PROCEEDINGS

SIXTH ANNUAL CONFERENCE
THEME: HYDROPONICS— SYSTEMS AND APPLICATIONS

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When Hydroponics was first disovered it was very simple: Fill a jar half full with dirt, add water, shake vigorously for one minute, let settle, then pour off the clear water to use for feeding plants. However just as with the first blood transfusions, the first few times it worked great but soon a patient died, so it was found that not every pile of dirt would grow a plant.

How fortunate we are to have a Hydroponic Society which makes it possible to find and speak with some of the most knowledgeable people in the field. To benefit from their knowledge, for some, the highest price is to take the time to learn a few of the major concepts and words so the questions and answers can have a common place to start from.

Whether you are a novice, hobbiest or into commercial hydroponics, a hydroponic conferance is a great place to learn something new.

I thank all those who have helped make our sixth annual conference possible.

David H. Peal
President

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PPOCEEDINGS OF THE SIXTH ANNUAL CONFERENCE

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THE FUTURE OF SOILLESS GROWING SYSTEMS

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The Future of Soilless Growing Systems

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Hydroponics[2] has only been a significant size industry in the U.S. since the mid 70's. However, commercial hydroponics has been in existence in the U.S. since the early 1950's. Sometimes one forgets that greenhouses have been used very successfully to grow vegetables in the U.S. for over a hundred years. In the early 1970's there were over 500 acres of greenhouse tomatoes in Ohio alone. These greenhouses have used good soil and good growing practices for many decades to produce excellent tomato crops and good profits. Many of the economic factors are the same whether one grows in soil or in soilless conditions. The question then is: why have soilless acreages increased while soil greenhouse

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2. "Hydroponics" - the technology of growing plants in a nutrient solution with or without the use of an inert medium (such as gravel, peat-lite, sand, rockwool, sawdust, etc.) to provide mechanical support, usually in a closed or recirculating nutrient system.

acreages have decreased? The answer is long and complicated, and requires knowledge of the past and knowledge of the current state of the art to answer correctly and completely.

Hydroponics, or "soilless"[3] growing, is a significant industry in the U.S. as well as many other parts of the world. Hydroponic systems have replaced soil growing in many areas, and often the change has been completely justifiable. If good soil is available, why do growers change to hydroponic conditions or select hydroponic systems for their new greenhouses? Soils change, sterilization becomes more difficult, more expensive, and sometimes impossible, and soilless systems continue to improve. More importantly, from an industry growth standpoint, more and more growers believe that hydroponics is an easier way to grow. There is also a certain excitement in growing with controlled nutrient conditions. Many believe the potential is unlimited.

Why, then, is the greenhouse vegetable industry in the U.S. relatively small in comparison with the population and high level of spendable income? Let's review the size of the U.S. and look at

3. "Soilless" - the technology of growing plants in an inert medium (without the addition of soil) using a nutrient solution, usually in an "open" or non-recirculating system, such as bag culture.

the amount of productive land available for vegetable growing. In the U.S. at any time of the year, you can find fresh vegetables. If enough fresh produce is not available from the U.S., then Mexico, our friendly neighbor to the south, is more than willing to fill the gap. With this size of industry and capability, why would anyone consider hydroponics? One must believe he can produce higher quality in sufficient quantities and capture a significant share of the market during the "off season" when prices are high. Many growers have made greenhouse vegetable growing a profitable business in the U.S.

There are many research reports and books that describe the evolution of hydroponics. However, within the scope of this paper, it is only possible and necessary to reflect back to what is referred to as the recent boom in hydroponics dating back to the late 1960's. Gravel culture[4] was then claimed to be the answer to the world's food shortage problem, and the answer to those looking for a highly profitable and exciting business venture. Obviously, it was not the answer to either. In 1975, there were over 1000 growers in the U.S. using gravel culture hydroponic systems. In 1984, there are less than a dozen. Sand culture systems have had

4. "Gravel Culture" - sub-irrigation hydroponics whereby plants are mechanically supported by gravel in a trough and fed with a recirculated nutrient solution.

a similar fate, but more systems have survived, almost entirely in the state of Texas, where some 30-40 acres are still in operation. In "Sand Culture" systems, drip irrigation without recirculating is preferred, as well as being more reliable.

