CA, 95501. ISBN 0-916422-07-0.
15. **Web sites:** Search the plant, variety, etc. for more information including recipes. For medicinal prices: <http://www.pacificbotanicals.com> or <http://www.starwest-botanicals.com/> For strawberries: <http://ceac.arizona.edu/strawberries>