Wolf Peach Farms

Operations Handbook

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Chapter 1

General Tomato Info

Botany Basics

Photosynthesis

Photosynthesis is the process used by plants to produce simple sugars or carbohydrates which it then uses for food/energy. Carbon dioxide (CO_2) from the air combines with water (H_2O) under the influence of chlorophyll to produce simple sugars (glucose, $C_6H_{12}O_6$) and oxygen (O_2). This is represented by the chemical equation below:

$$\mathbf{6CO_2 + 6H_2O + Light \rightarrow C_6H_{12}O_6 + 6O_2} \qquad \text{(Photosynthesis)}$$

$$\mathbf{C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + Energy} \qquad \text{(Respiration)}$$

Chlorophyll is present in the chloroplasts in the leaves and stems of plants. It is responsible for the green color of the leaves as it reflects green light. This indicates that the green portion of the light spectrum does not contribute much to photosynthesis. The blue and red portions of the spectrum contribute the most. Blue is used more in vegetation and red more in fruiting and flowering.

The purpose of chlorophyll is to absorb the energy from light and transfer it to the rest of the *photosystem* which then uses that energy to turn the CO_2 into sugars. The sugars produced are sent all over the plant and used to manufacture all of the other molecules needed for life (simple and complex carbohydrates, proteins, and fats). Some are metabolized right away while others are stored in starches and saved to metabolize at night when photosynthesis stops. Water is required in turning the CO_2 into sugars. The splitting of water produces oxygen, which is then released in transpiration through the *stomata*.

Respiration

Respiration is the opposite of photosynthesis and is referred to as a plant's method of breathing. Plants take up O_2 through their roots and use it to break down the sugars created by photosynthesis, which results in the release of CO_2 and water vapor. The primary product of respiration is energy in the form of ATP (referred to as the cellular energy currency), which is used locally (relative to the metabolized sugar) to carry out all sorts of tasks. The equation above doesn't represent the entire process, as ATP production is much more complex, but it shows how plants convert their sugars into usable energy and the products and reagents required to do so.

Respiration takes place at a much slower rate than photosynthesis, so plants release much more O_2 than they do CO_2. However, respiration doesn't require light like photosynthesis, so it occurs during the day and night. This is why the CO_2 supply in grow rooms should be shutoff at night because the plants are releasing their own CO_2 and won't consume any until the lights come back on and they begin to photosynthesize again.

The sugars plants respire at night are the ones that were stored as starches during photosynthesis. With its own internal biological clock, the plant is able to sense the length of the night and adjust its rate of respiration so only a little bit of starch is left at dawn. If the length of the night remains constant, then the rate of respiration during the day is equal to the rate at night.

Plants often desire cooler temperatures at night to help cool them off. Without photosynthesis there is much less evaporative cooling going on, so the plants need a little extra help. This happens naturally outdoors when the sun goes down, and plants evolved to learn to take advantage of the temperature drop. This is why it is important to supply the temperature drop for the plants in a grow room.

Transpiration

Transpiration refers to the evaporation of water from plants. It occurs mainly at the leaves while the stomata are open for the passage of CO_2 and O_2 during photosynthesis. Air that is not fully saturated with water vapor (100% relative humidity) will cause drying of the cell surfaces with which it is in contact. Transpiration provides many benefits for the plant: it plays a role in photosynthesis, draws water and minerals up from the roots, and helps cool down the plant. That being said, too much transpiration leads to more water loss from the plant.

The rate of transpiration is affected by the following factors:

> **Light** – light stimulates the stomata to open and warms the plants, both of which increase the rate of transpiration.
>
> **Temperature** – water evaporates more readily at higher temperatures and warmer air has greater capacity to hold more water vapor. A leaf may transpire three times faster at 86°F than 68°F.
>
> **Humidity** – lower humidity increases the rate at which water evaporates
>
> **Wind** – with no breeze, the air surrounding the leaf becomes more humid as the plant transpires and the rate of transpiration will decrease, however a breeze will move this air and replace it with drier air causing the plant to transpire even more
>
> **Soil Water** – a plant will not continue to transpire if the transpired water is not replaced by water from the roots. When the water is not replaced, the plant loses *turgor pressure* (cellular water pressure) causing the stomata to close. This also reduces production from photosynthesis. If the loss of turgor pressure spreads through the leaf to the stem, the plant will begin to wilt.

Osmosis

Osmosis is the spontaneous movement of water through a semipermeable membrane, moving from a lower salt concentration to a higher salt concentration; if the concentrations are equal, osmosis does not occur. Osmosis is responsible for almost all of the water movement in plants and is necessary to keep a healthy turgor pressure inside the plant. In plants, fluids are *pulled* through xylem/phloem (similar to veins) unlike animals where they *pushed* (i.e. blood) through veins.

When water is drawn through osmosis, water-soluble salts move with it. This is how nutrients are absorbed from the soil and dispersed across the plant. If the concentration of salts in the soil is less than that in the plant roots, the roots absorb the water along with the dissolved nutrients. However, if the concentration of salts in the soil is higher than that of the roots, then water is sucked out of the roots and into the soil, burning the roots and eventually killing the plant.

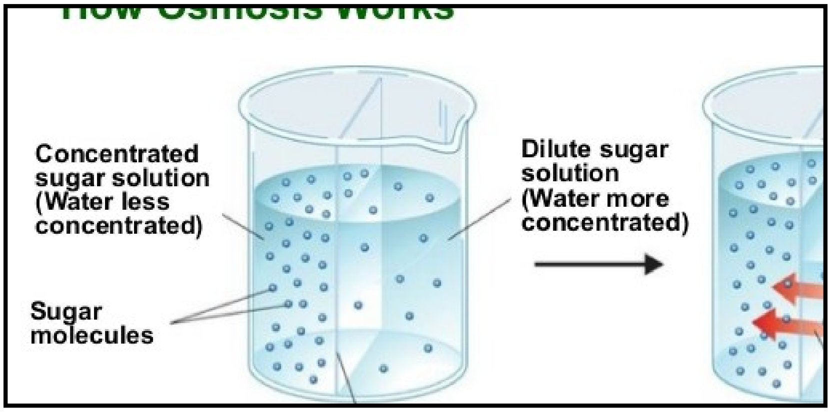


Figure 1: *Visual demonstration of osmosis.*

Stomata

Stomata are pores in the protective cuticle on the underside of leaves. The main organelles are the stoma's two guard cells; they are the door/window into the leaf. Stomata play a large role in both photosynthesis and transpiration.

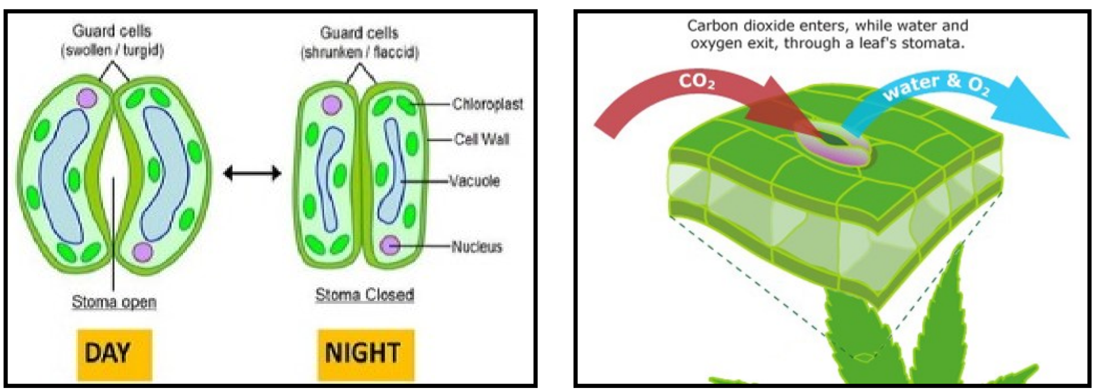


Figure 2: *Guard cells of the stomata (left). Water and oxygen leave stomata as CO2 enters (right).*

In photosynthesis, the presence of light triggers stomata to open, allowing carbon dioxide to flow in and oxygen to flow out. Stomata respond to low CO_2 levels by opening so they can gather more of it. Contrarily the stomata close if the carbon dioxide concentrations in the atmosphere are increased. This is good as it will conserve water, however it could also suffocate and overheat the plants as they are not allowed to transpire and cool themselves off as much. Therefore CO_2 PPM levels in the grow room must be monitored and kept at a target value of 1200 PPM (1500 PPM max).

The action of the stomata is what makes humidity so important. With higher humidity, water vapor escapes at a slower rate through the stomata as the surrounding air is more saturated with vapor. This allows the plant to hold on to more of its water. However higher humidity increases the threat of fungal attack, so humidity control and good airflow are essential to maintain.