Shortly after the decline of the gravel and sand culture eras, a truer form of hydroponics was promoted as the replacement for soil. This system is referred to as the Nutrient Film Technique, more commonly referred to as NFT.[5] The system was invented by Dr. Allen Cooper in England. In 1980, there were over 1200 NFT systems in the U.S. In 1984, there are less than 200. As we speak of these relatively large numbers of 1000 gravel culture systems and 1200 NFT systems, we have to remember that the average size was probably 6500 square feet or 650 square meters. Why did a large percentage of these systems fail? It wasn't due to lack of production. In most cases it wasn't due to high energy costs. In many cases, the production level was equal to or greater than projected, with excellent quality, which demanded and received reasonable prices. Many things happened that could be considered as the prime reason for failure. However, in the case of these hydroponic failures, it can probably be summed up in one sentence - "not enough attention to the business part of the greenhouse." This

5. "NFT" - nutrient film technique or the technology of growing plants in a plastic film, with no growing medium, other than the starter block, using a recirculating nutrient solution.

included poor or non-existant marketing programs. Hydroponic systems were expensive, generally over-priced and poorly designed. The buyer was not aware of the total cost of buying and installing a "Hydroponic Unit"[6]. Many growers were not even aware of their total overhead costs! Of these unknown overhead costs, marketing was one of the biggest expenses. From the early years of the industry, up until the present, the single most important issue is marketing. Greenhouse growers are not considered marketing experts. However, some growers do a good job of selling their own product locally.

There are still over 2000 hydroponic or "modified hydroponic"[7] growers in the U.S. with a total of over 500 acres ranging from about .20 acres to 22 acres. These soilless greenhouses grow many varieties of vegetables, consisting mainly of seedless cucumbers, lettuce, and tomatoes, with some herbs.

6. "Hydroponic Unit" - a total greenhouse and hydroponic growing system package, usually sold as a kit and advertized to be complete.

7. "Modified Hydroponic" - any soilless system using a nutrient solution, whether recirculating or non-recovered spray or drip irrigation.

One of the most commonly used soilless system in the U.S. today is the "Bag System".[8] There are basically 2 types of grow bags, the horizontal or "layflat bag",[9] and the "up-right bag".[10] The vertical bag system, which is a long, hanging bag, has not been used to any extent in the U.S. Many different types of growing medias are used in these bags. However, the most commonly used media is "Peat-Lite".[11] Quite often peat-lite is mixed with aged or composted bark or wood shavings. In the western U.S. and

8. "Bag System" - the technology of growing plants in poly bags, either up-right or layflat, filled with peat-lite, sawdust and bark mixes, rockwool, Oasis foam, etc., and fed with a nutrient solution via drip irrigation.
9. "Layflat Bag" - usually a plastic bag containing 1.5-2.0 cubic feet of peat-lite growing media, designed for 3 tomato or cucumber plants. The bags are normally purchased pre-filled.
10. "Up-right Bag" - a poly-EVA bag containing .60 cubic feet of media (20 liters) and approximately 12 inches (30 cm) high and 12 inches in diameter. These bags are normally filled on site by hand or by machine with any suitable growing media. These bags are also available in 12 and 16 liter sizes.
11. "Peat-lite" - approximately 40% peat-moss, 30% vermiculite, and 30% perlite or styrofoam, blended with a wetting agent and dolomitic limestone for pH adjustment. Peat-lite mixes are available with and without starter fertilizer added.

Canada, most all soilless systems for cucumbers and tomatoes are in bags containing straight, aged or composted, bark or wood shavings. Some rice hulls are used in California and Louisiana. The horizontal or layflat bag normally contains a peat-lite mixture and is filled at the factory or plant and shipped to the greenhouse. If an up-right poly bag is used, then many types of media are available since bags are filled at the greenhouse site. In many instances, peat-lite is mixed with another media using semi-automatic bag fillers that are available for under $4000.00. The layflat grow bags are usually more convenient, but more expensive, than the up-right bags laid in the greenhouse ready for planting. However, either of these systems are less costly than any of the other hydroponic systems, including European rockwool.[12] Drip irrigation systems are basically the same for bags and rockwool slabs.

