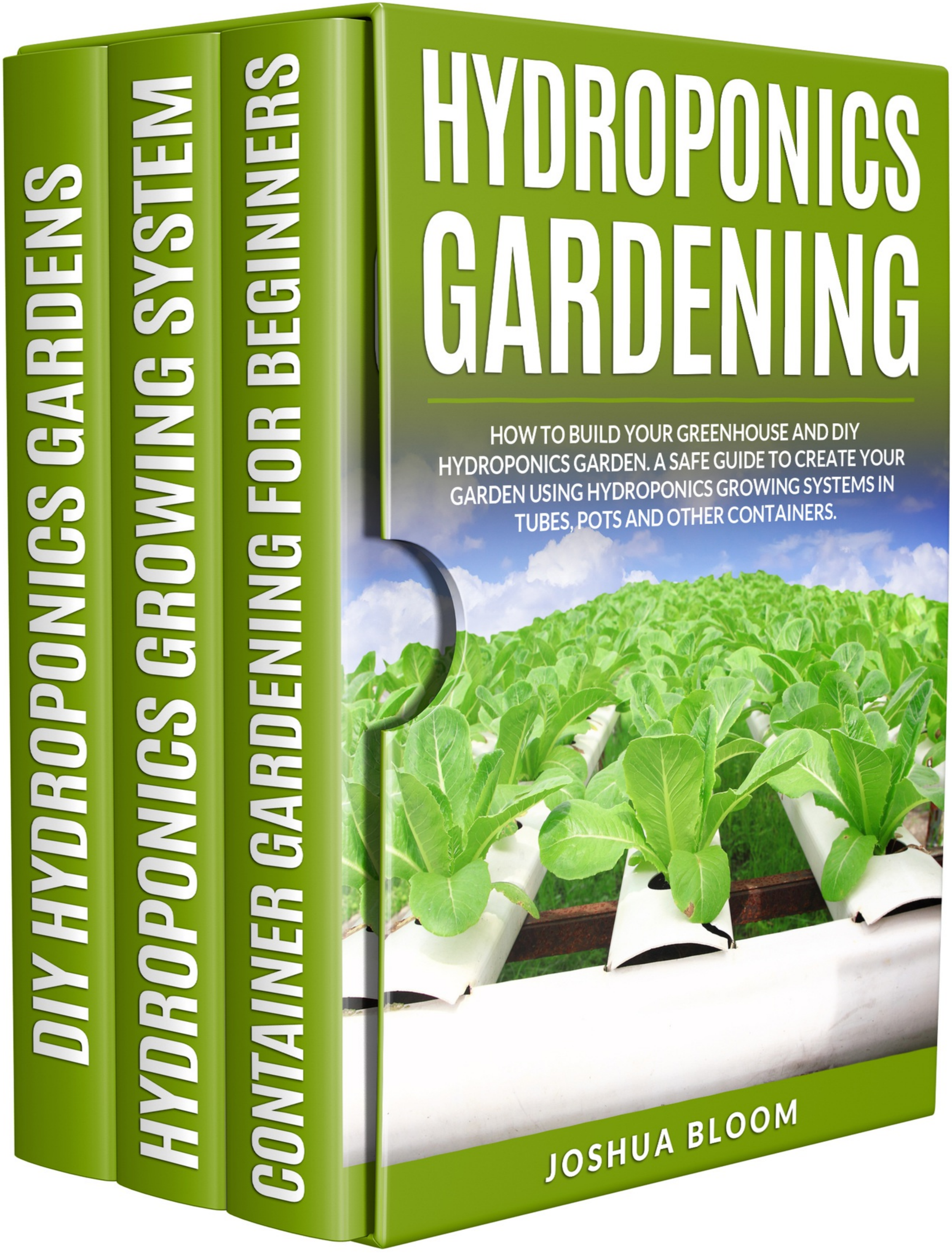
HYDROPONICS
GARDENING
HOW TO BUILD YOUR GREENHOUSE AND DIY HYDROPONICS GARDEN. A SAFE GUIDE TO CREATE YOUR GARDEN USING HYDROPONICS GROWING SYSTEMS IN TUBES, POTS AND OTHER CONTAINERS.
JOSHUA BLOOM
DIY HYDROPONICS GARDENS
HYDROPONICS GROWING SYSTEM
CONTAINER GARDENING FOR BEGINNERS

HYDROPONICS GARDENING

How to build your greenhouse and diy hydroponics garden. A safe guide to create your garden using hydroponics growing systems in tubes, pots and other containers.

DIY HYDROPONICS GARDENS

How to build quickly your greenhouse and self sustainable garden with hydroponics growing system. A complete guide to create your perfect diy hydroponic garden.

Introduction

There are three aspects that many people associate with gardening: soil, a large space and hard work. Although this may be partially true, there is an alternative way to develop a lush and profitable garden without at least two of these being required. This is called gardening with hydroponics. Many might even claim it is less laborious than a typical garden. There is no digging, bending, weed tending which sounds better for me. Hydroponic gardening is a way to grow plants without using soil. Hydroponic plants are grown in solutions which are water dependent. These water solutions contain the majority of the minerals and salts required for healthy plant production.

Hydroponic plants can usually be grown directly in the mineral solution alone. Alternatively, plants can also be planted in an inert growing medium such as coconut fibres, rockwool, growing rock, etc. Hydroponic growth has not only become a common pastime hobby; it has become a profitable enterprise. When proper mastery of the skills and techniques of hydroponic gardening, you can literally grow any plant as you wish using hydroponic process.

Using the hydroponic method, you can easily install a hydroponic garden or greenhouse inside or on the rooftop of your home. When large-scale use of hydroponic gardening technique can become a very effective way of growing commercial crops.

Like growing plants with traditional soil cultivation, there is no need for the roots system of hydroponic plants to search for nutrients and minerals in the soil. In the nutrient solution, all the much-needed nutrients and minerals are given, readily to be supplied to the root system. The plants will then concentrate on the top growth in order to produce more flowers and fruits, rather than exerting energy to look for nutrients.

In hydroponic growing, the root systems often supply oxygen and carbon dioxide to the nutrient solution to improve the absorption of nutrients. This assists in fostering higher growth rate and healthy plant growth.

Besides that, when growing plants using hydroponic techniques, you'll also have less problem with plant diseases and pest problems. As most plant diseases and pest problems relate to soil use.

CHAPTER ONE

What is Hydroponics Gardening?

The idea of growing your beautiful plants indoors using a method called: hydroponics is something which has been buzzing in the growing culture. Sure, Hydroponics is something that isn't ideal for those of you who actually garden to get down into the dirt and dig around in the manure, but for those of us who don't have vast tracts of arable property, or any property at all, hydroponics starts to sound like a much more enticing deal.

Why Hydroponics?

• Hydroponic Gardens are lightweight and can be built anywhere.

• They use and reuse water over and over again and need limited extra water to operate properly.

• The need to look out for garden pests such as aphids, caterpillars, potato beetles and fungi is removed.

• They are highly productive plant growers-plants grow very quickly in a hydroponic system.

• They're versatile and most systems are easy to automate, requiring minimal input from you. In a hydroponic system, any plant can grow (or begin to grow) regardless of the time of year, or how north or south you are.

There are other reasons why one should choose hydroponics over a conventional greenhouse, but there are negative ones as well. For example, many people equate hydroponic gardening with the growth of some illicit plants that are exploited as controlled drugs in general. It seems like every week in a nice neighborhood there's some big house being bustled by the cops with hundreds of compact fluorescent fixtures, water sprayers, containers, rising soil, extracting nutrients and plants. Like everything though, a small number of people will ruin a good thing for everyone else.

In fact, the main benefit to Hydroponic Gardening is to offer the ability to grow plants to people who would otherwise be unable to grow. It is very popular for avid gardeners to start their tender young plants in a hydroponic system, and then move those plants after the ground thaws to their gardens.

In particular, orchid growers seem to gravitate toward the hydroponic growing systems. The fascination with orchids that many people have, is serious. This fascination, combined with the disappointment of not being able to fulfill the orchid's exacting needs in the unaltered back yard of a individual, leads many to try to grow in greenhouses or in a hydroponic system.

In addition the hydroponics technology is everywhere. In many applications light timers are used to save energy, just as they are used for plants in hydroponics to time the light cycle. The compact fluorescent, metal halide, T5 and other forms of extreme lighting used in Hydroponics are often used on aquarium systems that aim to fulfill challenging freshwater plant life needs or fragile corals and anemones. Water drip systems are widely used in greenhouses and in large-scale cultivation, as well as in outdoor gardening and landscaping. Plant nutrients have been in production for quite a long time-as long as people in partly depleted soils have attempted to cultivate non-native plants. PH meters are used in science, and again in all types of gardening. If we didn't use a PH tester, apart from expensive trials and error, we wouldn't know where the acidic soils to grow grapes were located.

Hydroponics developed out of a combination of need and desire. We want fresh tomatoes, we want fresh basil, we need to cultivate them somewhere, because we no longer all live in farms. The more we learn about wax-coated plants and chemicals, the more we think about these contaminants getting into our children and ourselves, and we want to be sure about our food supplies in some way. Although thinking that we should go from buying our food in the supermarket to growing it all in our apartments is unrealistic, it's good to know that we can supplement some of our items in this way. For example, specialty sauces or your own personal herb garden for fresh cilantro, basil, and oregano are a tempting reason for going Hydroponic.

Hydroponics may not be your cup of tea for the die-hard, natural gardens only humans. If you're using plants native to your area, you'll just sow your seeds and let nature take its course. However, waiting for spring is too far off for those in northern climes. Such people admire the plant life that technology will bring home.

Many people mistakenly believe that the art of growing plants successfully without using soil, known as hydroponics, is a new technology. Leading Hydroponics experts and suppliers, Great Stuff Hydroponics, aim to throw some light on the origins of this ancient technique.

It is commonly thought, amongst gardening experts that the famous hanging gardens of Babylon could be the earliest example of a complex use of hydroponic techniques. Fresh water containing plenty of oxygen and nutrients were used to keep plants alive without having any soil surrounding their root structures. Other possible uses of hydroponics in the ancient world have also been suggested within Aztec culture.

However, it was not until the middle ages when scientific knowledge about the workings of plant life began to develop. In 1600, Jan Van Helmont deduced that plants take their nutrients only from the rainwater, rather than from the soil itself. He realized this because plant mass rises according to plant growth over time however soil mass stays much the same. This paved the way amongst scientists and chemists to find out more about exactly which nutrients need to be present in water to promote healthy plant growth.

Then the English scientist, Joseph Priestly, discovered that plants photosynthesize, converting carbon dioxide into oxygen, and that this process is speeded up when the plant is exposed to bright sunlight. This was also an important development regarding the lighting techniques which are now used for commercial hydroponic growth.

By the mid 1800's as a result of much interest in the subject and many experiments, a definitive list of minerals and nutrients needed by plants in order to thrive had been developed, with nutrient solutions created by the German botanist Wilhelm Knop.

The techniques of hydroponic growth, such as controlling the amount of light, water and nutrients available to the plant, are ideally suited to growing plants indoors. For this reason, in the early half of the twentieth century, commercial greenhouse growers began to realize the potential of hydroponics. Hydroponic plant growth uses only 1/20th of the water which traditional (soil based) agriculture demands. Also, soil borne diseases and virtually all pests are eliminated. These growth techniques are not only environmentally friendly, using less water and reducing agricultural 'run off' which would normally find its way into the water table, but it is also ideally suited to arid climates. This was proven brilliantly during the war, when American troops stationed on barren Wake Island in the Pacific, were able to survive by growing fresh food hydroponically.

Dr. William Gericke perfected hydroponic techniques during the 1940's, and even decided upon the name for them, amalgamating the Greek 'hydros' (meaning 'water') and 'ponos' (which means 'working') into one word.

Since then, hydroponic growth techniques have diversified into a variety of ways to grow plants in 'soil-less cultures', although they use other media instead of soil which means that not all soil-less cultures can strictly be defined as hydroponic any more. Not only that, but there is now also a plethora of different growth promoters, nutrient solutions and hydroponic lighting designed for different aspects of plant growth on the market.

No single person or culture developed hydroponics, however the broad depth of modern scientific knowledge on the subject, drawn from many developments and experiments over time, mean that it is a viable commercial agricultural method and is also well suited to researchers, hobbyists and enthusiasts alike. Amazingly, this ancient technique can be practiced at home, using one of the hydroponic kits available online from Great Stuff Hydroponics. Kits can be supplied to beginners and advanced growers in addition to all other hydroponic equipment and specialist supplies.

Hydroponics means working water and it comes from the Greek words 'hydro' and 'ponos' which mean water and labor. Many different cultures throughout history have used hydroponic growing techniques so they aren't a new plant growing process. Over the years giant steps have been made in this revolutionary agricultural field.

Scientists and horticulturists have experimented with different hydroponic methods over the last century. One of the possible applications of hydroponics that helped to continue work has been to develop produce in the world's non-arable areas. As hydroponics easily blends into their development plans, Hydroponics was also incorporated into the space programme. Work is underway for their plans.

By the 1970s, not the only people involved in hydroponics were scientists and critics. Traditional farmers and eager hobbyists started to be drawn to the virtues of hydroponic production. Some of the positive aspects of hydroponics include the potential to generate higher yields than land-based farming, and allowing food to be produced and eaten in areas of the world that can not sustain land crops.

Hydroponics also reduces the need for extensive use of pesticides, making air, water, soil and food much safer. Commercial farmers are as never before moving into hydroponics because the principles surrounding the growing techniques focus on issues that most people are interested in, like world hunger and making the environment cleaner.

Everyday people have started buying their own hydroponic systems to grow great tasting and fresh food for their friends and family. Educators have also started to understand the wonderful uses hydroponics can have in the classroom. Many gardeners have realized their dreams by making a living in their greenhouse backyard and selling their produce to local restaurants and markets.

The promise of hydroponic culture is unbelievable, but industrial hydroponics in the U.S. was held back until hydroponic systems were available on the marketplace which were economical to develop and relatively easy to operate. This occurred in the late 1970s, when high-tech plastics were introduced and product architecture simplified. The energy-saving poly greenhouse coverings, the PVC pipe used in feed systems, and the nutrient pumps & reservoir tanks were all made of plastic materials not available before the 1970s.

Due to the growth of both small and large hydroponic farms in the late 1970s, it has been shown that hydroponic cultivation can yield quality produce and be a profitable enterprise. As hydroponics attracted more farmers, it encouraged nutrient formulas for the whole plant, and greenhouse hydroponic systems. In addition to the ideal plant diet, environmental management systems have been developed to provide the ideal plant environment for the growers.

Growers of commercial crops are slowly moving less and more towards soil cultivation. Development velocity combined with rising climate stability means higher quality crops. There is significant interest in the concern about soil-born diseases and pests plus weeding is a thing of the past. For commercial growers, rapid harvesting and higher yields are major reasons for the hydroponic growth. Home gardeners are now exposed to the methods that commercial growers employ.

In underdeveloped countries, hydroponics can be used in confined space for food production. Also in areas with poor soil conditions, such as deserts, hydroponic production is possible. The desert sand serves as a good growing medium and the marine water can be used to mix nutrient solution once the salts have been removed. The effectiveness of Hydroponics has increased dramatically in a very short span of time. Experimentation and work in the field of indoor and outdoor hydroponic development is a continuing operation.

CHAPTER TWO

How Plants Grow

The ancient thinkers questioned how the plants were growing. They concluded that plants received nourishment from the soil, calling it a "particular juyce" that occurs in the soil for plant use. In the 16th century van Helmont found water to be the primary plant resource. Upon performing the following experiment he came to this conclusion: growing a willow in a large, carefully weighed soil tub, van Helmont found at the end of the experiment that only 2 ounces of soil were lost during the experimental phase, while the willow increased in weight from 5 to 169 pounds. He concluded that plant growth was generated solely by water, because only water was applied to the soil.

Later in the 16th century, John Woodward grew spearmint in various kinds of water and found that growth increased with water impurity growing. He concluded that plant growth increased in water that produced increasing quantities of terrestrial matter, and when water moves through the soil, this matter is left behind in the soil. The thought of the times was dominated by the belief that soil water brought "food" for plants and that plants "live off the soil." It wasn't until the mid- to late-18th century that experimenters started to understand clearly how plants really are growing. A book entitled The Theory of Agriculture and Vegetation, published by the Edinburgh Society in 1757 and written by Francis Home, introduced a number of factors that were believed to be related to plant growth. Home recognized the importance of pot experiments and plant analysis as a way to evaluate certain factors that influence the growth of plants. His book attracted considerable attention and led experimenters to investigate more intensively both the soil and the plant. The famous experiment with an animal and a mint plant contained in the same vessel by Joseph Priestley in 1775 established the idea that plants would "purify" rather than deplete the air, much as animals do. His results opened up a whole new field of study. DeSaussure determined twenty-five years later that plants absorb CO_2 from the air and emit O_2 while in the sun. Thus, the mechanism that we call "photosynthesis" today was discovered even though DeSaussure or others at the time did not understand it well. The "humus" theory of plant growth was proposed and generally accepted at around the same time, and as an extension of earlier observations.

The idea of plants receiving carbon (C) and essential nutrients (elements) from soil humus was postulated. It was probably the first explanation of what we would call today the plant growth and health principle of "organic gardening." The fundamental idea of the "humus theory" that plant health comes only from soil humus sources has been debunked by studies and observations made by many ever since. In the mid-19th century, an experimenter called Boussingault began to study plants carefully, measuring their growth and assessing their composition as they grew in different types of treated soil. This was the beginning of several experiments showing that the soil could be modified to influence plant growth and yield by adding manure and other chemicals. These findings, however, failed to understand why plants reacted to changing soil conditions. Then came a popular study by Liebig in 1840, who said plants in the air receive all their C from CO_2. A new age emerged of plants understanding and how they evolve. It was first recognized that plants use substances in the soil as well as in the air. Subsequent attempts were made to classify or add to the soil certain substances that would promote plant growth in desirable directions. The importance and effect of some chemicals and manures have taken on new significance when growing plants. Lawes and Gilbert's field studies at Rothamsted (England) led to the theory of plant production being influenced by factors other than the soil itself. By this time, water studies by Knop and other plant physiologists (Steiner [1985] offers a history of how the hydroponic concept was conceived) have proven conclusively that K, Mg, Ca, Fe, and P along with S, C, N, H, and O are all important to plant life. It is important to remember that the formula produced by Knop for growing plants in a nutrient solution can still be successfully utilized in most hydroponic systems today.

Bear in mind that mid-19th century was a time of rapid scientific discovery. The above-mentioned researchers are but a few who have made significant observations that influenced the thought and course of scientific biological research. Many of their day's major advances centered on biological processes for both plants and animals. As Russell (1950) has confirmed, the theoretical basis for plant growth had been well established before the turn of the 19th century. Researchers have shown conclusively that plants obtain carbon (C), hydrogen (H) and oxygen (O) required by the later photosynthesis1 cycle for carbohydrate synthesis from CO_2 and H_2O, that N was obtained by root absorption of NH_4^+ and/or NO_3^-–ions (although leguminous plants can supplement this with symbiotically fixed N_2 from the air), and that all the other elements are taken up by pluminum. Today, this general definition is still the basis for our modern understanding of the functions of plants. We now know that there are 16 essential elements (C, H, O, S, N, P, K, Ca, Mg, B, Cl, Cu, Fe, Mn, Mo, Zn), and we have broadened our knowledge of how these elements function in plants, at what levels they need to maintain stable, vigorous growth, and how they are absorbed and translocated. While we know a lot about plants and how they grow, there is still a lot we don't understand, particularly the role of some of the essential elements. Balance, the relationship between one element and another, and its forms within the plant, may be as critical as any element's concentration in optimizing the plant's nutritional state. There is still some controversy about how the plant roots absorb the elements and how they move within the plant afterwards. The elementary type, whether it is individual ions or complexes, can be as important as movement and utilization concentration. Chelated iron (Fe) forms, for example, are effective in regulating Fe deficiency, whereas unchelated ionic Fe is similarly effective but at higher concentrations, either as ferric (Fe^{3+}) or ferrous (Fe^{2+}) ions.

The biologically active portion of an element in the plant, often referred to as the labile type, may be that portion of the concentration which determines the plant growth character. Examples of these labile forms will be the NO_3 form of N, the SO_4 form of S, and the soluble Fe and Ca form of plant tissue — forms of these elements that decide their sufficiency. The use of tissue testing is partly based on this principle, calculating the portion of the product present in the plant sap and then compared to plant growth concentration . Plant nutrition research is gaining tremendous interest today as plant physiologists decide how the essential elements are used by plants. Additionally, plant characteristics can now be modified genetically by adding and/or removing traits that modify the plant's ability to withstand biological stress and boost product quality (Mohyuddin, 1985; Waterman, 1993–94; Baisden, 1994). With these many developments, all types of growth are now becoming more competitive, whether hydroponic or otherwise. Most of this research is being done for growing plants in space in compact environments where the inputs have to be closely monitored due to limited resources, such as water, and regulation of releasing water vapor and other volatile compounds into the atmosphere around the plant. Most of the future of hydroponics that lie with plant cultivars and hybrids being created that will adapt to the precise control of the growing climate. Plants' ability to use water effectively, and the essential elements can make hydroponic and soilless growing methods superior to what is possible today. The genetic yield potential of the cultivars currently in use is unclear, and it has not been determined whether that potential could be increased. A recent report by Moreno et al. (2003) suggests that among 18 tomato cultivars in their analysis, those described as "the least efficient in taking up nutrient elements, particularly N," provided the highest yields of fruit. High efficiency in the use of nutrient elements may also be an unnecessary trait — something that might seem contradictory to what one might expect. It should also be remembered that a cultivar or hybrid's adaptability for responding to one set of environmental conditions that restrict its use to that set of conditions. Therefore, much remains to be learned about how plants react to various conditions and how best to change those conditions to achieve high plant production and yield.

CHAPTER THREE

Hydroponic Herb Gardening

There's been a big trend for organic and more natural food over the last few years. One of the best ways for a person to get more sustainable, and thus safer, food is to cultivate it on their own. Hydroponic herb gardening is a perfect way for home-gardens to cultivate their own plants. Hydroponics is a farming process without the use of soil. Instead of a conventional soil nutrient base this system uses water. One of the main benefits of hydroponic gardening is that it can cultivate plants and herbs all year round.

Another advantage of hydroponics is that this method of gardening is more available to humans. The growing of herbs in a hydroponic setting is much simpler for people who have limited space than in a conventional garden. This makes hydroponic gardening ideal for people living in urban areas or with only small room for plants to grow. This style of gardening often cuts down on how much work people need to put in their gardens. Traditional gardening involves weeding and maintenance but very little care is needed for plants which are grown in a hydroponic gardening setting. Since there is no soil, pests such as insects, groundhogs and other things that could kill plants to damage the herbs are more difficult. This ensures that the gardener would have a higher yield in their crop because they are not going to lose plants to those causes. When indoor hydroponic herb gardening is completed, it will keep the plants away from harsh weather, insects, and other annoyances that allow herbs to be grown throughout the year.

Hydroponics has one major benefit in reducing the use of toxic pesticides and fertilizers. Pesticides and fertilizers used in conventional gardening are detrimental to the environment and can lead to the emissions of water and air, and even greenhouse gases.

One of the drawbacks of hydroponic herb gardening is that a significant amount of electricity is needed. The ultraviolet lights needed for this form of gardening use a large amount of energy and can boost a home's electricity bills quite a bit. The benefits of hydroponic herb gardening are immense, so if you are interested in growing herbs that taste better, last longer, and don't ruin the area where you may want to start your own hydroponic herb garden.

Benefits of Hydroponic Herb Gardening

One of the most common phenomena that is happening right now is that people grow their own greens and herbs to cook. This used to be something you needed outdoor space for but technology has made it so that even someone living in an apartment with limited space can grow their own herbs in the last couple of years. Instead of purchasing it, the movement towards growing produce has piggybacked on the move towards organic and healthy food as obesity is that in the United States, and since there's nothing better for you than the vegetables you grow yourself, gardening has gained popularity. Some of the technology that has helped people to take out gardening from the garden is a growing method called hydroponics. Hydroponics is a method of growing plants using water, hence "hydro" in place of soil as a growth medium. It makes all year long growing herbs in your home or apartment. Year-round growth is one of the many advantages of hydroponic herb gardening which will help you achieve a lifestyle that is more organic and self sustaining.

Another of the benefits offered by hydroponic herb gardening is that this method of cultivation is available to many more people than conventional gardening. Since hydroponic gardens take up much less space than a traditional garden, it is possible for people who could never have grown plants to. This can be a huge benefit for people living in small apartments or urban areas where space is limited. It also reduces the amount of work that has to go into the garden as the room is smaller. You are not going to have to weed the plants you cultivate hydroponically, nor are you going to have to worry about pests that can kill or consume the herbs. Many advantages of hydroponic herb gardening include protection from extreme weather conditions, pesticide and fertilizer removal and closer proximity to your plants. All these advantages make hydroponic herb gardening a good choice for individuals looking to grow their own herbs. The one negative aspect of hydroponic herb gardening is the amount of energy it takes for plants to grow in that way.

You can find great resources online if you want more resources about the benefits of hydroponic herb gardening. Start by searching on any search engine, and proceed from there. There are items like growing tips and online shops where you can also start your own hydroponic garden with everything that you need.

Keeping Your Herb Garden Pest Free

Millions of people around the world are opting to grow their own herbs and vegetables to get the great benefits that gardening has to bring. Not only can you save money when you grow your own produce and herbs but you also eat healthier. Herbs and vegetables grown at home have a higher nutritional value than those bought at the supermarket as they can be harvested at full maturity and not sprayed with pesticides and other harmful chemicals. Sprinkling plants with chemical-based pesticides can be harmful, particularly if the vegetation is not cleaned thoroughly before eating. That's why a lot of people chose not to use these chemicals in their gardens. Since no pesticides and chemicals are being used, it's necessary to find a way to otherwise keep your herb garden free of pest.

Herbs are also some of the most durable and insect-resistant plants that can be grown but you'll still need to take some precautions to keep away insects and other pests. One of the first things you'll want to worry about is where you'll be planting your herbs. If you're planning on an outdoor garden, you'll need to do a lot more to protect your plants from destruction. One of the first things you want to do about securing an outdoor herb garden is install some sort of fencing around it. A fence keeps out tiny critics who would steal your herbs and vegetables. Next you may want to take a look at ultrasonic devices that discourage pests. Such devices hold pests away by sending out sound waves that can not be detected by humans while their usefulness is still out of the jury.

Checking for pesticides that are chemical-free can be used indoors or outdoors, and can be used up to the harvest day, while attempting to manage insects. Organic and insecticidal soap based products (e.g. Safer) are available and can be used safely and efficiently if thoroughly sprayed on, including the underside of the leaves. If your plants are in containers you can dip the plant upside down into a soap solution tub as well. Realistically you can't remove insects from your garden and plants fully as they are highly adaptable to man-made pesticides, so the goal should be to reduce insect infestation.

Another thing you would want to remember is planting with your partner. There are plenty of plants insects don't like and will stay away. Marigolds and basil give off a scent which can serve as a repellant for bugs. It can be a perfect way to keep predators from your herb garden, obviously.

One easy way to keep the pest away from your herb garden is to cultivate it indoors. Hydroponic herb gardening can potentially save you a lot of space and can make growing herbs and other plants much easier. Hydroponic gardening is a planting system that does not use soil, meaning pests are nowhere to live and reproduce. Whatever system you use to keep your herb garden free from pests, you'll be able to enjoy fresh herbs without the pesticides used on commercially grown plants.

CHAPTER FOUR

Setting Up Your Own Hydroponic System

You should build your own system. One of the primary favorable circumstances of making your own system is that you can modify it. It is additionally easy to build. Here you have three choices to consider.

Profound water culture

Right now, we will show you step by step how to construct a simple Deep water culture system for 6-12 plants. This sort of system is extremely easy to construct in any event, for a beginner.

MATERIALS NEEDED

- Air pump 3+ watts
- 12 inch Air stone
- air tubing a couple of feet will do
- 18 gallon tote(Rubbermaid) container with lid, this will be the reservoir
- 6-12 3 inch net pots
- Clay pellets growing medium-1.5 liters per net pot
- Rockwool cubes
- Marker
- Box cutter
- Power Drill with ½ bore
- Hydroponic nutrients

Directions:

First thing you are required to do is make sense of where the net pots will be situated. Use a marker to make somewhere in the range of 3 inch circles where the net pots will go. After this is carried out start cutting the holes out with a box cutter.

Since this is done set the lid aside and start washing out the tote, ideally with 5%-10% blanch to 90%-95% water mixture.

Presently drill a small ½ inch hole at the top of the tote by the handle part, make sure it is close to the top so water won't escape out. This hole is the place the tubing from the air pump will go.

Presently measure some tubing from where the air pump will be outside the system entirely through the hole you penetrated and to the bottom of the tote. Presently cut the bit of tubing and associate one end to the air pump and run through hole and interface air stone to opposite end and place air stone on bottom of tote.

Presently you can fill with water. Attempt to fill well beneath where you penetrated hole, you can add or subtract water later on if necessary. Next, add wanted nutrients to water, follow the headings that accompanied the nutrients cautiously. *optional, run pump medium-term to evaporate chlorine is water source is known to contain chlorine.

Next, introduce the net pots to the holes in lid, they should fit pleasant and cozy. Fill the net pots with clay pellets. After this is done put the lid on the tote and make sure the bottoms of the net pots are submerged in the nutrient solution.

I recommend first starting plants in rockwool cubes at that point transplant into the net pots filled with clay pellets. In any case, your starter medium of decision ought to be fine.

That is it; you presently have a completely practical, profound water culture hydroponic system.

Drip feed system

This how to guide will show you how to build a simple hydroponic system with 4 plant drip-feed.

NEEDED MATERIALS

- 5-8 gallon cubicle with a lid
- Small submersible water pump 105 GPH will do
- air pump
- 6 inch Air stone
- 5 feet of ¼ inch drip tubing
- 3 "T" connectors for the drip tubing
- 3 feet of ¼ inch air tubing
- Four 3 inch net pots
- 1 ½ pounds of clay pellets hydroponic medium
- Box cutter
- Drill for drilling holes
- Hydroponic nutrients

INSTRUCTIONS

Start out by following four, 3 inch distance across hovers on the lid where the net pots will go. Next utilizing a box cutter deliberately cut out the holes. Presently drill a ¾ inch hole legitimately in the center of the lid, this be for the drip tubing. Furthermore, presently drill a 1 inch hole close to the edge of the lid; this will be used for the force line running structure the water pump and air tubing originating from the air pump.

The early term for defining a greenhouse was "hothouse," a term that is not widely used today. The hothouse is described as "a greenhouse maintained for the cultivation of tropical plants at high temperatures," in the Merriam-Webster Dictionary. This concept derives from the fact that a greenhouse will collect solar radiant energy which heats up the interior. Jensen and Malter (1995) described a greenhouse as 'a framed or inflated structure, covered by a trans-parent or translucent material which allows optimum light transmission for plant production and is protected from adverse climatic conditions.'

Hanan (1998) states that 'greenhouses are a means of overcoming climate adversity using a free source of energy, the sun.' The term 'glasshouse' is a European phrase for a building that is artificially heated for growing plants' (Gough, 1993). Beytes (2003a) describes three basic greenhouse designs, one-bay free-standing as low-cost entry into the greenhouse market (Thompson, 2003); multi-bay gutter-connected as the most effective practical greenhouse (Grosser, 2003), yet lacking in flexibility; and withdraw.

Presently you should simply connect everything and add seedling to the net pots and you're done. I propose starting seedlings in rockwool cubes or desert garden cubes and afterward transplant-ing to the net pots with clay pellets.

Ebb and flow

An ebb and flow system is a relatively easy system to construct and any kind of water pump is discretionary and not needed, with is absolutely one of a kind then different systems, while still accomplish ideal outcomes.

MATERIALS NEEDED

- Two 15-20 liter containers, buckets or Rubbermaid tots
- Growing medium: I propose all clay pellets or a 50/50 mix of perlite and vermiculite
- Large gravel rocks or a couple of liters of clay pellets
- 3 meters of adaptable tubing, any tubing intended for irrigation will do
- 2 tubing joints
- 2 tubing grommets
- 1 table: a generally medium sized table will do, as long as it is sufficiently large to oblige the 2 buckets
- hydroponic nutrients
- Drill to make holes
- Silicone

INSTRUCTIONS

Leading you need to use a drill and make a hole as an afterthought close to the bottom of both of the buckets, ensuring the measurement is equivalent to the inside of the grommets that you will use to connect the tubing and joints. These holes ought to associate with 3-5cm over the bottom on each bucket.

Presently insert the grommets into the holes you've recently made, make sure that it is a tight fit; whenever done accurately, this ought to be fairly watertight. I recommend applying silicone around the holes before inserting the grommets to be sure that it is 100% water tight. Let this sit until silicone is totally dry.

Presently connect the 2 joint pieces to each end of the irrigation tubing and insert each end of the tubing into the grommets of each bucket.

Presently connect the 2 joints to each end of the irrigation tubing and afterward insert each end into the grommets on each bucket. Presently the 2 buckets ought to connect together by the tubing.

Presently use the gravel shakes and fill one of the buckets sufficiently only to cover the bottom hole, this is basic so no perlite or vermiculite will stop up in your tubing. Since this is done add your growing medium of decision to a similar bucket and fill until it is about 6cm from the top.

You can now add your seedling to the growing medium. Fill the other bucket with water and hydroponic nutrients up to around 6 cm or lower from top after this is finished.

You are now finished. Your bucket you are going to grow in should stay on the table at all times and to flood system place other bucket on the table and water will be moved to growing bucket. Put the same bucket under the table to deplete, easy enough right? You will flood your machine for 20-30 minutes one after another approximately 5 times a day, and then channel it likewise.

LIGHTING REQUIREMENTS FOR HYDROPONIC SYSTEM

Sunlight is basic for plants' growth. Sunlight provides the vitality for growth, germination, flowering and photosynthesis. In Hydroponic gardening, sometimes regular light is missing or difficult to provide. To beat this disadvantage, we provide light to the plants through counterfeit means utilizing fake lighting. Generally lighting is provided for 16 to 18 hours consistently to advance growth. Care must be taken to provide total murkiness for the rest of the span of 6 to 8 hours. Explicit plants like roses have 'photoperiodism' – which means, the flowers sprout depending on the length of daylight.

There are numerous types of lighting accessible:

- Fluorescent tubes
- Incandescent lights
- High Intensity Discharge
- Metal Halide
- High Pressure Sodium

Fluorescent tubes are low wattage bulbs that emanate low-temperature light. This lighting is generally suitable for the initial two weeks of a plant's life. From there on, the intensity and heat generated from fluorescent lighting won't get the job done for plants' lighting prerequisites.

Glowing light bulbs radiate light and an equivalent amount of heat; they are costly to operate and are not stimulating for plants' growth. You may consider changing over radiant bulbs into growth light bulbs by covering the inside – yet it only occasionally works!

HID – High Intensity Discharge lighting is the most prudent way to provide light-ing for your plants; it is additionally the most secure way. You can find HID lighting in parking garages, play areas, and at places that need high productivity effortlessly.

Blue-white range is most appropriate during the vegetative phase of a plant's growth; this is provided by Metal Halide lighting. This lighting helps the development of solid leaves, stems and branches. If you are intending to have just one lighting system for your Hydroponic garden, this is the best decision.

Most appropriate for: Roses, Zinnias, Marigolds, Chrysanthemums, and Geraniums

Red range light is generally positive for the plants during the flowering and fruiting process. This lighting can be provided by High-Pressure Sodium Lights. This lighting is usually used for Metal Halide illumination. Under this light, herbs such as dill and coriander grow well, and this light is generally used in greenhouses for industry.