Pollination/Fruiting

Tomatoes are self-pollinating in that each flower has both the male and female parts that are needed to fertilize the plant. Once fertilized, the flower will produce fruit. Even though the plant carries both parts and is considered "self-pollinating", it still needs help getting fertilized.

Stamen – the male part which surrounds the pistil and is comprised of anther and filament

Anther – the pollen of the flower is located in these

Pistil – the female part made up of the style and stigma, located in the center of the flower

Style – the long stalk extending from the ovary to the stigma

Stigma – the bumpy and sticky site that accepts the pollen for pollination

Ovules – the part of the flower that gets fertilized to form a seed

Ovaries – the part of the flower that houses the ovules

As mentioned above, the blossoms are said to be self-fertile, but there is no fruit formation if the pollen does not move from anther to stigma. In nature, the vibration from bees' wings causes the whole flower to vibrate and release a cloud of pollen inside the stamen. Because the blossoms normally hang downward, the pollen drops down through the stamen and falls on the stigma, and pollination occurs. The pollen then grows down the style until it reaches the ovary and fertilizes the ovule to form a seed.

In the absence of bees, tomato flowers are typically wind pollinated or fail to pollinate and drop off. For this reason, flowers must be hand pollinated in the grow room to ensure fertilization (see section **2.6 Growing Method and Plant Care**).

Figure 3: *Reproductive organs of tomato flower.*

Liebig's Law of the Minimum

Liebig's Law of the Minimum states that plant growth is controlled not by the total amount of resources available, but by the scarcest resource. More simply, a chain is only as strong as its weakest link. This doesn't just include nutrients, but growing conditions as well (i.e. sunlight quality, CO2, climate, length of days, etc.).

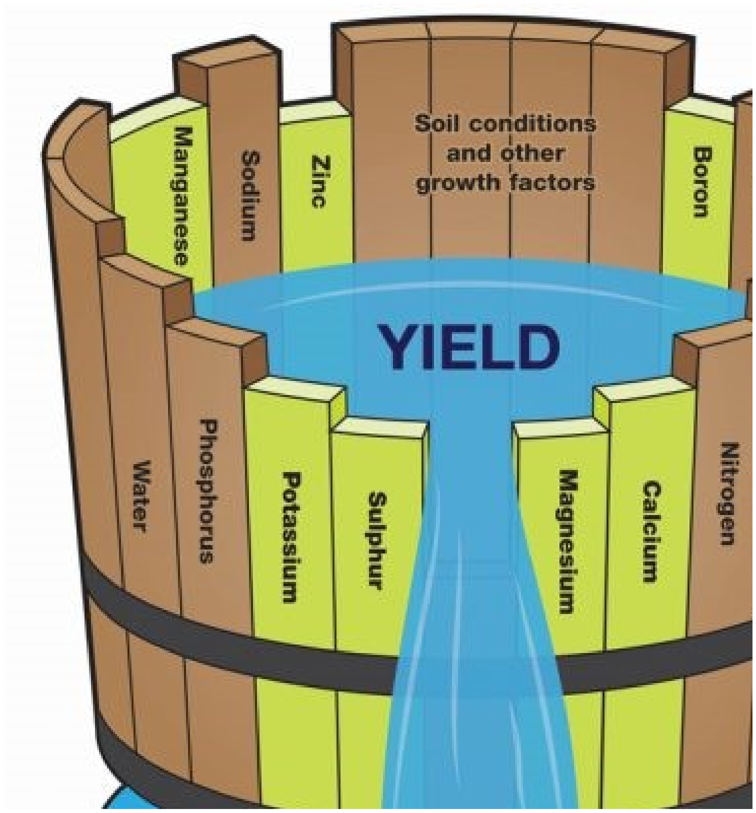


Figure 4: *Liebig's Barrel, exemplifying the law of the minimum*

Growth Stages of Tomato Plant

Germination
Plant is not much more than a seed and has not fully developed any leaves. Germination lasts about 6-12 days.

Seedlings
Plant has penetrated past the soil and has developed two "seedling" leaves. Seedling stage lasts about 7 days.

Vegatative
Plant has developed it's "true" leaves. These are the first leaves grown after the seedling leaves, and they are unique to the plant species.

Flowering
The first flower buds appear on the plant. It is now okay to begin pruning.

Fruiting
The first fruits appear on the plant. In a greenhouse environment an indeterminant tomato plant will continue to fruit, and its main stem will continue to grow as long as the plant is kept healthy and properly maintained. The number of days to harvest varies depending on the variety.

Seedling **Vegatative** **Vegatative** **Flowering** **Fruiting**

Figure 5: *Growth stages of tomato plant.*

How to Prune Tomatoes

When growing tomatoes, the ultimate goal is to help the plant yield as much ripe fruit as possible. If you're growing indeterminate or "vining" varieties, pruning your plants to remove unwanted shoots and leaves ensures that all the nutrients are going to the tomatoes. If you're growing a determinate variety, too much pruning is counterproductive. Indeterminate varieties grow like vines, and they must be trained upright and pruned in order to grow correctly. Determinate varieties contain themselves before they grow into a bush, and they naturally direct their energy toward fruiting without needing as much intervention. Here are some examples of each:

> **Indeterminate:** Big Boy, Beef Master, Paul Robeson, Brandywine, Black Prince, German Queen, most cherry tomato varieties and most heirloom varieties.
>
> **Determinate:** Ace 55, Amelia, Better Bush, Biltmore, Heatmaster, Heinz Classic, Mountain Pride and Patio.

When To Start Pruning
Check the plant for signs of yellowing. One way to know when it is time to start pruning is to wait for the stems and leaves below the first set of flowers to turn yellow. When you notice this color change, you can start pruning.

Look for flowers. It is a good idea to start pruning your tomato plants early, as soon as there are flowers on the plants. At this point, the plants should be between 12 and 18 inches. Make sure the vine-like plants are tied to supports after flowering occurs. Otherwise, the vine will grow along the ground and won't produce healthy tomatoes.

Prune suckers regularly to keep the plant healthy. They grow quickly, so you may need to prune once or twice a week.

Identifying Suckers
Look for the tiny new branches sprouting in the crotch of the plant where a branch meets the main stem. These are called "suckers" and they're what you want to remove. Suckers left to grow will eventually grow to the same size as the main stem, using up energy and nutrients from the rest of the plant, causing the plant to bear smaller, lower quality fruits. Strategically removing suckers will help your plant bear large fruit all season long.

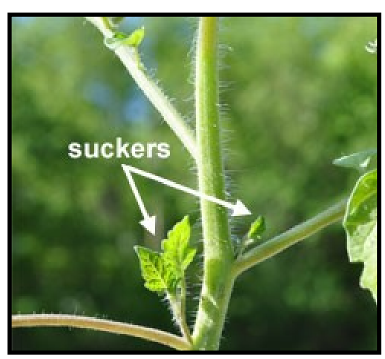


Figure 6: *Examples of suckers on tomato plants.*

Remove all suckers and their leaves below the first flower cluster. Do this no matter what kind of tomato plant you have. This keeps the plant strong by helping it grow a sturdy central stem. This should ensure that the majority of the nutrients are sent to the fruits, instead of being wasted on the unwanted growing tips.

As for stems and leaves, not the suckers, growing below the first flower cluster: If your plant is in a humid environment (such as a greenhouse), remove *everything* below the first flower cluster to improve ventilation. Humidity can make it easier for sicknesses to flourish. It also causes the wounds that are created while pruning to dry up more slowly, making the plant vulnerable for longer. By improving ventilation, you're helping to protect the plant.

Removal Techniques
To remove a sucker, grab a growing tip by the base between the thumb and forefinger (with clean hands) and bend it back and forth until it snaps cleanly. This should ideally be done when the shoot is young and supple. The small wound will heal quickly. This is called "simple pruning".

Leave the thicker shoots. Thicker suckers should not be snapped off, since this could damage the whole plant. If it's thicker than a pencil, use the "Missouri pruning" method and pinch out just the tip of the sucker, leaving one or two leaves behind for photosynthesis and to protect developing fruit from sun scald. The drawback is that suckers will develop from the stem that you leave behind, which will require additional pruning. This technique is better when you're dealing with large suckers; if the wound becomes diseased, it will be further away from the main stem. This method also leaves a few inches on the sucker to reduce the shock to the plant.

Maximizing Fruit Production
Pinch off all but four or five fruit bearing trusses for indeterminate varieties. These are the branches that grow from the main stem above the first flower cluster. Four or five will produce large, healthy fruit, but any more than that and the fruit will be small and scant. Choose four or five sturdy trusses to keep, then pinch out any additional side shoots, leaving the plant's top shoot intact, known as the terminal shoot.

Remove yellow leaves. Yellow leaves are leaves that use up more sugar than they produce. As the plant begins to mature, the lower leaves will naturally begin to yellow and wilt. This is perfectly normal, so pull these from the plant when they appear. It will keep the plant fresh and help ward off disease.