Rockwool is now available in two forms, "Rockwool slabs"[13] and

12. "Rockwool" - as mineral rockwool formulated in a density specifically for vegetables. Available in blocks or slabs from Grodan in Denmark, or in bulk or pre-filled bags from Hydro-Gardens in the U.S.
13. "Rockwool Slabs" - a block of rockwool approximately 36" long X 8" wide X 3" thick, usually wrapped in plastic (approx. 90 cm X 20 cm X 8 cm). The volume is .5 cubic foot at 4 lbs. per cubic foot and each slab is designed for 3 plants.

"Garden Wool".[14] Bulk rockwool is used to fill up-right or layflat bags, and replaces peat-lite or bark. Although U.S. rockwool costs about the same as peat-lite, it has several advantages. It wets very easily, retains moisture well, never deteriorates, and has a very good air and oxygen content. The U.S. rockwool contains more material per cubic foot, 7-10 lbs/cu.ft. vs European rockwool at 4-4.5 lbs./cu.ft. Trials in the U.S. indicate excellent growth of tomatoes and cucumbers, as well as lettuce, in U.S. rockwool. Recent research indicates less volume of U.S. rockwool may be required per plant than is being currently recommended. This material is still in the early stage of research.

The European rockwool in "slabs" uses only .17 cubic foot per tomato plant and .17 cubic foot per cucumber plant. The U.S. recommendations for U.S. manufactured rockwool is .30-.50 cubic feet minimum for cucumbers, and 0.25 cubic foot per plant for tomatoes. The amount of growing media to be used for each plant

14. "Garden Wool" - a mineral rockwool manufactured in the U.S. with a density of 7-10 lbs./cubic ft. Usually put into a 20 L (5 gal.) or 16 L (4 gal.) plastic bag, and each 16 L (4 gal.) bag is designed for 1 cucumber plant (.50 cubic ft. per plant) or 2 tomato plants (.33 cubic ft. per plant) in a 20 L (5 gal.) bag. With proper feeding techniques, 2 cucumber plants can be grown in one 20 L bag.

has been more of an economical issue rather than being determined from scientific studies. Tomatoes and cucumbers are sometimes stressed heavily during extended periods of clouds or periods of hot and dry sunny conditions, especially if there is a low volume of growing media per plant. Trials in greenhouses in the U.S., as well as Europe, have indicated that the volumes presently used are basically adequate, as long as watering frequencies are also adequate. The cost of "Garden Wool" is presently about $.75 for each cucumber plant and $.45 for each tomato plant, delivered price to almost any greenhouse in the U.S. "Garden Wool" is also compressable to a certain extent (approx. 30%) to reduce shipping cost. The European rockwool is about $.90/plant, but uses only 1/3 to 1/2 as much volume. The chemical analysis of the U.S. and Danish rockwool is compared below.

Chemical Elements	U.S. Garden Wool	Grodan Rockwool
SiO_2	42%	47%
CaO	22%	16%
Al_2O_3	10%	14%
MgO	10%	10%
Fe_2O_3	10%	8%
Na_2O	2%	2%
K_2O	2%	1%
MnO	1%	1%
TiO_2	1%	1%

Rockwool/NFT systems are seldom used in the U.S., except in NFT lettuce systems whereby the growing cube is rockwool. However, growing tomatoes and cucumbers in net pots filled with rockwool, then placing them in an NFT system, is an excellent combination. Many NFT growers in the U.S. use very small growing cubes or blocks. These blocks are often too small for the proper root support and therefore growth is slow in the first few days following transplant. Later, any type of stress on the plant is aggravated by not having a growing block or pot large enough to support the plant roots. The selection of the grow block has been based on the least amount of cost for the block, rather than on the proper size required.

Another hydroponic system that is gaining recognition in the U.S. is the "Oasis Bag."[15] This is a relatively new media showing good results over the past two years of testing. The media is contained in a .75 cubic foot layflat bag similar to the peat-lite layflat bag. This material appears to be competitive to peat-lite mixed with bark and rockwool on a per cubic foot basis, but freight can be a major cost.