When utilizing HID lights, the dividing must be 12 to 14 inches from the plants for 250W and 16 to 24 inches for 1000W lights. Dividers are generally painted with light intelligent coatings to increase the dispersion of light. Some normal divider medications include:

- Aluminum foil – provides 60% to 65% reflection
- Yellow paint – provides 65% to 70% reflection
- Mylar – provides 90% to 95% reflection
- Gloss white paint – provides 70% to 75% reflection
- Flat white paint – provides 75% to 80% reflection

You can use light movers with HID for best outcomes. By utilizing movers, you kill the need for plants to grow toward the light.

There are two types of movers – direct and roundabout.

- Linear movers, as the name proposes, move in a straight example (to and fro). These are around 6 feet long and carry a single light – most beneficial for thin and long grow areas.
- Circular movers can carry one, a few lights and spread the growth area in roundabout example covering 10 x 10 foot area. These are suitable for growth areas that are wide and long or square.

Support

Each kind of hydroponic system must be clean every so often. Do it about once every month. With regards to appropriately cleaning out a hydroponic system it is simpler than it sounds. Simply soak you reservoir in heated water and wash, at that point mix 10% blanch and 90% water in a spray bottle and altogether spray total inside and scour. With respect to the drippers and irrigation parts simply let these soak in a 10% blanch/water mix for 10 minutes at that point clean completely.

CHAPTER FIVE

Hydroponic Grow Tents

Growing plants and vegetables for many people have long been a favourite pastime. The advent of Hydroponics has really changed the way people start thinking about growing plants as having no need for soil opens up a variety of opportunities. Growing plants and vegetables in tents and growing boxes are excellent ways to make use of hydroponics by providing them the nutrients without soil or compost that they need. Other benefits of using Hydroponic grow tents are that they require easy, less time to grow, and less space. You will have more influence over the plant climate, such as temperature in the humidity and root zone.

Typically a rising tent is square in shape as a box and is filled with specially ordered Full Blackout White / Black / White Sheeting for high light (lumen) levels inside the tent. These are typically quite easy to set up and are generally very cheap from around £40-£ 600. The tents' inner walls will help radiate light as the exterior black walls absorb the sun. There are several different types and sizes of tents that, of course, my advice is to select the best fit size for where to store them. The fact that they can suit anywhere you need them is a huge asset, this ensures that anybody, everywhere, can use them in practice.

Why is it they are working?

Hydroponic growing tents allow you to monitor every aspect of the plant / vegetable environment for maximum efficiency production. This includes Fire, Water, and Light power. Controlling these factors means you can grow virtually any plant, because you can imitate different plant environments. It only becomes good and solid if a plant has the right amount of sunlight and nutrients. You may also set up enclosures with a hydroponics grow tent for various plant types to be grown at the same time.

Even more?

Hydroponic growing tents can also be environmentally friendly and can save you a lot of money because hydroponic systems need far less water than traditional gardening systems. You can set timers on all your fans, lamps, and heaters to conserve energy. Not only does this help with your energy costs, it is also important for the plant because you can then give your plants the correct amount of light and heat.

Reasons You Should Think About Owning a Hydroponic Grow Tent

A hydroponic growing tent is an important instrument for those in the hydroponic gardening sector. It is a great hobby to begin with, as at the same time you can grow beautiful and healthier plants and ease stress. A hydroponic growing tent is the area where you'd put your seedlings and smaller plants so they're healthy and protected; much like a miniature greenhouse.

There are several different types of tents which are also known as grow quarters. There are quite a few hydroponics places that will give you all kinds of knowledge about tents. Certain devices such as air purifiers and dehumidifiers are often needed and are used in combination with these tents to make the climate optimal for growth depending on your seedlings.

Hydroponic grow tents can be found as low as 2 feet by 2 feet by 4 feet, and can also be found in incredibly large sizes. Based on the stores visited, the total cost for the smallest models is just over one hundred pounds or up. Such small models are still made from top-of-the-line materials, which allow you to easily enclose your plants for less money. Many of all are made of durable and reflective materials, and for your comfort they have steel tubes and fan brackets. With zippers and vent holes, easy to use and set up, even a watertight floor makes your plants the best they can be without being in a house.

The first reason you should think about having a growing tent is that your seedlings are healthy. The plants are at their most fragile as they start growing first and are easy to offend. Holding your plants protected from the winds and punishing the sun, depending on the types of plants you have, will mean their survival. Of starters, during seedling stages African violets or Iris plants need to be kept out of the direct sunlight. Of those types of plants, rising lamps and tents are the best choice.

The second reason to hire a tent is to help with your soil's moisture content. The soil in which your seedlings grow, will make the difference between wilting and thriving. Growing tents help to keep your seedlings safe and add more moisture to the soil.

The third reason your plants need a tent is sustainability. While it's not recommended to hold your plants in the tent for long periods of time after they are grown, you can place ailing plants in the tent to nurse them back to health; whether it's insects or the environment your plants are healthier here when recovering.

The fourth purpose a tent is made of livestock. Gardens are vulnerable to chewing away wildlife on the vegetation. You don't have to fear the animals chewing away at your seedlings with a growing tent anymore before they even sprout.

The fifth reason you should get a tent is to extend your garden. You can start and transplant more seedlings in a growing tent without having to worry about digging up the ground immediately in winter months.

How To Choose The Best Grow Tents

Grow tents are boxes of cloth that are inside lined with reflective material for heat and light. When combined with the right ventilation, bed materials and growing lights as well as nutrients for the plants being grown, the tents provide power over the indoor growth and function very well. Establishing a system of indoor cultivation which is required to be sufficiently successful ensures that all these essential components will work together. But the tent provides the best
security to the indoor plants and so it should be carefully chosen to achieve optimal performance.

Growing tent benefits

• A growing tent's reflective surface ensures the plants get enough light output from growing lights used inside for ad production.
• Tents also maximize the penetration of the canopy for the plants by rediriging the light up and sideways. You can be sure, when you have a rising tent, that a good percent of the light can reach below the canopy.
• The tents are built to sustain humidity and temperatures in the growing area.
• The confined space provided by the tent provides improved efficiency of the bed ventilation system compared to whether it had a full room to manage.
• Growing tents are also useful in promoting moisture, heating and odor removal from indoor growing area.

Considerations to be made when shopping

Today there are so many options available on the market that it's easy to get lost for preference. But with some considerations before or when you buy your grow tent, you'll certainly be able to pick the most appropriate for your plants.

Size-Grow tents come in various configurations and you can choose the type of plants you want to grow and the number of plants you want to fit in your room. Larger layouts are best to provide more maneuverability within the can room, whereas smaller layouts can be easier to set up and manage. Select a style which you believe fits best for your indoor plants and their needs.

Height-While some tents come in standard heights, it is possible to find growing tents which allow you to change the height within the indoor garden space according to plant or space requirements. The adjustable tents have extension poles which can be modified as needed and in various indoor growing situations they come in handy. Make sure the growing tent height you are going for is good enough for your plants depending on how big they will expand and appropriate enough to accommodate other growing indoor accessories as well.

Materials-A rising tent will only be able to withstand the outdoor conditions if it is constructed from strong materials. Consider the thickness and strength of the material, as well as the price, so you can select a tent that will fit your growing needs for long to come. You should also consider the materials used for protection, so that all surfaces remain clean and usable. A decent tent should also come with durable features such as stitching and bug resistance.

CHAPTER SIX

Different Hydroponics Systems

Hydroponics is a method of growing plants by providing nutrients which they need to grow in water. A medium can be used to soak the roots and provide steady water supply when no soil is being used. These media lead us to consider the hydroponic systems discussed below.

There are basically six types of hydroponic systems including wick, stream, ebb & flow (also known as flood & drain), drip, nutrient film (NFT), and aeroponic. Though there are several variations in these 6 systems, these 6 are a blend of all the hydroponic methods.

The Wick System

By far the simplest type of system, the wick system is a passive hydroponic system, which means that there are no moving parts therein. The nutrient solution is drawn from a reservoir with a wick up into the liquid media.

The wick device can use several plant growing media such as Perlite, Vermiculite, Pro-Mix, and Coconut Fiber-all of these are the most common ones.

The wick approach has a drawback, which is that the plants are large or that the nutrient solution will take up a lot of water, much quicker than the wick approach can deliver it.

Water culture

The water culture is the simplest of all active hydroponic systems. The frame that houses the plant and floats directly into the nutrient solution is a Styrofoam structure. An air pump delivers air to the soil stone, and so the nutrient solution is caused by bubbles, supplying oxygen to the plant's roots.

The method of water culture hydroponics is suitable for the cultivation of leaf lettuce, as these grow very quickly through this method. With the water culture hydroponics system, however, few other plans do develop well.

In addition, the water culture hydroponics system is very popular with students, as it can be made from an old aquarium or water tight containers to create a very inexpensive system.

The greatest drawback of the hydroponic water culture system is that it does not accommodate large or long lasting plants.

Ebb & Flow System

The hydroponic system Ebb and Flow briefly fills the plant's rising tray with a nutrient solution and then drains the solution back into the tank. In this device typically a submerged pump is connected to a timer. The timer pumps the solution of nutrients onto the grow tray. Once the time is shut off the nutrient solution flows back into the reservoir. This is designed to be activated several times a day, depending on the size and type of plant, temperature, humidity and the type of medium used to grow plants.

The hydroponics device Ebb & Flow can be used with multiple plant growing media. The growing tray may be filled with Rockwool gravel or granular, or it may grow rocks. If the plant growing medium is filled with individual containers, it is easier to move the plants around or even inside and out of the system.

The downside of the Ebb & Flow system is that certain plant-growing material, such as rising rocks and gravel, can be vulnerable to power outages as well as failures in pump and time. Consequently, when the watering cycles are disrupted the plant roots may dry out quickly. However, this issue can be solved somewhat by using rising media that store more water, as can be somewhat eased by using rising media that preserves more water, such as rockwool, vermiculite, and coconut fibre.

Drip Systems-Recovery / Non-Recovery

Drip systems are the most commonly used type of hydroponic systems in the world. They are easier to run, and a timer controls a pump which is submerged. When the timer triggers the pump, a short drip line drips the nutrient solution down to the base of each plant.

There are two types of drip systems available, Recovery Drip, and Non-Recovery Drip. The left over nutrient solution in the recovery drip system is accumulated back into the reservoir for reuse, whereas the excess nutrient solution is not collected back into the reservoir in the Non-Recover Drip system. Therefore, the timer is inexpensive and effective in the recovery drip system, because it does not allow precise control of the watering process. On the other hand, the non-recovery drip method needs a specific timer to change the watering cycles for the plants to get a sufficient amount of nutrient solution and the solution is less wasted. It also means that the non-recovery system needs less maintenance, while the recovery system will regularly require testing and adjustment to have significant changes in the nutrient intensity levels.

Nutrient Film Technique (N.F.T)

The Nutrient Film Technique (N.F.T) method is the most well known of hydroponic systems. N.F.T. systems include a continuous supply of nutrient solution and no timer is needed of the submersible pump. The nutrient solution pumped into the rising tray, flows over the plant's roots, and then collects back into the tank.

There is generally no rising medium required but air in the Nutrient Film Technique. This then proves to be a cheap device, because there is no need to replace the that medium. Within a small plastic tub, the plant is normally protected, and the roots dangle into the nutrient solution.

The N.F.T hydroponic systems are very susceptible to power outages and pump failures, and nutrient solution flow disruption causes the roots to dry out.

Aeroponic

Maybe the most advanced of hydroponic systems, the aeroponic systems primarily use air to work. The roots remain in the air and get moisture from the solution of the nutrients. Moistening happens every few minutes, but when the roots (like in the N.F.T. system) are floating in the air, they dry out if the moistening cycles are skewed. Each few minutes the monitoring timer operates the pump in the Aeroponic hydroponics systems for a few seconds.

Hydroponics Kits Famous Now

Hydroponics kit has all the equipment you need to grow strong and healthy plants easily in your house, with all the warmth and food you need to eat. Two Greek terms were merged to form Hydroponics, 'hydro' meaning 'water' and 'ponos' meaning labor that pulls in energy and time to give you the final product to eat. And this is the hydroponics job that allows the vegetables use the water and extracting all the minerals to grow food. As convectional gardening creates mess in the surrounding environment, but this method is suitable for people as it does not require fertilization and soil. Apart from the decreased mess and the opportunity to grow plants in small spaces, depending on the needs of your plants, a hydroponics kit can also be tweaked and toyed with.

Those who are interested in gardening and want to grow plants in their own homes, and gardeners who want to go out from small gardening for the first time, hydroponics kit is the perfect tool for them to teach. The kit is packed with all the supplies and equipment that will help you grow your own green vegetables and other food products. Hydroponics is very useful for those in recession times where you can cultivate your own plants and food for a healthy life.

Hydroponics are primarily built in kitchens so that they are easy to use products are easily observed like herbs, fruits, vegetables and so on when a package is purchased you are given proper directions and guidance so that you can grow it well and without any problems. For more guidance searching on Google and other search engine will help you grow food for your help.

Hydroponics starter kits not only help to produce outstanding relaxing and de-stressing activities but also to make perfect gifts! Sending one to a close friend or relative lets them know that you're not only interested in their well-being and soil health, but also the health of their wallets! When the hydroponic systems are fully set up, they can reliably grow crops at an absolute fraction of the cost of the same species of fruits and veggies purchased from the supermarket. Hydroponics systems can generate wonderful family experiences as they can be assembled by team effort and each member will then be assigned a particular duty to manage and grow the crops.

The lighting and equipment are the normal parts used in hydroponics kits. One last item that you will need to ensure good growth and development in your plants is food that is referred to as hydroponic nutrients in hydroponics gardening. Hydroponics nutrients provide all the macro- and micro-nutrients your plants would need, and there are hundreds of formulations from which you can select the ones that best match the needs of the different plants you want to grow in hydroponics kits so you can relax and carry on with your gardening skills.

CHAPTER SEVEN

Selection of the Best Hydroponics Medium

The key reason behind any media use is to provide a stay for the plant's roots.

Most books appear to show that one can use any form of accessible material, such as gravel, coarse sand, scoria, perlite, or vermiculite, etc. It is a fallacious assertion. The key considerations when selecting a media are its water holding capacity and the amount of root air circulation that the media provides. A media with a high capacity for retaining water would usually induce poor root air circulation because the water (or nutrient solution held) displaces the air. If one thinks of a cup, it may be full with water; thus, there may be no air or it may very well be unfilled with air, but no water. When our media absorbs a lot of water it will only have a small amount of air, so if it only maintains a small amount of water it will aerate.

Media proper determination is critical for machine accomplishment.

A) a tray system requires good water media and the holding power of nutrients, but it must be open and aerated. An expanded mixture of clay, perlite and vermiculite, coarse gravel mixed with expanded sand, scoria, and so on is part of the suggested media. The mixture of perlite / vermiculite gives a lightweight paper, so he has no trouble moving the trays. If the trays are going to be as heavy as they could be when using expanded clay or gravel combined with expanded earth.

B) sub-inundated or gravel cultivation requires low water and a medium holding of nutrients along with good qualities of waste. Recommended media section includes gravel, gravel with expanded soil, expanded clay, or perlite (then again, when it's dry it actually glides). He wouldn't regularly use combinations of vermiculite or perlite / vermiculite. I f gravel is used without anyone else; the bed is going to be extremely deep, it's going to dry out quickly (and require constant flooding or topping), but the big problem is that it's dry without hold when the media dry. It should therefore be combined with expanded soil which gives water holding power, keeps the bed cool and keeps the media safe. Perlite or vermiculite, or a combination of perlite and vermiculite, will briefly improve the capacity of the gravel to retain water; however, the heaviness of the gravel will crush the vermiculite and square the growth of free air.

Different properties of a media to be considered.

a) inert, eg. no dissolvable salts that will meddle with the nutrient solution or with the growth of the plant. Gravel from certain quarries has been found to affect plant growth because it breaks down gradually discharging sodium sulfate. The outcome is that the salt degree of the nutrient solution will increase in any event, when no additional nutrient is added to the solution.

b) sterile, eg. opportunity from illnesses or contaminations; there ought to be no organic matter in the media.

c) easy to clean when the crop is finished. Scoria is a difficult media to clean adequately because the roots of the plants are difficult to remove when the crop is finished. With a media, for example, expanded clay, the particles of expanded clay will tumble off effectively and it would then be able to be cleaned with some weaken liquid chlorine (sodium hypochlorite) which separates to give water and some basic salt or basically washed with water.

d) consistent in particle size (doesn't pack down). A major issue with blue metal gravel is the high extent of fine particles which must be washed out; else they will settle to the bottom of the container as a thick mud. If the particle size isn't consistent the smaller particles will fill the voids between the bigger particles and reduce air circulation (despite the fact that water holding capacity is typically increased).

E) thermal defense (slow to cool or heat up). Perlite/vermiculite mix and expanded clay are good media as they help maintain temperature even in the media. Expanded earth gives similar properties to holding the gravel beds temperature... it gives warm security property. Gravel beds without expanded earth are easy to heat up and quickly cool down.

AVAILABLE MEDIAS

1) Gravel—there are numerous types of gravel, including blue metal (used for street construction), basalt, rock, riverbed stone, coarse sand, and so on. Gravels from calcareous quarries ought not to be used, because they react

with the nutrients, interfere with pH, and affect the salt level fixations. Specifically, they hasten phosphates, causing phosphorous inadequacies.

Crushed blue metal gravel ought to be washed to remove the fines. It is a heavy media. Gravel is not difficult to wash and sterilise after the plants have been removed. Next to no gravel is lost when the plants are removed. Gravel has exceptionally poor water and nutrient holding capacity tends to dry out quickly and tends to heat up in blistering climate. Its vital advantage is that it is a minimal effort material. Lighter shaded gravels tend to stay cooler in summer than darker gravels.

2) The mixture of Perlite and Vermiculite— an amazing process. The perlite gives the properties of receptivity and diffusion of air while the vermiculite has high capacity for retaining water and nutrients. It has the advantages of being lightweight, strong defensive properties, and is freely accessible in general. The plant roots continue to tie in with the media, and when the crop is removed, a few media get lost. It's hard to clean and it's hard to remove all the old roots once the harvest is over. To boost the soil it needs to dive into a soil garden. It should not be combined with gravel or other heavy media, because it will be squashed and its assets will be lost.

A major advantage is that it is a lightweight media, with strong capacity to hold water and nutrients. The tray method is suitable because the tray can be transferred around and is relatively fair and freely accessible.

3) Scoria, or volcanic stone — is commonly used when easily accessible, but it appears to be expensive. The media has good capacity for retaining water and nutrients, and provides plants with a good stay. When the crop is finished it is difficult to remove it from the plant roots. The plant roots get into the scoria pores and will suffocate and die, making it hard to desinfect. It is not uniform in size and the fines will continue to block and spout, and fly if used in a distribution system.

4) Sand—needs to be coarse. It has comparable properties to gravel in that it has poor nutrient and water holding capacity, poor warm protecting properties, is heavy, and isn't consistent in size. If fine sand is used, at that point the water holding capacity is improved however root air circulation is reduced. Sand can contain shell coarseness which can react with the nutrient solution causing phosphorous insufficiencies, interfere with pH control, and

affect the salt level focus. Stream sand can contain nematodes which can crush the crop.

5) Expanded Clay—is an ideal hydroponic media. The privately fabricated expanded clay was intended for hydroponics. It is idle, clean, easy to clean and disinfect; it has good water and nutrient holding capacity, and is a perpetual media that doesn't separate. The underlying expense is high yet whenever used effectively the expense is supported. It is used for the most part for indoor plants or for plants with a long life, for example, citrus trees, locals, bushes, or for strawberries utilizing the cup in a funnel system. It is currently imported in enormous amounts.

6) Expanded Earth—is a media that is presently readily accessible from R&D Chemicals Pty Ltd. It could be used all alone yet the suggested use is mixing it with coarse sand or gravel (in the proportion of three of gravel to one of expanded earth) to bestow attractive highlights, for example, improved water and nutrient holding capacity, and thermally protecting properties. While it isn't as changeless as expanded clay it is especially less expensive. At the point when mixed with gravel it is ideal for a fixed bed circumstance (where weight isn't a problem). It grants numerous attractive highlights to the gravel. It doesn't smash or breakdown Iike vermiculite or perlite in these beds. Likewise, it doesn't stick to the roots of the plant to any great extent—it falls away freely.

7) Rockwool was a media accessible from CSR or Bradmill Insulations. It comes as squares around 56 cm long by 28 cm wide and around 10 cm thick. It has a high water-holding capacity and poor air circulation. It is like protection bats. My experience with it has not been exceptionally encouraging. It requires a lot of attention, for example, pertinent to the business growing ordinary light watering. It was difficult to manage the water holding capacity to give controllable outcomes—it was either excessively dry or excessively wet, and difficult to decide when it had dried out. The right way to use it is to start your plants off in the engendering squares.

8) It is then transferred to a growing square, and afterward sat on the growool squares to arrive at development. At the point when the crop is finished you should discard it, however it is suggested that it be reused for another growing season. It is widely used for starting off business tomato crops and afterward transferred into the nutrient flow channels.

9) Polystyrene dabs—are not truly suitable as media. The globules repulse water, subsequently poor water holding capacity. They glide on the water, and can be overwhelmed even in light breeze. A few dots can radiate dangerous chemicals in solution.

The ideal particle size for a hydroponic media is around 8-10mm or 2-3 mm for spreading plants.

CHAPTER EIGHT

The Roles of Plant Root

Plant roots have two main functions:

- They connect the plant physically to the growing medium.
- They are the avenue by which water and ions join all areas of the plant for redistribution.

Though the first role given above is significant, in this discussion it is the second role that merits our attention. Carson's (1974) edited book offers extensive details on plant roots and their other essential roles, and Wignarajah's (1994) book chapter addresses the latest nutrient-element uptake concepts.

Water Content and Uptake

The early term for defining a greenhouse was "hothouse," a term that is not widely used today. The hothouse is described as "a greenhouse maintained for the cultivation of tropical plants at high temperatures," in the Merriam-Webster Dictionary. This concept derives from the fact that a greenhouse will collect solar radiant energy which heats up the interior. Jensen and Malter (1995) described a greenhouse as 'a framed or inflated structure, covered by a trans-parent or translucent material which allows optimum light transmission for plant production and is protected from adverse climatic conditions.' Hanan (1998) states that 'greenhouses are a means of overcoming climate adversity using a free source of energy, the sun.' The term 'glasshouse' is a European phrase for a building that is artificially heated for growing plants' (Gough, 1993). Beytes (2003a) describes three basic greenhouse designs, one-bay free-standing as low-cost entry into the greenhouse market (Thompson, 2003); multi-bay gutter-connected as the most effective practical greenhouse (Grosser, 2003), yet lacking in flexibility; and withdraw.

The plant's shape is dictated by its water content, for wilting occurs when the water content decreases and the plant starts to lose its shape and drop. Wilting initially occurs in newly formed tissue which has not yet formed a firm cellular structure. Conditions that exist where water uptake and movement within the plant are insufficient to keep the plant completely turgid, especially when the atmospheric demand is high and/or when the rooting environment is such that water uptake through the roots is restricted (see below). Field-grown plants are typically less sensitive to water stress than plants grown in controlled environments, which may explain in part why plants in the greenhouse are especially sensitive to water stress, which in turn significantly impacts growth rate and development.

Water is essentially drawn up the conductive tissue (primarily in the xylem) by water loss from the plant's leaves through a mechanism called "transpiration," which occurs primarily through open stomata on the surfaces of the plants, as well as through lenticles and cuticles (Srivastava and Kumar, 1995). Visualize a continuous column of water from the root cells to atmospherically exposed leaves to understand this process; the rate of water movement is regulated by a possible gradient of water between the leaves and the ambient air. Transpiration has two significant effects, it decreases the foliage temperature by evaporative cooling (as plant leaves consume solar energy, much of the absorbed energy is converted to heat), and it is the primary means for translocating elements from the rooting area to the upper portions of the plant. Leaves that are exposed to direct solar radiation can rise in temperature if water movement is restricted up the field. Leaf temperature influences photo-synthesis levels, respiration levels and growth rates. The amount of water lost by transpiration will depend on the vapor pressure differential between the leaf and the ambient air. Leaf and air temperatures have an effect on diffusional gas levels, thus photosynthesis levels and leaf respiration (all decrease with increasing leaf temperature). At specific stomata aperture openings, the rate of transpiration increases dramatically with rising air movement over the leaf surfaces. Additionally, water loss by transpiration is caused by the dynamic relationship between air temperature and relative humidity, as well as the plant organ's taxonomic classification and ontogenetic age. In C3 plants, stomata are more susceptible to water stress and thus more receptive than C4 plants are to the CO2 content of the ambient atmosphere under ideal water conditions.

The roots have to be fully functional for water to penetrate the roots. Plant root water absorption decreases with decreasing temperature, decreases with rising ion content of the water around the root, and decreases with decreasing

O_2 content of the root mass environment. A greater root mass can lead to increasing absorption potential in soil and soilless mixes, while root mass is less of a contributing factor in a hydroponic growing system. A plant's nutritional status may be a factor, as a safe, rapidly growing plant provides the carbohydrates required to support the roots in an active respiratory condition. Most of the water absorption by plant roots is commonly assumed to occur in younger tissue just below the root end. Water movement through the root cortex occurs mainly intercellular but with increasing transpiration rate, it may also occur extracellularly.

When water is drawn into the plant roots, the dissolved compounds will also be brought into the plant, but a highly selective mechanism controls the ions are brought in and which are held out. Therefore, as the quantity of water consumed by plant roots increases, the quantity of ions taken through the root will also increase, as there is a regulatory mechanism. This explains in part why the plant's elemental content may differ depending on the rate of water taking up. Atmospheric demand will therefore impact the plant's elemental content which can either be beneficial or detrimental. Furthermore, several water-soluble compounds can be brought into the plant and join the xylem in the rooting medium.

Ion Uptake

The plant cells accumulate all important mineral ions to a higher concentration than that present in their environment; the accumulation is selective. Jacoby (1995) poses the following questions: How is passage done through the impermeable liquid layer?

How will accumulation be achieved against gradient of concentration?

Why does metabolic energy interact with such transportation?

Which is the Selectivity Mechanism?

How does vector transport work?

Six processes define the principles of absorption of ions and the passage up the plant:

1. Free room, and volume osmotic

2. Metabolic conveying

3. Proteins conveying

4. Load balance, and

5 stoichiometry. Protein transport

6. Transportation to the shoot Depending on the specific ion, transportation is by passive uniport through channels or by carrier-assisted cotransportation with protons (Jacoby, 1995).

The root absorption of ions is both a passive process and an active one. Passive root absorption means that the flow of water brings an ion into the root; that is, it's sort of "carried" along in the water that's brought into the plant. It is assumed that the passive mode of transport explains the high concentrations of some ions present in the leaves and stems of certain plants, such as K^+, $NO_3^–$, and $Cl^–$. Passive absorption control factors are the amount of water flowing through the plant (which varies with atmospheric demand), the concentration of these ions in the soil, and the size of the root system. Passive absorption is not the whole story however, as a chemical selectivity cycle occurs when an ion-bearing solution hits the root surface.

The root cell membranes provide an important barrier to most ions flowing through the heart. Water can pass into these cells but in the solution surrounding the center, the ions found in the water are left behind. Another mechanism is also at work: ions are only physically traveling from an region of high concentration to one of lower concentration. In the case of root cells, however, the concentration of the majority of ions in the root is higher than that of the water surrounding the root. The ions will then pass from the root into the ambient water, and indeed this does and does happen. The question is, "Why are ions going toward this gradient of concentration and getting into the root? "Response is through active absorption.

Solutes can be located in three compartments inside a typical plant root. The outermost compartment is called obvious (AFS), or outer free space (OFS), and the one where solutes have ready accessibility. This compartment includes two subcompartments, Water Free Space (WFS), which dissolved substances (such as ions) can pass freely by diffusion, and Donnan Free Space (DFS), the cell walls and membranes of which have a number of immobile negatively charged sites that can bind cations. The ability of plant cells to exchange cations is determined by DFS. Ion diffusion through these cell walls and membranes involves both energy and a carrier network, and so the mechanism is called "active absorption." Active absorption works based on carriers and Michaells-Menten kinetics. Such hypotheses are based on the cell membranes' existence. Cell membranes act in a variety of ways to regulate the movement of ions from outside to within the cell. Thinking about "transporting" an ion across the cell membrane is normal and, yes, this could be what happens. An ion may be complexed with some material (probably a protein) and then "carried" into the cell over (or through) the membrane against the gradient of concentration. A carrier must be present and energy spent to get the device to work. No one has yet been able to ascertain the exact type of the carrier or carriers, but it is assumed that they are proteins. The carrier principle, however, helps to clarify what is observed as ions are moving through root cells. The other theory applies not to individual carriers but to the presence and role of ion or proton pumps. Energy is required for each of these systems to operate, one linked to respiratory energy, and the other from adenosine triphosphate (ATP), a high-energy intermediate associated with most energy-requiring processes. Respond to Wignarajah's article (1995) for a more detailed description on the mechanism of roots picking up ions.

While we don't know the full explanation for active absorption, there is common consensus that some sort of active mechanism controls the movement of ions into the root of the plant.

Such three things we learn about root absorption of ions:

1. The plant is capable of selectively absorbing ions as the external concentration and ratio of elements can be very different from those in the plant.

2. Root ion aggregation occurs through a large concentration gradient.

3. The root's absorption of ions involves energy that is generated by cell metabolism.

One remarkable characteristic of plant roots' active ion absorption mechanism is that it experiences ion rivalry, antagonism, and synergism. The competitive effects reduce the absorption of some ions in favor of others. Examples of enhanced uptake relationships include: Potassium (K^+) uptake is favored over uptake of calcium (Ca^{2+}) and magnesium (Mg^{2+}).

The uptake of chloride (Cl^-), sulfate (SO_4^{2-}), and phosphate ($H_2PO_4^-$) is stimulated when the uptake of nitrate (NO_3^-) is severely deprimed.

The absorption rate for various ions is also special. The monovalent ions (i.e., K^+, Cl^-, NO_3^-) are absorbed more readily by roots than are the divalent ions (Ca^{2+}, Mg^{2+}, SO_4^{2-}).

Active absorption also increases the absorption of other ions. If the NO_3^- anion is the main source of N in the rooting system, then there appears to be a balancing effect marked by increased intake of K^+, Ca^{2+}, and Mg^{2+} cations. If the NH_4^+ cation is the key source of N, then the cations K^+, Ca^{2+} and Mg^{2+} are reduced to take up. The involvement of NH_4^+, however, improves NO_3^- uptake. If Cl^- ions are present in significant concentrations, NO_3^- uptake will be decreased.

Such effects of ion rivalry, antagonism, and synergism are of con-significant importance to the hydroponic grower to avoid the risk of producing elementary imbalances in the nutrient solution that, in turn, would affect plant growth and development. The nutrient solution must therefore initially be correctly and carefully formulated, and then held in balance throughout its usage time. Imbalances resulting from the effects of these ions may influence plant production. Steiner (1980) explored his principles of ion equilibrium in great detail while making up a nutrient solution.

Unfortunately, many existing nutrient solution management programs don't tackle the question of imbalance effectively. This refers not only to systems where the nutrient solution is handled on the basis of weekly dumping and reconstitution, but also to systems with continuous flow. Nonetheless, in minimizing the interacting effects of ions in the nutrient solution on absorption and plant nutrition, the principle of quick, constant-flow, low-concentration nutrient solution management is made to look deceptively promising.

Eventually, through mass flow, nonionic substances, mostly molecules dissolved in soil water, can also be brought into the center. Substances such as amino acids, simple proteins, carbohydrates, and urea can easily reach the plant and help it grow and develop.

Metabolic transport to the xylem via root structures governs the amount of ions transported to the tops; curiously, the amount is little affected by the speed of xylem sap flow. When within the xylem, ions and other soluble solutes travel through mass movement, mainly to the apoplast core.

Physical Characteristics

Root architecture is determined by the plant species and the surrounding physical environment. Plant roots expand outwards and downwards, although the majority of rooting containers are not constructed in this way. Root architecture may indicate a container shaped like a pyramid, narrow at the top and wide at the bottom. Feeder roots have been found to rise up in soil, not down. This is why plants, particularly trees, do poorly when compacting or physically disturbing the surface of the soil. In soil, due to the reduction of soil – root interaction, any root restriction can have a major effect on plant growth and development. Root pruning, whether done deliberately (to bonsai plants) or as a consequence of natural events (plow or clay pans), can also affect plant growth and soil production. Hence, in most hydroponic / soilless growing systems, roots can spread to a much greater volume of growing area or average than would occur in soil.

Root size, measured in terms of branching length and duration, and color are characteristics that are influenced by the nature of the rooting environment. The robust plant growth is usually associated with long, white, and strongly branched roots. If vigorous top growth results from vigorous root growth is unknown, or vice versa.

Tops continue to grow at the cost of the roots, slowing root development during fruit setting. Shoot: Root ratios are also used to define the relationship between them, with ratios from as low as 0.5 to as high as 15. Root growth depends on providing the tops with carbohydrates, and in effect the top is dependent on the root for water and essential elements. The root loss or restriction can have a significant effect on top production. It is therefore believed that the goal should be to provide and maintain certain conditions that promote good, stable, neither excessive nor restrictive root growth.

The root's physical characteristics themselves play an significant role in elementary take-up. The rooting medium and the elements in the medium will evaluate root appearance to a significant degree. For example, root hairs on roots exposed to a high concentration (100 mg / L, ppm) of $NO_3^–$ will be almost absent. High P in the rooting medium will also reduce the production of root hair, although increasing concentrations of the major cations K^+, Ca^{2+} and Mg^{2+} will have no effect on the development of root hair. Root hairs significantly increase the surface available for ion absorption and also increase surface contact in a soilless medium between roots and water film around particles; thus, their presence can have a marked effect on water and ion absorption. Hydroponic-plant roots do not usually have root hairs.

The problem that arises is, "What constitutes the hydroponic / soilless growing system with good working roots? "Root devel-opment size and scale are not as important as in soil. It has been shown that one working root is sufficient to provide all the essential elements needed by the plant, with primarily the size and extent of the roots being critical for water uptake. Hence, root growth and extension are likely much larger than needed in most hydroponic systems, which can actually have a detrimental effect on plant growth and performance. It should be remembered that the root growth and function require a continuous supply of carbohydrates that photosynthesis generates. Hence an ever-expanding and active root system can take away carbohydrates from vegetative expansion and growth of fruit. Hence some degree of root growth control may be required for high yields of plants and fruits.

Aeration

Another essential factor influenceing root and plant growth is aeration. Oxygen (O_2) is essential to the development and functioning of cells. If not available in the rooting medium, it will result in serious plant injury or death. The energy required for root growth and absorption of ions is extracted from the "respira-tion" cycle, which requires O_2. Despite adequate O_2 to sustain respiration, the absorption of water and ions stops and the roots die.

Oxygen rates and the distribution of pore space within the rooting medium may also affect root hair growth. Aerobic conditions promote root growth, including root hairs, with equal distributions of water- and air-occupied pore spaces.

If the flow of air between the medium and surrounding environment is disrupted by overwatering, or compaction decreases the pore space, the supply of O2 is reduced and the growth and function of the root will be adversely affected. Generally speaking, if the pore space of a solid substrate, such as dirt, sand, gravel, or an organic mix of peat moss or pine bark, is equally filled by water and air, there will be sufficient O2 for normal root growth and work (Bruce et al., 1980).