Topping the Plant
To get the best out of the last growth of the season, it is necessary to "top" the plant. About a month before terminating the plant, remove the plant's terminal shoot. At this point in the season, the tomatoes currently growing will have a limited time to reach maturity, so all nutrients must be directed straight to the fruit.

Common Disease and Pests

Indoor Garden Pests

All gardeners eventually face the problem of pests in their gardens. Indoor growers have a difficult situation when it comes to harmful garden insects as there is no rain to wash insects from plants, no natural predators (unless we introduce them), insecticide choices are limited because we grow in structures where people live, and to top it all off, the insects have become immune to many of our available pesticides. Damage to crops grown indoors is predominantly caused by 5 insects: spider mites, thrips, aphids, whiteflies, and fungus gnats.

Spider mites are probably the most common uninvited garden guest when growing inside. Often because of their small size (less than 1 mm), they may not be recognized until their population grows to the point of causing severe damage to our crop. However, there are a few telltale signs to look for that will make it easy to spot their presence.

First, they produce fine spider-like webbing, which if left unchecked will have the room looking like it was decorated for Halloween. The second sign we have a problem is stippling (small specks or dots of yellow) on the leaves. This is caused by the mites piercing the leaf and sucking out the sap. One mite’s damage will likely go unnoticed, but a few hundred will make the leaves look like they were spray-painted yellow. To check for mites, take a white tissue and gently rub the underside of the leaves. If there are streaks of red (mite blood) then we probably have mites.

A useful thing to keep in mind is that mites eat more when the humidity is low, so raising the humidity can slow them down, giving us more time to eradicate them. They also multiply faster in warmer temperatures, so try to keep temperatures down if there is an infestation; it will make them more manageable to get rid of them.

Figure 7: *Spider mites*

Thrips are a very destructive pest. They are small (~5 mm long), fast moving, and adults can often fly. Thrips come in an array of colors including green (the most common), brown, or tan. They often congregate near the veins of leaves.

They can be hard to recognize except by the trained professional; however, the damage they inflict is unmistakable. The damage caused by thrips will look like small metallic black specks on the top of leaves, often in areas of the leaf that have turned brown and dry from the sucking and rasping of the thrips. The black metallic speckling is their feces and can be easily noticed without any magnification. In warmer temperatures thrips reproduce and mature more quickly; making it advisable to keep the grow room cooler when combating them.

Figure 8: *Thrip*

Aphids, also known as plant lice, are capable of causing large amounts of damage. They are easy to see and identify because they are visible to the human eye. They can grow to be between 1 mm and 10 mm and can vary in color from colorless to green, black, brown, or pink. They tend to congregate at the top of the plant; as they have a preference for the newest, most tender growth and stems.

The presence of ants in the room could be a warning sign that there may be aphids. Ants are known to “farm” aphids; moving them around from plant to plant. The ants drink the excrement of aphids which is a sugary substance known as honeydew. If the honeydew is not washed off of the plants, it acts as a perfect host for sooty mildew. Damage from aphids is often seen as contorted yellowing or browning growth, dieback of growing tips, and a rapid decline in plant vigor.

Figure 9: *Aphid*

Whiteflies derive their name from the white waxy covering on the adult's wings and body. The adults are about 1mm long, and look like small, white moths. They prefer to feed on the undersides of leaves. Although they are easy to spot, they can be hard to eradicate because when disturbed, they immediately abandon the plant and fly to a new host. Whiteflies suck the sap from plants, and a large population can cause leaves to turn yellow, appear dry or necrotic, and even fall off the plant. Whiteflies develop rapidly in warm weather and can quickly go from a small problem to a big one. Like aphids, whiteflies also secrete honeydew which can invite sooty mold(s) to grow on the plants.

Figure 10: *Whiteflies*

Fungus gnats are an almost guaranteed sight in all but the best maintained indoor gardens. The adult fungus gnats are tiny black or grey flying insects that look similar to fruit flies. They can often be seen flying about after watering the plants. They deposit their eggs in the top few inches of moist growing mediums, which then hatch into larvae that are tiny (3-4 mm) translucent/white worms with a black dot on their head. A female fungus gnat may lay up to 300 whitish eggs in clusters of 20 to 30 on the surface or in the crevices of potting media that is rich in organic matter. Although the adults are harmless, feeding mostly on algae and decomposing organic matter, the larval stage feeds on the tender root hairs and feeder roots, slowing plant growth and inviting bacterial infection.

Figure 11: *Adult fungus gnat*

Other Pests

Other, less common indoor pests include tomato fruitworms, leafminers, tomato pinworms, and cabbage loopers. Tomato fruitworms chew the fruits, making deep holes, and tomato pinworms make tiny holes. Leafminers tunnel into leaves, leaving raised squiggles throughout that foliage, and the presence of large holes in the leaves can signal the presence of cabbage loopers.

Combatting Indoor Pests

All of the pests discussed earlier are best controlled by prevention, early detection, and treatment, as well as sanitary growing practices. Below are some methods to carry out detection and prevention. See **2.7 Disease and Pest Prevention** for the methods used in our grow room.

Sticky Traps – these can be an excellent way to monitor pest populations and alert increases in pest pressure. This form of early detection allows us to proactively treat our plants with an appropriate pesticide and closely monitor pest populations before they are capable of causing serious crop damage. **Blue** stick cards are good for thrips. **Yellow** cards attract fungus gnats and whiteflies. Make sure some cards are at the soil/medium level of the plants where fungus gnats congregate. The only downside of these traps is that they can trap beneficial insects as well.

Various Sprays – we want to avoid chemical poisons like Avid or Eagle. Homemade sprays from household items like garlic, etc. are options but aren't always effective. Some growers have reported good results from organic "pesticide" interventions like Azamax. Another non-toxic way to protect your plants before an infestation is to use Rhino Skin (Advanced Nutrients)—a foliar application potassium silicate product that basically puts a coat of armor on your plants (protecting against pests & diseases).

Beneficial Predators – some growers report success using beneficial predatory creatures like nematodes. Put these live predators into your medium and they can hunt down and kill the pests. Ladybugs are great beneficial predators that feed on aphids, mites, and the larvae of whiteflies. Conditions must be provided to keep these bugs alive and attracted to remain in the grow room as they are known to leave or die if conditions are not sufficient.

Housekeeping – keeping the grow room clean of debris and dying or dead organic matter, such as leaves. Keeping the floors free of dirt can reduce the likelihood of insect invaders. Pests can be introduced from outside soil/clippings, so shoes must be removed before entering the room, along with any dirty clothing.

Indoor Plant Diseases

The following fungi and diseases are the most common to occur in indoor plants. Almost all of these can be prevented with good growing practices and close attention to plant responses. See **2.7 Disease and Pest Prevention** for the methods used in our grow room.

Powdery Mildew – This looks like someone sprinkled white powder over the leaves and stems. If left untreated it results in stunted plant growth, leaf drop, and yellowing of plant tissue. If it gets too far, the plant will die.

Downy Mildew – Don't get these two confused. Downy mildew mostly appears on the underside of leaves and doesn't look like a powder the way "powdery" mildew does. They both can cause yellowing of leaves which makes them easy to misidentify though.

Gray Mold – Also called ash mold & ghost spot. It will start out as spots on leaves that lead to fuzzy gray abrasions and will continue deteriorating until the plants are brown and mushy.

Root Rot – This can occur when there is too much water and pathogens in the medium/soil. Plants will wilt and turn yellow. Roots can get mushy too.

Iron Deficiency – Plants lacking iron will lack chlorophyll, so you'll see the leaves turn bright yellow while retaining green veins. Sometimes this is misdiagnosed as some other type of disease when your plants are simply lacking iron.

Tobacco Mosaic Virus

Although tobacco mosaic virus (TMV) is named for the first plant in which it was discovered (tobacco) back in the 1800s, it infects over 150 different types of plants. Among plants affected by TMV are vegetables, weeds and flowers. Tomato, pepper and many ornamental plants are struck annually with TMV. The virus does not produce spores but spreads mechanically, entering plants via wounds.

Figure 12: *TMV symptoms in foliage and fruit.*

TMV does not usually kill the plant that is infected; however, it does cause damage to flowers, leaves, and fruit and stunts a plant's growth. With TMV damage, leaves may appear mottled with dark green and yellow-blistered areas. The virus also causes leaves to curl. Symptoms tend to vary in severity and type depending on the light conditions, moisture, nutrients and temperature.

Touching the infected plant and handling a healthy plant that may have a tear or nick, whereby the virus can enter, will spread the virus. Pollen from an infected plant can also spread the virus, and seeds from a diseased plant can bring the virus to a new area. Insects that chew on plant parts may carry the disease as well.

There has not yet been found a chemical treatment that effectively protects plants from TMV. In fact, the virus has been known to survive for up to 50 years in dried plant parts. The best control of the virus is prevention. Reducing and eliminating sources of the virus and the spread of insects can keep the virus kept under control.