It is difficult to say which system will be the most popular or

15. "Oasis Bag" - a layflat plastic bag filled with a foam granulate of phenolic resin base weighing about 1.5 lbs/cubic foot. Produced also in Germany, with a different resin base.

the best at this time. However, it is probably safe to assume that there will be a fairly close percentage between rockwool, peat-bags and Oasis bags, with a lesser acreage of NFT except, perhaps, in lettuce operations. Up-right and layflat bags filled with peat-lite and bark mixes will probably have the edge for the next few years because of lower cost and a more successful history in the U.S. and Canada.

NFT lettuce systems have given the U.S. a major boost in acreage in 1982 through 1984. Various types of nutrient film systems have been attempted. Many types are still being used. All NFT lettuce systems are utilizing the same basic theory. Nutrient solutions are recirculated through the growing trays in which the lettuce plant is placed, usually after being grown in a soilless block. A flat bottom tray is the most successful and gives the most consistant results. However, some growers still use round PVC pipe which has holes drilled on 6-7 inch spacing especially for lettuce and other leafy vegetables. Round pipe is less desirable than special flat bottom growing trays. The biggest concern is finding lettuce varieties suitable for the various changing climates in the U.S.

The greenhouse industry will grow at a relatively moderate rate for the next 2-3 years. If proper marketing techniques for produce are employed, then the growth rate will increase significantly. With the availability of fresh produce from so many areas, such as California, Florida, Texas, Arizona, and Mexico, we need to concentrate on better marketing techniques such as "nutritious", "freshness", "locally grown", and "vine ripened", etc. Probably less than 5% of the buying public purchased greenhouse produce in 1984.

The per capita consumption of tomatoes in the U.S. is over 14 pounds per year. This equates to over 2 million tons of tomatoes consumed annually in the U.S. If only 10% of the people ate greenhouse tomatoes, we would need to grow 40 million pounds or approximately 1,300 acres. Similarly, the consumption of greenhouse grown cucumbers would be some 20 million pounds or over 500 acres in addition to what is now in operation. These figures do not include the possibilities of potential exports.

Fresh produce transport and distribution in the U.S. is very good. Quality does suffer somewhat, particularly from a nutritional standpoint, but the public is generally unaware of this factor. Trucks, planes, and even trains transport everything from apples to watermelons across the U.S. in very short periods of time if the demand and prices are right. Currently growers and produce brokers are looking for better, more attractive packaging and ways of increasing shelf life. Various box sizes are being tried to increase sales and decrease losses. Lettuce is being sold as

"Live Lettuce" with the root still attached. These types of ideas will increase sales of greenhouse products.

Promotion and marketing are the key to vegetable greenhouse expansion in the U.S. There is no reason that the U.S. could not support several thousand acres of fresh vegetables in the next 5-10 years by stressing quality and nutritional superiority. Chemical analysis of greenhouse grown tomatoes, lettuce, and cucumbers show much higher levels of vitamins than "shipped in" produce from Controlled Atmosphere Storage (CA)[16] warehouses. If the public consumed only greenhouse produce, there would be little need for synthetic vitamin supplements. A certain percentage of the U.S. buying public will pay a higher price for quality.

Other major items that tend to slow down the growth of this industry are: 1) lack of technology (available but not utilized), 2) application of existing technology (as it applies to different crops in different locations), 3) ignorance of the market demands and conditions, 4) uneconomical unit size for reasonable returns on capital employed for the business, 5) lack of business knowledge (as it applies to cost of goods sold), 6) loss of tax benefits and investment tax credits, 7) overall knowledge of the greenhouse

16. "Controlled Atmosphere Storage" - commonly referred to as CA, whereby an inert gas, such as nitrogen, replaces air and oxygen in a temperature controlled chamber.

vegetable industry (as it applies to design and cost of greenhouse and growing systems for different climates), and 8) general fear of an unstable economy.

Other not so surprising factors include: 1) capital cost of greenhouses and growing systems, 2) high land cost, 3) high labor cost, 4) high fuel costs for heating, and 5) high electricity cost for cooling. These factors have been around more than 10 years and are being addressed continuously by potential greenhouse owners and by greenhouse suppliers. Interest rates will always be a factor.