In hydroponic systems where the plant roots grow in a standing solution or a nutrient solution flow, the grower faces a "Catch-22" problem in high temperature cycles. O2's solubility in water is very small (about 0.004 percent at 75 rpm) and decreases dramatically as temperature increases. Because plant respiration, and thus O2 demand, is increasingly increasing with rising temperature, significant attention needs to be paid to supplying O2. The nutrient solution must therefore be kept well aerated either by bubbling air into the solution, or by exposing as much of the solution's surface as possible to air by agitation. One of the major benefits of the aeroponic system is that plant roots are essentially developing in air, and are thus still sufficiently supplied with O2. Root death, a common problem in most Nutrient Film Technique (NFT) systems, and probably other rising systems, is due in part to lack of sufficient root mass aeration in the rooting channel.

Root Surface Chemistry

Many plant roots have the potential to alter the world around its roots instantly. The most common alteration is that the release of hydrogen (H+) ions decreases the pH. Additionally, some plants have the ability to emit substances from their roots (such as siderophores) which enhance ion chelation and uptake. These phenomena have been most frequently observed in species that are capable of obtaining the required Fe under adverse conditions and are characteristic of so-called "iron (Fe)-efficient" plants (Rodriguez de Cianzio, 1991).

This roots' ability to modify their immediate environment may be hindered in hydroponic systems where the nutrient solution's pH is continuously upward changed or in systems where the nutrient solution is not recycled. In these situations care must be taken to ensure that the correct balance and supply of the vital elements is given, as the plant roots may not be able to change the rooting environment to match a specific need.

The effect of roots on a standing aerated nutrient solution system will adversely affect plant growth by either elevating or lowering the solution pH, as well as by adding complexing substances into the solution. So regular monitoring of the nutrient solution and close observation of plant growth and development can alert the grower to the changing status of the solution.

Temperature

Temperature is another important factor affecting root growth, as well as water absorption and critical ion elements (Nielsen, 1974; Barber and Bouldin, 1984). The optimum root temperature can differ slightly with plant species, but root temperatures below 68 ° C (20 ° C) typically begin to affect root growth and behaviour. Under optimum temperature-tures, growth and branching are reduced and root systems are more coarser-looking. Also, water and ion absorption is delayed, as the permeability of cell membranes and root kinetics is decreased with rising temperature. At less than optimal root temperatures, trans-location in and out of the root is delayed as much. When root temperatures are small, plants wax during times of high atmospheric demand, and elemental deficiencies emerge. The ion absorption of the P, Fe, and Mn elements tends to be more influenced by the low temperature than most other critical elements. It should also be noted that water viscosity decreases with decreasing temperature which in turn affects the movement of water in and around the root of the plant.

The average root temperature that can be tolerated until root activity significantly decreases is not well known. Roots seem to be in a role withstand short high temperature times. Roots at 86 ° F (30 ° C) are fully functional and can possibly withstand temperatures of up to 95 ° F (35 ° C). The current literature, however, is not clear on the exact limitations of the optimum temperature range for best plant production.

To avoid the hazards of low or high temperatures, the roots and rooting medium should be maintained at a temperature between 68 and 86 F (between 20 and 30 C).

Reduced growth and other poor nutrition symptoms may occur if root temperatures are held below or above this required temperature range.

Root Growth and Plant Performance

A wide and comprehensive root system may not be the best for most hydroponic growing systems. Active efficiently working roots are what is required instead of the largest size (mass), as the nutrient solution continually bathes much of the root system, thereby requiring less surface for absorption. One of the major problems with the NFT tomato hydroponic system, for example, is the large root mass that grows in the rooting channel, which eventually restricts the penetration of O2 (Antkowiak, 1993) and nutrient solution; the end result is an issue called "root death." Similar extensive root growth occurs with other types of growing systems, particularly with ebb-and-flow systems, where roots are released.

Similar extensive root growth is obtained with most hydroponic/soilless systems; roots sometimes fill bags and media blocks, and often expand through openings in bags and media containers' outer walls. The question is "does a broad root mass translate into good production at the plant? "The answer is probably no, if there is more root surface to absorb than is required. Furthermore, roots need a continuous carbohydrate supply, which can be best used to increase top growth and contribute to fruit yields.

Unfortunately, the root size problem has yet to be properly discussed. It should also be remembered that to stay healthy and functional, roots need a continuous supply of O2. In anaerobic conditions, the roots won't grow. Hydroponically speaking, a broad, ever-expanding root system is unlikely to automatically translate into increased top growth and yield, and may actually have some detrimental effect.

CHAPTER NINE

Aeroponics Systems

Instead of soil or water, aeroponics systems use 100 per cent humidified AIR as the rising medium for plant life. The plant roots dangle into a growing chamber which is kept at 100 percent humidity by misting nozzles, which at regular intervals spray a misted solution of nutrients.

This helps the plant to take all the nutrients and moisture it needs Since its introduction some 30 years ago, it is safe to say that aeroponic techniques have proven to be very effective for propagation but have yet to prove themselves on a commercial scale. Indoor herb and vegetable gardens are very common. For many years they have been tested, confirmed, and refined, and are used by scientists around the world, including NASA. Indoors or outdoors, Aeroponics systems are the perfect option for year-round gardens. Grow plants without soil and get a greater abundance of fresh fruits, flowers, vegetables, and herbs than traditional methods of gardening. Aeroponics systems do not suffer many of conventional gardens' problems, such as root rot, weather disruption, drought, predator loss of produce, soil depletion and others.

Advantages

The roots of plants can also obtain as much oxygen or CO_2 (carbon dioxide) as they need. This increases the photosynthesis output, and the plant's growth cycle can also be significantly increased using aeroponics systems instead of other available growing media.

Another benefit is their ability to ease the spread of plants from cuttings, due to the lower rates of bacteria and pathogen. That allows you to clone your favorite plant varieties. Since they save water and resources, the modern hydroponics systems mostly use 1/10th of water.

Universally considered a method of growing good, natural plants and crops that is ecologically and economically sustainable, Aeroponics systems are enjoyable, simple and easy to maintain. They provide an effective and automated way to deliver optimal levels of water, nutrients and oxygen to your plants for quick growth and higher yields. Experience faster growth rates, higher yields, higher nutritional value, improved fragrance levels and ease of maintenance with fully automated aeroponic systems.

Disadvantages

Aeroponics devices also have fairly high startup costs and are often very complex mechanically and vulnerable to malfunctions. Such malfunctions of the mechanisms used to regulate the accurate management of water and nutrients can cause plant damage in a very short time. Hence it is important to check periodically for blocked nozzles or breakdowns. (End Disadvantages) Advancements in technology and aeroponics systems' increasing popularity going forward will continue to boost the results obtained through aeroponic gardening practices. Aeroponics provides the ability to dramatically increase the quality and productivity not only of our home planting but also of commercial food production. I strongly believe that in the 21st century, aeroponics will continue to rise in popularity and become a staple technology within the plant and food industry. Developing countries and countries with limited natural resources, especially water, will have no choice but to adopt aeroponic systems technologies and the rest of the developed world will certainly note the quality, quantity and eco-friendliness of the processed plants and foods.

You may want to garden indoors, but you've been stopped short because you don't have an suitable area to garden in. However, there are ways that anyone can use to grow plants indoors, even those who live in towns and have no garden, or those at the top of apartment buildings, or those with inhospitable climates. One of those approaches employs an indoor aeroponics system to raise plants. An aeroponic system allows the gardener to grow plants without using soil, which is a great advantage if you don't have any soil or if it's inconvenient or impossible to get soil home. Alternatively, an aeroponics device helps the plants to expand in the sun, exposing the roots to sunlight.

And though you may have heard of an aeroponic hydroponic system, an aeroponic hydroponic system is a misnomer indeed. Although plants grown in an aeroponic system grow in the air without soil, plants grown in hydroponic conditions often do not use soil, but rather use a soilless growing medium, such as coir, where the plants grow.

The use of aeroponic kits is one of the easiest ways to get started with setting up your own aeroponic system. Aeroponic kits have all the individual components you'll need for this gardening form. Aeroponics kits must provide some means of supporting the plant's crown while the roots hang freely underneath. In aeroponics kits different forms of foam or even netting are used to hold the plants in the air. Like any plant, food is required for those grown within an aeroponics system. The food is known as nutrient, and the nutrient solution is dissolved in water. The nutrient solution enters the plant roots by using aeroponic misters, which at regular intervals spray the plant's roots gently with nutrients.

Use of an aeroponics system has benefits. One is that growing plant's roots are exposed to a significant amount of oxygen. This is important, because plants need oxygen so they can grow strongly and mature quickly. One is that in aeroponics fewer plant diseases cause problems, as the plant is never exposed to soil-borne disease.

Aeroponic Systems: 4 Reason Why to Choose It in Indoor Growing Gardening

Nowadays, Aeroponic system is gaining popularity particularly in indoor herb gardening. Aeroponics system was first implemented in the hobby hydroponic market in the 1990s and nowadays all the researchers' efforts have finally created a new hydroponic gardening system known as aerogarden. Pleasant to say, this system is the easiest, cheapest, and best hydroponic system to grow plant in your indoor herb garden particularly.

How Aeroponic systems work

Aeroponic systems can be thought of as an ever-developed high-tech hydroponic gardening method. It needs no medium to supply the required nutrient. A homemade aeroponic device consists of a reservoir, channels with holes made in 7 to 8 inches used to carry plants and lines along the channel about 1/2 inch in diameter. The channel is required to spray nutrients from the reservoir to the plant's roots. Nutrient pump used to inject organic aeroponic nutrients to the roots is the most essential component of these homemade aeroponics systems.

Benefits in indoor gardening.

1. As I said earlier, aeroponic gardening does not require any kind of medium to provide the plant with the necessary nutrients. Yet this type of indoor growing systems also effectively gives the roots maximum supply of 3

critical growth elements including oxygen, water, and nutrients. That's why, regarded as the best hydroponic system ever installed, this system was. Before aeroponic systems were introduced in the hobby hydroponic market I used the traditional hydroponic system to build my indoor herb garden. It's very hard to maintain, though, and the medium itself will bring impurities to my home. My friend introduces me to this amazing technology and it has been a perfect decision.

2. A homemade aeroponic gardening device is very cost effective and easy to build. You can use materials to build these systems which can easily be found near your home. Other than that, you can opt to recycle whatever materials are available at home. I built my home-made device, including my easy-to-make aeroponics squirter, spending just $50. Of course, for a better result you need to buy a ready-made product that can give you a beautiful view of the aeroponic garden.

3. The primary and most of the aeroponic systems known as reservoir, work to store and retain mixed water solution for nutrients. Plant roots hang in the reservoir, and the main benefit of this feature is that it is easy to track the growth and health of the root of the plant. Other than that the roots quickly consume nutrient supply in the reservoir by mixed water solution.

4. Development of roots is an integral part of indoor gardening. No need to worry anymore in these structures, it was built to promote a wonderful growth and health of the roots. Aeroponic cloner systems ensure that the roots from the reservoir are exposed to an evenly distributed nutrient supply. Changing the nutrient in this method is super simple because we put directly on nutrient-containing solution to the root without compromising the roots.

All needs to be able to select herbs and vegetables freshly grown for use in the kitchen. Growing them does take time, experience and a fair amount of dirty work, however. That's why this system was created to help us grow plants quickly in a clean and easy manner.

Growing hydroponic plant with aeroponics systems is now a very easy to perform for me. Compared to the other systems it is also the cheapest and inexpensive hydroponic growing system available today. You won't believe how your plants are growing much faster than any other method, nor how good they are, as you can see. With guarantees that this awesome system creates consistent nutrient-rich climate, the plants are more likely to grow faster and at a consistent pace.

Difference Between Aeroponics and Hydroponics

Planting has been simpler than it was before with the agricultural revolution that has come in the past century. Two of the breakthroughs, hydroponics and aeroponics have gone a long way in developing farming and food production that has resulted not only in individual progress, but also in economic growth. But when does the aeroponics and hydroponics differ?

The difference between aeroponics and hydroponics is that hydroponics is the soilless planting means that requires little to no soil at all. The nutrients are supplied through a nutrient solution or a nutrient film in which the formulation was tested to meet the plants' needs adequately. Meanwhile aeroponics is similar to hydroponics, growing plants without soil use. The difference between the two is that while the former uses water, the latter uses nothing as the medium.

However, the agricultural methods and the distinction between aeroponics and hydroponics have been confusing to many. Aeroponics is a type of process for hydroponics. This is the water which serves as the carrier of nutrients when the nutrient solution is then sprayed into the plant's roots.

A further distinction between aeroponics and hydroponics is the set-up of the system. Although the plants are grown in a restricted area such as the greenhouse in hydroponics, the plants grwons through aeroponics are in a closed or semi-closed environment. The environment is not that restricted which can become a potential source of problem. This is because the aeroponically grown plants are not kept free from plant hazards such as pests and diseases.

An important difference between aeroponics and hydroponics that plants can easily mature with air as there are abundant sources of essential in the growth of plants. Which are oxygen, water and the nutrient solution.

You may be quetsioning why some farmers choose aeroponics rather than hydroponics. This is because aeroponics can have stable oxgen supply that can yield much higher output yields.

In set-up terminology, the process between hydroponics and aeroponics often varies. The aeroponics procedure allows the root of plants to be suspended in a hydro-atomized nutrient solution that will make some parts of the roots, such as the crown, stretch to the top. The method varies depending on the equipment used as compared with hydroponics. These technologies range from static solution to continuous flow. In addition, certain measures are often made in the irrigation system to prevent contamination of the disease.

There is a variety of differences between aeroponics and hydroponics. Despite these, the manner in which these innovations enhanced food production and the lives of many can not be ignored.

How to Prevent Root Rot in Aeroponic Cloners

Have you tried to clone your plants in an aero cloner and not got much luck? Will the stem get slimy and the roots rot? The explanation for this much of the time is that you made a common mistake. By using an aeroponic cloner this is your first time make sure you follow these guidelines.

The first thing you need to do is ensure that your cloner is completely clean, right down to the spinner of the pump. When you have to reuse the neoprene collars they make you very thoroughly washed. Avoid using food grade cleaners but if you don't have anything else, bleach can be used. By using bleach ensure that all traces have been rinsed out. If you think you've had fully rinsed it out, do it again. There may be some explanations why you get root rot.

Water Temperature-Most gardeners don't really know how warm their water is. Just because this is sitting in the summer on your basement floor doesn't mean it's cool. Make sure your temperature in the water isn't too high. It is probably too warm if you stick your finger in the water and it feels lukewarm. Have you ever swam in water to 70 degrees? At 70 degrees the skin feels cold. Water times can get pretty high with summer time. Hold it about 70-75, and be healthy. Growth of the bacteria takes off in higher periods. Make sure you do not have the aero cloner on a basement floor for winter. There will be nothing happening a lot of times and gardeners asking what is wrong. The cold water stunted the cutting and the rising roots ceased to grow. You wouldn't want your plant to take a cold shower in the winter so why would it?

PH-The pH standard for the aeroponics must be between 5.5-5.8. This isn't soil or hydro, since a pH of 6 gets too high. You may want to get one if you don't have a wireless pH meter.

Preparing your cloner-Some people in their water use a clearn or clone solution, but you don't have to. However, to help avoid nastiness, you should add 3 percent hydrogen peroxide (H_2O_2) to your drink. Add about 1 tablespoon of H_2O_2 per gallon of water (the measuring kind, not the one you cook with).

CHAPTER TEN

Hydroponic Culture Systems

True hydroponics is plant growth without a rooting medium, in a nutrient solution. Plant roots are either suspended in a standing aerated nutrient solution or in a nutrient solution that flows through a root tube, or plant roots are sprinkled with a nutrient solution regularly. This description is somewhat different from the widely accepted hydroponics term, which in the past included all types of hydroponic / soilless production. These three hydroponic growing techniques will be addressed in the first section of this chapter.

Mediumless Hydroponic Systems

Standing Aerated Nutrient Solution

It is the oldest hydroponic process, dating back to those early investigators who used this method in the mid-1800s to determine which elements were important for plants. In the 1840s Sachs and the other early investigators grew plants in aerated solutions and observed the effect of adding different substances to the nutrient solution on plant growth (Russell, 1950). This method is still of use for various forms of plant nutrition studies, although some researchers have switched to nutrient solution streaming and continuous replenishment procedures.

The criteria for the Technique for aerated standing nutrient solution are:

1. A suitable vessel with rooting

2. A solution to the nutrient

3. An air tube and pump to continually bubble up air into the nutrient solution.

The bubbling air helps both to add and inject O2 to the nutrient solution. The formula widely used is Hoagland's or some version of it, as Berry (19850) built. The nutrient solution may need periodic replacement, usually every 5 to 10 days, frequency dependent on plant number and size, as well as nutrient solution volume. Water loss from the nutrient solution would need to be replaced daily, either using nutrient-free water (pure water) or a diluted (1/10th strength) nutrient solution, as there is a danger that any additional nutrient elements that alter the initial element balance and adversely affect the plants. It should also be noted that with each day of use, root behavior and element uptake may alter the pH and composition of the initial nutrient solution, changes which may have an impact on plant growth. The question becomes "is it appropriate to restore the pH and elemental content of the nutrient solution to its original levels regular before replacement? "An adaptation other than water loss replacement is usually recommended in most instances.

Clark (1982) identified another aerated standing nutrient solution system; this method was used to research the basic demands of corn and sorghum. Many plants are grown in a nutrient solution of 1/2 gallon (2 L), with change periods ranging from 7 to 30 days depending on the stage of growth and plant species. The ratio of 8 to 1 of NO3 to NH4 in the nutrient solution is used to ensure a certain degree of stability in pH. While Clark's methodology is mainly intended for maize and sorghum nutritional studies, its method of handling nutrient solutions may be applied effectively to other plant species.

The hydroponic growing method of aerated standing nutrient solution has limited commercial application while lettuce and herbs were successfully grown on styrofoam sheets floating on an aerated nutrient solution. Within the styrofoam the plants are put within small gaps, with their roots expanding into the nutrient solution.

Another explanation why this hydroponic growing method is not well suited for commercial use is that water and chemical usage are very high due to the regular replacement requirements. In addition, the nutrient solution's composition is continuously changing, requiring monitoring and modification to maintain the pH and elemental ion balance and concentration levels of sufficiency over the usage duration, which can vary from 45 to 65 days. Temperature and management of root disease are additional criteria if this growing approach is to produce positive results.

Nutrient Film Technique (NFT)

A major advancement in hydroponics occurred during the 1970s with the implementation of the technique of nutrient film, also referred to as NFT

(Cooper, 1976, 1979ab). Some have changed the name by using the word "flow" instead of "film" (Schippers, 1979), as the plant roots actually grow in a nutrient solution flow. When Allen Cooper first presented his hydroponic growing system NFT (1976), it was heralded as the future hydroponic process. While it was the first significant improvement in the technique of hydroponic development since the 1930s. At the conference entitled "Hydroponics Worldwide: State of the Art in Soilless Crop Production" (Savage, 1985a), Cooper and his colleagues presented their experiences with this process, which left those present with the impression that hydroponics research had taken a significant step forward.

However, experience has shown that the NFT approach does not solve the common problems that most hydroponic growing systems inherit. How-ever in many parts of the world, particularly in Western Europe and England, this has not deterred its rapid acceptance and use. NFT has been extensively debated and tested (Khudheir and Newton, 1983; Hurd, 1985; Cooper, 1985, 1988; Edwards, 1985; Gerber, 1986; Molyneux, 1988; Hochmuth, 1991b), but its future remains highly uncertain unless there are effective ways to manage the disease and nutrient solutions. Cooper (1985) proposed a shift in the design of the trough, from the "U" shape to a "W" (called a divided gully system), in which the plant base sets at the top of the W center with the roots separated on either side of the W. To keep the roots moist with nutrient solution, a capillary mate is placed on the inverted "V" portion of the "W" This redesign of the single-goully NFT system, as originally suggested by Cooper (1976, 1979ab), has a range of advantages. A portion of the plant roots — that on the inverted "V" — is in air; a portion of the roots lies on a moist surface (capillary matting), which allows for improved rooting system oxygenation; and the remaining root mass is now split into two channels, which would reduce the problems associated with a large mass of roots in a single channel. Through flowing water, or various forms of nutrient solutions down either path, it is now possible to use two separate irrigation systems. Sadly, design has now made the NFT channel system more complex, and it is unknown whether this reform will dramatically improve plant efficiency. Cooper (1996) recently published a revision of his 1976 NFT book, in which he acknowledged some of the problems that can emerge with this hydroponic growing technique.

In the NFT system, the roots of plants are literally suspended in a trough, pipe, or gully (through is the word used from this point on) through which a nutrient solution passes. The trough containing the plant roots is placed on a slope (usually about 1 percent) to allow the nutrient solution to be applied at the top of the trough by gravity at a required flow rate of 1/4 gallon (1 L) per minute from top to bottom. The volume rate down the trough decreases as the root mat increases in size. When the nutrient solution flows down the trough, plants at the top end of the trough rising the nutrient solution's O2 and/or elemental content, a decrease that may be sufficient to significantly affect plant growth and development at the bottom end. In fact, as the root mat gets thicker and denser, the flowing nutrient solution continues to travel over the top and down the root mat's outer edge, raising its interaction within the root mass. This disruption of flow results of poor mixing of the current flowing nutrient solution with water and the elements left behind from previous applications of nutrient solutions in the root mat. One way to mitigate these effects is to make the drill no longer than 30 feet (9 m) in length. Additionally, with longer-term crops, the trough may also be made wider, which may be more appropriate for root production.

One of NFT's main benefits is its ease of establishment and the relative low cost of construction materials. Morgan (1999c) and Smith (2004) address the nature of the NFT troughs and materials suitable for producing troughs. Simply folding a wide strip of polyethylene film into a pipe-like or triangular-like shape may form a trough. The polyethylene film may be either black or white but it must be opaque in order to keep out the light. As light reaches the trough, the growth of algae becomes a grave issue. The sheet of polyethylene is pulled around the stem of the plant, and closed with pins or clips, pipe-like rooting trough. If the trough is made from polyethylene film strips, it can be discarded after each harvest, thus allowing the permanent piping and storage tank of nutrient solution only to be sterilized.

Most troughs in use today are made of different plastic materials, with clarity, structural strength and ultraviolet (UV) resistance being the requirements. The trough size (width, height, and shape) is generally determined by the crop being cultivated. Lack of structural strength in the bottom of the trough can lead to unevenness that causes nutrient solution to lie in depressions that can lead to anaerobic conditions.

At the spacing indicated for that crop, the plants are placed in the trough.

Plants are normally started in germination cubes made from fiberglass or similar material. The cube is placed directly in the trough with its plant started. Experience has shown that the cube of germination should not be made from materials which disintegrate over time. A sturdy germination cube in the NFT trough helps to hold the plant in place.

NFT systems are usually closed systems, i.e. the nutrient solution which exits the end of the trough is recovered for reuse. Bugbee (1995) addresses the management criteria of hydroponic recirculating rising systems. The introduction of maquillage water, the need to reconstitute the content of the pH and nutrient components, filtering and sterilization are procedures that must be developed. An open system will mean discarding the nutrient solution leaving the trough which is costly in terms of water and reagent usage as well as posing a problem for proper disposal.

If the NFT system is run as a closed system (i.e. the nutrient solution is recirculated several times until it is discarded), Cooper (1979a) has suggested the use of a special nutrient solution, called the topping-up solution, to be applied to the starting solution in order to preserve its composition during use. The nutrient solution is usually tracked by regular EC tests, which specify the correct times to add a nutrient solution to retain the initial volume and when to dump and produce a new batch of nutrient solution.

Formulations of nutrient solutions suitable to NFT growing systems were recommended based on conditions of crop and field management.

Aeroponics

Another interesting hydroponic strategy for the future was thought to be aeroponics, which is the delivery of water and vital elements through an aerosol mist that bathes the roots of the plants. Some of the major benefits of this method is aeration compared to the flow of the nutrient solution through the plant roots, because the roots are basically growing in air. The method was designed to achieve substantial savings in both the use of water and the basic elements. The critical aspects of the technique are the aerosol quality, the root exposure frequency and the nutrient solution composition. Adi Limited (1982) described an aeroponic device as having proved highly effective, it said. The system is operated by computer and includes a special fogging unit, troughs, and a number of sensing devices. While crop yields obtained with this growing system have been reported to be significantly higher than those obtained with traditional hydroponic systems, initial costs for the Adi system plus operational costs are very high, jeopardizing its commercial viability although its value in plant propagation is considerable (Soffer, 1988).

Most approaches employed a nutrient solution spray rather than a fine mist; the crucial factors are the droplet size and the degree of roots exposure to the nutrient solution. Continuous root exposure to a fine nebula provides better results than occasional spraying or misting. A small pool of water is allowed to remain at the bottom of the rooting vessel in most aeroponic systems, so that a portion of the roots has access to a continuous supply of water. The nutrient solution composition will be modified according to the time and duration of root exposure to the nutrient solution.

Medium Hydroponic Systems

Plants are grown in some form of inorganic rooting medium in the cultivation systems mentioned in this section, with the nutrient solution being applied by flooding or drip irrigation.

Ebb-and-Flow Nutrient Solution Systems

This type of hydroponic growing system has been in wide use for many years, but it is not widely used commercially today other than for growing units of the hobby / home type. The growing system consists of a watertight rooting pad, a rooting pad containing an inert rooting medium, such as gravel, coarse sand or volcanic rock, a nutrient solution sump (equal in volume to the growing bed(s)), an electrical pump to transfer the nutrient solution from the sump to the growing bed(s) and a piping system to handle the growing bed(s). The sump must be below the growing bed(s) in order to allow gravity return flow of nutrient solution from the growing bed(s) into the sump. Since this is a "closed" device, it will recirculate the nutrient solution until it is no longer available when it is discarded and replaced with a freshly made solution. The nutrient solution should be checked for pH, EC and likely elemental content before each application, and then modified accordingly. After each circulation through the rooting bed the nutrient solution can also require filtering and sterilization.

This method of hydroponic growth was the one used by the U.S. In World War II the army provided new tomatoes and lettuce to soldiers fighting in the Pacific (Eastwood, 1947). After WWII, this hydroponic growing technique was used by farmers in many southern states in the United States and elsewhere (Eastwood, 1947), mainly tomatoes growing in outdoor hydroponic gardens. The author has advised growers who grow in both greenhouse and outdoor settings using this method.

The drawbacks of this system are vulnerability to root diseases, excessive use of water and nutrient reagents, and the requirement that the rooting medium, which is usually gravel, be replaced regularly. In the 1960s and 70s an ebb-and-flow device designed to grow greenhouse tomatoes was promoted. The sump contained 2000 gallons of nutrient solution that required daily water volume adjustment as well as potential pH and nutrient item make-up changes (based on an EC measurement). Around every 2 to 3 weeks the nutrient solution required complete replacement — a considerably inefficient use of valuable water and reagents. Over time, plant roots started to develop into the pipes that supplied the nutrient solution back to and from the rising bed(s) and sump, thus reducing the flow. One diseased plant injected into the system will result in a complete crop failure. Cleanup also required scraping and replacing the rooting substrate on gravel. Another problem with this method was that when they were in the field, the sump and sealed nutrient solution would have a temperature similar to that of the surrounding soil, implying that the nutrient solution would be cooler than the temperature of the ambient air for much of the season, an unwelcome feature that would damage plants when the nutrient solution was dispensed into the growing medium.

The ebb-and-flow growing system is fairly easy to install and run on a small scale for homeowner and hobbyist, and provides reasonably good plant production with a moderate level of care.

The timing schedule for flooding the growing bed(s) will depend on the crop's atmospheric demand and growth level, as well as the growing medium's water-holding capacity. The composition of the nutrient solution is usually identical to or some variation of the basic Hoagland solution, depending on the crop and growth level.

This hydroponic growing method has proved to be difficult to operate economically and is very inefficient in its use of water and vital elements, significant reasons for its lack of use today.

Drip/Pass-Through Inorganic Medium Systems

There are two such growing methods, one in containers, pots, or buckets, using perlite or similar inorganic rooting media, and the other using rockwool slabs.

Inorganic Rooting Medium in Bags or Pots/Buckets

This hydroponic growing technique is commonly used today in commercial production where the plant(s) are grown in a container, bowl, or bucket of inorganic material, with perlite as the most common rooting medium (Gerhart and Gerhart, 1992; Morgan, 2003f). For one method, the bag used to transport the perlite is laid on its side, small holes are cut along the bottom edge of the bag to allow excess nutrient solution to flow out, an access hole(s) is cut in the top of the bag to position a plant, and then a drip tube is placed at the edge of the access hole next to the plant. Initially, the plant can be planted in a rockwool cube or other similar material, then placed on an opening on the container, with the drip line mounted at the plant base. Outside of the shipping container, a pot or bucket like the BATO bucket, filled with perlite or similar inorganic material, may be used. These systems, which mostly use BATO buckets, are widely used for tomato and cucumber growth.

The nutrient solution is not collected and recirculated, since this is a "safe" device. The supplied quantity should be adequate for a minor excess flow from openings cut at the bottom edge of the bag or from openings in the base of pots and buckets (the BATO bucket has a small reservoir at its base). Scheduling of the rate and timing of application of the nutrient solution depends on different factors, such as atmospheric demand, crop, and growth level. The effluent from the growing vessel may be tracked during the growing cycle for its pH and EC and changes made in the supplied nutrient solution, or the medium leached with water to eliminate any accumulated salts. A solution aliquot can also be drawn from the medium itself shortly after irrigation to conduct the same measurements as made on an effluent sample.

The perlite-containing vessel may be used or discarded one more time at the end of the growing season, making the device fairly straightforward to mount and repair at fair cost. The formula for the nutrient solution is usually based on, or some variation of, the Hoagland / Arnon nutrient formula.

Diverse changes have been made to this growing device to accommodate various crop types. One example is a vertical hanging bag with plants of lettuce put on the side of the bag in holes, a system defined by DeKorne (1992–93). Another example is strawberry plants put in perlite holes on the side of the vertical polyethylene container. At the top of the container, the nutrient solution is added, usually through a dripper, and the solution goes down through the container and out the bottom. The same issues with the NFT method apply to this device, as the nutrient solution composition is modified as it moves through the container.

A very recent unique system consists of a column of interlocking styrofoam pots in which plants are mounted at the four corners of each pot; the system is built primarily for the growth of strawberry, lettuce, and herbs. Nutrient solution positioning and flow are similar to the vertical sac system.

The use of vertical space is an benefit of these vertical systems, while retaining lateral space if plants are grown in an enclosed shelter or greenhouse. The bag or column of pots can be slowly rotated to give the plants a more consistent light exposure.

Rockwool Slab Medium

Rockwool is probably the most commonly used hydroponic growing medium for tomato, cucumber and pepper production in the world today, although attempts are being made to find an appropriate replacement because disposal of the used slabs is becoming a major problem. Rockwool has excellent capacity to hold water, is fairly inert and has proven to be an excellent substratum for plant production.

Rockwool is an inert fibrous substance formed from a mixture of volcanic rock, calcareous and coke; melted between 1500 and 2000 C; extruded as fine fibers; pressed into loosely woven sheets. The sheets are made of slabs of varying widths [16 to 18 inches (15 to 46 cm)], usually 36 inches (91 cm) in length, and between 3 and 4 inches (5 to 10 cm) in diameter. The slabs are usually covered with sheets of white polyethylene.

Normally, the slabs are laid flat on a prepared floor surface, which is typically first covered with white polyethylene ground sheets. The spacing between the slabs will depend on the growth area layout and the crop to be cultivated. After the slabs have been placed in place, cuts are made along the lower edge of each slab on the bottom of the polyethylene slab to allow excess nutrient solution to flow out of the slab. On top of the slab sheet, an access hole is then cut to accommodate a rockwool block which contains a growing plant. A drip irrigation system is then supplied to each rockwool by nutrient solution.

Since this is a "free" device, the nutrient solution is not retrieved and the supplied solution is adequate for an excess flow from the cut openings at the bottom of the slab. A solution sample is regularly drawn from the slab, its EC calculated, and if it is found to reach a certain amount, the slab is leached with water. A pH calculation can also be performed, and the composition of the nutrient solution can alter if necessary. The elemental content of the slab-retained nutrient solution is not usually determined, although Ingratta et al. have provided optimum and appropriate ranges for the two crops, tomato and cucumber solution.

HYDROPONICS GROWING SYSTEM

How to start growing plants, herbs, fruit and vegetables all year with your hydroponic system. The ultimate and safe guide to create your diy hydroponic garden.

Introduction

There are a variety of ways of growing plants using hydroponic / soilless crops. The classification scheme proposed by Dr. John Larsen of Texas Agricultural Extension Service is being followed for the purposes of this book. Hydroponics is one distinct technique in its classification scheme for plant growing where no root-supporting medium is used, while the other methods use either inorganic or organic rooting mediums.

As indicated earlier, hydroponically growing plants are different from non-media systems for systems that employ a support or rooting medium. Control of the nutrient solution is very different for these two types of systems. However, it is important to keep in mind not only the differences but also the similarities between these growing systems, as some of the management procedures can be transferred successfully while others cannot.

Container Growing

All types of hydroponic / soilless cultivation include growing plants in some type of container — a box, pot, bag, bowl, enclosed slab, or trough. The rooting vessel's volume and dimensions are often selected depending on the convenience or availability. The Number 10 food can, for example, have been commonly used in the past because of its low cost and availability. More recently, containers have become popular with so-called "gallon" and "2-gallon" (actual volumes are 3 and 6 quarts, respectively) Growers today put soilless medium in a free-standing plastic bag and use it as the growing container, or they grow directly in the bag used for packaging and transporting a soilless mix or perlite.

Whether the vessel is a container, slab, bowl, bath, trough, or bed, what should the volume and dimensions of the rooting vessel be to provide adequate space for normal root growth and development? The response to this question has not been sufficiently defined as far as most hydroponic / soilless growing systems are concerned. It is surprising how little good knowledge is available about the importance of plant-required rooting volume, and the relationship between rooting habit, rooting medium, and container environment and volume.

Despite the uncertainties surrounding the relationship between rooting vessel size and plant efficiency, there are some guidelines which will assist the grower in determining the rooting volume required for the crop and the device used: 1. For all tanks, when the plant reaches its full size the depth will be one-and-a-half to two times the width of the surface area protected by the plant canopy. For example, the growing container should be 18 to 24 inches (46 to 61 cm) deep if the canopy covers (or will cover) a surface area of 12 inches (30 cm) in diameter.

2. In bed culture systems, increased plant spacing may partly replace a lower depth. For instance, plants with a canopy occupying a surface area of 12 inches (30 cm) in diameter growing in a bed less than 12 inches (30 cm) deep should be spaced 18 inches (46 cm) from one center to the next. This ratio of 2 to 3 can be applied when growing in bed systems, to plants with smaller or larger canopies.

It is widely accepted that adjacent plant roots impede development for one another. Boring plants (the product of a close spacing or shallow rooting depth) should therefore be reduced by providing the necessary area and depth.

Some feel that our understanding of plant growth in general is limited by the current lack of awareness about root growth in different environments. The advice for the cultivator of hydroponic / soilless crops is that he or she must experiment with the growing method to determine the rooting volume needed to achieve optimum plant efficiency. Starting with the above guidelines, plants should be spaced closely together until a noticeable improvement in plant growth and yield occurs.

Needless to say, the requirement for root volume becomes theoretical as plants need to be widely spaced to allow enough light to reach the canopy of the plants for those plants that are widely branched and/or grow tall. Today, though, the trend is that to cut costs in the minimum of medium.

Media Hydroponic/Soilless Culture

Since the 1930s to the late 1950s, gravel or sand was widely used as the rooting medium in sys-tems of closed recirculating commercial ebb-and-flow soilless culture. Gravel, lava rock, expanded clay, or Hadite are the materials chosen for use as the rooting medium for small home hydroponic systems. Perlite and rockwool are the most widely used inorganic rooting media materials for the today's commercial hydroponic systems.

Today a wide range of different organic rooting media materials are used, most of which are blends of different materials, primarily mixtures containing peat moss and/or composted milled pinebark or peat moss, and composted milled pinebark combined with inorganic substances, such as vermiculite and perlite.