Sanitation is the key to success. Garden tools should be kept sterilized. Any small plants that appear to have the virus should be removed immediately from the garden. All plant debris, dead and diseased, should be removed as well to prevent the spread of the disease. In addition, it is always best to avoid smoking while working in the garden, as tobacco products can be infected and this can spread from gardener's hands to plants.

Chapter 2

Hydroponics System Setup

Water Cycle and Storage

Water Filtering

Water comes in from tap and gets run through a 0.2 micron filter (remove sediment), a carbon filter (remove chlorine and other charged particles), a reverse osmosis filter (remove remaining dissolved salts and solids), then UV filter (disinfect and sterilize). Check product information for instructions on replacing filters.

Filtered water is the only water to be used for any nutrient solution, foliar sprays, media maintenance, cleaning, etc. and should be used over tap water whenever possible.

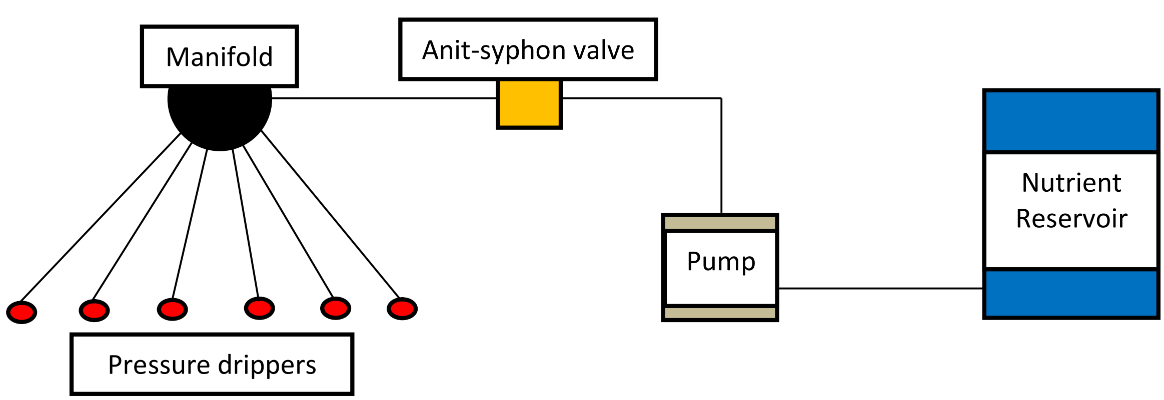
Water Cycle

Water is fed to plants from nutrient reservoir via the feed line. Plants only retain about 5% of the water they take in through their roots; the rest is released through transpiration as water vapor. The vapor is then collected by the dehumidifier. The most important thing is to have a dehumidifier that is rated to remove more GPD than volume of nutrient solution used per day. The collected water is then collected into a sterile reservoir where the volume will be measured and emptied daily. Be sure the reservoir is made of a dark material to prevent algae growth clean the reservoir weekly to prevent growth of mold/bacteria.

Drain water is collected in aluminum pans below the plants. Watering times should be adjusted to minimize drainage. Drainage bins should be emptied and sterilized with hydrogen peroxide weekly to prevent buildup and fungi/algae promotion. Drainage water should be disposed of and <u>NEVER</u> be reused in solution. A utility sink will be used for waste water and will have to be kept clean at all times.

Feed Line

Water is fed to plants using a timed inline pump and pressure-compensated drip feeders (see diagram below). Intake of pump should be kept at as low of an elevation as possible in order to stay primed. For the same reason, the nutrient level in the reservoir should never go below the pump intake elevation. The line is to be run so the anti-syphon valve is higher than the maximum elevation of nutrient solution. This will prevent seepage when the pump is off. The anti-syphon valve will break the syphon created when the pump turns off. Pressure compensating drippers will ensure all plants are experiencing the same flow rate.



Media are watered until flooded. They are then allowed to drain and sit until the top 1” of medium has dried, at which point they are watered again. Media should never be allowed to dry completely. Drying out the top 1” will help prevent fungus gnats and fungal attack in the medium.

At least once a month, the feed line should be sterilized (ideally sterilize in between reservoir switches). This can be done by pumping hydrogen concentration? peroxide through the line. The hydrogen peroxide will kill the plants, so the discharge drippers will have to be removed from the plant bases so the hydrogen peroxide goes directly into the drain water bin instead of through the medium.

Measuring Volumes

We will keep track of the volume in the nutrient reservoir to calculate how much nutrient a plant requires throughout the different stages of its life. It will be measured using a dipstick method. A stick devoted to this purpose will be marked out at certain lengths that denote the volume in the reservoir. The dipstick should get wiped off when done to reduce salt buildup and be sterilized when necessary.

We will keep track of total drainage volume to help us optimize feed times and reduce waste. The volume in the drainage bin will be calculated by adding up the total of all the bins. When done measuring, all drainage gets poured down the drain, and measuring devices get cleaned. This process should be done daily.

If collecting water in the dehumidifier for measurement, mark out the collection bins with volume lines to make quick and easy measurements. The dehumidifier numbers will be used primarily to ensure proper maintenance and performance of the unit. For example, if a dehumidifier is rated at removing 70 pints per day and we measure 35 pints after 24 hours, then we know the unit was running for 12 hours.

Nutrient Solution

Making the Solution

Filtered water is measured and added to a *sterile* nutrient solution storage bin (all parts of the bin including the nozzle, equipment, etc. should be sterilized immediately after a reservoir is emptied). The pH and EC of the filtered water is then measured and recorded. Using the “pH Up” and “pH Down” solutions, carefully adjust the water to the target pH of 5.5, following the instructions on the bottles (**Table ##**). Keep track of the volume of each added and record.

We will use the recommended Advanced Nutrients nutrition plan (see **7.2 Nutrition Plan** for measurements). Add Part A nutrient to the water and mix. Once uniformly dissolved, add Part B and mix. Once dissolved, add the remaining nutrients one at a time and mix after each addition. It is essential that each nutrient is added one at a time and mixed well before adding the next, as they will react and create a white precipitate if mixed without being diluted. Plants cannot absorb nutrients unless they are completely dissolved in water, so if any precipitate forms the plants will not be receiving the full nutrients they need. Take a final reading of the pH and EC and record. Once mixed, turn on the air pump, circulation pump, and reservoir heater.

> *Note: If the pH is outside the optimal range, it will be difficult to make any adjustments due to the Advanced Nutrients “pH Perfect” technology (it uses a pH buffer which essentially holds the solution at a desired pH, and won’t change unless a large amount of acid or alkaline is added to the solution. That being said, it is still critical to get the pH of the water as close as possible to 5.5 before adding nutrients).*

After making the solution it is essential to put a light-blocking lid on the reservoir to prevent the growth of algae. We will have multiple reservoir bins, so every time a reservoir is switched out it should be replaced with a clean one. The old one must then be cleaned and sterilized and stored with the lid removed to prevent mold.

Monitoring

Nutrient solution will be monitored daily for EC, pH, and temperature. None of these should really be a problem. We will use a reservoir heater to keep the nutrient solution at the desired temperature, the Advanced Nutrients diet will control our EC levels (dissolved salts), and their “pH Perfect” technology will keep our pH at 5.5 for at least a week, maybe more. Again, all of these parameters should be okay, but it’s still good to monitor them daily in the case that any issues arise.

It would be ideal if we could get a reservoir to last two weeks if not more. Monitoring all of these parameters along with visual inspection for mold/algae, salt buildup, and formation of precipitates will help determine if it is healthy to keep a reservoir for up to two weeks without exchanging solution.

Temperature
Since the air temperature during the day is 70 degrees, the reservoir heater only has to be on during the nighttime hours when air temperature is dropped to 60 degrees. To keep the reservoir well insulated, we can wrap it in Styrofoam or stack it inside an empty reservoir. Reservoir temperature must be kept below 72 degrees for the solution to hold on to the dissolved oxygen.

Circulation
The nutrient will be circulated using a basic aquarium circulation pump. This will help disperse the heater from the reservoir heater, maintain a uniform solution, and prevent mold/algae growth. The pump must be mounted toward the bottom of the pump so it remains underwater at all times.

Aeration
An air hose will be utilized in the reservoir to aerate the solution. Roots feed on dissolved oxygen and use it in respiration. Too much aeration could cause damage to the plants or cause precipitates to form in the solution, but it is unlikely this will happen. If there is no precipitate after mixing, but gradually occurs throughout the week, it is most likely due to aeration. If this occurs then reduce or eliminate aeration. If precipitation continues other factors need to be investigated (temperature, pH, nutrient compatibility).

Hydrogen Peroxide
For extra sterilization and oxygenation, hydrogen peroxide (35%) can be added to the nutrient solution at the concentration of 2-5 mL (5mL = 1 tsp) per gallon of water. When using this method, the hydrogen peroxide should be added to the water and allowed to sit 30 minutes to stabilize before adding the other nutrients. The effects will last about 4 days. Some farmers add more peroxide every 5 days to continue the benefits. This must be done well before the next feed time to allow the solution to stabilize.

pH Meter Care
The pH meter <u>MUST</u> be stored in the pH storage solution or else the meter will be damaged.

Climate Control

Air Quality

To ensure all target values are maintained throughout the day, a unit will be installed to read CO_2, air temperature and RH%. The unit has the capability to log all of the data it records, so we will be able analyze the atmospheric conditions throughout the span of the entire day even if we weren't there to collect the data. This will help us lock in CO_2 regulator settings.

To make sure CO_2, humidity, and temperature are distributed evenly across the room, one or two oscillating fans will be utilized to stir the air. Constant air movement will also help reduce fungal attacks. Air movement must be gentle though, as too much could cause stress on the plants and more water loss through transpiration.

An air purifier will be used to help circulate air as well as remove pathogens. The purifier removes 99.97% of allergens and pollutants as small as 0.3 microns (mold spores are 10-30 microns, bacteria 0.3-60 microns) and uses UV-C radiation to disinfect the air.

Humidity

Humidity control is important for photosynthesis, transpiration, and respiration. The plants will naturally humidify the air through transpiration day and night. A dehumidifier will be utilized to reduce this and will be set to 50% RH 24 hours of the day. The tank will be measured daily and sterilized weekly. The water collected in this unit theoretically should be clean and sterile and can most likely be used again, but this remains to be determined. If not, we can pour the water down the drain.

If necessary, a humidifier will be utilized to kick in if the humidity ever drops below the target RH. The unit must be filled with water that has been run through our filtration process. The humidifier will be set to 50% RH 24 hours of the day and will be sterilized on a weekly basis.

Condensation collection on leaves and other surrounding areas is a sign that humidity is too high. Flower drop is a sign air is too dry.

Air Temperature

The lights and other equipment will naturally produce heat and raise temperatures, so for the most part A/C is the only temperature control that will be needed. LED lights do not produce nearly as much heat as halides, so temperature control should be fairly easy.

A mini-split A/C and heat pump unit will be utilized to keep the room at 70 degrees during the day and 60 degrees at night. The system comes professionally hooked up with a thermostat for easy 7-day programming. The mini-split A/C requires professional installation, and is much more expensive upfront, but it is much more reliable, efficient, and safer than a portable A/C unit. It also allows for more space in the room as the unit is wall-mounted. The unit also has a heat pump in it, so we won't have to worry about temperature control during the cooler months.

CO_2 Control

CO_2 levels in the grow room will be controlled using a CO_2 tank and a Titan CO_2 regulator. This will be automated to release CO_2 at certain intervals to keep the CO_2 level in the air at 1200-1500 PPM (see **Figure 15** for regulator settings). The flow rate on the regulator can't be set too high as you don't want a rapid release of CO2 over a short amount of time. The unit can also freeze up if CO2 is released too quickly. However it does take more CO2 to bring the room up to concentration when released slower, so a flow rate around 8 cubic feet per hour is best. Duration of release and duration of off time should be adjusted to keep CO2 levels at optimal concentration.

The CO_2 will be released through a ¼" tubing rain system hung above the plants. CO_2 is heavier than air, causing the gas to "rain" down and distribute over the plants. We will have a unit that reads temperature, humidity, and CO_2 PPM, which we will use to log readings on all of these levels.

CO_2 is needed for photosynthesis; however it is produced by the plant during respiration. Therefore the regulator will be turned off during nighttime conditions and turned on an hour into the daytime. The Titan Controls Apollo 12 has a photocell that easily allows for this kind of operation.

Electrical and Lighting

Electrical

The circuit board will have to be rigged to have three 20A circuits supporting all of the equipment. One circuit will be for lighting, one for A/C, and one for everything else. All of the equipment will be on scheduled timer outlets (see **7.4 Equipment Information** for equipment schedule).

If we tried to put everything on one circuit we run the risk of blowing a circuit which would turn everything off and kill the plants if not flipped back on. The even bigger risk is getting close to 20A and having it run for an extended period of time. This could cause the circuit cable to overheat and spark an electrical fire.

Lighting

The lights will be on timers to be on for 12 hours during the day and 12 hours at night, with nighttime centered around midnight. Lights will have to be raised and lowered throughout the plant's lifespan to keep the light at the optimal height above the plant canopy. For this project LED lighting is the better and safer option. For this project we have chosen the Optic 6 LED. See **7.6** Error! Reference source not found. for more specifications on the Optic 6 and a comparison of LED to CMH lighting.

Cleaning and Sterilization

The grow room will have to be kept as sterile as possible. This includes ourselves as we can also introduce pests and disease to the room through our shoes, clothes, etc. Therefore we must wash our hands, take off our shoes, and remove any dirty clothing before entering the grow room. Tobacco products are prohibited inside the room, even if they are not being used. Tobacco mosaic virus can easily spread to the plants, forcing us to kill of off plants and sterilize the room.

Hydrogen peroxide will be used to sterilize pipes, filters, drippers, etc. Hydrogen peroxide is the best means of sterilization as it is composed of only hydrogen and oxygen and decomposes into water and oxygen gas. That being said, it is still extremely toxic to plants in high concentration, so you need to be careful when using it. The bottle in the grow room is 35% because it is more stable than over-the-counter 3% concentration and doesn't require added compounds to remain stable. The 35% peroxide must be diluted before using (see **Table dfgdsf** for dilution instructions). If for any reason hydrogen peroxide will not suffice, use a bleach solution instead (1:10 bleach to water) and be sure to rinse when done to remove the remaining bleach.

Hydrogen peroxide at 35% is much stronger than the medical 5% stuff, so it must be used with caution as if it were an acid, as it will burn skin. It is highly recommended to wear rubber gloves and safety goggles while handling the chemical.

Clorox wipes can be used whenever left over chemical residue is not a concern (i.e. drainage bins, sink, plant shelves).

Cloth and traditional rags will be used sparingly if at all. Single-use paper towels are much more sanitary. Lint-free paper towels will be used if necessary.

Growing Method and Plant Care

Starting from Seed
Soak coco coir with nutrient solution from spray bottle (some brands of coir may need to be soaked and wash beforehand as coco coir is naturally high in salt, but the higher quality brands like CANNA do this for you). With the coco coir still moist, place 2-3 seeds ¼" deep and pat down lightly. Place seeds in covered container to keep moist and let them rest in a 70-80 (77-79 optimal) degree room.

Once the seeds sprout, remove the covering and place seeds under a light source until the first "true leaf" has grown. The true leaf is larger and different in appearance than the first one or two "seed leaves" (10-14 days from planting). If more than one seed sprouted in the same cell, remove and discard the smaller seedlings, leaving the largest to grow. During this period be sure to keep the substrate moist, but do not over water, as more plants in this stage are killed by overwatering (root rot) rather than too little water. For this reason it is best to use a spray bottle to water the seedlings. Be sure to follow the recommended diet for seedlings.

Transfer
Carefully transfer seedlings into growing bags and add them to the hydroponic system. Plants are now in the vegetative state so be sure to follow the grow instructions outlined in **7.1 Target Values**. Plants in vegetation use up less nutrients, so make sure they are not on the same schedule as more mature plants as it could drown the roots or waste nutrient.

Maintenance
Plants will need to be trained along garden twine as they grow to support them vertically. Once the plants reach maximum height (24"-28" below lights), they will be lowered by adding slack into the twine and will be allowed to grow back to the roof. If plants get too close to the plants they may get "sunburn" and get permanently damaged. This process will be repeated until it is decided to terminate the plant.

In the garden we will designate only a portion of the plants to grow perpetually. This is so we can gather more data on the early stages of the plant life, try different diets, and experiment with different tomato varieties. We may want to consider having a separate vegetative area, but with LED lights it may not be necessary.

The growing medium and grow bag should be rinsed once a week with filtered water just before the next feeding period. The rinse will have to be performed just before a feeding is about to occur so that nutrient will come in directly after. This method will prevent the plant from starving from lack of nutrients and suffocating from blocking air to the roots.

Plants must also be pruned as needed to maximize growth (see **1.3 How to Prune Tomatoes** for more details).

Pollination
Naturally, wind and bees are responsible for carrying out pollination; however in the grow room, we the farmers are responsible. This can be done easily either with an electric toothbrush or by

gently shaking the rope the plants are climbing. With the electric toothbrush you simply turn it on and hold it on the stem behind the flower you wish to pollenate. The vibration should be good enough to fertilize the plant.

Disease and Pest Prevention

The best way to combat disease and pest problems is through prevention. Good housekeeping such as removing dead plant debris, cleaning spills, sweeping, sterilization of tools, bins, etc. Eventually we may implement the use of Rhino Skin to let the plants build up their cellular structure and build a physical defense.