The use of a rooting medium, be it inorganic or organic, poses a variety of challenges. Although the medium itself may be inert, such as gravel, sand, perlite, or rockwool, it harbors pore spaces that retain nutrient solution, which may eventually be absorbed by plant roots; the elements pass by mass flow or diffusion inside the solution with the solution, and are also reached by root extension (growth). Organic products, such as peat moss and composted milled pinebark, have similar pore spaces as well as an exchange potential of cation / anion that can absorb ions from the solution and bring them into solution for later release. A precipitate of elements that occur in both media forms, generally as a mixture of calcium phosphate and calcium sulfate, which may also include other elements, primarily the micronutrients. Although this precipitate is ultimately insoluble, parts will become soluble, which will then contribute by repeated passage of the nutrient solution through the rooting medium to the critical element supply provided to the plant roots.

Regulating Water and Nutrient Element Requirements

Two simple nutrient solution systems are used: a "open" system in which the nutrient solution is passed through the rooting vessel and discarded A "closed" system in which the nutrient solution is passed through the rooting vessel and then collected for reuse.

Both systems offer both advantages and disadvantages. The main downside of the "open" approach is its inefficiency due to water loss and unused critical elements, as the nutrient solution flows larger than the plants need. The nutrient solution can be considerably modified for the "closed" method after moving through the rooting tube, involving some volume adjustment (replacement of the missing water) and pH and replenishment of the absorbed critical elements. Additionally, any disease or other species picked up by the nutrient solution in its passage through the rooting vessel will be recirculated into the entire system unless some sort of nutrient solution treatment eliminates or inactivates them. Wilcox (1991), Schon (1992), and Bugbee (1995) discussed the controls and specifications for a recirculating hydroponic method.

The nutrient solution, in its flow through the rooting vessel, is expected to provide both water and the essential elements required by the plant. Such two physiological requirements, the need for both water and vital elements, are conveniently and erroneously believed to occur in tandem. However, on warm days when plants are rapidly transpiring, only water may be required to satisfy atmospheric demand, while the crop does not need the nutrient elements in the nutrient solution in other than their normal quantities. The result is that water requirement with the feeding cycle is out of phase. This juxtaposition of events presents a major problem, as it is not usual to have a water-only device functioning in conjunction with the distribution system of nutrient solutions. Increasing the circulation of the nutrient solution to meet the demand for water can therefore lead to an elementary imbalance and an unwanted accumulation of unwanted elements.

With automatic control and a "free" device, the nutrient solution composition can be changed by introducing water into the flowing stream of nutrient solution that passes through the rooting vessel, thus reducing the concentration of nutrient elements. A delivery – collection system would be needed with a "closed" device to move water through the rooting vessel only. Giacomelli has recently spoken about these "technical" elements of hydroponic society.

Active and Passive Systems of Nutrient Solution Distribution

The movement of the nutrient solution involves either electrical power (active) or gravity (passive), or a combination of both in both commercial and most other forms of hydroponic / soilless culture systems. Less dependency on electrical power can be of great benefit in certain cases. However, the need for uninterrupted electrical power is becoming necessary with the requirements for greater control over the composition, application criteria, etc. of the nutrient solution more commonly recommended and implemented in commercial systems.

Additionally, computer-programmed programs replace manual processes of managements. Sensors are mounted in the through storage tanks for the medium and nutrient solution to control the flow and the nutrient solution composition, respectively. Parameters such as light intensity and length, and plant atmosphere temperature, are variables used to control the nutrient solution's flow and composition. And passive nutrient solution flow systems are becoming redundant.

CHAPTER ONE

Systems of Hydroponic Culture

True hydroponics is the growing of plants in a nutrient solution without a rooting medium. Plant roots are either suspended in standing aerated nutrient solution or in a nutrient solution flowing through a root channel, or plant roots are sprayed periodically with a nutrient solution. This definition is quite different from the usually accepted concept of hydroponics, which has in the past included all forms of hydroponic/soilless growing. In the first section of this chapter, these three techniques of hydroponic growing will be discussed. In the second section, hydroponic systems using inorganic rooting media will be presented.

Mediumless Hydroponic Systems

Standing Aerated Nutrient Solution

This is the oldest hydroponic technique, dating back to those early researchers who, in the mid-1800s, used this method to determine which elements were essential for plants. Sachs in the 1840s and the other early investigators grew plants in aerated solutions and observed the effect on plant growth with the addition of various substances to the nutrient solution (Russell, 1950). This technique is still of use for various types of plant nutrition studies, although some researchers have turned to flowing and continuous replenishment nutri-ent solution procedures.

The requirements for the aerated standing nutrient solution technique are:

1. A suitable rooting vessel

2. A nutrient solution

3. An air tube and pump in order to bubble air continuously into the nutrient solution.

The bubbling air serves to add O2 to the nutrient solution as well as stirring it. The commonly used formula is Hoagland's or some modification of it as has been designed by Berry (1985), with the plant nutrient solution volume ratio of 1 plant per 2 to 4 gallons (9 to 18 L) of nutrient solution.

The nutrient solution will require periodic replacement, usually every 5 to 10 days, the frequency based on the number of plants and their size as well as the volume of nutrient solution. Water loss from the nutrient solution will need to be replaced daily, using either nutrient-free water (pure water), or a diluted (1/10th strength) nutrient solution, although there is the danger that any further additions of nutrient elements could alter the initial balance among the elements and adversely affect the plants. It should also be remembered that with each day of use, the pH and composition of the initial nutrient solution will be altered by root activity and element uptake, changes that can have an effect on plant growth. The question becomes “should the pH and elemental content of the nutrient solution be restored daily to their original levels before replacement?” In most instances, adjustment other than water loss replacement is normally recommended.

Another aerated standing nutrient solution system has been described by Clark (1982); this technique has been used to study the elemental requirements of corn and sorghum. Several plants are grown in 1/2 gallon (2 L) of nutrient solution, with change schedules varying from 7 to 30 days depending on the stage of growth and plant species. The ratio of 8 to 1 of NO3 to NH4 in the nutrient solution is used to maintain some degree of constancy in pH. Although Clark’s technique is primarily designed for nutrient solution management could be successfully applied to other plant species.

The aerated standing nutrient solution method of hydroponic growing has limited commercial application, although lettuce and herbs have been successfully grown on styrofoam sheets floating on an aerated nutrient solution. The plants are set in small holes in the styrofoam, with their roots growing into the nutrient solution. The sheets are lifted from the solution when the plants are ready to harvest.

Another reason why this system of growing hydroponically is not well suited for commercial application is that water and chemical use are quite high due to the requirement of frequent replacement. In addition, the composition of the nutrient solution is constantly changing, requiring mon-itoring and adjustment in order to maintain the pH and elemental ion balance and sufficiency concentration levels during the use period, which may range from

45 to 65 days. Temperature and root disease control are additional requirements if this method of growing is going to produce successful results.

Nutrient Film Technique (NFT)

A significant development in hydroponics occurred in the 1970s with the introduction of the nutrient film technique, frequently referred to as NFT (Cooper, 1976, 1979ab). Some have modified the name by using the word "flow" (Schippers, 1979) in place of "film," as the plant roots indeed grow in a flow of nutrient solution. When Allen Cooper first introduced his NFT system of hydroponic growing (1976), it was heralded as the hydroponic method of the future. It was, indeed, the first major change in hydroponic growing technique since the 1930s. At the "Hydroponics Worldwide: State of the Art in Soilless Crop Production" conference (Savage, 1985a), Cooper and his colleagues discussed their experiences with this method, which left those in attendance with the belief that the science of hydroponics had made a major step forward.

Experience has shown, however, that the NFT method does not solve the common problems inherent in most hydroponic growing systems. How-ever, this did not deter its rapid acceptance and use in many parts of the world, particularly in Western Europe and England. NFT has been widely discussed and tested (Khudheir and Newton, 1983; Hurd, 1985; Cooper, 1985, 1988; Edwards, 1985; Gerber, 1986; Molyneux, 1988; Hochmuth, 1991b), but its future continues to be highly questionable unless better means of disease and nutrient solution control are found. A change in the design of the trough has been suggested by Cooper (1985), from the "U" shape to a "W" (called a divided gully system), in which the plant base sets on the top of the W center with the roots divided down each side of the W. A capillary mate is placed on the inverted "V" portion of the "W" to keep the roots moist with nutrient solution. There are a number of advantages to this redesign of the NFT single-gully system as initially proposed by Cooper (1976, 1979ab). A portion of the plant roots — that on the inverted "V"— is in air; a portion of the roots lies on a moist surface (capillary matting), which provides for better oxygenation of the rooting system; and the remaining root mass is now divided into two channels, which should minimize the problems associated with a large mass of roots in a single channel. It is now possible to use two different irrigation systems by flowing water or various types of nutrient solutions down either channel. Unfortunately, the NFT channel system has now been made more complicated in design, and it is uncertain whether this change would significantly improve plant performance. Cooper (1996) recently published a revision of his 1976 book on NFT in which he recognized some of the problems that can occur with this technique of hydroponic growing.

Simply put, in the NFT system, plant roots are suspended in a trough, channel, or gully (trough will be the word used from this point on) through which a nutrient solution passes. The trough containing the plant roots is set on a slope (usually about 1%) so that the nutrient solution is introduced at the top of the trough can flow from the top to the lower end by gravity at a recommended flow rate of 1/4 gallon (1 L) per minute. As the root mat increases in size, the volume rate down the trough diminishes. As the nutrient solution flows down the trough, plants at the upper end of the trough reduce the O2 and/or elemental content of the nutrient solution, a reduction that can be sufficient to significantly affect growth and development of plants at the lower end. Furthermore, as the root mat thickens and becomes denser, the flowing nutrient solution tends to move over the top and down the outer edge of the root mat, reducing its contact within the root mass. This interruption in flow results in poor mixing of the current flowing nutrient solution with water and elements left behind in the root mat from previous nutrient solution applications. One of the means for minimizing these effects is to make the trough no longer than 30 feet (9 m) in length. In addition, the trough can also be made wider, which can be more accommodating for root growth with longer-term crops.

One of the major advantages of NFT is the ease of establishment and the relative low cost of construction materials. The design of NFT troughs and materials suitable for making troughs is discussed by Morgan (1999c) and Smith (2004). A trough can be simply formed by folding a wide strip of polyethylene film into a pipe -or triangular-like shape. The polyethylene film may be either white or black but must be opaque to keep light out. If light enters the trough, algae growth becomes a serious problem. The polyethylene sheet is pulled around the plant stem and closed with pins or clips, lightproof, pipe-like rooting trough. If the trough is formed from strips of polyethylene film, it can be discarded after each crop, thus only necessitating sterilization of the permanent piping and nutrient solution storage tank.

Most troughs in use today are made of various plastic materials, the requirements being opacity, structural strength, and ultraviolet (UV) resistance. The design of the trough (width, height, and form) is usually determined by the crop to be grown. Lack of structural strength can lead to unevenness in the trough bottom that allows nutrient solution to lie in depressions that can lead to anaerobic conditions.

The plants are set in the trough at the spacing recommended for that crop. Usually, plants are started in germination cubes made of fiberglass or similar material. The cube with its started plant is set directly in the trough. Experience has shown that the germination cube should not be made of materials that disintegrate with time. A durable germination cube helps keep the plant set in place in the NFT trough.

Normally NFT systems are closed systems, that is, the nutrient solution exiting the end of the trough is recovered for reuse. Bugbee (1995) discusses the requirements for the management of recirculating hydroponic growing systems. The addition of make-up water, the need for reconstituting the pH and nutrient element content, filtering, and sterilization are procedures that need to be established. An open system would mean that the nutrient solution exiting the trough is discarded, which is costly in terms of water and reagent use as well as posing a problem for proper disposal (Johnson, 2002c).

If the NFT system is operated as a closed system (i.e., the nutrient solution is recirculated a number of times before being discarded), Cooper (1979a) has recommended the use of a special nutrient solution, referred to as the topping-up solution, to be added to the starting solution to maintain its composition during use. Normally, the nutrient solution is monitored by periodic EC measurements, which determine the appropriate times to add make-up (or topping-up) nutrient solution to maintain the initial volume and when to dump and make a new batch of nutrient solution.

Nutrient solution formulations suitable for NFT growing systems have been recommended based on crop and crop management conditions.

Aeroponics

Another promising hydroponic technique for the future was thought to be aeroponics, which is the distribution of water and essential elements by means of an aerosol mist bathing the plant roots (Nickols, 2002). One of the significant advantages of this technique compared to flowing the nutrient solution past the plant roots is aeration, as the roots are essentially growing in air. The technique was designed to achieve substantial economies in the use of both water and essential elements. The critical aspects of the technique are the character of the aerosol, frequency of root exposure, and composition of the nutrient solution. Adi Limited (1982) described an aeroponic system that it said had proven to be highly successful. The system is computer controlled and requires a special fogging device, troughs, and an array of sensing devices. Although yields of crops obtained with this growing system have been reported to be considerably above those obtained with conventional hydroponic sys-tems, the initial cost for the Adi system plus operating costs are very high, bringing into question its commercial viability (Soffer, 1985), although its value in plant propagation is considerable (Soffer, 1988).

Several methods have employed a spray of the nutrient solution rather than a fine mist; droplet size and frequency of exposure of the roots to the nutrient solution are the critical factors. Continuous exposure of the roots to a fine mist gives better results than intermittent spraying or misting. In most aeroponic systems, a small reservoir of water is allowed to remain in the bottom of the rooting vessel so that a portion of the roots has access to a continuous supply of water. The composition of the nutrient solution would be adjusted based on the time and frequency of exposure of the roots to the nutrient solution.

Medium Hydroponic Systems

In the culture systems described in this section, plants are grown in some type of inorganic rooting medium (Straver, 1996a,b; Morgan, 2003f), with the nutrient solution applied by flooding or drip irrigation.

Ebb-and-Flow Nutrient Solution Systems

This type of hydroponic growing system had been in wide use for many years, although it is not commonly used commercially today other than for hobby/home-type growing units. This system has also been called “flood and drain.” The growing system consists of a watertight rooting bed, rooting bed containing an inert rooting medium, such as gravel, coarse sand, or volcanic rock, a nutrient solution sump (equal in volume to the growing bed(s)), an electrical pump for moving the nutrient solution from the sump to the growing bed(s), and a piping system to accommodate the delivery of the nutrient solution from the sump to the growing bed(s) and its return. Such a commercially designed system is shown in Figure 9.5. In order to have gravity return flow of nutrient solution from the growing bed(s) to the sump, the sump must be below the growing bed(s). Since this is a "closed" system, the nutrient solution is recirculated until no longer usable, when it is dumped and replaced with freshly made solution. Prior to each use, the nutrient solution should be tested for pH, EC, and possibly elemental content and then adjusted accordingly. The nutrient solution may also require filtering and sterilization after each circulation through the rooting bed.

This hydroponic growing system was that used by the U.S. Army in World War II to supply troops operating in the Pacific with fresh tomatoes and lettuce (Eastwood, 1947). Following WWII, this system of hydroponic growing was put into use by growers in several southern states in the United States and elsewhere (Eastwood, 1947), in outdoor hydroponic gardens growing primarily tomatoes. The author has advised growers using this method of growing in both greenhouse and outdoor settings.

The disadvantages for this system are susceptibility to root diseases, inefficient use of water and nutrient reagents, and the requirement for the periodic replacement of the rooting medium, which is usually gravel. An ebb-and-flow system designed for greenhouse tomato production was marketed in the 1960s and 70s. The sump held 2000 gallons of nutrient solution that needed daily volume water adjustment as well as possible adjustments in pH and nutrient element make-up (based on an EC measurement). The nutrient solution required complete replacement about every 2 to 3 weeks — a considerably inefficient use of valuable water and reagents. With time, plant roots began to grow into the pipes that delivered and returned the nutrient solution to and from the growing bed(s) and sump, thereby restricting the flow. One diseased plant introduced into the system would result in a total loss of the entire crop. Cleanup frequently meant the removal and replacement of the gravel rooting medium. Another problem with this system was that because they were in the ground, the sump and enclosed nutrient solution would have a temperature equal to that of the surrounding soil, meaning that during most of the season, the nutrient solution would be colder than the ambient air temperature, an undesirable trait that would harm plants when the nutrient solution was dispensed into the growing medium.

For the homeowner and hobbyist, the ebb-and-flow system of growing is relatively easy to construct and operate on a small scale and gives reasonably good plant performance with a moderate level of care.

The timing schedule for flooding the growing bed(s) will depend on the atmospheric demand and stage of growth for the crop, as well as the water-holding capacity of the growing medium. Normally, the composition of the nutrient solution is similar to the basic Hoagland solution or some modification of it, depending on the crop and stage of growth.

Commercially, this system of hydroponic growing has proven to be difficult to manage and is very inefficient in its use of water and essential elements, important reasons for its lack of use today.

Drip/Pass-Through Inorganic Medium Systems

There are two such growing systems, one using perlite or similar inorganic rooting medium (Morgan, 2003f) in bags, pots, or buckets, and the other using rockwool slabs.

Inorganic Rooting Medium in Bags or Pots/Buckets

This system of hydroponic growing is in wide use today for commercial production in which the plant(s) is grown in a bag, pot, or bucket of inorganic medium, with perlite as the most common rooting medium (Gerhart and Gerhart, 1992; Morgan, 2003f). In one system, the bag used for shipping the perlite is laid on its side, small holes are cut along the bottom edge of the bag to allow excess nutrient solution to flow out, an access hole(s) cut in the top of the bag for placement of a plant, and then a drip tube is placed on the edge of the access hole next to the plant. The plant may initially be seeded in a rockwool cube or other similar substance and then placed on an opening on the bag, with the drip line placed at the base of the plant. A pot or bucket, such as the BATO bucket, filled with perlite or similar inorganic substance, can be used in place of the shipping bag. These systems, mostly using BATO buckets, are in wide use for the production of tomato and cucumber.

Because this is an “open” system, the nutrient solution is not recovered and recirculated. The amount delivered should be sufficient for a slight excess flow from the openings cut on the bottom edge of the bag or from openings in the base of pots and buckets (the BATO bucket has a small reservoir in its base). Scheduling of the rate and timing of nutrient solution application is dependent on various factors, such as atmospheric demand, crop, and stage of growth. During the growing period, the effluent from the growing vessel can be monitored for its pH and EC and adjustments made in the nutrient solution delivered, or the medium leached with water to remove any accu-mulated salts. Also, an aliquot of solution can be drawn from the medium itself shortly after an irrigation to make the same measurements as made on an effluent sample.

At the end of the growing season, the perlite-containing vessel may be used one more time or discarded, which makes the system relatively easy to install and replace at a reasonable cost. Various modifications of this system of growing have been made to accom-modate different types of crops. One example is a vertical hanging bag with lettuce plants placed in holes in the side of the bag, a system described by DeKorne (1992–93). Another example is strawberry plants set in the holes in the side of the vertical polyethylene bag of perlite. The nutrient solution is applied at the top of the bag, usually through a dripper, and the solution passes down through the bag and out the bottom. The same problems associated with the NFT technique apply to this system, as the composition of the nutrient solution is modified as it passes down through the bag.

A very recent unique system consists of a column of interlocking styrofoam pots in which plants are placed at the four corners of each pot; the system is primarily designed for the growing of strawberry, lettuce, and herbs. The placement and flow of nutrient solution are similar to the vertical bag system.

An advantage of these vertical systems is gained from the utilization of vertical space, thereby conserving lateral space if plants are grown in an enclosed shelter or greenhouse. The bag or column of pots can be rotated slowly to obtain more uniform light exposure for the plants.

Rockwool Slab Medium

Rockwool is probably the most widely used hydroponic growing medium in use in the world today for the production of tomato, cucumber, and pepper (Bij, 1990; Ryall, 1993; Morgan, 2002a), although efforts are being made to find an adequate substitute because disposal of used slabs is becoming a major problem (Spillane, 2002a,b). Rockwool has excellent water-holding capacity, is relatively inert, and has proven to be an excellent substrate for plant growth (Sonneveld, 1989).

Rockwool is an inert fibrous material produced from a mixture of volcanic rock, limestone, and coke; melted at 1500 to 2000˚C; extruded as fine fibers; and pressed into loosely woven sheets. The sheets are made into slabs of varying widths [16 to 18 inches (15 to 46 cm)], normally 36 inches (91 cm) in length, and ranging in depth from 3 to 4 inches (5 to 10 cm). The slabs are normally wrapped with white polyethylene sheets.

The slabs are normally laid flat on a prepared floor surface, which is usually first covered by white polyethylene ground sheeting. Spacing among the slabs will depend on the configuration of the growing area and the crop to be grown. Once the slabs are set in place, cuts are made along the lower edge of each slab of the polyethylene slab covering on the bottom to allow excess nutrient solution to flow from the slab. An access hole is then cut on the top of the slab sheeting to accommodate a rockwool block containing a growing plant. Nutrient solution is then delivered to each rockwool cube by means of a drip irrigation system.

Because this is an "open" system, the nutrient solution is not recovered, and that delivered is sufficient for an excess flow from the cut openings on the bottom edge of the slab. Periodically, a solution sample is drawn from the slab, its EC determined, and if found to exceed a certain level, the slab is leached with water. A pH measurement may also be made, and the nutrient solution composition may be changed if required. Normally, the elemental content of the slab-retained nutrient solution is not determined, although Ingratta et al. (1985) have given optimum and acceptable ranges for the solution of two crops, tomato and cucumber. These same values would also apply to other inert substrates, such as perlite.

CHAPTER TWO

Organic Media Soilless Culture

The key ingredients in most organic soilless media are sphinum peat moss and composted milled pinebark. Commercially prepared organic soilless mixes are readily available which were formulated for a specific use and/or crop; the mixing characteristics are typically defined by the manufacturer. Such organic rooting media have low cost advantages and user-friendliness. Adding other materials, including vermiculite, perlite, and sand, to the organic substratum is normal practice to provide desirable properties, such as increased porosity, water-holding capacity, or weight. While much has been said and written about creating a suitable mix (Bunt, 1988), there are usually few data available to substantiate those statements. Hence, most growers rely on past experience when choosing a mix that is made commercially or when making their own. Adams and Fonteno (2003) identify the physical and chemical properties and biology of various mixtures of media. Morgan (2003f) provided some of the physical and chemical characteristics of organic substrates which are widely used.

Physical and Chemical Properties

The physical and chemical properties of organic media make their use distinct compared to inorganic media. For instance, sphagnum peat moss (Bunt, 1988) and composted milled pinebark exhibit both adsorptive and absorptive properties to some degree and therefore behave more like soil. The inorganic substances such as gravel, sand, perlite, and rockwool do not contain these characteristics. Such organic substances have a buffering ability that can function to the grower's benefit, acting as a storage system for the critical elements, thereby reducing the possibility of both elementary excesses and shortages. Furthermore, the organic substances used can intrinsically contain some of the essential elements that plants need in adequate quantity to satisfy the crop requirement. For example, the composted milled pinebark contains enough Mn to meet the requirement of that item for most crops.

Many organic soilless blends are various combinations of peat moss sphagnum, composted milled pinebark, and vermiculite. In some cases the mix composition may reflect more of the cost and availability of the major ingredient materials than the physical and chemical characteristics they offer to the mix. For example, the increased cost and decreased supply of sphagnum peat moss has led to other materials being substituted, such as composted milled pinebark (Pokorny, 1979). More recently, coconut fiber (sometimes called "coir") (Handrick, 1993), rice hulls, and sawdust were used alone or applied to a mix mainly because of their quality, low cost and ease of disposal (Morgan, 2003f). Fresh coir can be toxic to plants; composting is therefore necessary to decrease the presence of phenolic compounds (Ma and Nickols, 2004), similar to what pinebark needs before use. Abad (2003) calculated the effect of coir particle size upon the physical and chemical properties of a soilless medium.

Compounds of different kinds have been applied to the mixes, such as coarse sawdust, composted refuse, and other industrial waste and sewage sludge (Carlile and Sweetland, 1983; Handreck and Black, 1993). Their relatively low cost and the need for recycling have contributed to these composted materials being incorporated into some organic soilless mixes. Unfortunately some composts contain heavy metal residues that are toxic to plants if they are present at high concentrations. Cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), and zinc (Zn) are common parts found in waste and sewage composts (Chaney, 1983; Hayden, 2003). Although such composts can be used to minimize concentrations of heavy metals to below levels harmful to plants, their use should be restricted to the growth of non-edible crops.

Particle size and distribution are essential in a soilless organic mix, as they determine both the water-holding capacity and the mix aeration. For germination and seedling and cutting production, high water holding capacity and humid air spaces in the mix are critical, while good aeration and moderate water holding capacity are necessary for long term planting. For seed germination and short-term plant growth of seedlings and cuttings, a fine-particle mix is better for long-term use, such as growing potted flowering and woody ornamental plants. Some of the particles in a fine mix are less than 0.59 mm in diameter and can clear an NBS Sieve Number 20. Most of the particles in a coarse mix, as they are 2.38 mm or larger in diameter, do not pass an NBS Sieve Number 8.

In order to reduce waterlogging, the percentage of particles below 0.59 mm in size should not exceed 20 to 30 per cent for long-term container production. At the other side, small particles 2.38 mm or larger should be excluded from the mix entirely for short-term use.

In general, the majority of ingredients in fine-particle organic mixtures are mixtures of sphagnum peat moss and vermiculite and/or perlite, while composted milled pinebark alone or with perlite comprises most of the coarser blends. However, this is a generalization that does not necessarily apply for composted milled pinebark, which can be processed to produce a mixture of fine particles similar to mixes based on sphagnum peat moss.

A common component added to some mixes is sand; when required, it is added to provide porosity in fine mixes or weight to hold plant containers in either fine or coarse mixes upright. Sand will not be more than 20 to 25 per cent of the blend, however. When more than 50 per cent of a mix is sand, the issue is weight and decreased water holding capacity. The preferred grade of sand is "builder's" sand, which is a coarse-particle material; a 10-mesh sieve is transferred by 100 percent but a 40-mesh sieve only by 30 per cent.

During the preparation and handling of an organic soilless mix, segregation can occur, as most components (sphagnum peat moss, composted milled pinebark, perlite, vermiculite, sand, calcareous, fertilizer, etc.) differ in particle size and density. Therefore caution is required to avoid segregation when cooking, combining, and handling. It is especially important when ingredients from fertilizers are blended into a mixture. Also when using an automated potting machine, when it is moved from the mixing bin to the pot-filling chute, an organic soilless mix can be separated. Having or keeping the mixture slightly moist when handling and combining helps to prevent components from quickly segregating.

Due to the separation during shipping, component segregation is a common issue in prepared mixes, as the less dense and larger particles travel up through the mix. Careful turning of the mix may be needed upon receipt and before use to return the materials to their original blend.

Organic Soilless Mix Formulas

Although there are many formulas to prepare organic soilless mixes today, Sheldrake and Boodley and Boodley and Sheldrake have developed the basic formulating principles in their Cornell Peat-Lite mixes and from the University of California basic mixes. A variety of similar mixes for various uses have been devised from these simple formulas.

Long-term use of an organic soilless mix involves a different nutrient factor charge, as demonstrated by three different types of mixtures and usage: a composted milled pinebark mix for container-grown nursery stock, a growing-on mix for ornamental plant growth using sphagnum peat moss, and a mix for tomato bag culture. The Tapia mix is used for growing seedlings, vegetables and nursery plants using composted milled pinebark, and is designed for use with low and high Ca-containing irrigation water.

The reader can be confused at this point regarding the correct constitution and usage of an organic soilless mix and this misunderstanding is still widespread. There are no rules which are set. There is little commercial literature about the use of organic soilless mixes for plant growth and little uniformity about growing techniques. For example, in the Ball Redbook (Ball, 1985), a commonly used 720-page text on plant greenhouse cultivation, only three pages are devoted to explanations of soilless mixes and their use, while the more recent issue (Adams and Fonteno, 2003) devotes nine of 724 pages to soilless mixes.

It is obvious that a wide range of conditions can be tolerated in terms of mix constitute and fertilization methods for short-term development. Observation and understanding of the grower are the primary controls. The rate of growth or the appearance of plants can be easily adjusted by adding or removing fertilizer. It is when an organic soilless mix is used to expand over the long term that the mix constitutes and the technique of fertilization becomes essential. Many of the issues that occur in other types of soilless and hydroponic production, such as soluble salt accumulation, disease control, pH shifts, and stress on the nutrient factor, appear. The grower can only monitor these factors by observation and testing to avoid reductions in plant growth and yield.

Limestone and Fertilizer Additions

Traditionally, lime stone has been applied to organic soilless mixes to both increase the water pH of the mix and provide a source of both Ca and Mg, which are essential elements. Recent work does, however, raise concerns about this method, because even marginally increasing the pH of the mix will dramatically reduce the availability of certain important elements.

A mixture of organic soillessness does not reach a water pH of 5.5, with an optimal pH range of 4.5 to 5.5. Calcium sulfate, $CaSO_4$, or calcium nitrate, $Ca(NO_3)_2.4H_2O$, and Mg as magnesium sulfate, $MgSO_4.7H_2O$, are needed to remove calcium from organic soilless mixing formulae.

Furthermore, the quality of irrigation water may change the pH of an organic soilless mix with time if the water contains significant amounts (> 30 mg / L, ppm) of either or both Ca or Mg. The mix is basically "limed" with increasing irrigation, and the water pH of the mix increases a little bit. In time, the pH can reach the point where the supply of some of the essential elements is adversely affected, with one or more deficiencies in the nutrient elements. The problem can be solved in part by not initially adding Ca- or Mg-containing sources to the mix, thereby depending on the Ca and Mg quality of the irrigation water to supply these two important plant elements. In such a situation, it is important for the grower to know if Ca or Mg has been applied to the mix or whether the mix is intended for use where the irrigation water is to meet the plant's Ca and Mg requirements.

The addition of N, P, and K, typically as a chemical fertilizer, is calculated primarily by the use of the organic soilless mix. From a practical point of view and for short-term cropping (growth duration of less than 8 weeks), when defined, these elements and the other necessary elements will be added to the mix. From a control point of view, however, and for all long term cropping, it is best to add the critical elements as needed. For practical reasons, some of the elements, such as the micronutrients, may be added when the mix is created, reserving the three main elements, N, P, and K, to be added as needed by the crop. Unfortunately, there is no one recommendable best route. The best balance between practicality and control considerations seems to be to initially add the micronu-trients and the major elements P, K, Ca, and Mg to the organic soilless mix and then supplement them as needed based either on a plant analysis and a mix assay or on plant growth and appearance. Based on growth and plant appearance, the major elements, mainly N and K, can be added periodically to meet crop requirement. For the above category, the element P may be added if a complete NPK fertilizer is used to supply the necessary N and K.

Chemical fertilizers, such as 20-20-20 (N-P2O-K2O), are also used in addition to the irrigation water for supplementation. Depending on crop requirement the concentration is varied. A common recommendation is for N to be between 50 and 100 mg / L (ppm).

Growers should be aware that repeated long-term use of a fertilizer, such as 20-20-20 applied through the irrigation water, will result in excesses in P if this factor has already been added to the mix. Therefore consideration should be taken to ensure that P excess will not occur either by not initially inserting it in the mix or by choosing a liquid fertilizer not containing P. Slow-release fertilizers are applied to an organic soilless mix for elemental release control. Osmocote (Grace-Sierra Horticultural Products Co., 1001 Yosemite Drive, Mippitas, CA 95035), MagAmp, ureaform, and ordinary chemical-based fertilizer in small perforated polyethylene bags put in the mix offer some degree of control by providing plants with a steady supply of vital elements during their growth cycle, as well as reducing leaching losses. For example, osmocote can be obtained with varying release-rate characteristics in various formulations. The high cost of some of these slow-release fertilizers, however, needs to be balanced against the advantages of the control obtained.

Growing Techniques

Traditional organic culture of soilless media is performed with the medium placed in a bed, pot, or can. Water, whether added with or without fertilizer, is distributed regularly by either overhead irrigation or drip irrigation into the container in amounts relative to the plant's atmospheric demand. As is the case with gravel and sand systems, the medium can need regular flushing with water to remove accumulated salts; a soluble reading of the medium itself or the effluent from the container may assess the need to flush. The container is typically discarded after one use although some growers have established interesting schemes to use the medium for more than one crop; one example is growing a tomato crop followed by an ornamental tree or shrub outdoors. The selling of the ornamental plant also offers the container and medium as a means of disposal.

Another growing technique is to plant by drip irrigation directly into the medium shipping container, adding the critical elements necessary and water.

The combination is usually supplemented with micronutrients and the main elements are added in a nutrient solution, the composition of which may be similar to that of a Hoagland / Arnon nutrient solution, with or without micronutrients, or some other formulations.

The nutrient solution's flow through the drip irrigation system must be adequate to meet water requirements. If plant growth is natural, there should be adequate elemental utilization to prevent significant accumulation of excess salts. If plant growth is slow due to poor external growing conditions, then only water without added elements is best applied, and the application of nutrient solution is resumed as growth conditions improve. In lieu of the Hoagland / Arnon formula, some growers substitute a mixture of an equal ratio of potassium and calcium nitrates, KNO_3 and $Ca(NO_3)_2 \cdot 4H_2O$, respectively, for a solution containing 100 mg / L (ppm) N. If this is achieved, adequate P and Mg must be in the medium to satisfy the crop requirement.

Different Application A special use of an organic soilless mix for long-term growing is a sub-irrigation method based on a technique first developed by Geraldson (1963) to grow staked tomatoes in south-western Florida's sandy soils (Geraldson, 1982). In fields where it is possible to monitor the water table level, raised plastic-covered beds are prepared with a band of fertilizer put on each side of bed. Tomato plants are put in the center of the beds, and the roots expand into the balanced region of the soil of water and elemental material. The author duplicated the same method by putting a coarse organic soilless mix in a watertight box to maintain a steady water table below the mix.

A growbox system of 4 x 30 ft (1 x 9 m), using composted milled pine bark as the growing medium supplemented with calcareous and fertilizer, has been successfully used to grow greenhouse tomatoes, cucumbers and snapdragons over a period of 8 years. The constant water table with a depth of 1 inch (2.5 cm) is held under 7 inches (18 cm) of composted milled pine bark with an automated float value system. No overhead water is applied. An elemental assay of the medium is used to apply fertilizer to the medium between crops. The tomato crop is regularly supplemented by a mixture of potassium and calcium nitrates, KNO_3 and $Ca(NO_3)_2 \cdot 4H_2O$, respectively, at a N concentration of 100 mg / L (ppm), based on a requirement determined by plant physical appearance and/or periodic plant analysis.

Over the 8-year cycle of usage the composted milled pinebark retained its original physical properties, requiring only minor annual contributions of new composted milled pinebark to retain the initial amount. Some boxes were initially packed with a peatlite mix that did not retain a strong physical character after the first year and was therefore discarded and replaced by composted milled pinebark.

The success of this growbox sub-irrigation method is primarily due to the continuously maintained water table, which helps the roots to grow to the ideal portion of the medium in terms of water, aeration, and elemental supply. The grower need not worry about watering on days of high atmospheric demand, because water is still available to the plant. Since the growing system is basically self-regulating, the grower may focus on managing the crop culturally.

The grow-box can be made to fit a wide range of uses in almost any scale, including outdoor family vegetable gardening (Jones, 1980). The only important factor is the depth of the organic soilless medium, which must not exceed the water table by more or less than 7 inches (18 cm). In this use, the composted milled pinebark seems to be the strongest of all the organic substances.

CHAPTER THREE

Hydroponic Lights

For safe plant growth hydroponic gardening needs three things. Air, hydroponic resources, and hydroponic lights special. Most hydroponic household gardeners grow their plants either inside a greenhouse or in their home or garage space. You may grow more plants in a smaller space since this method of gardening needs less room than soil gardening.

Installing the Hydroponic Garden

The home gardener may choose to buy a special package that includes all the containers and the water system for his garden when setting up this type of garden. To ensure that your garden grows as it should, you need to purchase special hydroponic nutrients that not only contain nitrogen, potassium and phosphorus, but also all the trace elements that your plants need to be safe. The type of hydroponic lights you'll need is going to rely a lot on what you expect to develop.

Hydroponic lights

If you're planning to grow a small-scale herb garden then you'll want to use hydroponic fluorescent lights for this sort of garden. Florescent lights are positioned near the plants, and they help to give them the light they need to grow healthy and solid.

Development in vegetables and fruits involves using hydroponic HID lights. In this style of gardening two types of HID lights are used. Metal halide, and sodium with heavy intensity. The Metal Halide lights are used to stimulate overall plant growth while the High Pressure Sodium is used to allow plants to bloom and bear fruit.

Now, there are HID lamps designed to allow you to use both the Metal Halide and the High Pressure Sodium bulb in the same lamp making it possible to have only one lamp instead of two. You're going to want to look for a Hydroponic Lights kit that comes with reflectors to help you guide the light where you want to go.

How Much Light Do You Need

The amount of light you need varies according to the type of plant you are growing. The amount of artificial light you'll need for your garden will depend on where you live and whether you're using a greenhouse or room with minimal outside light or not.

If you use a greenhouse for your garden during the late spring and summer months you would more than likely need very little artificial light. However, to supplement the sunlight during the fall or winter months, you would need artificial hydroponic lights, particularly if you live in an area where there is very little sunlight and regular storms that prevent the natural light from reaching your greenhouse.

Some rooms indoors rely almost entirely on artificial light because they have insufficient sunlight entering the plants. You simply have to give it the right amount of water, the correct hydroponic nutrients and the right amount of light to ensure that your garden grows and produces the way you want. Through supplementing natural sunlight with hydroponic lights, your plants can get the correct amount of light that they need. Hydroponics Light plays a significant part in your hydroponics project success. Most hydroponic gardens are indoors, and require some kind of lighting as such. While your hydroponics system that tempt you to try using incandescent bulbs and lamps for light, they will not provide the right kind of light that your plants will need to survive and grow. Hydroponics systems require full spectrum lighting that emulates the sunlight. Specific types of hydroponic gardens may also require a particular kind of lighting.

Many of you searching for a hydroponics package should find there's a variety of hydroponics lighting on the market.

Hydroponic vegetables grow best in the light of the blue spectrum, which is a more cool type of light. The most common type of blue spectrum illumination is metal halide lights. Plants that flower in hydroponics grow best in red-orange sun. High pressure Sodium Light (HPS) is the strongest form of red-orange light.

Blue spectrum light is perfect for leafy plants like Lettuce, Radish or Collard, for example. It also assists in keeping the plant healthy and compact. Many will find the plants becoming leggy in their hydroponic garden as it struggles for light, blue light helps to combat this. This is the best form of system light from hydroponics for a primary light source. The typical Metal Halide light provides good light for about ten thousand hours. This will then start pouring out less and less light. The typical sold Metal Halide light will put out a light range from 175 watts up to 1000 watts or more. The output of wattage that you select depends on how big your hydroponic system is. Just put together a small, homemade hydroponics kit or set up a larger hydroponics garden?

High Pressure Sodium lights that emit an orange-red spectrum last about 18,000 hours of use. Of flowering plants like paper whites and iris it is best. The orange-red light activates hormones in plants, which helps the plant flower more. Be careful that a young plant is placed under red-orange sun. It will grow really quickly but you'll only see vertical growth and it'll become lanky and thin. This is because the new plant lacks the blue spectrum light available. The mean wattage for red-orange lights is around the same, varying from 175 to 1000 watts. Naturally, if you want to cover more ground, you can find professional rising lights with a higher wattage in any range.

The easiest way to light up the hydroponics device appears to be with a blue and red-orange light mix, keeping plants compact and flowering. Or you just can buy a full spectrum flash. For that you can buy fluorescent lamps. They come in tubes or small bulbs. Fluorescent lighting is often used to grow seedlings, but a plant is likely to grow to maturity. This form of lighting can be an simple way to illuminate your hydroponic system without the hassle of hooking up blue and red-orange lights or recalling which one is.

Hydroponics agriculture-agriculture with the aid of hydroponic tents and hydroponic lamps. Hydroponics, better known as water culture, is a method in which plant varieties are cultivated under hydroponic tents and soilless hydroponic lights to provide nutrients to the plants. Instead of using soil as an agent to supply the plants with nutrients, water combined with minerals and nutrients is used as an agent for supplying the plant with all essential nutrients and minerals. Hydroponics has seen great growth, particularly in the last century due to the larger harvests that one could get while growing the plants under Hydroponics tents and Hydroponic lights, irrespective of the seasons and weather.

However, initial findings from the early 1900s showed that the yield from plants grown under hydroponic tents and hydroponic lights is by no means greater than the yield from soil-growing plants. There was a big development when the whole world believed that hydroponics is yet another hoax.

Wake Island, an island in the North Pacific Ocean, has been the place where, one may claim, hydroponics had some great success. The island barely had any soil for plants to grow, and the islanders were able to get good harvests by using hydroponic technique to grow the plants. Some of the important reasons why a lot of people still think hydroponics will be a big success in the near future is that the farmer will know precisely how much water he / she needs to use to grow a plant, unlike growing the plant in soil where he / she has far less knowledge about how much water he / she needs to be fed to it.

And, since the plants' roots are in constant supply of oxygen due to the hydroponic solution, the plant is usually much healthier. And there is a great possibility that you can door all of your gardening and farming indoors as the light needed for the plants is provided by the hydroponic lights and plant safety with the aid of the hydroponic tents. In addition, total rising costs less than half of what you spend on actual farming.

One of the great advantages that you have when growing your plants under hydroponic lights in hydroponic tents is that you can move the tent with minimal effort, and even recycle the water used to grow the plant.

Everyone has its own downside, hydroponics too. Although the cost of maintenance is very low as compared to actual farming, the starting cost of purchasing hydroponic tents and hydroponic lights is a little higher than that. To ensure a good harvest, the person who does hydroponic farming should have sound knowledge of the solutions to be used and the plant conditions. But most hydroponic farmers agree that hydroponic farming is nothing but pure pleasure once you're in it!

The Single Best Hydroponic Lighting System for Flowering and Budding Plants

Hydroponic lighting is the first important approach to plant production in hydroponics gardening, in which the nutrients are supplied through a solution absorbed by plant roots. Indoor Hydroponic Gardens. There are 2 things to do when building the lighting system in hydroponics: the light intensity and the light spectrum.

The early hydroponic device design employed regular fluorescent bulbs. Foot candle was the measurement device used to assess the strength of light. The light of one candle in that device is equal to one foot away from the vine. In the world of today, the same force is called one lumen. Grown indoors, the plants need 2,000 lumens per square foot.

The light is known to have various colors, in the light spectrum. Plants need growth of the blue and green wavelengths. Red and orange colors are important for budding, flowering plants. The light spectrum with a wavelength of between 400 and 700 nanometers should be visible for photosynthesis to take place.

Today's hydroponic lighting comes with different systems with different benefits and disadvantages. The fluorescent is the cheapest of all. Growing herbs is always a option. However this does not seem to be true all the time for hydroponic gardening. Bluest temperature with 5000 degrees of Kelvin is favored for vegetative plants. A warm light between 2500 K and 3000 K is required for flowering and fruit production plants.

The HID or High Intensity Discharge Light, the lamp produces light using high pressure gas. It has high lumen per watt, with a light output of 120 to 140 lumens for each watt of electricity used. To make them work, a ballast is required for the HID lamps. We get hotter though than a fluorescent one does. Most hydroponic gardeners do use HID, as it creates light that closely matches natural sunlight.

There are 2 types of HID lamps-the metal halide or MH that contain the blue light spectrum and high sodium pressure or HPS that emit the red light spectrum. The MH is perfect for promoting fast plant growth while the HPS is best for plants that produce fruit and flower.

A new lighting device, called Light-Emitting Diodes or LEDs, provides benefits such as less power consumption than most rising lights do. These also don't generate more heat, and can therefore be put closer to plants. The bulbs that are used always last longer and the light spectrum is adjustable.

Hydroponic lighting can use 2 or more systems to achieve optimum results. A more comprehensive lighting system in hydroponics is required in certain places where the sun doesn't always shine.

Different Types of Hydroponics Lighting

What does Lighting have to do with plant growth? Will plants grow better under illumination from the hydroponics? Does use of hydroponic lights improve success rate? Why does the growing plants system benefit from this? As everyone is aware, without the use of soil, the idea of hydroponic gardening is growing plants and crops. It contributes to large quantities of fuel, fertilizers, man power and energy saving. This idea is where the future will come as land shortages to feed the millions of people are felt. Many countries have a variety of hydroponic gardening systems in place and many more countries around the world are exploring the possibilities. As hydroponic gardening gives one the option to grow plants throughout the year it raises concerns about the need for lighting in order to grow plants healthily.

This method of farming is quickly gaining popularity and will save us from food shortages in the coming years and will keep us from going hungry. Plants need sufficient light to grow, and they derive their energy from sunlight. The biggest advantage is that you can grow your plants even indoors. Your car basement, balcony, and terrace could become a possible hydroponic farming network. Such areas may or may not have ample amount of sunlight, so hydroponic lighting comes into play at this point in time. This solves the lighting issue and thus gives plants and crops the energy required to grow and blossom.

Any of the types are you can choose from incandescent lamps, fluorescent lamps and high-intensity discharge lamps. If growing plants is a hobby you indulge in and have a small collection of your favorite flowering plant on your balcony or kitchen window, then the incandescent lamps are the perfect for this reason. These lights provide enough energy enough to grow the plant normally. They are comparatively inexpensive, and they are easy to repair.

Fluorescent lamps are suitable for starting seeds or cuttings using hydroponic lighting method. These can be conveniently fastened into the tray or fixture where the farming hydroponic device is adopted. You can have 2 lamps in one fixture in this form of hydroponics lighting. There are various sizes with the most common being the size of four feet. Small nurseries are ideally suited for these. High intensity discharge lamps are built for those for whom farming is an entrepreneurial undertaking. It is intended for people who are serious about hydroponic gardening and have acquired extensive knowledge of the various lighting systems in use. 400 to 100 watt lamps are used and can be further categorized into Sodium Pressure, Metal Halide, Sodium Low Pressure and Mercury Vapor. And depending on the size of the garden you want to introduce you can select the farming system and the lighting you want to use.

Hydroponics Success Grow With LED Lights

Hydroponics-the method of growing plants without the use of soil-was almost two centuries ago. Scientists at Berkeley and the University of California researched hydroponics in greater detail in the first half of the twentieth century, and promoted it to produce agricultural products.

Hydroponics was all the rage in the world of botany for a couple of years in the 1930s and scientists made major statements about higher crop yields and more productive land use. However, in 1938 the more overblown arguments regarding hydroponics were debunked by an agricultural paper by Dennis Hoagland and Daniel Arnon They argued that hydroponics had many limiting factors, especially the quality and the amount of light.

Indoor Grow Lights

Later in the twentieth century, when more powerful indoor growing lights were invented, Hydroponics received a boost. However, the high intensity rising lights (HID lights) still had some inconveniences. They were generating an enormous amount of heat for example. This heat has meant that additional fans and/or complex ventilation systems had to be used in confined spaces. The heat and intense light created by a HID light tended to scorch plants as well.

Hydroponics is gaining a second wind today, thanks to researchers rising with led lights. As part of its ongoing work into Controlled Ecological Life Support Systems or CELSS, NASA, for example, is experimenting with hydroponic plants that thrive with led lights. The most prominent CELSS was Biosphere 2, the massive glass facilities in the Arizona desert that grow food using hydroponics.

The Future of Hydroponics

Now that hydroponic plants can grow very effectively with led lights, hydroponics could enter a new age of experimentation and study. Because LED lights don't have the unwanted side effects of generating excessive heat and distracting types of light, they can be used in small spaces without needing fans to cool or external ventilation systems.

The range of light emitted by LED rising lights is being refined as the LED technology continues to advance. Perhaps one day, hydroponics and other indoor gardeners will be able to grow with led lights built specifically for the plant or herb they want to grow. Not only NASA but every hydroponics enthusiast will finally be able to conquer the obstacle of sufficient light that Hoagland and Arnon so long ago established as the key barrier to successful hydroponic efforts.

Speed Up Your Growth With a Hydroponic Light

The origins of hydroponic gardening can be traced back to the ancient Egyptian period, as some Hieroglyphic documents have shown. Some claim that the technique was also used for growing cucumbers in the ancient Babylon Gardens, as well as by the Roman Emperor Tiberius. The modern day history dates back to the 17th century, when John Woodward experimented with soil-free production of spearmint. It has been noted from the experiment that the soil-free spearmint grown using this technique was stronger and larger in size than the organic spearmint.

A hydroponic kit is a soil-free crop growing process, in which water is used as a medium to supply plants with nutrients rather than soil. A significant benefit over conventional approaches is its immunity to rodents and other waterborne illnesses. These kits do not require fertilizer use or the crop rotation rule. Growth of weeds is highly restricted because of its sterile environment. It thus makes for more efficient use of time and energy.

There are different types of soil-free plant growth kits, including the Aeroponic System, the Ebb and Flow system, and the Wick System. Aeroponic method requires the use of mist to spray the plants nutrients. Ebb and Flow method involves the pump flooding with water a rising container and then draining it back into a tank. A Wick device consists of a water tank and a rising tray that is put above it. The two are linked by a wick. This is one of the simplest hydroponic system types, and is preferable for beginners.

Typically a hydroponic system consists of containers; water tank, growing medium and a water circulation pump, some of which often come with a light to assist with indoor gardening. In an artificial gardening device hydroponic light is undoubtedly one of the most critical components. It can be contained in various intensities, and thus serves different purposes. They're specially made for gardening indoors.

Spotlight bulbs, Led Grow Lights, Metal Hallide, High Pressure Sodium and Rail lights are the principal forms of hydroponic light. The most common and cheapest of these spotlights consists of a small bulb and provides artificial lighting. Led Grow saves substantial space because of its slim properties. Metal Hallide provides light similar to natural light and heat properties which promote plant photosynthesis. For large greenhouses, where individual lights are hard to mount, the Rail lights are preferable.

The Hydroponic light is an essential part of the soil-free pack. The strength of it will decide your indoor garden's growth rate and provide an artificial lighting medium in the absence of natural light to ensure your garden's continued and proper growth.

LED Grow Lights

Has LED light day finally arrived? This is a problem that many, and with good reason, eco-minded hydroponic gardeners have been asking themselves with years now. Research on the web explains different light spectrums and realistic watts per square foot ratios that sound incredible, but there is very little practical advice on the topic for the inexperienced gardener. Especially when they ask the question-is it time to buy?

Are LEDs useful? Completely. Totally.

Driven lighting has obvious benefits that mean they're here to live.

The extended life span is between them first. You actually won't need to change the bulbs for the typical LED owners. These incredible bulbs have an average life span of around 10 years, or 25,000-100,000 hours. Another major advantage is the absence of a heavy ballast and chords. Since LED lights weigh less physically, they're easier to mount, take up less room and are less susceptible to fire.

The enormous advantage is energy conservation. In addition to the extended bulb life, LED lights mean a reduction of the landfill's conventional mercury filled bulbs. There is little energy loss by heat generation, which means more productivity due to a reduction in cooling costs as fans and air conditioners are no longer required by the hydroponic gardener to maintain a steady temp. Driven through lights produce much less heat than their counterparts with HIDs.

Despite their many benefits, the fact remains that the risks associated with the modern technologies make this a burdensome option for everyone but the hobby grower. The key danger of using LED lighting instead of conventional HID lights is of course lower yields or poorer quality product. This is a very real problem, despite claims from corporations for making LEDs. While the promise of the savings associated with eliminating one's energy costs is seductive, the current decline in yield does sadly not easily compensate for those savings.

Synopsis: LED lighting is still the future, but it's still the future. Using this tool right now to light up the parks, workplaces, traffic lights and other applications.

The benefits are still not significant enough to justify a full switch for the

Experienced Hydroponic Grower:
To the grower / environmentalist novice: Go ahead and try it. Increased sales will only help young companies grow, and will help improve this great technology all the faster.

Using Grow Lights For Indoor Soil and Hydroponic Gardening

For growing healthy plants the use of growing lights for indoor and hydroponic gardens would be of great importance. Plants use the energy from the sun to transform carbon dioxide through photosynthesis into organic compounds. Indoor soil gardening and hydroponic gardening need this light that grows lights produce. Nowadays, high pressure sodium (HPS / SON) and/or metal halide (MH) lamps are the most commonly used grow lights for indoor and hydroponic gardens. Using reflectors, the lights from these HPS / SON or MH lamps are usually directed to your indoor or hydroponically grown plants. In this way light is generated in the most effective manner for your indoor garden.

For indoor soil gardening and/or hydroponic gardening several types of growing lights are available: • Incandescent lights are usually used to highlight indoor plants and are not "real" growing lights.

• Fluorescent growing lights are useful for growing vegetables such as leaf lettuce, spinach and herbs or for jumping by growing seedlings using this lighting season. High performance fluorescent lamps emit much more light than a fluorescent standard lamp. There are compact fluorescent lamps in house. These are smaller and are used for propagation as well as for growing bigger plants.

• High pressure Sodium lamps appear to produce taller plants with longer stem growth. In general, they are used in greenhouses as secondary lighting, where plants receive their main source of sunlight rather than rising lamps. Plants grown with this form of lighting appear to look bland and washed out but in general the plants are good.

• In dual reflector systems, the mixture of high-pressure sodium and metal halide grow lights. Manufacturers claim these lights create an optimal combination of spectrum and high outputs. This style of lighting really is a compromise. The lamps use two smaller lights instead of one larger light, so the time that the light penetrates is shorter.

• Switchable, two-way, and reversible lamps in the same fixture will burn either a metal halide bulb or an equivalent high pressure sodium blue. Such lamps must also be swapped out and can not be burned simultaneously. First plants are cultivated for propagation and vegetative growth under the metal halide sun. The transition to the high pressure sodium bulb has to be made for the fruiting and flowering periods.

• LED grow lights are relatively inexpensive, bright and durable. As they do not consume as much fuel, they are attractive to indoor gardeners and hydroponic gardeners. Today's technology makes LEDs an attractive choice to develop.

In combination with and to increase light directed at the plants, indoor gardeners and hydroponic gardeners often cover with light reflective materials the walls of their growing enclosures. It can range from light-transparent white paint walls to transparent isolating panels along with a variety of other materials. This controlled illumination directed towards the plants. The larger plants are getting the brighter they deserve.

Light for various plant types and sizes should be controlled with the use of a timer. Seedlings require fewer planting hours than medium or fully grown plants. Lighting hours for seedlings will start at 4-6 hours, and then growing as your plants grow. The rule of thumb for medium or fully matured plants is eight hours or more a day.

Indoor gardening and hydroponic gardening give people who love to work twice as much (or more) gardening time in their gardens as seasonal changes do not impose restrictions on growing vegetables, herbs, flowers, berries, etc. Indoor and hydroponic gardening is a smart way to start gardening for senior citizens as planting beds can be elevated to reasonable heights. No more backbreaking digging pits, weeding, and bending and stooping all that.

Growing lights are important for indoor gardening and hydroponic indoor gardening for photosynthesis development, and generally accelerate your plant growth.

CHAPTER FOUR

Hydroponics Supplies

What equipment you need to get started with hydroponics? Let's take a look at some of the hydroponics basics to help make your venture a success. Hydroponics is an indoor gardening method that uses hydroponic nutrients, rather than soil. This nutrient solution gives the plants all they need to grow well. There are many specific forms of hydroponic supplies you'll need if you'd like to hydroponically start growing plants.

Of course not everyone wants the same supplies of hydroponics-what you buy can vary depending on the type of device you choose to use. Many systems require a tank or wide bath, an aerator and pump to push around the solution to keep it oxygenated properly, and a means of keeping the plants above the water, such as a tray or net. The roots have to be able to come to the solution without drowning the plant.

Lighting is also a huge preoccupation. Please be sure to test your lighting choices when purchasing hydroponics supplies. If you are trying to grow large numbers of plants, or plants that normally need a lot of sunlight, you would need to buy relatively strong lights. Note-the intention is to imitate the sun's light. Some growers select lights primarily in the blue and green spectrum to encourage faster growth, especially in seedlings. Yet those are not the only lights in the supplies portion of the hydroponics.

You'll also need red-spectrum lighting. Those mimic late summer lighting, and help to encourage fruiting and flowering in mature plants. Try using reflectors to improve the visibility of the sun. Using digital ballast to monitor the power flow, which will help to keep the lighting even. Some lights of course run pretty fast. Use the fans from your hydroponics supplies store to cool them off and stop scorching or wilting your plants.

It is essential to develop the medium, too. You may buy a commercial product, or use a kit or chemicals to blend your own. Add a cloner, and you'll get a complete hydroponic supplement. It takes a bit of an investment to get things going, but when you grow your own hydroponic plants indoors, you'll be glad you made it! Take a bit of time to evaluate your available room and budget, decide what you'd like to expand, and find out which supplies are available to you.

Create a list before going shopping, and make sure to compare prices before buying. You'll end up with a variety, and the opportunity to grow plants like you've never had before. To get the best results out of your through efforts, choose the right hydroponics supplies. You don't want to be sorry.

Many who are new to hydroponic gardening sometimes overbuy on supplies they do not need when starting out first. After all, the most basic hydroponic supplies you need in and around your home when you start can be found readily! Using these first before expanding to hydroponic supplies which are more costly. Starting tables for your plants may include things as simple as plastic tubs and a swimming pool for a kid!

You can wish to buy a package called a hydroponic gardening package called 'plug and go.' These kits will include all the nutrient solution, plant blocks, heating pad, and seeds you need. The only supplementary things you need to add are sun and water.

As a hydroponic gardener you'll need a dedicated gardening room. A 'development room' which is simple to install is preferred for the beginner. It can typically be fully assembled in less than an hour and depending on the features the price will vary from $250 to over $500.

A small greenhouse may be much more expensive. The cost of a greenhouse will vary from $500 to several thousand dollars, depending on the features. Usually a greenhouse would need a cement floor and drainage system, or some other form of flooring like gravel.

Depending on how many plants you grow in your growing room or greenhouse a temperature control device will be required. The hotter your greenhouse will be usually the more plants you have. The temperature control unit is set to turn on fans or blowers. It can also be programmed to open and close the air ducts.

Hydroponic gardeners often use a different form of illumination-lighting in the blue and green spectrum. These are instrumental for the growth of plants.

You should upgrade to a more sophisticated irrigation and drainage system as you become more experienced in hydroponic gardening. The types and quantities of plants that you grow will decide what other equipment you'll need.

A temperature control panel, light fixtures for your blue and red spectrum lamps, heating pads, exhaust ventilator, aeration system and other incidentals are the usual hydroponic supplies that you can buy over time.

In a hydro shop beginners can consider all of their hydroponic supplies. They specialize in the selling of hydroponic gardening supplies and are very helpful in offering practical and useful advice. You can also find that the fellow gardeners are more than happy to help.

Info On Hydroponics Supplies

Hydroponic systems provide a method for greenhouses or home hobbyists to develop plans by using mineral nutrient solutions as an alternative to soil. The market currently includes several different hydroponic systems. While the use of hydroponics was not known until the 1800s, hydroponics became a key player because of their ability to be used where the soil and/or environment can not sustain increasing plant life.

There are a number of benefits of using your one of the many hydroponic systems for indoor gardening:-plants growing indoors that use hydroponics tend to grow faster than their counterparts grown in the soil-indoor gardening can be done year-round-hydroponic systems can be installed in small spaces anywhere; suitable for hobbyists and classrooms in the apartments; Any of these hydroponic supplies are:

-fans

-air cleaners

-huts

-ionizers

-pumps

-lighting systems

-cooling systems

-items for scent control

Various systems are available; but there are only a select few hydroponic systems on which the others are based. Such hydroponic systems are:-Ebb and Flow: this works by periodically flooding the bed of the plant with the aid of a pump and at various fixed intervals. This pump will for a short time fill the plant roots with nutrient solution. When the timer turns off the pump the nutrients are drained back into a holding tank, supplying the plant roots with a rush of oxygen.

-- Drip: This hydroponic device is often operated by a pump and a timer, and can be used either as a recovery or non-recovery. This method drips nutrient solution at the plant roots when storing and re-using the excess nutrients inside a holding tank. The non-recovery indoor gardening drip system works the same way, except it does not encourage nutrient accumulation, and does not recycle the waste.
-- Nutrient Film Technique (NFT): This worldwide used growing method has been developed to enable plants to grow in areas known for their deprived soil quality. This device allows to position a slow moving stream of fertilizer solutions (film) over the plant roots that have been put on sloped channels. Once this stream reaches the end of the pipe, the stream runs into a holding tank and is used again during the next feeding period over the plant roots.
-- Aeroponic: one of the hydroponic systems containing on top of the plant rooms a persistent thin mist of nutrient solution.

What to Look For When Buying Hydroponic Supplies

If you're a person who loves gardening, then you need to learn about hydroponics. The word "hydroponic" comes from the Greek word "hydro" meaning water, and "ponos" meaning work. It is the most recent craze among gardeners worldwide. It includes growing indoor plants, but with the same freshness as those grown by conventional methods. Through this method, plants are grown in the absence of soil, using only water and mineral nutrients.
A conventional gardening technique requires the correct weather to grow specific plant types; however, a hydroponic kit allows you to experiment with different plant types because it does not need any particular weather. In addition, it also saves you from the trouble of putting on fertilizers or other forms of pest control. Because no soil is used, soil-borne disease threats from the plants are absolutely eradicated. Their growth is higher than other commonly grown plants because the nutrients are placed directly into the plants.
Before buying hydroponics supplies you need to note some important points. These come in different configurations including the Aeroponic system, the Ebb and Flow system and the Wick system. A typical device consists of tanks, water tank, and water circulation pump, a increasing medium, and a light for indoor gardening. This makes starting a diy garden perfect.
If you're going to purchase one of those kits then look for the basics.

Even the hydroponic supplies depend on the type of plant you want to grow. So make sure the kit you're buying is appropriate for growing your desired plant. The Wick method, for example, allows for simple setup and maintenance, and is thus most commonly used. It involves a tiny hole being formed and a wick being inserted through that hole. In an Ebb and Flow method the rising medium is positioned directly on the nutrient-filled tub. Every few days, the pan is replaced. Rotary absorption is maximized because the root surface is in close contact with water, oxygen and nutrients.

Of these the Aeroponic system is the most advanced. Plants are held without any growth medium or rock, allowing the plants to take in more air through their roots. Certain things that you should bear in mind are through media such as clay pebbles and coconut fibres. You have to pick the one that fits your plant's unique needs better. Be careful when buying them, as a low-grade growing medium can actually impede your plants' production.

You may want to take a look for the correct supplies online. There are currently several specialist online resources in this field of gardening and you will also be able to find a lot of information to support you along the way.

CHAPTER FIVE

Hydroponics Grow Box

If you've wanted to grow your own plants, then you need to make a decision right now. Do you want hydroponics to grow your plants indoors, or do you want to grow your plants outdoors in nature. Growing outdoors and indoors with hydroponics pose many advantages and disadvantages. This paper will address the similarities between growing indoors with hydroponics and growing outdoors with soil, and the many benefits of growing indoors with hydroponics versus growing with soil.

Let's begin by speaking outdoor gardening. Outdoor planting has many advantages and drawbacks over hydroponics indoor growing. Next we are going to think about some of the benefits of developing outdoors. This is the sun. This sun is the brightest light bulb you'll ever find. The amount of lumens put out from the sun is not balanced by any light bulb that can be created by man. This means that plants which are grown in nature with direct sunlight will grow like monsters. The light costs nothing to you. Unless you own a nice piece of land that is, light bulbs can get a little expensive versus this sun which is in a massive source of free energy. As you grow in nature, you have to deal with getting water to your plants. You would need to develop some form of irrigation system to make sure fresh water gets to your garden. If you carry the water with a pump and generator from a river, or water your garden manually every couple of days, this will entail some work set-up. You never know who could come across your garden and trespass as you grow outdoors too. Animals will also eat your new fruits and vegetables you've spent so much time growing up. Not to mention the outdoor pests that threaten your garden outdoors and cripple your crops.

However with hydroponics you can start growing indoors using a grow enclosure. If you grow indoors with hydroponics, I would highly suggest purchasing a pre-constructed hydroponics grow box [http:/www.homegrown-hydroponics.com] to easily grow your indoor garden throughout the year. A hydroponics grow box is a system designed specifically for the purpose of growing plants indoors hydroponically without mess, and not a hike away. A growing box will also contain a light, hydroponics, some sort of device, and timers, as well as the nutrients and everything you need to grow a plant in a self-contained growing cabinet. The grow boxes are delivered assembled and ready to use when you get them so no problem setting them up like the outdoor garden which takes a lot of time to plan, working in the hot sun. Everything you have to do is simply push the grow box into a space and after you plug it in, you're ready to expand.

You have full power of your growth with a hydroponics grow box. You don't depend on nature or the seasons of the sun, so you can set and forget your timers for the maximum production. You have full power over when the water pumps are used to get water from the farm. You have more leverage over your hydroponics because you know you're not going to have rats and other forms of intruders. So growing indoors is more convenient, healthier, and much cleaner than growing in the soil outside. If you think the yield you get indoors is as high as the yield you can get outdoors, it's a no-brainer. Hydroponics indoor growth is the way to go ...

Constructing a Grow Box

What one is cheaper, buying a growbox for hydroponics or constructing your own grow box for hydroponics?

Lately, if you've spent some time in forums, you'll find that quite a few people are suggesting that beginners build their own hydroponics to grow box machine for their first development. How does the novice or amateur really know about constructing a hydroponics box grow? When you're about to embark on an attempt to create your own grow package, there are plenty of safety issues you really need to remember. Just think about how much power you actually do, and how to properly wire it. In close proximity to water you will be dealing with a very high wattages and a harmful amount of energy. Know you healthy how to work around water with electricity and high voltages? Do you have hydroponics background in cabling applications. Do you know the difference between live wires and cables on the ground? Essentially at some point you'll probably need a licensed electrician to supervise your job and make sure it's safe and operate. Failure to do so can have devastating consequences for many bad growers.

Besides being a professional electrician, in keeping your hydroponic grow box running super cool, you really need to know your ventilation stuff. To light your hydroponics grow box rig, you'll be using very efficient lighting systems. To light up your grow box rig, you can use 600 Watts, or even 1000

W lamps. These types of lamps are known to produce enormous amount of heat. Many people in the forums would recommend that you build your hydroponics from some kind of particleboard or cheap painted wood to grow box. This is a bad idea, absolutely! Threat! Peril! Threat! Peril!

I've seen a number of posts where users are going to suggest that beginners build their hydroponics grow box from cheap clothing cabinets and constructed from wooden furniture found in hardware shops such as Home Depot. Can you imagine how dangerous it is to place 1000 W high-powered lamps inside a wooden closet which I was meant for clothing and is nothing more than a particleboard. Not a suitable material to make a growbox from. If you know what you are doing, really. Wood is among the worst materials you can use while making your own hydroponics grow package. And I would consider using metal. Metal however is much more difficult to deal with. Another justification professionals would buy it. For protection and durability a good growing box should be built out of metal. Metal is very hard to work on, and impossible to do alone.

There's no way you can get into bigger trouble than making your hydroponics grow box catch on fire can be an problem when it's made from a hardware store wooden cabinet. Fire is a common amateur mistake that occurs more often than you know when you're thinking about combining large concentrations of electricity and water together in a very small space or enclosed space like in a wooden case. Also trying to save beginners money and those on a budget won't be using sufficient fans to keep their through box system running cool. There are very strong fans to keep your grow box running cold, because heat will kill your plants. These fans must also be set up in a very particular configuration so that they can operate properly. To get a really good yield you just need to learn a bit about the ventilation to get the best plant growth is a rising box to avoid starting a fire in one you build on your own.

Many forum members suggesting building your own hydroponics grow box fail to mention a lot of items that are needed to build a good growbox system from scratch. Often you'll see user posts on a forum saying you can create a grow box that's much cheaper than what the commercial grow box manufacturers sell for. Is that really true? Can we believe we read all on a forum? How do we know those posting the messages about qualifications? People like chatting, but on forums they can hardly walk the walk. Of course some know what they're talking about, but you have to be an expert to know the difference between those who are eligible and others who aren't qualified to offer advice on how to build your own box. There's plenty of false and inaccurate details going around like flames on his forums.

These kinds of remarks about creating your own hydroponics grow box [http:/www.homegrown-hydroponics.com] at such low prices is totally insane when a hydroponics supplier buys parts for their inventory or buys directly from the suppliers, mainly in the case of quantity and having the lowest selling prices you don't get! If you buy one off parts from a hardware store you pay a very high rate for the full discount. You don't get any discounts on any of the items you purchase when you purchase in small quantities from a hardware store one at a time. You pay a huge premium on everything you buy plus you even pay tax and waste gas.

Besides, there are hundreds of small parts that completely slipped your mind that you will actually need to build your own growbox, such as junction boxes, lighting systems and reflectors, ballasts and pumps, to name only a few. Of all these necessary bits, you'll pay the top dollar. Yet the costs just aren't stopped there. On top of that, I'm sure there are plenty of options to use to build your own hydroponics grow box that you probably don't already own. To build the proper hydroponics grow box from parts from the hardware store you will need a range of types of drills, saws, cutters and all types of lighting and an electronics like timers.

Oh and not to mention, besides the tools, you're going to need all the accessories that go with these devices that can be really pricey when you buy from Home Depot or Lowes. Maybe if you're fortunate you can own some of these devices but definitely not all of them, and certainly not the right attachments in the right sizes. And now you're buying all the equipment and all the products at complete retail costs, instead of just purchasing small pieces. Are you going to use all these resources that you used to create your hydroponics box to expand later? I definitely hope so, because they are costing you enough!

Now you have a whole garage full of parts and you'll have to find out how to put them together from scratch based on on online sketchy plans. Think how much money is worth your money too? It can take quite a while to build this kind of project. Often it may take two weeks or months or more of a complicated period for basic design. Did you think your concept works very well? Have you ever designed one of those boxes that grow? How eligible are the people in the forums who suggest those box configurations that they are creating. How is there an lack of know-how? How many boxes have they designed and what makes them eligible to provide guidance on how to build a grow box? I don't follow the advice of someone with little or dubious experience who posted on a website anonymously? It's very difficult to ask what someone's true credentials are because you really ask nothing about them. And you have to take with a grain of salt what you read on the forums.

Now let's consider buying your own box increasing hydroponics from a reputable supplier who has been developing box machines for many years and has a lot of experience. Keep in mind that the company involved in making hydroponics grow boxes every day is a company for this. Everything they do during the whole day revolves around building the best boxes they can create.

In research and development they have done a whole lot to come up with the new designs they use in their products. If you're a professional growbox manufacturer you get a lot of input from customers who bought the units, so they can make suggestions for potential box design improvements. Not to mention experienced grow box manufacturers have been making a product for a while and understand both inside and out their products. Obviously, when you have input from hundreds of consumers of a specific produced product you can see how much a grow box can be enhanced. So naturally when you buy from a reputable box manufacturer who grows hydroponics you get a well-built product from an expert in their industry.

When you take the time to build your own hydroponics grow box there is no guarantee that the first time you'll get it right. But when you buy from a reputable hydroponics grow box supplier chances are the growbox that you're going to perform reasonably well only based on the business from which it originated. You know the amount of light that is used in the growbox would be safe to handle as the manufacturers know what types of fans to use to keep the growbox machines working cool and secure.