We can also prevent disease and pest problems by ensuring we don't bring them into the room in the first place. We can do this by starting all plants inside the grow room, using sterilized growing media, washing our hands, removing shoes and dirty clothing, and not allowing pets or tobacco products in the room.

Ladybugs
Our primary defense against pests will be through the use of ladybugs. Ladybugs are natural predators of aphids, whiteflies, and spider mites. To prevent the ladybugs from dying or leaving the grow room, we have to provide them a home and favorable conditions. For the home we will use a cloning container with holes in the lid of the container to allow the bugs to leave as they wish. We will provide water with a wet sponge soaked with filtered water and keep 10-15 raisins in the home to provide them with food. The house will have to be maintained regularly to ensure there is enough food and water and the place stays clean. Dead bugs and feces are problems that will have to be monitored and maintained.

We will have to reduce external light from outside the grow room as they may be attracted to leave. With ladybugs, we will also have to limit the usage of foliar sprays as they can harm and kill ladybugs. Organic sprays are generally safe to use, but some organics such as neem oil can be an irritation to them.

Fungus Gnats
To prevent fungus gnats we will allow the top inch of medium to dry out before rewatering. This is the best way to prevent eggs from being laid in the first place and will also help prevent fungal attack.

To monitor fungus gnats, we will cut a slice of potato weekly and place it face down on the medium. If there are any larvae in the medium they will be attracted to the potato. After 24 hours if we find any larvae then we will have to put Gnatrol WDG into the nutrient solution to remove minor infestations. If there is a major infestation we may have to remove infested plants or sterilize the room entirely. Another way to monitor fungus gnats is by placing yellow sticky traps face up on medium to catch adults before they lay eggs. This however will be a last resort as we don't want to trap ladybugs.

Sticky Traps
Ladybugs are attracted to yellow sticky traps, so these will not be used inside the room; however they will be used outside the room to prevent pests from entering and ladybugs from exiting. Blue sticky traps will be used inside the grow room, as the blue is very attractive to thrips but not so much to ladybugs.

Disease Prevention

Fungal attack will be prevented with low humidity, good air flow, air purification, and proper watering techniques as described with fungus gnats. If fungal attacks become a problem, we can look into organic foliar sprays, essential oils, or sporekill/quatro if mold in the reservoir becomes a problem.

Root rot will be prevented by providing plenty of oxygen to the nutrient solution via air pump and possibly hydrogen peroxide. Coco coir is also known for its fantastic drainage abilities, so getting oxygen to the roots should not be a problem.

The only way to prevent tobacco mosaic virus is through good housekeeping, sterilization, hand washing, and prohibition of tobacco products in the grow room.

Chapter 7

Appendix

Target Values

Table 1: Optimal Conditions for Nutrient Solution

	pH	EC (mS/cm)	T
Germination	5.3-5.5	<0.5	
Seedlings		1-1.5	
Vegetative		2.5-3.0	
Flowering			

Table 2: Evaluation of pH Values for Plant Growth

pH	Qualitative Relativity
≤ 4.5	Very Acidic (extremely low plan
4.6-4.7	Very Low
4.8-4.9	Low
5.0-5.1	Slghtly Low
5.2-5.5	**Optimum**
5.6-5.8	Slightly High
5.9-6.3	High

Table 3: Optimal Atmospheric Conditions

	Day	
Duration (hr)	16	
Temp (°F)	65-75	
RH%	50-60	
	1200	

Nutrition Plan

The following concentrations are in mL/L, meaning “X” mL of nutrient for every liter of filtered water. Our maximum reservoir size will be 25 L to start. As growing continues and we collect more data, the feed times and reservoir sizes will be adjusted.

Seedlings: Advanced Nutrients recommends using Coco Grow at **1 mL/L** during seedling stage.
Small Plants: Advanced Nutrients recommends using **2 mL/L**.
Mature Plants: Advanced Nutrients recommends using **4 mL/L**.

Table 4: Advanced Nutrients' Diet Recommendation (mL/L of water)

		Vegatative				Flower			
	Nutrient	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	V
CG	Sensi Coco Grow - A	4	4	4	4				
	Sensi Coco Grow - B	4	4	4	4				
CB	Sensi Coco Bloom - A					4	4	4	
	Sensi Coco Bloom - B					4	4	4	
V	Voodoo Juice					2	2		
B	Big Bud						2	2	
5	B-52	2	2	2	2			2	

Table 5: Estimated Solution Volume Usage

	Feed Duration (s)	Times per Day	Flow rate (gph)	# Plants	Volume p day (L)
Vegatative	10	10	1	10	1.05
Flowering	10	12	1	10	1.26

Nutrient Deficiency Symptoms

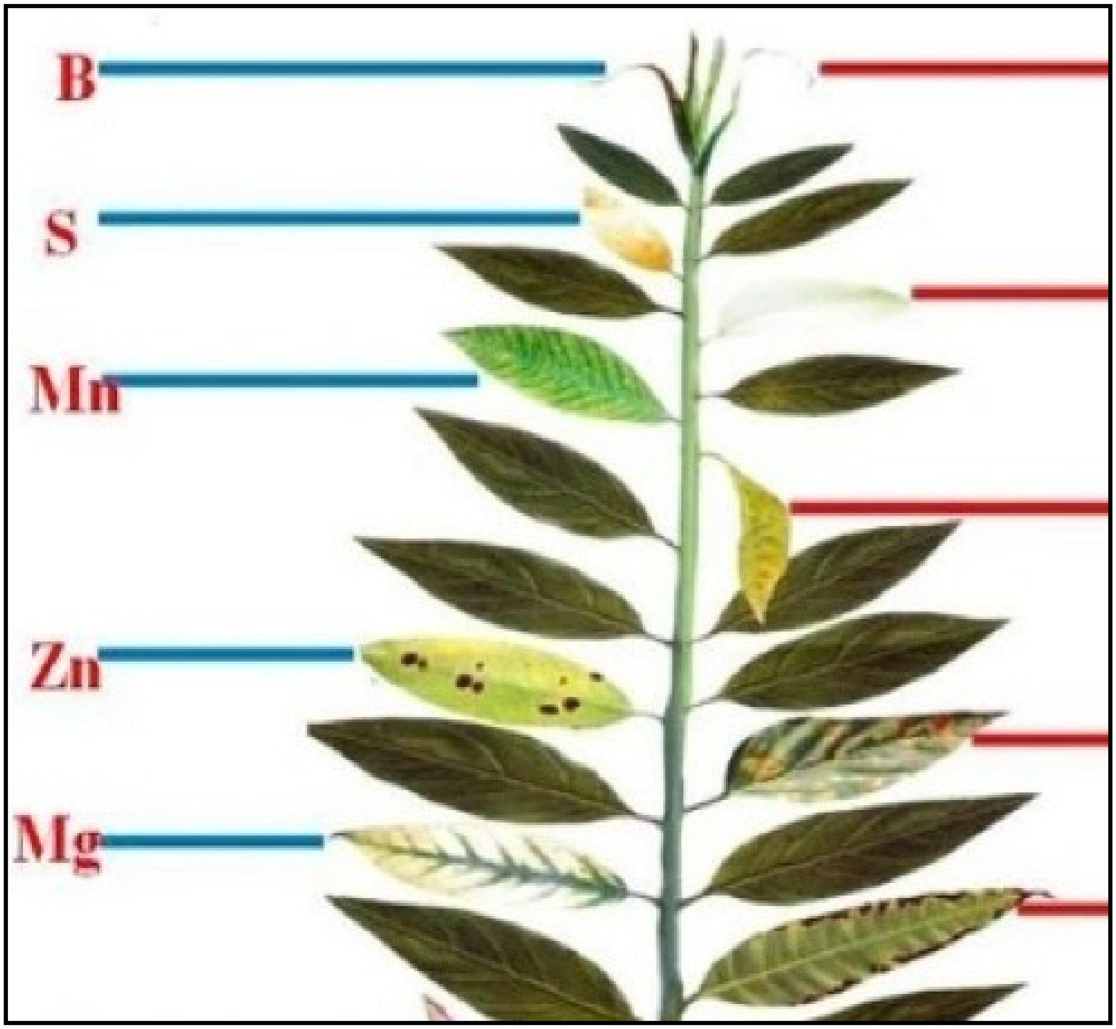
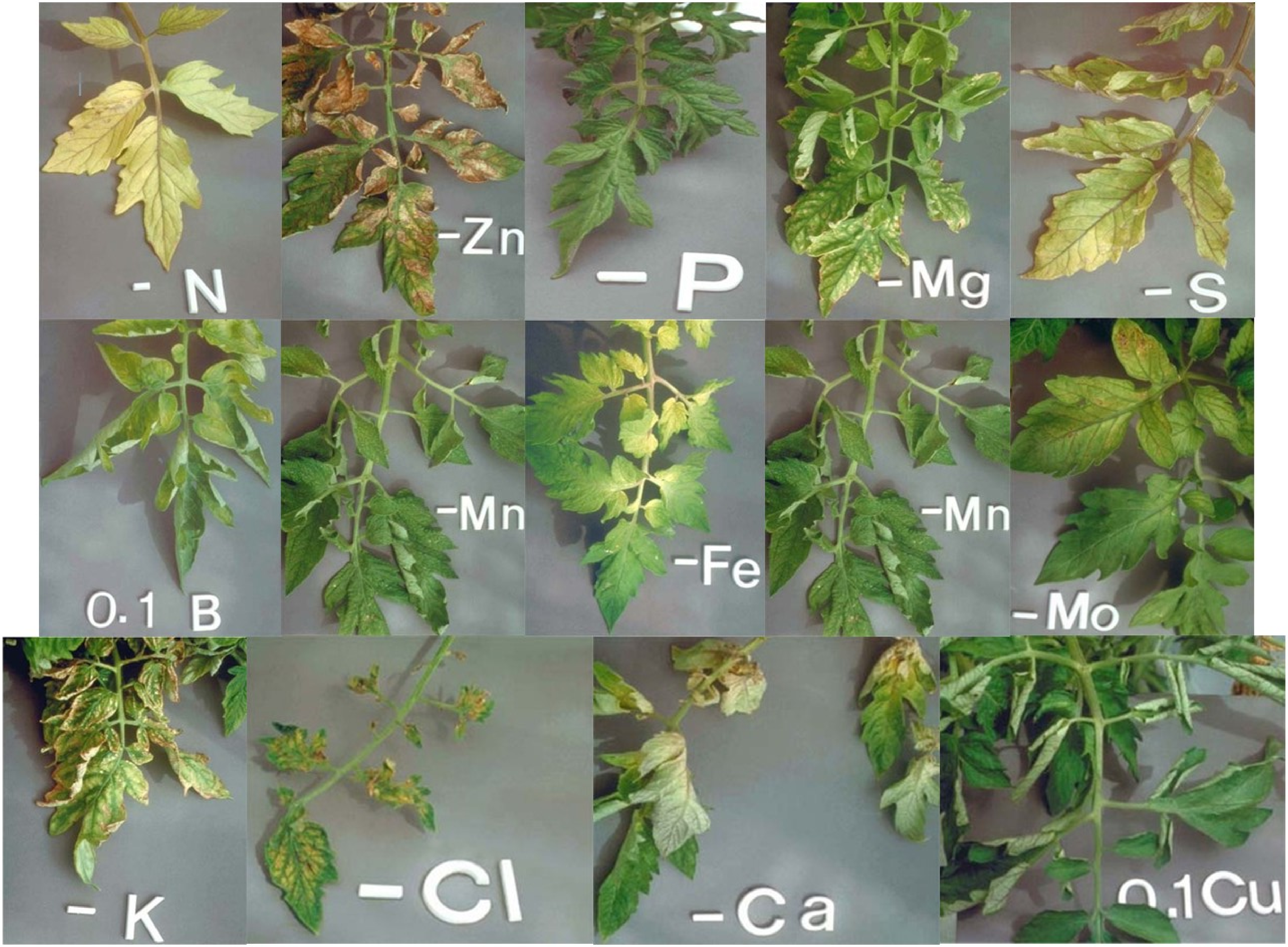