You know the wiring in that professionally designed grow box would run healthy because trained electrician had done the electrical wiring. There'll be no mess when you buy a growbox versus creating your own growbox. Typical growbox manufacturers will send out fully assembled units ready to grow the day you get them. And when you buy a professionally constructed hydroponics grow box chances are that it will actually be quite a bit cheaper than building your own when you consider all the money you save on those little tools and all the little parts plus the time added together a grow box purchase would cost a lot less money than building your own, and will be guaranteed to work.

It's my opinion that building your own hydroponics growbox would have little to no benefit unless you are an expert in electrical, metal working, wood working and learning the science of hydroponics inside and out. Those types of people who already use software and have certification styles might probably create a very nice grow box on their own. For the rest of us who have little to no experience in the various necessary fields, I was certainly recommended that you play it safe and go with the that box of pre-build hydroponics is sure to function and be safe to use.

Nevertheless, if you do want to try to create your own, I would recommend that you take a look at the video on this website for hydroponics. They have some of the best growboxes I've ever seen, and look rock solid in their style. If you're trying to make one yourself make it as these guys have. We know their stuff very well. Or think better yet about buying one, and saving your money. So when you want to do so, it is always entirely up to you. I just figured I'd throw out some of the usual mistakes newcomers posted in the that boxes that went wrong in the past on forums.

Fluorescent Lights in a Grow Box

The value of a fluorescent light in a hydroponics grow box When most people are looking for the first time to buy a hydroponics grow box, they always look at the primary light wattage which is included in the hydroponic device. Generally speaking, it's best to get the highest HPS or Metal halide light you can. The explanation for this is that the higher the yield you'll get, the more lumens the light can put out. So often the first question from a lot of people's mouths will ask for the wattage of the primary light when a first buy a pre-build hydroponics grows package. These are good questions to ask because you may forget a minor factor.

When you start seedlings or clones first you don't want to place them in a very powerful light. The explanation is that the plants at this stage of their life are very small. A plant of this small size need not be overwhelmed by a super-powerful high-pressure sodium light which is much too much for a small hydroponic plant. That is where the vertically installed fluorescent lamps first get in. When purchasing a hydroponics grow box seek to find a package which is sold on the side of the grow box system with T5 vertically mounted fluorescent lights. The more vertically mounted fluorescent lights are always the easier to develop in a hydroponic tub. The main difference to bear in mind here is that the fluorescent light for your tiny seedlings sends out just the right amount of blue light. The fluorescent light would not overpower the tiny plant at this early stage of growth is a much safer option. In the cool blue spectrum the fluorescent light is ideal for their first few weeks of vegetative development. Starting seedlings and clones with vertically installed fluorescent lights is undoubtedly the best approach rather than placing them at this early stage of their growth under too powerful HPS or MH lights.

In addition to only starting seedlings and clones, there are additional benefits of having vertically positioned fluorescent T5 light in your grow box. Later when your plants begin the cycle of flowering the plants can sometimes grow up as much as four times in size from where they were during the vegetation period. During the flowering part, as your plants develop so thick and bushy, so much of the light will be absorbed by the tops of your plants a little going through the dense canopy above. That ensures that the canopy absorbs much of the lumens from your high pressure sodium or metal halide light and does not make it farther down the bottom of your plants, where they can do some real good. Vertically mounted T5 fluorescent lights will give you plants in their vegetative stage additional light on the underside to help them grow all those leaves and mass you will need to get a good yield.

CONTAINER GARDENING FOR BEGINNERS

A beginner's guide for growing plants, herbs, fruits and vegetables in pots, tubes and other containers. How to create your perfect garden safely

CHAPTER ONE

Hydroponic Cropping

Upon initial commercial implementation of hydroponics, only three crop species were widely grown: tomato, basil, and lettuce. A large variety of crops (i.e., cucumber, pepper, strawberry, roses, and potatoes) are successfully grown hydroponically today. Even so, most commercially available hydroponic systems are still based on either tomato or herbal and lettuce growing requirements. The author visited a hydroponic greenhouse in the early 1970s where the grower successfully moved from growing tomatoes to chrysanthemum flower production in a gravel-sump ebb-and-flow method (sometimes referred to as flood-and-drain) using the same procedures as those for tomatoes. It indicated to me that many different plant types could be successfully grown hydroponically, although the chosen hydroponic system was not planned specifically for that crop. This continues to be proved true after the initial encounter. Today, using mainly two nutrient solution distribution methods, ebb-and-flow and drip irrigation, a wide variety of fruits, flowers, and even tree crops are cultivated hydroponically. The only exceptions will be for herbs and lettuce, where the Nutrient Film Technique (NFT) approach is favored (Christian, 1997, 1999; Furukawa, 2000; Morgan, 2000b; Alexander, 2001a; Smith, 2002c); and some lettuce growers do use the raft system (Morgan, 2002f; Spillane, 2001).

On view at the Kraft Show in the Disney EPCOT Center, Orlando, Florida, an outstanding example of what is possible hydroponically can be seen (Ricks 1996). Visitors who take the boat ride through the show can see several different crop plants developing in various hydroponic setups. Another fascinating application of hydroponics is at the Hydroponicum, located on the west coast of Scotland (Savage, 1995; Farquhar, 2003). A closer look at these rising systems, and what experiments are being performed but not on show, can be seen if the visitor takes the "behind the scenes tour." In three dif-ferent climatic regimes within the Hydroponicum a variety of temperate to tropical plants are being grown hydroponically. Many of the plants are grown in a specially built Pyramid Pot in which a passive Wick System provides the nutrient solution, both created by the

Hydroponicum founder Robert Irvine (Savage, 1995).

For the most part, hydroponics and growth are associated in an environmentally regulated setting, such as a greenhouse, as hydroponics is usually not considered a method of growth in the open (outdoor) world. Nevertheless, it is important to note that open-environment hydroponic systems were commonly used during the Second World War, when vegetables were hydroponically grown to provide fresh produce for troops serving in the Pacific camp areas. Following WWII in 1950, the author visited a number of hydroponic farms in southern Florida; in ebb-and-flow gravel beds, the crop cultivated was tomato. Some of the early hydroponics literature in the 1950s and '60s.

Today, much of the existing hydroponics literature addresses this problem as a type of "Regulated Agriculture Environment (CEA)." Hence, much of the success associated with hydroponics may have more to do with advancements in environmental management than those associated with the hydroponic system used. One wonders if the future of hydroponics as a major crop production system lies in settings other than open field, as it was in its initial years of use.

Hydroponic growing systems differ in size, operating characteristics and reliability, and are typically more costly and operationally complex than most other growing methods. High value cash crops (such as tomatoes) or specialty crops (such as herbs) are therefore more frequently selected for hydroponic production than lower cash value crops. While initial costs may be high, hydroponics as a crop production method can be highly profitable. Several of the major drawbacks of hydroponics are the high cost of capital for most widely used growing systems, regular incidences of root disease, and possible insufficiencies of nutrient elements. However, these issues are being tackled and strides are being made to solve the cost problems and insufficiencies associated with the hydroponic growing process.

It should be recalled that hydroponics is not a good panacea, irrespective of what crop is being grown or what growing method is being employed. For general, even if a hydroponic growing technique is used, the cultural requirements for a crop do not change. In certain cases, greater ability on the grower's part may be needed to be effective when using a hydroponic system.

Hydroponics will not invalidate the plants' genetic character; plant growth and fruit production do not surpass what is genetically feasible regardless of the growing method employed.

Hydroponics provides the ability to monitor the water supply and the vital elements to plant roots, thereby ensuring a continuous optimum supply, which in turn will boost plant efficiency. Greenhouse-raised crops such as tomato, cucumber, pepper, and lettuce may be cultivated over a longer period of time than is feasible for the cultivation of land. Hence yield comparisons may be misleading for that hydroponically grown versus grown-grown soil, for yields are likely identical if compared equally.

For example, hydroponic development may be the only choice when growing conditions are such that no other growing method is suitable due to poor soil conditions and extreme climatic regions, and for growing in outer space and roof-top gardening (Wilson, 2002a).

The growing interest of the public in wanting to purchase "organically produced" produce can have a huge effect on the future of hydroponics (Parker, 1989; Morgan, 1997c; Landers, 2001). Being only pesticide / herbicide-free is no longer the only aspect that draws environmentally friendly customers who are searching for "organically grown" food items. Schoenstein (2001) notes that "in addition to organic, environmentally-controlled, green-house agriculture enables farmers to enter more niche markets because of their ability to expand a crop to a much longer seas With the increase in North America's massive, large-scale greenhouses, the value of conventional off-season output is declining while the demand for organic crops remains high. "The change from inorganic to organic hydroponics will involve the creation of suitable growing media and formulations of nutrient solutions that qualify as organic. Schoenstein (2001) describes a greenhouse operation which uses an organic NFT growing system to produce lettuce and herbs.

Progressive Developments

The original hydroponic growing system was the form of standing aerated nutrient solution, a process considered unsuitable for commercial use. However, Cunningham (1997) explains the use of this technique (which he defines as the modified Gericke method for growing green bean, tomato and zucchini squash, a device that does not need electrical power and is fairly easy to use. Kratky (1996) explains the general principles and concepts of a non-circulating growing method for hydroponic growing lettuce, tomato,

Wilcox (1983) published a detailed analysis of those hydroponic systems currently in use around the world, water or solution culture, sand culture, aggregate culture, and nutrient film style at that time. The ebb-and-flow process (Fischer et al., 1990) was the original hydroponic growing technique for commercial applications and was closely followed by the gravity flow bed technique. Many methods have different uses, such as the lettuce raft system (Spillane, 2001; Morgan, 2002f) and the aeroponics (Nichols, 2002; Wilson, 2002b).

In 1979, Cooper's (1979b) developed the Nutrient Film Technique (NFT) was hailed as a groundbreaking move forward that would alter the hydroponic growing process for all crops. Yet this hasn't proven true (see pages). However, Smith (2000) mentions many places where the NFT approach is used for tomato growing (Christian 1999), strawberry, and pepper growing. Smith (2001e) offers guidance on the use of this method for tomato growing. Today, both the NFT method (Alexander, 2001; Smith, 2002c, d) and deep water NFT (Jones, 1990) are mainly used for the processing of lettuce and herbs in hydroponic form. Morgan (l999c) defines the various gullies and channels designs for use in NFT applications. Smith (2004) also offers guidance for designing and producing NFT gullies.

With the implementation of drip irrigation at a particular point and precise amount, water and/or a nutrient solution could be dispensed. Using this method, growers can grow hydroponically in inert media containers, such as perlite (Day, 1991) in bags (Bauerle, 1984) or BATO buckets or blocks and slabs of rockwool (Smith, 1987; Sonneveld, 1989; Van Patten, 1989, 1991; Johnson, 2001a). Today this is the primary technique of choice for tomato, cucumber, and pepper rising. Organic ingredients, such as composted milled pine bark (Pokorny, 1979) and coconut fiber (Morgan, 1999b), which have an environmental benefit over perlite and rock wool (Spillane, 2002a) because they are biodegradable (Johnson, 200 lb), are often used as the rooting medium. Morgan (2003e) explains the properties and uses of a broad variety of growing media (substrate) (rockwool and stonewool, vermiculite, perlite, coconut fibre, peat, composted bark, pea gravel and metal scrap, sand, expanded clay, sawdust, pumice, scoria, polyurethane growing slabs, rice hulls, spaghnum moss, and vermicast and compost). She then matches the substratum characteristics to a particular method of hydroponic production.

Selection of propagated substrates is based on properties suited to germination and growth of seedlings (Morgan 2003f; 2004c). Other factors will decide which substrate is best, such as seed size, drainage requirements and continued usage after germination. Rockwool is perhaps the most commonly used substrate for germination. Fine textured germination substrates (particle size) are peat, sand, perlite, vermiculite, sphagnum moss, and coconut fibre. Gravel, scoria, and expanded clay are coarse-textured substrates. Combinations of these materials may be used to create a particular characteristic, such as retention of moisture, drainage rate and weight.

Nutrient Solution Formulations and Their Use

The hydroponic literature is packed with different formulations recommended for a particular crop or use. For example, Jones and Gibson (2003) found 19 articles related to the formulation and use of nutrient solutions and some 32 different nutrient solution formulas recommended for various crops in The Rising Edge magazine in issues published between 1989 and 2002. Crop requirement is a significant factor that would determine the need for a particular formulation or application method. For most cases, usage directions are sketchy, which will leave the reader uncertain about how to dispense the nutrient solution to the plant (the application frequency and volume are not specified, for example). In general, automated methods are used for dispensing the nutrient solution, such as the dosing devices defined by Smith (2001f) and Christian (2001).

Throughout this chapter, formulations for use with a particular crop and/or hydroponic growing technique that have appeared in the literature are given. All guidelines for the formulation should be reviewed carefully before they are approved and used. The author's experience has been that only a few formulations are appropriate for widespread use. The type of hydroponic growing system, the growing crop and the environmental conditions are influencing factors that would require modification of the formulation / use recommendation. Many who want to make their nutrient solution from scratch should find Musgrave's (2001) guidance helpful, covering the Law of Conversion, the Calculation of Elemental Percentages, and the Rest of Conversion Theory.

Cultivar/Variety Availability and Selection

There are no crop cultivars / varieties known as best suited only for hydroponic production. Breeding and selection are based on the production of plants that are ideally adapted to a particular climate, such as day length and light intensity, or plant characteristics such as resistance to disease, drought and/or heat tolerance, fruit habit and fruit characteristics (Waterman, 1993–94, 1996b, 1997b). Much has been written about "genetically engineered" species, engineered to achieve a specific characteristic, a subject that has stirred significant debate and controversy (Baisden, 1994; Waterman, 1997). Most of the breeding research has centered on the most widely grown crops and those which would be rated as "high cash priced," like tomatoes.

Recently there has been interest in varieties of "heritage" (Male, 1999; Johnson, 1999), those with substantial history of recognition and use. But in some forms of growing systems, many varieties, like heritage, do not perform well, whether hydroponic or not. There is also a lack of unique tolerance to disease in many heritage plants, one of the main focuses in the introduction of new species. Additionally, much of the breeding work has centered on cultivar production where the greatest need is. For example, greenhouse tomato cultivar breeding and selection were for adaptation to low-light, low-temperature conditions, whereas cultivars that would have high-light, high-temperature tolerance were given little attention. Additionally, fruit quality in terms of physical appearance, colour, firmness to withstand rough handling, quality of storage, etc. are some of the qualities that are developed in the newly released cultivars. Cultivar / variety selection is a major decision facing the grower, where a misselection will result in poor plant output and low quality of fruit.

Grower Skill and Competence

As with any plant growing company, the grower's ability will indicate the difference between success and failure irrespective of the growing system's operational efficiency. Others attribute this to a green thumb skill that some people seem to have — the sense of knowing what to do and when the contributes to optimum production of the plants. The author has visited several greenhouses, so it doesn't take long to quickly determine the grower's abilities so ability to handle the crop and greenhouse facility just by looking around. Of example, only the crop's physical appearance, such as its freedom from infestations of insects and diseases, is a reasonable measure of growers' skills. Answers to questions such as "what was the timeliness of the cultural activities being applied? What is the general state, within and outside, of the greenhouse environment, its cleanliness, the quality and performance of heating, cooling and air distribution systems? "Providing additional detail. These are some of the measurable aspects that can be used to assess the grower's and the workers' competence. For example, Smith (2002a, b) gives advice on what an NFT tomato grower needs to do when the crop is in full production to sustain fruit yield, advice that can be extended to any evaluation of hydroponic growers. What were the impressions from past training? All can be learned under the tutelage of a professional teacher from practical experience and/or hands-on instruction.

The author's experience has been that most hydroponic growing device failures occur because of a combination of factors. I saw the fall of a hydroponic industry in the state of Georgia during the 1970s. It occurred because of two primary reasons, the poor design and inefficiencies of both the greenhouse and hydroponic growing system, and the lack of experience and technical expertise on the part of the growers needed to operate the green-house / hydroponic system successfully. At about the same time, I witnessed the performance of a small group of tomato-greenhouse growers in southeast Georgia who were educated and directed by an accomplished professional skilled individual. When that person left to take a different role, many of the growers he trained and led shut down their greenhouses, afraid that attempting to continue without his guidance would inevitably lead to failure.

Grower performance depends on several factors other than the individual's inherent skill. Getting professional expertise in all aspects of the through system will contribute significantly to the success. Nevertheless, the consequences of a poorly built greenhouse or hydroponic growing system can not be reversed by any amount of grower ability and professional guidance.

Home Gardener/Hobby Hydroponic Grower

Hydroponics presents a challenge that some have taken up to the home gardener and hobbyist. Most have developed their own hydroponic growing systems based on knowledge contained in and from the internet in books, manuals, and magazine posts. Smith (2001a, b, c, d), explains how to design and create your own hydroponic system in a four-part sequence. He says, "My hydroponic sequence of introductories delved into the basics of what makes hydroponics tick. We covered the quality of your water supply, the different types of systems and the hydroponic nutrients your plants need." "Hydroponics for the Rest of Us "is the title of an article discussing different hydroponic growing systems (passive — wick system and active — flood-and-drain, top feed, NFT) and their operating requirements. The two recommended for the home gardener are the hydroponic flood-and-drain and top feed systems because they "perfect for home design and construction without compromising durability and quality" (Van Patten, 1992). Additionally, Van Patten (1992) divides processes into two additional types, recovery or non-recovery (respectively recirculation or discard) of the nutrient solution.

Coene (1997) offers basic details on soilless gardening, focusing on media- and water-based crop systems, nutrient solutions, artificial lighting, and pest control, and then explains how to create a growing vessel with a drip system. Likewise, Creaser (1997) gives instructions for building a drip system growing tray which he used to grow a variety of vegetables and house plants.

Peckenpaugh (2002a) recognized the need for hobby growers to provide a reliable source of hydroponic techniques and procedures. He explains the design and operation of four hydroponic systems (NFT, floating raft, ebb-and-flow, and drip), the formulation and use of nutrient solutions, including organic, and discusses the most commonly grown crops (cucumber, lettuce, pepper, strawberry, and tomato) plus how to treat insects and diseases. For one who just wants to play with small growing systems, Peckenpaugh (2002a) explains hydroponic growing techniques that "can be built by anyone with the time and patience to go through the process." In his article, he explains three different growing systems, Passively Wicking Pot, Styrofoam Cooler Grower, and Dutch Pot Dripper, describing the materials required to create each system.

For those who want to create their own hydroponic growing system for drip irrigation, Peckenpaugh (2003b) lists the following items needed: growing container, drip irrigation lines, drip emitters, nutrient reservoir, submersible pump, nutrient return line, growing media (expanded clay), and timer. He notes that "drip irrigation approaches the height of growing complexity due to its highly economical use of water and precise application of nutrients to the root zone of the plant." Expanded clay is the growing medium because it "holds some moisture and nutrients for plant use after the irrigation process, but does not get soggy or too wet." Peckenpaugh (2003c) explains its performance in using its homemade hydroponic growing system in a follow-up report.

Alexander and Coene (1995–96) concentrated on certain hydroponic systems that would draw the cost-conscious grower who wouldn't want to make major equipment investments. A simple passive hydroponic system, described by Christensen (1994b), may be a good place to start one's initial hydroponic venture; it is a spin off of an earlier-described hydroponic noncirculating system (Christensen, 1994a). Roberto's latest book (2001) offers "a guide to building and running hydroponic indoor and outdoor gardens, providing comprehensive guidance and step-by-step plans." Resh (2003) has a book on hobby hydroponics "to provide the reader with knowledge on the fundamentals of hydroponics that can be applied to a small-scale or hobby system." Angus (1995–96) offers guidance on how to run a hydroculture device consisting of five basic parts — clay pellets, nutrients, water level indicator, insert pot culture, and outer container.

Both these papers and observations speak of the wide range of possibilities as well as through structures that those interested in experimenting with the hydroponic technique can use.

Outdoor Hydroponics

The type of the least studied hydroponics today is their ability for outdoor use. Although hydroponics is initially practiced outdoors (Eastwood, 1947; Schwarz, 2003), the majority of hydroponic growing systems in use today are located in greenhouses or other enclosures. The difficulty, when the growing vessel is enclosed, is to find a hydroponic growing device that is not greatly influenced by rainfall. The least applicable outdoor hydroponic approaches will be those systems that use the nutrient solution distribution strategy for the drip.

From their comprehensive knowledge and experience, Bradley and Tabares (2000 a, b, c, d) and Bradley (2003) explain how simpler hydroponic growing systems are being developed by those in developing countries not only to tackle hunger but also to build small business projects. Included are easy-to-follow guidelines and operating principles for increasing systems which would be of benefit to anyone interested in hydroponics starting.

The personal experience of Ray Schneider, an enthusiastic hobbyist who first started out indoors (Schneider, 1998) and then went outdoors (Schneider, 2000, 2002, 2003, 2004) with his hydroponic NFT system, is an example of the successes and pitfalls that might happen. An article by Schneider and Ericson (2001) explains Ericson's learning experiences, using 6-inch sewer pipes as the growing vessel to grow hydroponic lettuce, bell pepper, tomatoes, cabbage, parsley, and herbs. Christian (1997) describes an NFT lettuce-growing program based on what was done elsewhere and how crop safety systems were built and used to deal with severe weather events over time. Kinro (2003) explains how Larry Yamamoto turned a hobby into a hydroponic lettuce-growing career using a simple floating raft device in Honolulu, Hawaii.

In a system where a depth of nutrient solution is retained at the bottom of a watertight vessel (box or trough) the author has had good success developing hydroponically. The growing medium is either pure perlite or a 50/50 perlite mixture of composted milled pinebark. A detailed description of the basic operating principle for this method is available on the www. GroSystems.com web site.

CHAPTER TWO

Hydroponic Crops

In the crop portion given later in this chapter, instructions are provided in the greenhouse on the hydroponic procedures for those crops which are most commonly grown hydroponically (tomato, cucumber, pepper, lettuce, and strawberry). The author has also successfully grown these crops outdoors hydroponically so updates on my observations will be made. The author has had strong success in growing vegetable crops, green beans, okra, sweet corn, and melons (water and cantaloupe) hydroponically outdoors. Instructions are also included for growing certain crops.

There are many benefits of hydroponically growing outdoors; the primary ones are managing water and plant nutrient elements, and preventing soil-related challenges such as weeds, poor soil physical and chemical properties, disease, and poor soil moisture management. Frequent references to articles in the magazine The Growing Edge are made as many articles contain useful tips for the hydroponic grower, whether commercial or hobby grower. The geographical range for the included crops depends on the literature base for that crop.

Morgan (2000d) provides information on growing "Baby Veggies," which are "appealing because of their appearance and tender flavour, and are typical cultivars harvested in their immature stage." Snow peas, squash, pumpkin, potato, eggplant, tomato, hot and bell pepper are grown in NFT systems; while globe artichokes, carrots, onions, beets and corn are grown in medium hydroponic systems.

Factors for Success

In terms of process (ebb-and-flow, NFT, media systems plus drip irrigation), and control of the supply of water and nutrient solution (and its formulations) to a crop, there is no standard hydroponic technique applicable in every situation. A key aspect is the use of the hydroponic device, whether in a greenhouse with its broad variation in design and function, in a controlled room, or outdoors. The physical location of a greenhouse or outdoor site in terms of geographic location at a specific site and/or in regions with varying weather conditions (high and low temperatures, and high and low light intensity and duration) will determine what is needed to be effective.

The abundance of knowledge available on hydroponics can easily lead to wrong choices being made in the design of the that system and the operating procedures. A common mistake is to follow a that framework and/or collection of operating procedures that only apply to a given environmental situation. What would be expected under low temperature and light, for example, would not necessarily apply at high temperature and light. What would be expected for a crop under decreasing light, from summer to winter months, would not relate to that under may light conditions, for example, from winter to summer months, what will happen with a fall vs. spring crop.

The selection of crops and cultivars should be based on adaptability to the growing system and environmental conditions and the marketability of the harvested crops. A common mistake is to produce a crop that either meets or does not meet market requirements, and/or is not of sufficient quality to be approved by consumers. A grower may be very effective in growing a crop but may not be in a position to market it properly. As stated earlier, one of the reasons a group of greenhouse tomato growers in southeastern Georgia was successful was that each grower had their own local market, but in addition they were able to pool their surplus fruit that was taken to a centralized market in a large nearby town.

Grower's expertise and familiarity with a specific method of growing may not be easily transferable to an inexperienced grower. The author has visited growers whose performance may be directly linked to their innate capacity, a feeling (the phenomenon of green thumb) that guides what to do and when to do so. Being proactive is often better than reactive to changing crop conditions or growing method. It is especially true when dealing with infestations of insects and diseases, or when there are evolving environmental conditions that would alter the requirements of plants for water and nutrient elements, or when shade or increased light is required. Failure to predict severe weather events, such as sudden low or high air temperatures, snowfall, or high winds, can result in damage to the greenhouse structure and to the status of an enclosed crop.

It is important to rely on qualified experts for identification and advice when addressing plant nutrition and pest problems. Monitoring and periodic testing are necessary to ensure a nutritionally adequate maintenance of the crop. Using tracking tools such as yellow sticky boards may show the amount of populations of insects. Knowing the degree of tolerance for both disease species and insects will help to decide when control measures are required, as there is usually no complete absence of such pests.

Unfortunately, even in the hands of a professional grower, not even the best built growing systems and greenhouse structures can initially perform well. It can take a period of "shakedown" to make the total system function effectively, and the can crop to meet expectations. In one set of environmental conditions, what might work can not work in another. This was the experience of four farmers in the southeastern United States, who initially produced high-yielding and -quality fruit and then encountered low yield and quality in the years that followed (Jones and Gibson, 2001). It's the ability to locate a problem's root and then change it or fix it, which allows for performance and minimizes losses. Record keeping is important if a grower is to continue growing high-yielding, high-quality crops. There should be regular monitoring of the environmental conditions. It should also document the dates when major events happened, and the crop's changing status. Accurate records of yield plus assessments of the output are important. A greenhouse tomato grower kept detailed records of weekly fruit production and then compared those yields with the amount of weekly sunshine, data obtained from local weather reports. Two or three weeks before, the highest correlation observed between fruit yield and weekly sunshine was obtained, indicating that the impact of weather conditions did not appear in the crop until several weeks later. Additionally, if yields are compared with growing conditions daily and/or weekly, these data can be used to direct the grower when making future decisions (Nederhoff, 2001).

The author knew a grower who kept constant records of any occurrence occurring in his greenhouse, including the exact time he entered and left every day. Such logs given to be necessary when a successful litigation against the greenhouse and hydroponic growing system supplier was brought. The grower was able to demonstrate successfully to the court that what the supplier had claimed in his printed brochures and manuals — predicted yield based on specified inputs — proved not to be so.

Constance of growing conditions contributes to high yields and the production of high quality goods. Every element of the environment, such as the amount of radiation obtained, can not be precisely monitored or the constant cycle of atmospheric conditions in the greenhouse or outdoors can not be adequately monitored. For most greenhouses, the use of computer-driven control devices (Lubkeman, 1998, 1999; Nederhoff, 2001) will reduce the cycling of the air temperature, CO2 content, humidity etc. Growth chamber studies have shown what effect accurate control of the aerial environment can have on plant growth and development. The greenhouse system must therefore be so configured to replicate what is possible in a growth chamber if it is to achieve and sustain the environmental conditions needed for high growth.

Cycling of the supply of water and nutrient elements is not easily managed for most widely used hydroponic growing systems. There are three things occurring as a nutrient solution is added into the through medium. Plant roots absorb water and nutrient elements at varying levels in the nutrient solution (Bugbee, 1995), water and non-absorbed nutrient elements begin to accumulate in the rooting medium (Jones and Gibson, 2002), and some of the added water and nutrient elements leach from the rooting vessel. The effect is a rooting environment that continually varies and can adversely affect plant development. This is one of the driving factors that those engaged in hydroponic system research and development are not addressing adequately. Geraldson (1963, 1982) dealt with this problem in his work on the impact of the quantity and balance of nutrient elements on the growth of staked tomatoes grown in the field. Jones and Gibson (2002) use this basic principle in their creation of the Aqua-Nutrient growing system and forms the basis for a commercial product called the "EarthBox."

Much remains to be known on how plants can be best grown hydroponically. No major breakthroughs have occurred over the last few decades. Over past years most of the hydroponic growing systems in use today have been built. How the future holds for new technologies is unclear, as few are engaged in hydroponic system technology method.

CHAPTER THREE

Tomato (Lycopersicon esculentum Mill)

"Tomato story is a tale of three continents: South America, Europe and North America." The European chapter started in the 1500s, when Spanish and Portuguese explorers brought back unusual vegetables, one of which was tomato, to their respective countries (Bennett, 1997). The tomato has its roots in Ecuador and Peru's small, dry, tropical coastal areas but its domestication occurred in Mexico where it was discovered and brought to Europe. It's said the word "tomato" comes from Mexico's Nahuati language. Tomato was introduced to the United States in the 1700s, and is a major dietary vegetable plus a part in many food items (Smith, 1994; Jones, 1999). In the United States, fresh tomato fruit intake per capita is 19.5 lbs (8.8 kg), and that amount is expected to rise, primarily due to the health benefits that arise when it is included in the daily diet. There has been a significant change from beefsteak to cluster tomatoes in tomato type; the former are 30-40 percent, the latter 60 percent. Less than 10 per cent of overall production is in forms of cherry, plum and bell.

In the Netherlands there are the largest acres of greenhouse – hydroponic tomato, followed by Spain and England. In the Western Hemisphere, production figures are difficult to obtain, with an estimated 460 hectares (1134 acres) in Canada, 864 hectares (2134 acres) in Mexico, and 310 hectares (766 acres) in the USA. In Mexico the acreage is rising rapidly. Colorado State has fast behind in the U.S. Some have indicated that the future potential could bring the total acreage of greenhouse tomato production to 7000 acres (2833 hectares) in the United States. Wide greenhouse facilities [> 20 acres (8 hectares)] are situated at high altitudes [5000 feet (1524 m)], with high light (minimum cloud cover) and cool nights prevailing. Equally essential requirements for the selection of sites are the readily accessible sources of high quality water and natural gas. Since greenhouse tomatoes are not a crop tracked by the United States Department / Agriculture Research Service (USDA / ARS), it is difficult to obtain statistical data on acreage, rates of production, types of fruits, etc.

Tomato is the world's most commonly grown hydroponic crop, cultivated mainly in environmentally managed greenhouses and less often in open-sided shelters. Initially, some type of hydroponic growing method was used as an ebb-and-flow (Fischer et al., 1990), but in recent years, the nutrient solution has been preferred to go through irrigation. The tomato plant is either rooted in pure perlite (Bauerle, 1984; Day, 1991), rockwool blocks and slabs (Van Patten, 1989, 1991a, b; Robinson, 2002; Smith, 2003c), or some other substrate, such as coconut fiber (Morgan, 1999b). Johnson (2001b) compared the characteristics of rockwool versus coir as a increasing medium, finding that cocopeat has a high nutrient- and pH-buffer potential and is environmentally biodegradable. Handreck (1993) gives the cocopeat (often referred to as coir) properties for use in a soilless potting medium and Ma and Nickols (2004) provide guidance on detoxifying coir dust and coconut shell. Morgan (2003f) explains media-based increasing systems and media-free methods (expanded clay, scoria, pumice, sand, and gravel), such as NFT (Peckenpaugh, 2002; Smith, 2003a, b, c) and DFT (deep flow technique) (Alexander, 2003b) and aeroponics (see pages 142–143). Papadopoulos (1991) explains the growth of organic medium containers, rockwool slabs, and NFTs in different systems. Smith (2003c, d, e) explains the evolution of PTO (Percy Tregida Otahuhu) farmers, who first started growing tomatoes in the soil in 1949, in a sequence of three papers. The NFT and the drip irrigation rockwool slab systems are now growing tomato in 1.5 million square feet of greenhouses. Many of the major hydroponic tomato operations [> 20 acres (> 8 hectares)] grow in rockwool slabs because this substrate is commonly believed to have the best control of water and nutrient elements. Most of the technology that is emerging comes from the Dutch growers, who grow almost exclusively in rockwool.

In an environmentally con-trolled greenhouse, factors that affect tomato fruit production are:

1. Light, its intensity and spectral characteristics, and the length of the day (optimum: 1400 fc illumines, 14 hours of photoperiod)

2. The level of carbon dioxide (CO2) in the greenhouse, particularly within the plant canopy

3. Air and root temperatures (optimal day / night air temperature, roughly 86/77 F (30/25 C)

4. Relative humidity ambient (optimum 50 per cent)

5. Infestations of the insects and diseases

6. Composition of the nutrient portion of the nutrient solution applied and rooting mean

7. Tomato plant nutrition status

8. Cultivar Features

9. Days to bloom 50, days to ripen 100 10. Grower's Management Ability (high)

The tomato plant goes through four phases from seeding to final harvest, seedling period (4 to 6 weeks), vegetative period (2 to 3 weeks), early fruiting stage of first flowers to first fruit (6 to 8 weeks), and mature fruiting stage of first harvest before plant removal. Just before removal of the plant, the growing point is removed to promote the accelerated growth of the fruit of those still remaining on the plant.

Transplant Seedlings

The seed quality will decide the germination rate, which is expected to exceed 95%. If seed is placed, it should be at 32–40 as much as possible (0–4.4 as possible). Over-seeding at 15 to 25 per cent would usually ensure a sufficient number of transplant seedlings. The optimum seed germination temperature range is 72–75 F (22–24 C).

Tomato seeds can germinate at 70 F (21 C) in 8 to 11 days. Seed age is one of the important quality factors, and some growers do not consider seed if the date on the package suggests the seed is over 6 months old.

Tomato seeds are not seeded directly into a hydroponic growing medium, as in soil growing, but are seeded in germination cubes or trays of soilless medium to create a seedling that will then be transplanted into the hydroponic growing system. Leskovar and Cantliffe (1990), Vavrina and Orzolek (1993), Snyder (1995), Meyer (1998), Fauly (1998), and Morgan (2002c, 2004c) have provided seeding and seedling growing procedures that will produce transplants that will bear fruit early. The critical factors are temperature and light, as well as sufficient nutrition to ensure a hardy seedling grows. It is the so-called "hardening or conditioning" cycle which will decide how quickly seedlings adapt after transplantation to their new environment. Morgan (2003e) found that the number of flowers located on the first truss increases when seedlings are grown at low temperatures [53–57 uF (12–14 uF)]. After transplantation the seedling character can decide the initial plant growth and the timing and location of the first cluster. Morgan (2002a) indicates that the trans-planting period is when the young plant is about to bloom, and then the first fruit is expected to grow under good growing conditions in around 7 to 10 days. The author has found that transplantation of seedlings shortly after the first "actual" leaves usually leads to best initial plant growth and early setting of the first fruit truss under high light and temperature.

Grafting

Seedlings grown to establish a double-steme plant or grafting onto a rootstock to increase plant vigor is becoming an increasingly common practice. Grafting on 17- to 18-day-old plants is performed at the seedling point. A good graft requires considerable skill; hence this is not a activity recommended for most growers to perform.

Crop scheduling

A two-crop system is used to avoid low-light months, and a single-crop system to avoid high-temperature months, depending on the light and temperature conditions. In the two-crop system, for instance in the northern hemisphere, a fall crop is planted in August and finishes in December, followed by a summer crop planted in March and finished in June or July. The crop is planted in September for the single-crop method, and finished in June. With additional lighting during low-light months, and shade during high-temperature months, changes can be made in either cropping method in plant scheduling.

Growing Containers and Medium

The most widely used tool for tomato growing is slabs of rockwool. The second most commonly used would be perlite in either bags or BATO buckets. Growers have also used a number of other substrates (cocopeat, composted milled pinebark, expanded clay, pumice, sand, gravel, or mixtures of these substances created to produce different physical and chemical properties) put in containers of varying depths and physical size. Morgan (2003f), describes the physical and chemical properties of these through media. The number of plants per sheet, container, or bucket will depend upon the configuration of the crop spacing. The medium volume in either bags or buckets will dictate irrigation frequency; the smaller the medium volume, the more often irrigation is needed.

The Japanese Top Graft Method

The scion (variety) and the rootstock are cut off at an angle of 45 and the scion is put directly on top of the rootstock with this method. They're maintained with a silicon grafting film.

Grafting shall contain the following actions:

1. Rootstock Seeding

2. Variety Seeding

3. Prerequisites

4. Cruising

5. Merger

6. Potting and chopping

1. Seeding the rootstock

Seed the rootstock, Beaufort in rockwool plugs at 240 cells per tray according to DRS recommendations about 5 to 10 days before the variety.

The seedlings are to be picked because of the uneven emergence. Currently this happens in the third true leaf stage (after 18 days). The selected seedlings are put at only 120 cells per tray in 240-cell trays (this is too hard to graft a complete tray). Selection is made every four to five days. The first time about 100 plants are usually produced per tray.

Keep this in mind for the number of plants needed within one time span.

Experienced plant breeders have a 95 percent success rate.

To make them thicker and more durable (18 to 20 C), selected rootstock seedlings should be held at a lower temperature.

In the event that another rootstock (i.e., PG3) is used for a more uniform germination, the flats that be seeded at 120 per tray immediately. For this reason special seeding equipment is available.

2. Seeding the Variety

Sowing as per regular guidelines.

Graft some 17 or 18 days later.

3. Grafting P reparations must be performed in an environment with no direct sunlight.

Create plastic tent, approximately 30 cm high. We prefer transparent plastic. The film has got to have enough energy. A white film can be used under the high light conditions. However, transparent plastic is preferred, and a retractable screen or Styrofoam sheets will minimize the intense sunlight.

Desinfect the palms, for example, with Virkon.

Razor blades: Do use new blades, and sometimes replace them.

Climate: temperature: 21 to 22 ° C; relative humidity (RH) inside the tent should be around 95% (wet floor or plant misting as well as within the plastic tent).

No smoking (virus) during the grafting.

Make sure the rockwool plug is extremely wet, EC 2 to 3 mS. 4. Grafting Technique Cut the rootstock at an angle of 45 with a razor blade. Depending on the conditions this can be achieved either above or below the cotyledons. Cut under the seed leaves when light and dry, to prevent sucker growth from the rootstock. When it is dark, make the cut above the cotyledons to take advantage of the extra photosynthesis. Set the clip for the grafting.

Cut off at an angle the range. (Suggestion: if hot or low RH, briefly place the scion in a tray with clean or sterile water) Place the scion in the clip to ensure good contact with the rootstock (i.e., air between the two parts may fail).

Remark:

1. It is preferred to cut at an angle (45) over a straight cut because the surface of the fusion is greater and the probability of success is higher.

2. The ideal situation is to cut both the rootstock and the above-cotyledon variety.

3. Cut the rootstock no more than 2 cm above the rockwool base. When greater, there is a chance that the graft may fall over; when smaller, the variety will root into the media.

4. If the variety has grown too quickly, cutting it higher (even as high as the true 2nd or 3rd leaf) is advisable.

Immediately put the grafted plants within the plastic tunnel. The optimal temperature for fusion is 21 to 22 C. Under sunny conditions, the mean temperature is 28 to 29 C.

5. Fusion

Avoiding direct sunlight on the plants and maintaining a uniform climate is important. If it is sunny, shading will be necessary until the plants are hardened.

The most popular technique is to keep the tent closed for three days and to check on the fourth day whether the graft can survive. The plants are not to wane. When this occurs, mist the plants gently (don't use warm water).

Ventilate a little on fifth day. Making a small gap is preferred, and checking the condition of the plants every hour. If they wilt, spray the plants gently with clean water and cover the tent once more. The difference can be made again in the evening, or the next morning. Make the distance bigger on day 6, if the plants can handle it and remove the plastic on day 7 (preferably morning or evening).

6. Potting and spacing

The usual plant raising procedures can be followed after day 7. It is advised to transplant into a rockwool block from 9 to 10 days after grafting (when the rootstock and variety have firmly joined in). (If the grafting clips were silicone, removal is not required.) The normal rockwool slab is 36 in. (91 cm) 6 "tall. Broad (15 cm), and 3 in. (7.6 cm) wide, 0.375 in.3 (0.0106 m3) volume; A typical perlite grow bag contains 1-1/3 ft3 of perlite (0.037 m3); the bag is 44 in. (111 cm) 8 "tall. Broad (20 cm), and 6 in. (15 cm) Tall. The BATO Bucket volume is 0.57 ft3 (0.02 m 3). Jensen (1997) recorded growing six tomato plants at a thirty-fifteen by 7.5 cm; each plant had a rooting volume of 2438 cm3 and needed 30 times daily irrigation. He also indicated that tomatoes were being successfully grown at the University of Arizona in a rooting volume of 956 cm3, although continuous irrigation during the day was necessary. The rooting medium's design and scale is determined mainly by economics, using as little average as possible to reduce initial expense and disposal requirements.

The author has developed tomato plants into fruiting bottles containing perlite in 20 oz (591 mL) beverage in which the nutrient solution is continuously supplied to maintain a 1-in. (2.5-cm) solution depth on bottle foundation.

The root mass was collected from a number of perlite-containing BATO buckets after 6 months of commercial tomato production at three greenhouses located in the southeastern United States. The author found that much of the root mass was surfacing around the outer edge of the perlite mass with few roots in the middle where the two nutrient solution delivery drip emitters were installed. This indicated that during much of the growing period, the repeated applications of the nutrient solution necessary to supply the plants with the water needed kept the center of the perlite mass anaerobic and therefore not an suitable area for active root growth. It may have been one reason for the decrease in plant growth and fruit production as the season progressed (Jones and Gibson, 2001).

There has been no thorough investigation into the impact of root size, development, and function on tomato plant development and fruit production when regular irrigation is required to meet high transpiration demands. In field soil conditions but not hydroponically to the same degree, what effect root physical restriction has on plant growth has been studied. If the plant can be sufficiently supplied with water, a relatively limited amount of root will satisfy the demand if there are no constraints in the rooting medium, such as high or low temperature, low O2, and high EC. This has been demonstrated by the author in experiments performed in 20 oz (591 mL) beverage bottles; vigorous growth of tomato plants remained turgid under high atmospheric conditions. However, when the atmospheric demand is high, plant wilting is not uncommon, indicating insufficient absorption and transport of water from the roots to the transpiring leaves. Under those conditions, solutions would be possible to reduce atmospheric demand by shading and/or misting. The minimum root surface needed for a mature, active growing, and fruiting tomato plant is not known under ideal rooting conditions. Even under the best of conditions, the minimum that fluctuate with time as it is not possible to hold the rooting medium at the ideal condition continuously. So much needs to be investigated.

Plant Spacing

The region occupied by a plant is determined by spacing up the field. The region each plant occupies typically affects fruit yield per plant, as high plant densities normally result in lower fruit yield per plant. The light intensity decides what plant spacing is best for optimum yield. During the flowering and fruiting period, the greater the light intensity, the closer plants can be lined up. Canada, Mirza, and Younes (1977) suggest 2.7 plants per square meter in Alberta. Morgan (2003e) recommends a typical 2.5-plant spacing per square meter. New Zealand PTO growers use a plant density of 2.2 m2 per plant (Smith, 2003e). In a Canadian textbook, Papadopoulos (1991) recommends optimum room per plant as 0.35 to 0.40 m2, with a spacing of 31.5 in. in-row. (80 cm), the same as between rows in a double row arrangement, 3.9 ft (1.2 m) between two rows. Resh (1995) spaces plants in the row at 30 in. in a rockwool slab growing system under low light conditions. 18 to 20 in. (75 cm). (45 to 50 cm) between plants, corresponding to 6 ft2 (0.6 m2) per line. With improved lighting conditions the spacing is 3.0 ft2 (0.3 m2) per square foot. The rows are spaced 16 to 20 in. in a double row configuration. (40 to 50 cm) apart and spaced 12 to 14 inches in lines. (30-36 inches). The author spaces plants in the row in the southern latitudes, and at 18 in between double rows. (45 cm) across double rows, 3.0 to 3.5 ft (0.9 to 1.06 m). Wittwer and Honma (1979) gave 3.5 to 4.5 ft2 (0.32 to 0.41 m2) per plant as the optimum spacing.

Now, Mississippi space plants are greenhouse tomato growers in a setup to get 4 to 5 ft2 per plant, with 3 to 4 plants in 2-ft3 laid-flat perlite bags, and 2 plants per 5 to 7.5 gallon upright perlite-filled bags.

It is clear that the arrangement of plants and the number of plants per area are parameters which were not standardized. Many configurations may be used, such as single- and double-row setups, with often defined inter-row space to provide ample workspace. The greenhouse's physical design can be such that in order to fit in a certain number of rows a narrowing of the inter-row space is required.

Cultural Plant Practices Training the plant up a support chain, prompt removal of leaf axial suckers and vegetative stems from the fruiting truss, leaf pruning, flower pollination, fruit thinning on the truss and lowering of the growing plant are important daily activities for productive fruit development (Smith, 2001e). Both of these activities seek to hold the plant in a high fruit-productive state (Smith, 2002a). Depending on the cultivar and characteristics of the plant, the degree and timing of fruit truss thinning (removing small slow-developing fruit) and removal of leaves below the fruit trusses (generally, leaves below the lower fruit truss contribute little to the fruit growing above) can differ. A "single truss, single cluster" approach developed by the Rutgers University Cook College of Agriculture is being tested in a specific experiment, by restricting the tomato plant to one main stem and one fruit cluster. The hydroponic ebb-and-flow method is used, with the tomato plant grown in a cube of 3 inches of rockwool. Harvestable fruit is obtainable within 90 days of transplantation (Simon, 2003).

Environmental Conditions

The tomato plant is sensitive to both low and high air temperatures and to the strength of radiating radiation. The optimum daily temperature range for tomatoes is between 70 and 82 F (21 and 28 C), night time air temperature is between 62 and 64 F (17 to 18 C). Papadopoulos (1991) refers to acceptable minimum air temperatures with light conditions, a minimum night temperature of 64 F (18 C), a minimum daytime temperature of 70 F (21 C) and a minimum night temperature of 62,6 F (17 C), a minimum daytime temperature of 66 F (19 C) at low light. No fruit collection occurs at mean air temperatures above 86 F (30 C). Although air temperature is critical to best plant growth and set fruit, it is the temperature of the leaf that is equally or even more important. For example, if the air temperature around the plant is above that required, air movement over the surfaces of the plant's leaves and normal transpiration (water loss from plant tissues, typically through the stomata) will keep the plant "cold," and therefore in an active growing and fruit setting state. The author has found a lower temperature between air and leaf temperature as much as 10 degrees Fahrenheit as determined by infrared reflectance when the plants are actively transpiring in a moving environment. An average air push of 3.2 feet per second (1 meter per second) through the plant canopy is recommended. Air movement through the canopy will actively keep the plants transpiring, resulting in sustained photosynthetic activity (Srivastava and Kumar, 1995). The maximum relative humidity varies from 60 to 70%.

Harssema (1977) found the optimum root temperature to be between 60 and 86 u-F (20 and 30 u-C); plant growth was drastically reduced at temperatures less than 60 u-F (20 u-C). In addition, the transpiration rate increased with root temperatures varying from 54 F (12 C) to 95 F (35 C) respectively. Root temperature has not had the same effect on plant growth and fruit development as air temperature, and thus root temperatures within range 60 to 86 AF (20 to 30 AF) may not have a major impact on plant growth and fruit production.

Jones and Gibson (2001) found that there will be a decrease in fruit set and yield in southern latitudes where there is more than 10,000 minutes of monthly sunshine. Under conditions of high light intensity, shading is normally needed to control the amount of light entering the greenhouse, light radiation which generates heat in turn. For polyethylene-covered greenhouses when the greenhouse temperature begins to reach 85 ° F (29 ° C), it is usually recommended that a 40% white shade material be pulled over the greenhouse, while 50% white shade material is recommended for high altitudes and high light intensity areas (see Figure 12.15). The ideal greenhouse design will be to have movable shade that can be pulled over the crop when the light conditions are extreme and can then be quickly removed when the light conditions are lower.

Tomato irradiance requirement as per Manrique (1993) is 13 Mj / m2/d. Papadopoulos and Pararajasingham (1997) record a low of 2,01 to 2,65 kg of fresh fruit weight harvested for every 100 Mj of solar radiation the crop receives. So the main factors restricting fruit yields are short days and low radiation fluxes in northern latitudes in the winter months. The efficacy of supplementary light in winter months to address low radiation flux is doubtful. Gain, if obtained, exists by increasing the light time instead of attempting to raise the light flux during daytime. Photon flux within the wavelength range of 400 to 700 nm [photosynthetically active radiation (PAR)] is the one used effectively in photosynthesis, with light measurements represented as photosynthetic photon density (PPFD) (Mplekas, 1989; Parker, 1994a, b).

Since tomato is a C3 plant (the first photosynthesis product is a three-C carbohydrate-containing product, see page 378), the rate of photosynthesis activity peaks at relatively low light intensities and is significantly sensitive to the CO_2 content of the air surrounding the plant. The intensity of photosynthetic activity can be increased under low light conditions when the air's CO_2 content is maintained at 1000 ppm (Slack, 1983). The value of the ambient atmospheric CO_2 ranges from 300 to 400 ppm. At normal CO_2 levels, individual leaves reach optimum assimilation rates at approximately one quarter of the available radiation from full summer sunlight, with some leaves actually absorbing 80 to 90 percent of the PPFD light incident.

When tomato plants enter the wire that supports the lines of the plant bond, the plant canopy becomes thick and no air movement occurs within the canopy unless air is introduced at the bottom of the canopy so that air passes through the canopy. Having air moving through the canopy has two major benefits, preserving the CO_2 content in ambient air (300 to 400 ppm) and increasing transpiration, which keeps the plant foliage cool. The author claims that the air movement up through the canopy of the plant often prevents white flies (Bemisia argentifolli Bellows and Perring) from landing easily on the plant foliage. Even with the use of high-velocity fans, it is very difficult to move air from above down into the plant canopy.

Tomato plants also greatly reduce their absorption of water as the root temperature decreases (Figure 11.20). Water use declines dramatically as the temperature of the rooting falls below 68 F (20 F) and above 86 F (30 F) (Tindall et al., 1990). For example, on days of high atmospheric demand, the tomato plant may wilt even if there is enough water available when the rooting medium is cool [less than 68/F (20/C)] or the EC is high (> 4 dS / m). The effect of the moisture stress is slow plant growth and poor fruit collection, as well as increased fruit blossom-end rot (BER) incidence.

Additionally, there is a substantial drop in nutrient absorption as root temperature decreases. Tindall et al. (1990) found that since the rooting temperature ranged from 50 ° F (10 ° C) to 104 ° F (40 ° C), tomato plants greatly affected the absorption of the major elements and micronutrients. The influence on temperature did not affect all major elements and ions as well as K, Ca, and NO3--while P, Mg, and NH4 + were not. Fe, Mn, and Zn were substantially impacted for the micronutrients.

Water Requirement

Within this book earlier plant water needs were addressed. Some of the most important decisions to be taken by a grower is when to drink, and how much. The majority of hydroponic delivery systems are set on a time clock such that the nutrient solution and/or water is added to the rooting medium at regular intervals, whether the plant needs it or not. A system that involves radiation measuring devices and a computer program designed to estimate water requirements based on past atmospheric demand plus plant size and fruiting status (Rudder-Hasenohr, 2000). Some of the common fruit disorders, such as BER and cracking, are caused either by under- or overwatering.

The tendency is usually to overwater, which can contribute to anaerobic conditions in the growing medium. Carefully extracting the perlite from a number of BATO buckets that had been growing tomato plants for more than six months, the author found that most of the roots surrounded the perlite layer. In almost every case, the center where the nutrient solution was being applied to the surface through the drippers had little if any roots present. Examining the roots' location in the rooting medium, therefore, will say a lot about the current conditions of aeration.

There are fewer flowers per truss at low water supply, low fruit set and an increased occurrence of BER. Deficient plant production, later flowering, fewer flowers and lower collection of fruits occur under high water supply (overwatering). With regular water supply shifts the frequency of fruit cracking increases. Because of the concern of the PTO growers about water availability and the likelihood that the root zone could be periodically too dry, they moved from NFT to a rising rockwool substrates network (Smith, 2003c).

The water required by the plant is supplied via the nutrient solution in most of the hydroponic nutrient solution supply systems. Therefore carrying water to the plant roots requires all of the elements in the nutrient solution, elements that the plant does not require. Many of the high levels of nutrients contained in plants can be due to overfertilization from unneeded elements that are added only when water is needed. The ideal design would be to have two supply systems, one for the nutrient solution and the other for water, so it can be applied alone when only water is required.

Under normal growing conditions, water use varies from 17 oz (500 mL) to 0.26 gal (1 L) per day while the tomato plant is flowering and setting fruit. Ward (1964) developed that tomato plants use water to be 3 gal (11.3 L) per plant per week. It is estimated that it will take 4 gal (15 L) of water to produce 1 lb (0.45 kg) of the harvested fruit. The exact amount of water required during flowering and the fruit setting and growth cycle will depend on the rate of transpiration of the plant, which is associated with the degree of incoming radiation; the higher the radiant energy, the greater the water use. In addition, the level of air movement within the plant canopy, as well as the high air temperature and low relative humidity, would also increase water use.

The author and Wignarajah (1995) claim that aeroponics is the "ideal" hydroponic growing system where "nutrients are constantly flowing down the roots that have access to ready supply O2." Unfortunately, aeroponics is not an economically viable process for growing crops such as tomatoes, cucumbers and peppers.

Flower Pollination

Naturally occurring insects are typically necessary for adequate pollination of tomato flowers in the field. Nonetheless, in the greenhouse either hand flowers pollination at midday every other day when the relative humidity is minimal using an electric hand pollinator and/or the introduction of bumblebees (Bombus spp.) into the greenhouse is needed. The size and number of required hives would depend on the number of greenhouse plants. There will be approximately four flowers in bloom on each plant during flowering and fruiting. Insufficient numbers of bumblebees can be found to properly pollinate all the emerging flowers as well as too many bumblebees, which can result in flower damage and fruit loss. Those who provide bumblebees will advise on the size and/or number of hives needed based on plant number and greenhouse configuration. The environmental conditions of the greenhouse will decide the effectiveness of the bumblebees, and how long a hive will live. Bumblebee operation can be impacted by the use of pesticides and supplemental lighting as well as other greenhouse conditions. Information can be collected from bumblebee suppliers regarding certain conditions which will impact bee operation.

Some pollination happens as wind pushes the plants, or the flowering truss is pushed by physically shaking the plant. These methods of pollination, however, are typically not adequate to ensure complete pollination, resulting in incorrect fruit in turn.

Such unpollinated flowers should abort the fruiting truss. Certain factors such as low light levels, high air temperature, plant wilting, and nutritional insufficiencies (such as high N) can also cause flower failure. However, emerging flowers may abort when plants bear a heavy fruit load, and when environmental conditions are less than ideal.

When hand pollination is performed using a vibrator, enough force is required to dislodge the pollen. When the pollen is mature, while the truss stem is vibrating, a yellow pollen cloud can be seen dropping from the flower. Care must be taken to ensure the vibrator does not come into contact with small fruit that grows. If contact is made a scar may appear as it matures on the fruit.

Fruit Development and Yield

To understand how fruit grows, one needs to have an understanding of the relationship between source and sink. Through the photosynthesis cycle, carbohydrates (source) are developed and divided into one of three plant parts (sinks) to help plant roots, expand new plant growth, and develop fruit. The partitioning is affected by the growing conditions surrounding the plant, such as light intensity and length, air temperature and CO_2 content and plant water status, as well as how the crop is handled (sucking, removal of leaves, removal of flowers and fruits, etc.). Maximum carbohydrate transport to the fruit occurs when the air temperature is between 73 and 75 F (23 and 24 C) and when plants are sufficiently supplied with water and plant nutrient elements required to sustain adequacy. Fruit will ripen from 40 to 75 days after pollination; the time taken represents an association between factors dictated by cultivars and growing conditions. So long as there is a fruit left on the plant, its size will continue to grow. Fruit that is in the shade will ripen more slowly, so it will be larger at harvest than fruit that is in the sun. The weight of the fruit will depend on the quality of its water; the higher its quality, the greater its weight. Ninety-five per cent is water for tomato plants.

There is no clear term for reporting fruit yield weight, so that simple comparisons can be made between the different production methods. Fruit yield (weight) can be expressed on an area-based basis, on a per-plant yield over a specified time span, or total yield over a defined growing season for a production unit (i.e., whole greenhouse). For example, either 63 kg / m2, 1.0 to 1.5 lbs of fruit per plant per week during the fruiting / harvest time, or a total of 40 to 50 pounds per plant for the entire growing season (about 7 months) will be described as a "healthy" fruit yield. The author assumes a "high" fruit yield will be a sustained amount of 1.5 to 2.0 lb per plant per week of production. Smith (2003b) stated that "the Dutch have historically been the trend-setters for greenhouse cropping and research dedication has some Dutch growers now yielding around 70 kg / m2 (around 50 lb / plant)." Another factor not usually known is the actual number of fruits harvested. Moreover, most fruit yield data contain only "marketable" fruit — fruit that is defect free and appropriate in size. The main determinant of fruit yield is the number and weight of fruits. Fruit weight (size) is determined mainly by cultivar but may be influenced by growing conditions such as air temperature [higher than 72 ° F (22 ° C) increases fruit maturation levels] and shading, whether naturally shaded by the leaves of the plant or artificially shaded, which slows fruit maturation levels. Toping (removal of the growing point of the plant), a procedure used before the end of the growing season, may improve the rate of fruit growth and ripening.

The author performed a hydroponic greenhouse tomato experiment in which fruit yields were exceptionally high, primarily due to the weight of individual fruit, weights in the 12 to 14 oz (340 to 397 g) range when fruit weights were supposed to be 8 to 10 oz (227 to 283 g). One aspect determining yield (based on weight of the fruit) is the fruit's water content.

Those factors which would increase fruit's water weight would increase fruit yield. Ripe tomato fruit should be stored in a relative humidity environment of 85 to 90 percent at temperatures between 40 and 50 F (4.4 and 10 half C) and if so stored fruit quality can be preserved for 6 to 12 days. Fruit should not be stored with fruit which produces ethylene, such as apple or banana.

Fruit Quality and Flavor

Fruit quality is determined by many factors, grade (U.S. No. 1, U.S. No. 2, U.S. No. 3, color rating (green, breakers, turning, yellow, light red, red, defect rating (damage, extreme damage, very serious damage), and similar varietal characteristics (Jones, 1999). Fruit can be separated by size (diameter) and/or weight and marketability for "beefsteak" style varieties [free from blemishes, i.e. cracking (Peet, 1992), catfacing, misshapen, puffiness, BER, sunscald, green shoulders, russetting, more scarring, fracturing, and blotchy maturing. Morgan (2001e) discusses possible causes of fruit anomalies and then describes steps that can be taken to reduce them. Color uniformity, strength of color, and firmness are also factors which will decide the marketability of tomato fruit. At the "split" point, fruit can be harvested when the fruit initially turns from dark green to light green and then allows it to mature naturally or be handled with ethylene gas to speed up the process of maturation. Color production pictures of 10 to 100 percent ripe tomato fruit can be found opposite the Wittwer and Honama (1969) inside title page of the novel. Fruit from tomatoes picked when green never matures naturally.

While flavor is not a calculated fruit identification factor, high flavor (organoleptic properties) sensed by the customer can lead to repeated sales for known origin labeled fruit. There are two measured factors associated with the "strong" taste, a 5.8 to 6.2 dS / m EC fruit, and a 4.8 to 5.0 BRIX level. Flavour can be a subjective aspect because not everyone can taste the same thing. In general, fruit containing high acidity and sugar is usually called "flavourful." Much of the flavor in the tomato fruit occurs in the portion of the gel. Hence, the fruit's gel-to-wall ratio can affect flavour.

High flavor comes from two components of the fruit, sugar content (glucose and fructose), and volatile organic compound amounts. Forty-six per cent of the fruit's dry weight is sugar, 12 per cent organic acids, 8 per cent minerals, and the other organic compounds that remain. The longer the fruit is left on the vine, the stronger its taste will be. The cooler the temperature of the air, particularly the temperature at night, the greater the flavor of the fruit. In general, stressed plants grow higher-flavored fruit; this is the rationale behind the standard practice of raising the nutrient solution EC to approximately 4 dS / m or adding NaCl to the nutrient solution at a concentration of 35 ppm in solution during the fruiting cycle. A varietal aspect is present, as some varieties produce more flavorful fruit than others. Small-fruit varieties (cherry) tend to contain more flavor than large-fruited (beefsteak) varieties usually do.

Two other factors that will affect quality measured by consumers are skin toughness and firmness of the fruit, factors that offer a certain "mouth feel."

Plant Nutrition

The tomato plant is known as a plant requiring high nutrient elements. Primary nutrient elements of importance for this crop are N, P, Mg, and Zn. Among the micronutrients, the tomato plant has high Fe and Cu requirements, and modest B, Mn, and Mo requirements. Excess N is more likely to occur than its deficiency; excess results in abortion of the blossom, reduction of the collection of fruits and vegetative stimulation over reproductive development. Plant characteristics that suggest excess N are dark green foliage, robust plant growth, rapid growth and sucker production, and the presence of vegetative stems on fruit trusses. Plant N amount considered excessive varies with plant growth stage and environmental conditions. Moreno et al. (2003), for example, found that cultivars less effective in their use of N yielded higher fruit yields than those more effective. They also observed that total N in the leaf tissue declined with time; the average content was around 4.50 percent during the vegetative stage and then decreased to 3.00 percent during the fruiting phase at a gradually decreasing plateau rate. Though in agreement with Wilcox (personal contact), Ward (1964), and Reisenauer (1983), the 3.00 percent N amount is substantially less than what was recorded by some (Jones, 1999) as the optimum during fruiting. During this same time, Moreno et al. (2003) observed a decrease in leaf K (4.00 to 2.00%), Mg (0.90 to 0.70%), and S (0.32 to 0.20%), while P (0.75 to 0.95%) and Ca (2.90 to 3.10%) increased. Mason and Wilcox (1982) say that the NO3-N content of the petiole of mature leaves (> 14,500 ppm is excess) is a better measure of the tomato plant's N-status than total N of the entire crop.

While fruit quality is commonly thought to be closely correlated with elements K and B, little attention has been paid to N as an significant factor affecting the quality of the fruit. The author assumes that controlling the K supply to the plant does not affect the quality of the fruits unless the plant's N status is preserved at the lower end of the sufficiency range (3.0 to 3.5 per cent). Light intensity can also play a significant role in the tomato plant's Nutrition, requiring higher N levels under low light conditions, and lower N levels under high light conditions.

Blossom-end rot (BER) is a symptom of Ca deficiency due to inadequate Ca entering the blossom end of the fruit that grows. However, if there is no other stress condition that results in BER-affected fruit a serious Ca deficiency must occur. More often than not, BER occurs primarily as a response to plant stress, usually stress with moisture and/or low transpiration rate. Calcium moves through the plant's xylem conductive tissue, and if that movement is slowed down by impaired water uptake and/or movement through the plant, then Ca movement up the plant is also impaired, particularly movement into fruit growth. Furthermore, ample Ca in the rooting medium, while necessary, does not guarantee liberty from BER occurrence. As reported by Taylor and Locascio (2004), "BER is linked to several factors, including: high salinity, high concentration of Mg, NH4 and or K, inadequate production of xylem tissue, rapid growth rate, unfavorable moisture relationships (high, low or fluctuating), low soluble medium Ca, high temperature, and high and low transpiration." Calcium is not readily absorbed through the leaves into the plant, and then transferred through the fruit epidermis to the vascular tissue for transportation across the plant.

There is also a balance between the major cations, K, Ca, and Mg, and if these components are out of balance with each other, then it can impede Ca uptake and movement. The author observed BER-affected fruits when symptoms of Mg-deficiency on the visual leaf were present. The presence of NH4 in the nutrient solution will significantly increase the incidence of BER if it is greater than 10 per cent (Hartman et al., 1986).

Excess phosphorus is more likely to occur than its deficiency, and its excess (greater than 1.00 percent of the dry weight) may result in Zn deficiency in recently mature leaves (Jones, 1998a).

Not only can the source of Fe affect its absorption but it can also have a major effect on the plant. For example, the type of Fe in chelate ethylenediaminetetrateacetic acid (EDTA) is not recommended as EDTA is toxic to the plant (Rengel 2002). Fe's form of chelate diethylenetriaminepentaacetic acid (DTPA) is the approved chelated form since toxicity to DTPA is assumed to be absent. Rengel (2002) found that Fe-EDTA's inclusion in a nutrient solution resulted in a decreased absorption and translocation of the Cu and Zn micronutrients within the plant. It is not known if chelated Fe's DTPA shape would have the same impact on both of these micronutrients. They used other chelated forms of Fe, HEEDTA, NTA, and EDDHA, but to a lesser degree than either EDTA or DTPA. Several inorganic forms of Fe, such as iron ferrous sulfate, $FeSO_4 \cdot 7H_2O$; iron ferric sulfate, $Fe_2(SO_4)_3$; ferric chloride, $FeCl_3 \cdot 6H_2O$; and iron ammonium sulfate, $FeSO_4(NH_4)_2SO_4 \cdot 6H_2O$, have been found suitable as sources of Fe in nutrient solution formulations.

In tomato leaf samples submitted for review and interpretation the author has frequently found low contents of Cu and Zn. The questions to be answered are, "do these low levels represent an insufficient amount of Cu and Zn in the nutrient solution," or "is this a factor related to cultivar adsorption ability, or is it the nutrient solution effect of Fe chelate on Cu and Zn adsorption? "The effect of the presence of chelate in the nutrient solution would be my best guess. I have found in earlier experiments that if the source of Fe was an inorganic one, low content of Cu and Zn leaf was not frequently observed.

The plant's nutrient-element status is essential for normal vigorous growth and sustained fruit setting and production under varying environmental conditions. For example, the best plant output is obtained under high radiation (bright long sunny days combined with high transpiration rates) when the plant's nutrient content for the major elements, primarily N, P, and K, is at the minimum concentration required for their sufficiency. The best plant output occurs under low radiation (short and/or cloudy days with low transpiration rates) when the plant's nutrient element content for these same major elements is at the mid- or higher end of the concentration range needed for their sufficiency.

The absorption levels for the critical nutrient elements are not all the same as Halbrooks and Wilcox (1980) have found. For elements P, K, and Mn and for ions NO_3^- and NH_4^+, active uptake occurs; moderate uptake for elements

Mg, S, Fe, Zn, Cu, and Mo; and passive uptake for elements Ca and B (Bugbee, 1995). Actively transpiring plants can quickly pick up the NO_3^- and K^+ ions from the solution surrounding the roots, resulting in high N and K levels in the plant, which in turn contributes to imbalances between these and other components. Therefore there is a need to change the composition of the nutrient solution to prevent imbalances between the components.

Morgan (2003d) found that the concentration of the major elements in a nutrient solution would change over a period of 40 days, as the plant blooms and sets fruit. The K concentration, for example, decreased from 750 to 200 ppm, while Ca increased from 500 to 700 ppm, and Mg increased from 125 to 200 ppm, respectively. To account for these changes, Morgan (2003b) suggested that the nutrient stock solution be formulated in such a way as set out in Table 11.11 to account for those changes.

The plant's nutrient element content can be controlled by regular sampling (every 2 to 3 weeks) and analysis. The right sample is an end leaf from a newly mature crop. Physical signs of plants suspected of being due to a deficiency of the nutrient factor should be checked through plant analysis. The book by Roorda van Eysinga and Smilde (1981) gives color pictures of the visual symptoms of nutrient disorders in tomatoes. Bould et al. (1984) describes visual impairment symptoms for the elements Ca, B, Cu, Fe, Zn, and Mo in the novel. In a review article, Jones (2000) explains the tomato plant's nutritional characteristics, and how visual plant appearance and elemental leaf content can be interpreted as a means of ensuring adequate nutrient element. Insufficiencies of visual nutrient components in tomatoes are in video form (Jones, 1993c).

Varieties (Cultivars) Several varieties are available for outdoor production; the plant types are determined (the plant may end its growth by producing a flowering truss) or indeterminate (the plant continues to produce a vegetable stem), and the fruiting characteristics differ greatly in size, color and shape. The following favorite tomatoes were identified in a survey conducted by Organic Gardening magazine (vol. 50, issue 4, page 4, July / August 2003): Beefsteak — 37 percent, Cherry — 27 percent, Slicer — 20 percent, and Plum — 15 percent.

Bennett (1997) lists 'home garden favorite tomatoes,' including 19 cherry tomato varieties, 59 medium size tomato varieties (average fruit weight from

2 to 10 ounces), 27 big tomato varieties (average fruit weight 12 ounces), 15 paste tomato varieties and 22 rare tomato varieties.

Heirloom varieties are of increasing interest (Male, 1999), but many of these varieties are susceptible to various diseases and may lack adaptability to climate stress (Johnson, 1999).

Varieties used in earlier periods were beefsteak styles for greenhouse production, such as "Tropic" and "Jumbo;" while varieties produced by Dutch researchers such as "Trust," "Play," "Hunt," or "Blitz" have been used in more recent times. Most of the so-called beefsteak cultivars originally grew but today cluster tomatoes are becoming the variety of choice due to their special market presentation. It is estimated that about 60 percent of all today grown greenhouse tomatoes are a cluster, and that percentage can continue to increase.

CHAPTER FOUR

The Hydroponic Greenhouse

The analysis is strictly restricted to greenhouse systems of less than 0.5 acres (0.2 hectares) in scale, with particular regard to a 3000 to 3600 ft2 (279 to 334 m2) stand-alone greenhouse or multi-bay units consisting of two to five stand-alone unit bays. There are large greenhouse facilities, consisting of 20-acre (8-hectare) units which may be situated in a two to six-unit complex. Large greenhouse complexes are somewhat similar to what could be called the "single-owner / operator" greenhouse, but there are significant differences beyond the scope of this analysis in terms of design and operational requirements.

The size unit(s) best fits for the single owner / operator should be determined by the economic and market conditions. Pending the verdict, what follows in this chapter shall apply.

There is nothing unique about hydroponics that would significantly alter the basic structure or operating characteristics of a greenhouse, features that can be found in Aldrich and Bartok's books (1994), Hanan (1998), Nelson (2002), Betyes (2003), and Taylor (2003), as well as in Goldberg (1985) and Beytes (2003) papers. The basic requirements are focused on which plants to cultivate (Nelson, 2002). The only thing that may be different inside the greenhouse would rely on the method of hydroponic production, be it in containers, field beds or troughs, or in pits placed on the greenhouse floor or benches. Specialized equipment can also be required for supplying plants with the nutrient solution and water. For example, an ebb-and-flow or NFT system may need a particular means to store and distribute the nutrient solution for a drip irrigation system. For a hydroponic ebb-and-flow system the nutrient solution tank is usually placed below the level of the growing beds in the field. For example, the size of tanks that contain nutrient elements may be deciding their position inside or outside the greenhouse.

Placement can also require other means of temperature control to ensure the temperature of the nutrient solution supplied to the rooting medium is equivalent or equal to that of the greenhouse air temperature. If collected, the effluent flow from containers, slabs, and troughs would require a collection, pumping, and storage system, but if discharged it would require a floor design to manage such drainage. Such nutrient solution discharges now come under water quality legislation, requiring storage and treatment before discharge (Johnson, 2002c). The NRAES-56 publication (Anon., 1996) covers guidelines for effective management of nutrient solutions, concepts of root zone management, water quality and distribution, and related topics that that affect the operation of a hydroponic greenhouse; Savage (1985b, 1989) has two publications on the financial aspects of building and maintaining a hydroponic greenhouse.