Figure 13: *Visual symptoms of nutrient deficiencies.*

Symptoms	Ca	S	Fe	Mn	Zn	B	Cu	N	P
Chlorosis throughout leaves		Y/O citrus						O Starts @ tips	
Interveinal chlorosis leaves			Y	Y	Y/O legumes				
Chlorosis in tiny spots - dicot				Y					
Grey-green spots-monocot				Y					
Bleached/blanched leaves			Y	Y			Y	O	
Dark green/purple leaf/stem									O
Bronzed leaves possible					Y				
Marginal/tip leaf chlorosis burn								O starts @ tips	
Necrotic spots on leaves									
Growing tips die	Y					Y	Y		
Drooping leaves/wilting									
Leaf drop							Y	O	
Strap-like leaves					Y				
Rosetting of leaves					Y	Y	Y		
Distorted leaves	Y					Y	Y		
Reduced flowering/fruiting	*							*	*

Figure 14: *Plant nutrient deficiencies chart.*



- N
-Zn
- P
-Mg
- S
0.1 B
-Mn
-Fe
-Mn
-Mo
- K
-Cl
-Ca
0.1Cu

Table #: Plant Nutrient Properties and Signs of Deficiency

	Nutrient	Dry Mass %	Purpose	Deficiency Symptoms	Mobility	Leachable
Free	**Carbon**	45	- forms backbone of many biomolecules - part of carbohydrates that store energy inform of sugar			
	Hydrogen	6	- forms major part of all carbohydrates - important in cation exchange			
	Oxygen	45	- involved in cation exchange b/w roots and growth medium - terminal acceptor of H^+ cations in respiration			
Macro Elements	**Nitrogen**	1.5	- contributes to strong growth and lush, green foliage - used to produce amino acids for proteins for new cell growth - major component of chlorophyll, nucleic acids, vitamins, coenzymes	- yellowing of older leaves - darker foliage, reds and purples may intensify - reduction of lateral breaks	Very mobile	
	Phosphorus	0.2	- important role in bio-energetics, production of ATP	- reduced growth, flowering - color may intensify - older foliage may turn brown/purple, premature loss - purple veins	Very mobile	
	Potassium	1.0	- starch formation, sugar translocation, carbohydrates, protein synthesis, chlorophyll devolopment, tuber formation, cell division, water relations - regulates action of stomata via potassium ion pump - acts as activator, especially in production phase - improves resistance to disease/drought/cold, stem rigidity, flavor/color	- necrosis, interveinal chlorosis - mottled, spotted, or curled older leaves - burned look to to older leaves, withering of leaf edges - dead spots in leaf - reduction of lateral breaks	Very mobile	
	Calcium	0.5	- formation in stability of cell walls (acts as mortar) - enzyme activator - influences water movement - regulates transport of other nutrients, especially nitrogen	- blossom end rot - stunting/mishaping of new growth in leaves, stems, flowers - damage/die off of growing points - yellow leaf edges, black spots on leaves and fruit	Immobile	Easily leached
	Magnesium	0.2	- critical to structure of chlorophyll molecule - involed in functioning of enzymes for sugars, carbohydrates, fats, triglyceride, ATP	- yellowing b/w veins of medium/older leaves - leaves turn inwards	Mobile	
	Sulphur	0.1	- forms parts of proteins, amino acids, vitamins - manufacturing of chloroplasts - important for respiration, flavors/odors	- light green leaves - yellowing of leaves, begins in new growth - similar to N but N occurs in older leaves	Not very mobile	Easily leached
Micro Nutrients	**Iron**	0.01	- required by all plants and animals - chlorophyll production and young shoots - enzyme cofactor	- pale leaf color in younger leaves followed by yellowing - large greenish veins - necrosis, interveinal chlorosis	Not mobile	Prone
	Zinc	0.002	- important during flower/fruit/seed production - absorption of water, carbohydrate metablism, protein synthesis, stem growth - DNA transcription	- "little leaf", small leaves with chlorosis, necrotic spots - yellowing between nerves on older leaves, starting at tips and edges	Highly mobile	
	Copper	0.0006	- concentrated in plant roots - nitrogen metabolism - electron carrier as part of ezyme stsems that use carbs and proteins	- die back of shoot tips - terminal leaves develop brown spots, curl inwards - chlorosis	Slightly mobile	
	Molybdenum	0.00001	- structural component of the enzyme that reduces nitrates to ammonia - required for the formation of plant proteins	- blocked protein synthesis and reduce plant growth - nitrogen deficiency		
	Boron	0.002	- cell wall formation, membrane integrity, calcium uptake, cell division, protein formation	- tomato leaves/stems become brittle - younger growing points affected first	Not mobile	Easily leached
	Manganese	0.005	- necessary for chloroplasts - directlyinvolvedin production of oxygen and water in photosynthesis - enzyme activity in respiration and nitrogen metabolism	- resembles that of Mg, however Mg occurs on older leaves - elongated holes b/w veins	Relatively immobile	
	Nickel	0.001	- iron absorption - can substitue for zinc and iron cofactor responsibilities - essential for enzyme urease to break down urea and liberate nitrogen - seed germination	- shows up gradually, becomes serious when plants reach maturity and reproductive growth - formation of necrotic lesions from toxic levels of urea		
	Silicon	N/E	- component of cell walls, makes them stronger, mechanical barrier to insects - not essential but seems to benefit plant growth - significantly increases heat/drought tolerance and resistance to insects/fungi	Not essential		
	Chlorine	0.01	- required for photosynthesis	Needed in minute quantities, deficiency highly unlikely		