Greenhouse Defined

The early term for defining a greenhouse was "hothouse," a term that is not widely used today. The hothouse is described as "a greenhouse maintained for the cultivation of tropical plants at high temperatures," in the Merriam-Webster Dictionary. This concept derives from the fact that a greenhouse will collect solar radiant energy which heats up the interior. Jensen and Malter (1995) described a greenhouse as 'a framed or inflated structure, covered by a trans-parent or translucent material which allows optimum light transmission for plant production and is protected from adverse climatic conditions.' Hanan (1998) states that 'greenhouses are a means of overcoming climate adversity using a free source of energy, the sun.' The term 'glasshouse' is a European phrase for a building that is artificially heated for growing plants' (Gough, 1993). Beytes (2003a) describes three basic greenhouse designs, one-bay free-standing as low-cost entry into the greenhouse market (Thompson, 2003); multi-bay gutter-connected as the most effective practical greenhouse (Grosser, 2003), yet lacking in flexibility; and withdraw.

Location Factors

In earlier times (before 1970), greenhouses dedicated to vegetable production were located near major population centres, but with the ability to shift producing rapidly from one area of the country to another, and even from neighboring countries, site selection could be based on factors other than market closeness. Jensen (1997) announced the collapse of the greenhouse vegetable industry that once existed in the central United States around major population centers. He notes that "today ... light is considered the most important factor in greenhouse vegetable production, rather than being located near a population center." Some may refute this statement, as many single-operator greenhouse vegetable growers are successfully growing and selling their produce on local markets, which are often large population centers.

The location and placement of the greenhouse can decide how well the enclosed crop performs other than economic considerations. Resh (1995) lists the specifications of the following site: 1. Full east, south, west exposure to windbreaked sunlight on north

2. Level region or one conveniently levable

3. Strong internal drainage, with minimum 1-in./h percolation rate.

4 Have natural gas, three-phase electricity, telephone and water of good quality which can supply at least half a gallon of water per plant per day

5. On a good road near a wholesale business center and greenhouse retail market if you want to sell retail 6. Near to the residence for ease of greenhouse testing during weather extremes

7. Greenhouses focused north-south with rows even north-south

8. A area that has a maximum sunlight content of

9. Not situated in an environment of extremely strong winds

In addition, the greenhouse should be positioned so that the greenhouse is not shaded by features in the immediate region. Wind exposure may have a major effect on the heating and cooling requirements; thus, it may be highly beneficial to have a windbreak. Placement on hill tops in rolling terrain will expose the greenhouse to uncontrollable winds and cold air runoff, fog and polluted air in the valleys.

It is important to determine what exists upwind, even several miles away, to avoid either deposition of dust on the greenhouse or the possible intake of substances that would cause harm to the enclosed crop. To position the greenhouse in an actively cropped field, it is important to know what crops are being grown and what chemicals are being applied to those crops. Many crops, such as soybeans, are ideal hosts for insects; insects can be brought into the greenhouse via the ventilation system, thereby contributing to the requirements for pest control. Herbicides and other chemicals that are spread aerially to surrounding fields and fruit crops can be transported into the ventilation system by flowing into the greenhouse. Getting a windbreak may mitigate the accumulation of suspended material that can collect on the surface of the greenhouse or the immediate area. The author visited a massive greenhouse complex, which was situated in an remote area within miles with little human activity. Selecting such an isolated location would mitigate what the surrounding human activity could bring into the structures.

Therefore, the immediate environment surrounding a greenhouse must be kept as sterile as possible, with the minimal interference from activities that may churn up airborne particles, such as having adjacent service buildings that carry vehicle traffic close to greenhouse entrances.

At one time the author was responsible at different locations for a sequence of field plots of study. The yield results were significantly different from those obtained at the other sites at one spot, a site east of a highly traveled highway. It wasn't until I calculated the volume of ammonia (NH3) above the plots in the atmosphere that I understood why the results of yields at this site were always greater. The NH3 coming from truck and automotive exhaust was deposited as ammonium-nitrogen (NH4-N) on this field plot, which added enough N to the crops being grown on those plots to significantly influence yield.

The author was curious as to why a large greenhouse operator selected a certain region in the southeast for the foliage plant production. In addition to the availability of an educated work force and a suitable living environment, the specific location was decided based on long-term weather records which showed a high number of cloudless days for that environment during the year. A similar greenhouse location in upstate New York was chosen because for that specific site, the regular light conditions based on long-term sunshine data records were higher than those for the surrounding area.

Basic Structural Design

A greenhouse's structural design is important because the size and spacing of framing material will influence the degree of light shadowing, whereas other types of structural materials may serve as thermal accumulators, contributing either desirable or undesired heat to the greenhouse atmosphere. The ability to withstand wind and snow charges will dictate the strength required for the structure, which is a major factor in certain areas. A common mistake in greenhouse design is to underestimate the effect of extreme climatic events (wind, hail, and snow) on the structural integrity and protection of the interior. Treated wood, galvanized steel, aluminum tubing, and PVC tubing are widely used structural materials.

Greenhouse systems range from a loose covering over the top of the crop (Wells, 1996), with or without mobile side curtains built to shield plants from rain or from the extremes of outside temperatures, to a fairly airtight system for precise monitoring of the internal climate. Polyethylene film-covered greenhouses usually have end walls of solid, clean plastic (poly-carbonate). The typical style for polyethylene film-covered shelters is Quonset (mark for prefabricated shelter set on the base of bolted steel trusses and semicircular arching-roof).

A single-bay commercial greenhouse structure can differ dramatically in physical size: length from 90 to 130 ft (27.4 to 39.6 m), width from 24 to 40 ft (7.3 to 12 m), and height from 8 to more than 12 ft (2.4 to 1.6 m) to the gutter.

The greenhouse height can have a direct impact on the heating and cooling systems' ability to maintain a consistent air temperature within the structure. The greater the volume of air to be conditioned tends to minimize significant changes in temperature, humidity, and concentration of CO2 in the interior air.

Freestanding greenhouses and gout connected have different design requirements. Gutter-connected greenhouses give flexibility in construction and use of space but add additional criteria for managing the interior. Wide open areas present challenges to disease and insect control as well as special equipment in the system to maintain consistent atmospheric conditions.

The design of the entrances and the placing of screen coverings over air vents and other openings will determine how well insect and disease organisms can be prevented from entering the greenhouse (Jacobsen, 2003). The entry of the main door into the greenhouse will be installed in a door-shaped addition, close to entrances to most business buildings. Workers will change clothes before entering the device, step into a disinfectant room, etc., and then enter the greenhouse without injecting a blast of air into the greenhouse if the ventilation fans are working.

How well the various parts of the greenhouse fit together will decide how "tigh" the structure is going to be, a good feature to keep out unwanted air and insects, but if it is too "tightened," irregular air pressure from inside or outside will lead to cracks and deterioration of joined pieces.

For greenhouses covered with glass or rigid plastic, these structures either have mobile vent panels on the rigid side, or large mobile vents that can open the entire greenhouse roof. The typical design for most plastic film-covered greenhouses is to place an exhaust fan(s) at one end of the greenhouse, and an adjustable opening, with or without a cooling pad, at the other end so that air can be pulled through the greenhouse duration. Air baffles can be mounted in the gable at various locations, so that air pulled through the greenhouse by an exhaust fan(s) is regularly guided downward, ensuring that air mixes across the entire depth and duration of the greenhouse. A very efficient way to ventilate a greenhouse is to position the ventilation fans and cooling pads around the greenhouse length on opposite sides, so that air is drawn across the shortest distance. Unfortunately, it is so built that few greenhouses are.

Flooring In the greenhouse a variety of materials can be used as flooring; concrete is the best choice, and compacted soil or sand is the least suitable choice. The walkways may be concrete for initial cost considerations, while the crop rows may consist of sand or gravel, or similar materials. In order to act as a buffer, the crop rows and, if the whole floor consists of such materials other than concrete, the plastic ground cover should be placed over the crop rows or the whole floor. Crop waste, a source of disease and other problems, which falls on an open floor can not be cleaned up unless the floor is strong. The lack of flooring firmness will cause user issues, affect the flow of foot traffic in the greenhouse as well as interfere with the floor drainage system. With a smooth and solid flooring material in place, the entire greenhouse floor pays dividends in concrete to keep the floor clean and clear of waste. The greenhouse floor will have a slope of l to 2 per cent.

Glazing Materials Glazing refers simply to the type of material that covers or that is attached to the greenhouse structure. Another word used in the glazing literature is cladding (which, according to the Merriam-Webster dictionary, covers or overlays); Glass, polyethylene foil (high or low density, linear low density), ethylene vinyl acetate, and coex-truded films are the widely used glazing products. Fiberglass was used widely at one time, but its flammability has restricted its use almost completely today.

Coene (1995) lists five major considerations when choosing the green-house coverage:

1. Integrity of materials in direct sun, without losing clarity

2. Lifetime Guaranteed

3. Resistance to the Fire

4. Photosynthetic radiation transmission (PAR);

5. Assets on energy efficiency

Another function is the diffusion of light which passes through the cover. Light diffusion can more uniformly disperse light in the greenhouse, resulting in "a more even distribution of light without specified shadows" (Coene, 1995). Fiberglass has a high diffusion property as well as structural strength; for these purposes it was used as a glazing medium in wide use at one time.

Some types of coverings do not transmit all the wavelengths of light that reach their surface equally, thereby filtering the light and altering its spectral characteristics (Morgan 2003a). The characteristics of different types of glazing materials including glass, polyethylene film, polycarbonate, fiberglass, and acrylic are discussed in the Beytes (2003a) edited book. Both of these materials have different transmission properties which will have a direct effect on greenhouse radiation input and output. Cost, durability, and external environmental factors (i.e., wind, snow load, hail resistance etc.) can decide the selection of which glazing material is best. The so-called "greenhouse effect" is a phenomenon owing to a wavelength change. Radiation leaving the greenhouse contributes heat to the interior as radiation reflected back from the interior surfaces is longer than that leaving the greenhouse and is therefore stored as heat inside the greenhouse.

The effect of light filtering and diffusion on the color and design of the plant was demonstrated to the author in a greenhouse tomato experiment performed in two greenhouses a few miles apart. One greenhouse had fiberglass insulation, the other glass. The plants in the glass-covered house were dull green in color and had long internodes, while those in the fiberglass-covered house were dark green with short internodes in colour. Interestingly, there were only minor variations in fruit yield, but the tomato plants in the greenhouse covered with glass needed more regular adjustment due to their longer internodes.

Heating and Cooling

The specifications for heating and cooling will differ according to the location, form of structure, and crop to be grown (Anon., 1994; Ball, 2003; Rearden, 2003; Morgan, 2003a, b). Typically speaking, it is easier to oversize these systems to ensure that the atmosphere within is easy to manage. The location of ventilation fans, cooling pads, and heating equipment can dictate how well the temperature and moisture inside air can be managed. Air movement up through the plant canopy is favoured for certain crops, such as tomatoes and cucumbers. Floor heating can be beneficial to a crop especially in cooler climatic areas, keeping the rooting medium at or near the greenhouse ambient air temperature. The warming of the nutrient solution / water to that of the current greenhouse air temperature, or even 4 to 5 degrees F above ambient air temperature (Smith, 2002b), would decrease the potential for plant wilting due to decreased water absorption. The rate of plant roots absorption of water is correlated with temperature, decreasing as temperature decreases (Nielson, 1974; Harssema, 1977).

Heating

There are two methods mainly available for heating the greenhouse atmosphere, forced hot air or radiant heat. The most widely used is either a natural gas or propane-fired jet fan heater which is mounted on the ventilation fan end in the greenhouse gable (Figure 12.8). Heated air is forced through a wide plastic-holed tube gable-placed which runs the entire length of the greenhouse (Figure 12.9). The heated air is circulated through the holes in the pipes, the discharge force being sufficient to drive heated air into the cavity of the greenhouse. In the fossil fuel combustion contributes heat to the atmosphere. The moisture can condense as the ambient temperature cools the underlying greenhouse system, leaving the walls and internal structures wet, including the plants, which is highly unwelcome.

The other form of heating is by passing either boiler-generated hot water or steam through pipes that are installed at ground level down the sides of the greenhouse, and in some cases, pipes are installed between crop rows. This sort of heating system is called "hydronic heating;" through radiation from the heated pipes, it allows even heating of the greenhouse atmosphere. The greenhouse and canopy atmospheres are kept dry with hydronic heating, as hot air flows through the plant canopy into the gable from floor-level pipes. The moisture-laden air can then be expelled from the greenhouse using a small gable-placed ventilator.

Three processes result in heat loss from the greenhouse: conduction (heat loss from solid materials), convection (removal of heat from air currents), and radiation (heat loss from the glazing layer by short or long wavelength radiation). Additionally, heat loss can occur through the absorption of cool air and hot air loss through the greenhouse cracks and openings. A winter weather temperature can be estimated, based on the average of the coldest days of the year. For very cold environments, either outside or at the base of the gable as well as on the sides of the greenhouse, the use of thermal blankets can greatly minimize back radiation at night, or when the greenhouse is exposed to cold winds. Figure 12.10 (Bartok, 2000) shows the winter design temperature chart for estimating heat loss in greenhouses located in the continental United States.

Morgan (2001b) explains the greenhouse architecture and operating procedures required to mitigate the impact on plant growth and greenhouse functions of low temperatures. She focuses on the selection of glazing materials, the design of heating systems, and the procedures for air distribution, which can have a major impact on the maintenance of the interior environment within parameters necessary to maintain plant production. Double layers separated by continuously applied air reduce heat loss by both conduction and back radiation for plastic polyethylene film-covered greenhouses. Likewise, polycarbonate twinwall panels are widely used as end walls but they can be used as side walls as well as glazing material; the double-walled material is more energy-efficient than single-walled panels.

Floor heating can be beneficial in certain climatic regions. It is done by either putting on the surface or in the greenhouse floor itself hot water – heated pipes or electrical heating cables. A thermal barrier is installed beneath the greenhouse floor for the most effective floor heating effect.

The range of temperature in which plant enzymes are active ranges from 50 to 104 F (10–40 C). For most greenhouse-grown plants, the optimum air temperature ranges from 55 F (13 C) to 77 F (25 C). At low temperatures, plants may display signs of a P deficiency, a violet pigmentation of the new leaves, and below, some cases, symptoms of Fe deficiency — symptoms that will disappear when the greenhouse air temperature is brought into the normal range for best growth. Low air and medium temperatures can lead to pathogen development (especially Botrytus), as well as reduced water and/or nutrient solution uptake at the root.

For heating greenhouses alternative sources of both fuel and heat were used. For example, waste oil (Anon., 1977b) and methane emitted from a landfill (Simon, 2003) were used as sources of fuel, and hot water condensate from a nearby steam-powered electrical plant was used to heat a greenhouse (Peckenpaugh, 2004b). Kleemann (1996) explains how wind-powered generators can be used to provide a greenhouse with electric power.

Johnson (2003) describes a specific hot water storage system in which water is heated by a gas-fired boiler during the day to 200 F (93 C) and CO2 produced by combustion is introduced into the greenhouse after passing through an exhaust gas separator (see CO2 enhancement section). At night the greenhouse is heated with the accumulated hot water.

During the winter months (December through February in the northern hemisphere, June through August in the southern hemisphere) in some climatic regions where light intensity is small and regular average daytime air temperatures are typically less than 32 μF (0 ° C), there is little attempt to develop under these conditions.

Cooling

It should be recalled that a greenhouse, often referred to as a "hothouse," is a very powerful solar collector (thermal accumulator), probably ideal in cool / cold low-light climatic conditions but an undesirable function in high-light warm / hot climatic conditions (Morgan 2001a; Jones and Gibson, 2001). The so-called "greenhouse effect" is due to the trapping as heat of incoming radiation in the greenhouse — heat that is not readily re-radiated through the glazing material back out. Furthermore, incoming radiation that reaches the objects in the greenhouse serves as heat sinks, contributing significantly to the heat load that can either be advantageous or detrimental to regulating the interior. Buntyn-Maples (1994–95) talks about "Greenhouse Growing — Southern Style, where plants face adverse 40 F (4 ° C) temperature days and even colder nights without indoor supplementary heating or greenhouse solar power." Many growers in the southern regions do not grow due to high temperatures in the mid-summer months (June – August). Jones and Gibson (2001) linked poor growth of tomatoes and fruit yield to the amount of radiation (measured as sunlight minutes per month) entering greenhouses in southeastern United States. We found that the output of tomato plants was negatively affected by months of more than 10,000 minutes of cumulative sunlight.

The natural way to extract warm / hot air from the greenhouse can be as easy as raising side curtains or opening ventilation vents at the roof ridge line if the greenhouse is so built. For structures without these features, cooling is obtained primarily through the ventilation fans dragging outside air into the greenhouse (Ball, 2003). The fans are mounted at one end of the greenhouse or along its sides, and the openings at the opposite end or side draw air in. Those openings can be fitted with a cooling pad that is kept damp by passing or moving through water. The efficacy of the cooling pad in reducing the temperature of incoming air will depend on the relative humidity of the outside air; the higher the humidity, the less the temperature of the air will decrease. It is possible to measure the configuration and effectiveness of cooling pads based on the pad size and the amount of air drawn through the pad (Short, 2003). Any gallon of water evaporated through a cooling pad from the passage of air will consume 8100 BTUs of heat energy.

The author claims the greenhouse is much more effective in cooling the interior than dragging air through the longest distance. Few greenhouses are therefore equipped with side ventilation systems. Depending on the weather conditions, 60 air changes an hour could be required on days of high light intensity to maintain optimal air temperature inside the greenhouse by bringing cooler air in from outside.

Opening the greenhouse to outside air that flows into or out of the greenhouse would enable the entry of insects, disease species and other pests. Screens of different mesh sizes (below 500 micron mesh recommended for insect blocking) are required to minimize the entry. If the primary cooling system is via a cooling pad, it can require a wide screened plenum to allow sufficient air to move through (Jacobsen, 2003).

Shade cloth placed over the greenhouse will decrease the amount of incident radiation passing through the glazing or, when placed at the bottom of the roof gable above the canopy of the plant, decrease the air temperature in the greenhouse or canopy of the plant respectively. When to shade and the amount of shade depends on which crop is being grown and on the radiation intensity being provided. For example, shade should be applied to tomatoes when the daytime greenhouse temperature reaches 85 ° F (29 ° C), and shade should be applied to lettuce and herbs when the daytime greenhouse temperature is greater than 80 ° F to 82 ° F (26.6 ° C to 27.7 ° C).

Shade cloth pulled over the top of the greenhouse is not easily put or removed as shown in Figure 12.15, which offers little flexibility for sporadic use. More recently, at the gable base, the greenhouses are equipped with shade cloth inside the greenhouse that can be drawn over a crop or fairly quickly pulled back. The ability to position and eliminate shade can have a major benefit in controlling the amount of radiation that impacts the crop, and in maintaining better control of the interior.

The degree of radiation control can vary according to the shade material's mesh characteristics. Normally, white shade material over a polyethylene-covered greenhouse is recommended for 40%, whereas white shade material for high altitudes and high light intensity light areas should be recommended for 50%. Glass-covered greenhouses have been whitewashed in the past to reduce incoming radiation, a practice that is not in general use today.

Misting is another way to cool down the plant canopy. It is often used both to cool down and to provide protection from the effect of high light intensity to newly rooted cuttings or emerging seedlings. The disadvantages of this technique are the potential for the development of disease when there is a cool and humid environment, as well as the requirements for high pressure pumps, fine nozzles and water free of suspended particles (Beytes, 2003). For certain environments the amount of radiation entering the greenhouse can be greatly decreased by misting or running water over the greenhouse roof.

Nyun (1997) has built a unique side wall lath shading method "squiggly cut" for use with greenhouses of a hobby kind.

Morgan (2001a) discusses those procedures necessary to minimize the effects on greenhouse operations of high temperatures. The temperature effect on the enclosed greenhouse crop varies with species, and how well the cooling system functions. The basic influencing factors are related to greenhouse design, such as increased roof heights and roof vent inclusion, and the use of fans and aspiration screens to move cool air through the greenhouse at different heights.

For most greenhouses, the impact of uneven cooling on a crop between the cooling pad and the exhaust fan can be easily seen if the transporting air is pulled at a significant distance [> 50 ft (15 m)] and there is no air mixing in between. The difference in air temperature may be as much as 10 degrees Fahrenheit from the end of the cooling pad to the end of the ventilation ventilator. For example, if tomato is the crop and the height of the canopy is at the support wire, the cooled air that is pulled through the cooling pad would appear to move over the canopy top. Such a condition can have a significant effect on plant growth and fruit yield. The solution would be to have a pad-ventilation cross-flow fan system (pulling air through the greenhouse rather than down its length), and/or moving air from its base through the canopy. If the cooling pad has an inner door closure, the closure should be hanged at the top so that air coming out of the pad is directed at the base of the canopy of the plant.

The plant cools itself by transpiration, the removal of water vapor from the surfaces of the leaves, close to the effect evaporating suddenness has on the body. The effectiveness of this refrigeration method includes continuous air movement over the surfaces of the leaf. Inadequate O2 and/or water in the rooting medium and low temperature can impair the movement of water into the plant roots (Nielsen, 1974; Harssema, 1977). The nutrient solution's increasing electrical conductivity (EC) will also diminish water uptake (see page 106). Under either of these restricting conditions for water uptake, the plant may wane when there are high conditions for atmospheric demand. Low air temperature and stagnant air will slow down the upward movement of water in the plant's conductive tissue (xylem), thereby reducing the rate of water loss from leaf surfaces. Both conditions will affect photosynthesis efficiency, thereby slowing plant production, resulting in lower fruit yields in turn. Adequate air flow through the plant canopy is therefore important, particularly for certain crops, such as tomatoes and cucumbers. This can best be accomplished by installing air conditioning at the bottom of the canopy of the plant.

Air Movement

Air movement throughout the greenhouse, and particularly within the plant canopy, can have a significant effect on plant performance. In an enclosed greenhouse, air movement created by the operation of heating and/or cooling equipment may not be sufficient to thoroughly mix the air in the entire greenhouse (Short, 2003). Even the placement of fans in the greenhouse gable directing air into the plant canopy can be ineffective. With a dense plant canopy created by tomato and cucumber plants, for example, it is very difficult to push air into the canopy, as the canopy acts like a "box," and air movement directed at the canopy either passes over the top or glances off of it. Therefore the air within the canopy has characteristics (temperature, humidity, CO_2 content) of its own which can be quite different than those of the air surrounding the canopy. The only way that sufficient air movement can be obtained is by the introduction of moving air from the base of the canopy so that air is constantly moving up through the canopy. This air may be condi-tioned, that is, either heated or cooled. If no air is being brought into the greenhouse from outside, it is very important that the entire mass of air within the structure be constantly mixed as plant growth and function can be impaired by standing in still air.

Plant Support System

For tomato, cucumber, and pepper greenhouse production, a plant support system must be installed. The system usually consists of a strand of strong wire stretched over the plant row with hanging string attached to the wire at each plant location. The plant is tied to the string. Various systems have been devised to ensure that sufficient string is present at each plant location to provide for lowering and tying over a full season of plant growth. The attachment of the support wire to a structural greenhouse member is not recommended since the plant weight on a support wire can be several tons. Most greenhouse structural members are not able to hold such weight. The support wire should be attached to sturdy-set stanchions placed about every

30 ft (9 m) down the plant row, or the stanchion can be placed in the middle of a double row with a cross piece at the top to hold each support wire in place.

Supplemental Lighting

There are two key reasons for providing additional light: photosynthetic, the use of light sources to provide part or all of the necessary for normal plant growth, and photoperiodic, needed to regulate flowering and plant shape (Yoemans, 1991; Sherrard, 2003). The amount of light required for photosynthesis for many plants ranges from 100 to 1000 times that needed for photoperiod lighting. If used for any use, the cost of additional lighting will be either equal to or less than the financial gain achieved from its use. Supplementary lighting to prolong the hours of daylight could be the only permissible use for most crops for photosynthetic benefit. Enhanced lighting to improve light intensity during daylight hours is highly doubtful as regards the substantial gain calculated by improved yield and product quality. For example, the light level in the greenhouse for sustaining tomato and lettuce growth ranges from 800-1200-foot candles. The light requirement of plants varies considerably, and supplementary lighting will help those plants that are highly light sensitive. Parker (1994a) gave some of the crops commonly grown in the green-house the light requirements.

In a two-part article, Parker (1994a, b), describes the characteristics of light, its nature, intensity, and spectrum, and its effect on plants. In the second Parker (1994b) paper, the spectral distribution for different lamps (standard fluorescent, mercury vapor, metal halide, and high pressure sodium) is discussed. A light source's suitability for supplementation depends on its spectral distribution (how close the light emitted mimics of the sunlight) and its intensity. The running expense and life expectancy of lamps are likewise significant considerations. For certain cases, the best spectral coverage for optimum plant impact can be provided by a combination of lamp types, such as incandescent and fluorescent, mounted over a crop. Combination lamps are available today to provide a broad spectrum of emitted light. Some lamps produce considerable heat, which can either be an advantage as a heat source or allow dissipation of the unnecessary heat, which adds to their operating costs. Supple-mental light also has a "drying effect" which keeps the plant foliage dry during periods of low light.

The type of lamp, its emission strength and spectrum (long and short wavelength distribution), the use of reflectors, a combination of types of lamps, and the positioning Light quality (spectral distribution) and strength are important considerations when selecting the type of lamp. Van Patten (1998), concentrating on high-intensity discharge (HID), metal halide (MH), and high-pressure-sodium (HPS) lamps, defines the types of lamps available for plant use. Metal halide lamps emit a complete, close spectrum to that of natural sunlight. One type of HID lamp is the sulfur lamp, light that comes from a hot gas or plasma within a transparent shell.

Those seeking a thorough analysis of the effect of light, both quantity and quality, including the effect of supplementary lighting techniques on plant growth and development, will find considerable value in Mplekas' (1989) post. Mplekas (1989) notes "the the need for a scientific approach to horticultural lighting in order to increase plant production and boost the economic return on an increasingly competitive market combines to emphasize the importance of electric lights as a horticultural control tool to the commercial grower."

Carbon Dioxide Enrichment

Carbon dioxide (CO2) naturally occurs at between 300 and 400 parts per million (ppm) in the atmospheric atmosphere and is considered an important plant nutrient by some. Simply put, CO2 diffuses through open stomata of the chlorophyll-containing leaves of a live plant and, in the presence of light, is combined with a split water (H2O) molecule to form a carbohydrate; the whole process is called "photosynthesis" (see pages 14 and 383). Positive effects of CO2 enrichment have been documented on plant growth since the 1920s, but greenhouse CO2 enrichment was not put into action until the 1960s.

The atmospheric CO2 content in an enclosed greenhouse will decrease during the day due to photosynthetic activity (CO2 absorption) and increase at night as plants breathe (CO2 release); the change in concentration is as much as 150 ppm. This cycling of the CO2 content can be moderated by regular ventilation of greenhouse and air mixing within the plant canopy. The CO2 depletion rate is closely associated with the photosynthesis rate, with the depletion occurring rapidly within a few hours of daylight. The author was shocked when he found a 50 ppm decrease in CO2 content inside a canopy of a tomato plant just a few minutes after the greenhouse entered direct sunlight at dawn (Harper et al., 1979). Photosynthetic behavior of plants will reduce the CO2 content within the canopy of plants to between 200 and 250 ppm.

The photosynthetic rate is positively associated with the plant's CO2 concentration; the magnitude of this concentration effect varies with plant species (whether plants of C3 or C4, see pages 378–379) and light intensity (Carrathers, 1991–92). Therefore, the positive enhancement effect may be substantially enhanced if the CO2 concentration is three to four times that which is naturally present in the atmosphere, whereas photosynthesis can be halted when the CO2 concentration exceeds 200 ppm. Excessive concentrations of CO2 (2000 + ppm) can be harmful to plants, while concentrations of 5000 ppm can pose health hazards to those who work in such an environment (Morgan, 2003c).

Elber (1997) and Morgan (2003d) investigated the impact of CO2 enhancement on plant growth for crops such as tomatoes, cucumbers, bell peppers, roses, lettuce and herbs, and ornamental and forage crops. The magnitude of the enhancement effect varies with crop species and is not always advantageous.

Slake (1983) found that all-day CO2 enrichment maximizes the growth of tomato plants and their fruit yield, but more importantly, maintaining the CO2 level within the plant canopy constant during the day to maintain plant growth and fruit yield. It should also be recalled that newly emerging leaves should have less stomata per leaf area with sustained high concentrations of CO2 (1000 ppm), and it is through the stomata that photo-synthesis takes place. Therefore, although the CO2 content of the atmosphere around the plant is high, due to the presence of fewer stomata on the leaves, the photosynthetic rate will go down. In addition, some observed a fairly large drop in photosynthetic response of plants to elevated CO2 over time, with initial increases ranging from 30 to 50 per cent and then falling to 5 to 15 per cent (Wolfe, 1995).

The light intensity and the CO2 content of the air surrounding the plant are also substantially related (Mpelkas, 1989). Gaastra (1962) also observed a significant relationship between the concentration of CO2, light intensity and temperature of the leaves, and the rate of photosynthesis in the cucumber. Increasing rising light intensity, due to either CO2 concentration and/or leaf temperature, the rate of photosynthesis was approaching a plateau. These plateau events will restrict the efficacy of CO_2 enrichment with increasing environmental conditions and plant features.

Elber (1997) explains the different ways in which CO_2 can be released into the greenhouse by either constant ventilation, the use of fuel-burning generators (which can also produce excessive heat and water vapour), or the use of bottled-gas emitters. If CO_2 is produced using a combustion technique, care must be taken to ensure that there is complete combustion. Incomplete combustion will release greenhouse gasses, such as ethylene (C_2H_4) and carbon monoxide (CO), which will be harmful to plants as well as greenhouse workers, particularly if CO is released. Closed CO_2 generation and crop delivery loop systems have been developed for special applications, but need effective heating and cooling systems plus the ability to extract unnecessary combustion-generated released moisture.

Since CO_2 is heavier than air, it is usually added at the top of the canopy of the plant, and then spread through diffusion downwards. In tall green-houses (30 ft or more) with open roof vents, CO_2 can be added at the base of the canopy as it is then gradually transported from the base of the plant canopy to its top by the upward flowing air, thus improving photo-synthesis. If a greenhouse requires regular ventilation by bringing in outside air for cooling, the benefits of CO_2 enrichment will be reduced, and the generation cost will surpass that gained from whatever increases in plant growth and fruit yield occur.

Johnson (2003) explains how a rose grower in a gas-fired boiler extracts CO_2 from an exhaust gas separator that is then pumped into the greenhouse during the day from hot water production (200 F; 93 C F). The hot water collected at night is used to heat up the greenhouse. Likewise, for the introduction into their tomato greenhouse, the PTO growers produce CO_2 from their natural gas heating system (Smith, 2003c).

Climatic Control

The interior greenhouse climate needs to be monitored and managed continuously to maintain the optimal environmental conditions for the crop being grown (Beytes, 2003b). The performance characteristics and cost of the sensors used to track the greenhouse environment differ considerably. Some greenhouse control systems are based on devices which track some factor, such as air temperature, and then enable either heating or cooling devices to bring the temperature back to the set range or point (Roberts, 1985; Gieling, 1985). The sensitivity of the measuring tool, the location in the greenhouse and its reaction time will often result in a wide-ranging cycling character of the interior environment which may not be best for the growing crop.

Major improvements in sensing devices have been made, leading to improved performance. Sensors coupled with computer-activated devices can "feel" a change and then trigger those devices required to maintain the atmosphere at the desired level, thus minimizing the greenhouse environment's cyclical character. Lubkeman (1998) stated that "computer technology helps bring better quality plants onto the market as it provides full control of the greenhouse environment." In his article, he explains devices for measuring temperature, relative humidity, air movement, CO2, lighting and light intensity, timers and master controllers, all necessary to provide the required controls to manage the greenhouse properly. Computer monitoring of greenhouse operations and management decisions was found to minimize material and labor costs, reductions that range from 15 to 83 per cent (Lubkeman, 1999). Johnson (2000a) notes that "Central computer control is certainly the direction greenhouse management is heading into the future; it has already proved to be the most efficient labor-saving method of today." Today, the greenhouse operator has several different control systems to choose from, and the decision as to which system would function best for greenhouse operations would require professional input. The 1994 Greenhouse Systems International Conference (Anon., 1994) continuing contains papers relating to methods and procedures for managing the greenhouse climate in the interior.

For example, the installation of sensing devices outside the greenhouse for measuring air temperature, wind velocity, and light intensity will provide useful information to the greenhouse control system, thereby minimizing the impact of external conditions on the greenhouse climate.

Backup Systems

Sanitation warning systems should be standard equipment for informing off-site greenhouse managers and automatic backup equipment in any greenhouse. Failures are not always convenient; they typically do not occur even when workers are in the greenhouse or nearby so that appropriate action can be taken. Many crops were lost or severely damaged due to lack of electrical power or mechanical failures, as there were no quick-acting contingency measures in place. When high temperatures (both cold and hot) are present, it can take just a few hours of power or mechanical failure to seriously damage a crop. An electrical failure left under hydrostatic head pressure a hydroponic tomato grower to use urban water as he was unable to operate his water / nutrient solution delivery system as well as receive water from his reverse osmosis system. He had no backup electric generation system and had not stored enough treated water to meet the demand during the power failure period. Owing to the water stress and the water quality applied, no harm occurred in its plants. When treated water is required to create a nutrient solution and water plants, the amount of water should be enough in storage for several days to satisfy the demand. In terms of energy generation, it will be necessary, depending on the electrical demand, to compromise on what would be needed to withstand short power loss times. Having a greenhouse in an area where daily power outages occur wouldn't be a smart idea. The failure of heating and cooling systems presents a greater problem in terms of access to immediate service personnel and/or the availability of spare parts for rapid repair of a failed unit. It is critical that a contingency plan is in place for all potential failures, and that all greenhouse workers understand it.

Greenhouse design criteria for keeping insects and other pests out pose a problem in managing greenhouse entries as well as sanitation-conscious surrounding area management. On almost any item (clothing, shoes, equipment, containers, boxes, etc.) it is easy to carry disease species and insects into the greenhouse; thus, there is a need for strict sanitation procedures. Keeping greenhouse walkways and outer edges clean; prompt elimination of dead, diseased, and insect-infested plant tissue; and restriction of other operations (such as fruit sorting, measuring, packing, etc.), are some of the criteria that will keep the greenhouse free of damaging infestations. The type of greenhouse flooring and its ease of cleaning can have a major effect on the ability to prevent falling plant debris from being a source of disease and infestations of insects. Standing water on the greenhouse floor or moving water up through the flooring material may contribute significantly to the atmospheric humidity.

Some managers limit movement in and out of the greenhouse by making workers spend in the greenhouse all their working day. Removal of street wear and work in sanitized uniforms is not a uncommon custom. Having workers walk through a chemical footbath would sterilize boots before reaching the greenhouse. Managers also have tough nongreenhouse visitor policies. Both of these measures are intended to mitigate the potential for entry into the greenhouse of insects, disease species and other substances that could adversely affect the enclosed crop. The author was once a member of a group of research scientists who regularly visited tomato greenhouses in the Cleveland area, Ohio. We needed to pick our tour schedule carefully, because some greenhouse managers would not let us visit if we had already been in greenhouses where there was a reported disease, tobacco mosaic virus.

The inside of the greenhouse offers an perfect habitat for rising visitors, animals (mainly rodents) and insects. Their presence does not pose an immediate danger to the crop itself, but it may cause substantial harm to the greenhouse structure, as well as harm to electrical cables, piping and control equipment. We can also carry out into the greenhouse disease species, insects, and weed seeds.