Equipment Information

Table 6: Equipment Power Source Allocation

Equipment	Circuit	Outlet	Max Power (W)	Voltage (V)
LED (1)	1	1	415	120
LED (2)	1	1	415	120
Reservoir Heater	1	1	350	120
A/C Unit	2		730	220
Air Pump	3	2	2.8	120
Circulation Pump	3	2	5	120
Humidifier	3	2	30	120
Air Monitor	3	2	60	120
Oscillating Fan	3	2	60	120
Air Purifier	3	2	100	120

Table 7: Equipment Schedule

Equipment	Schedule																	
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
LED (1)																		
LED (2)																		
Reservoir Heater																		
A/C Unit																		
Air Pump																		
Circulation Pump																		
Humidifier																		
Air Monitor																		
Oscillating Fan																		
Air Purifier																		
CO2 Regulator																		
Nutrient Pump																		

CO_2 Distribution

1200 PPM TIMING CHART

GARDEN SIZE CUBIC FEET (L x W x H)

W METER SETTINGS

CUBIC FEET PER HOUR

CU/FT	100	200	300	400	500	600	700	800	900	1000	1200	140
1	7	14	22	30	36	43	50	58	65	72	87	101
2	4	7	11	14	18	22	25	29	32	36	43	50
3	2	5	7	10	12	14	17	19	22	24	29	34
4	2	4	5	7	9	11	13	14	16	18	22	25
5	1	3	4	6	7	9	10	12	13	14	17	20
6	1	2	4	5	6	7	8	10	11	12	14	17
7	1	2	3	4	5	6	7	8	9	10	12	14
8	1	2	3	4	5	5	6	7	8	9	11	13
9	1	2	2	3	4	5	6	6	7	8	10	11
10	NA	1	2	3	4	4	5	6	7	7	9	10
11	NA	1	2	3	3	4	5	5	6	7	8	9

Figure 15: *CO2 timing chart.*

Light Information

The Optic 6 LED lights chosen have the following specifications:

- Max Power: 620 W
- 6x 50W CREE COB LEDs
- 3000K daylight white
- 96x 5W supplemental LEDs (red, white and blue diodes)
- Veg: 5’ x 4’ (6’ x 5’ max) @ 24”-36” hang height
- Flower: 4’ x 4’ (5’ x 4’ max) @ 24”-28” hang height
- Manufacturer's Warranty: 5 years

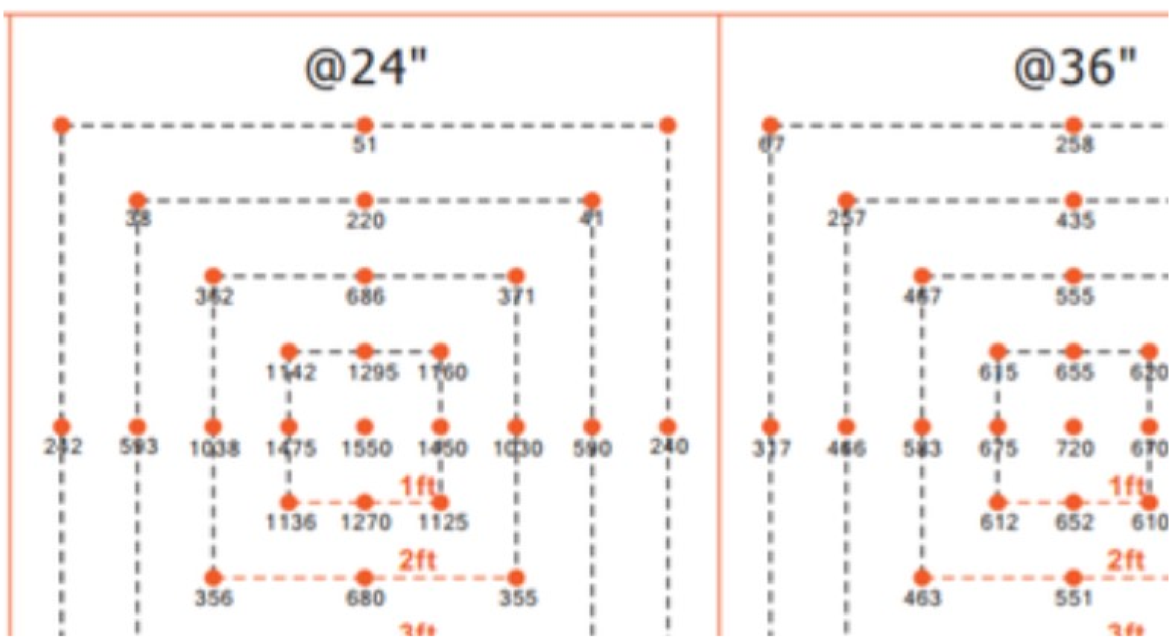


Figure 16: *PAR intensities for 24” and 36” hang heights. (umol/m2/s)*

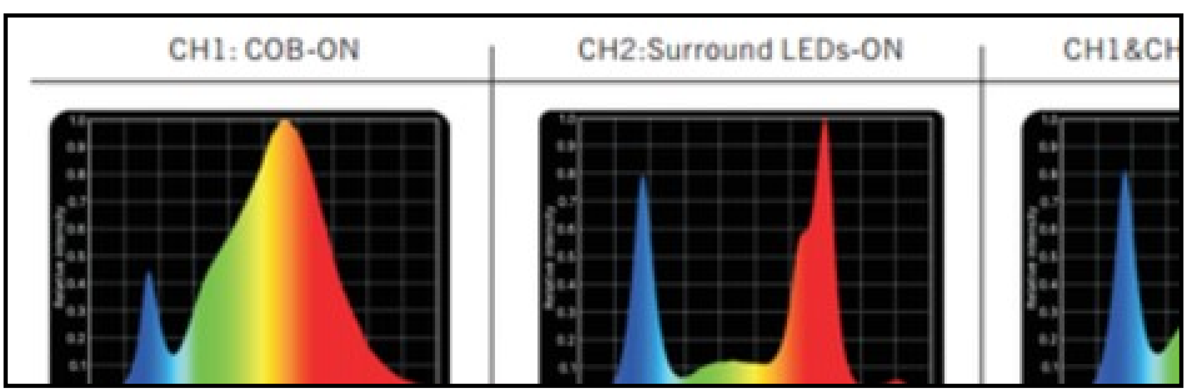


Figure 17: *Optic 6 LED spectrum.*

CMH vs. LED

The two best options for lighting are ceramic metal halide (CMH) and LED. CMH is good because it has low initial cost and produces a good spectrum along with UV and infrared rays. The downfall is that it produces more heat than LED, so it requires more cooling and poses a fire hazard. The bulbs also have to get replaced every year or so which adds up in the long run. Different bulbs or extra light units are required for the different stages as the vegetative stage requires blue light, while the flowering stage requires red light. These lights will require a cooling system that increases their initial cost in relation to LED that doesn't require extra cooling. CMH lights also require a ballast that also uses up power. So a CMH light may be advertised as a 315W light, but really uses 400W once you consider the power usage of the ballast.

LED is more expensive upfront, but in the long run comes to be about the same if not cheaper. It is easier to implement as the light intensities of certain spectrums can be adjusted to shift red or blue, so one unit can be used for all plant stages. It is much safer as the unit doesn't get nearly as hot, so it is much less of a fire hazard. Some units also have the capability to produce the UV and infrared light that plants like. Unlike the CMH lights, bulbs do not have to get changed and have a lifespan of up to 10 years.

Figure 17 **-** ***Figure 19*** compare the spectrums of CMH vs. LED vs. natural sunlight on a scale relative to the max intensity in the McCree Curve (black line in the CMH figure). The McCree curve is a well-accepted representation of the spectrum plants desire.

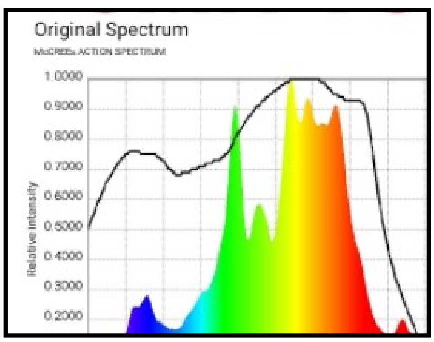


Figure 18: *General CMH fixture spectrum, McCree Curve shown in black.*

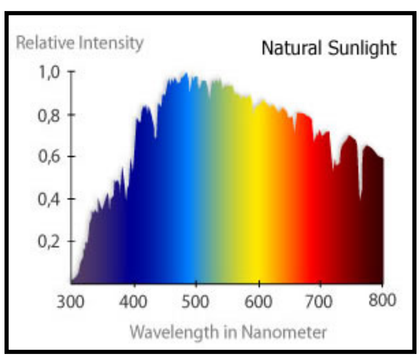


Figure 19: *Spectrum of natural sunlight.*

Conversions and Numbers