Energy cost is not the only reason for slowing down the growth rate of the greenhouse industry, but it will continue to play a major part in the new expansion areas of the U.S. Sites established in warmer, sunnier climates will be one major area of expansion. Though sun is a very important factor in determining greenhouse profits, it is not the only important factor. Greenhouses must be located near major population areas or have adequate, dependable, and inexpensive transportation to the market.

Other energy sources will play a big part in the greenhouse industry expansion in the next few years. Geothermal[17] sources

17. "Geothermal" - a natural source of hot water ranging from about 100 degrees F to super heated steam. Sources may be at the surface or available from shallow and deep wells.

are plentiful in the western U.S. Almost every state from the eastern slope of the Rocky Mountains to the coast of California has geothermal reserves ranging from 120 degrees F to over 210 degrees F. Many of these sites are remotely located. This creates problems with installation, management, labor, trucking, and marketing. However, if careful thought is given to the location, design, and size, these problems can be overcome and turned into an asset rather than a liability.

Co-generation is another source of energy in which the discharged hot water may be classified as "waste heat."[18] Discharge water is 120-150 degrees F (66 degrees C), and large volumes must be cooled and returned to its source. Co-generation plants may be located anywhere there is a good source of fuel, such as geothermal, coal, and natural gas. Waste heat from factories will also make a major impact on the industry in certain areas of the country. However, one must be well aware of the total capital costs when using waste heat, particularly if the temperature of the water is below 120 degrees F. The potential is unlimited, but again other factors enter into the picture, such as site location, sunlight, labor, and marketing.

18. "Waste Heat" - a source of heat normally from manufacturing plants, power plants, alcohol plants, processing plants, and electrical co-generation facilities.

Sources of waste energy are available from power plants, manufacturing or processing plants, and alcohol plants. Waste heat may be available from warm water or warm air. Sometimes carbon dioxide is available, as is the case in ethanol production plants.

The average production figures on tomatoes, cucumbers, and lettuce in the U.S. indicate that those growers getting above average yields are making reasonable profits, even with the high cost of heating and relatively inefficient building designs. Cucumber production in the U.S. averages approximately 9 lbs./sq.ft. or 44 kilograms/square meter. Tomato production in approximately 150 tons/acre or about 33 kg/M2. Many growers exceed these production figures since averages include poor growers' figures as well as those figures from seasonal growers.

Lettuce production ranges from 1 million to 1.5 million heads per acre per year, depending on the size of heads harvested. Generally a bibb or limestone type lettuce ranges from 6-10 ounces per head in weight from the greenhouse.

What is required to boost the greenhouse industry in the U.S? We already know high production and high quality can be achieved with good greenhouse design and good management. However, this is only the beginning. There are many other business aspects to be considered. Long term financing with reasonable interest rates is necessary (which is true in almost any business venture). Greenhouses and growing systems must be reasonably priced so the return on investment is adequate to attract new growers. Better greenhouses are needed with much better environmental control and greater heating and cooling efficiency. Automation is an extremely important factor which should be closely examined for any operation. High light transmitting, low cost, long life greenhouse covers that save energy by trapping infrared heat are available in polyethylene formulations. These include I.R. blocks from one direction plus anti-condensate materials as a component part of the plastic and are significant improvements. Polydress Sun-Saver and Monsanto Cloud Nine polyethylene have been in use for almost 2 winters in the U.S. They provide energy savings in the 15-25% range as compared to standard U.V. stablized polyethylene. Polydress Fog-Bloc additive for condensate control has greatly reduced condensate drips and increased light transmission. In 1985, yet another improvement has been introduced - a clearer, long life polyethylene with all the additives above.

Lexan, the new polycarbonate profile sheet from General Electric with an acrylic coating, is a long life, permanent covering. Lexan is similiar to Polygal, an Israeli material that is available with or without acrylic coating in the U.S. Prices are relatively high, ranging from $1.35 - $1.65 per square foot, depending on quantity purchased and material thickness. The energy savings should be 30-40% over glass or fiberglass. At

$1.00 to $1.25 per square foot per year heating cost in the northern U.S., it doesn't take long to get the initial investment back.

Some areas of research that are needed worldwide are: 1) better environmental controllers and recorders at reasonable costs, 2) improved greenhouse structure designs that accomodate various coverings and strong enough to support heavy crops, 3) roof vents and controls at reasonable prices, 4) clearer, more permanent, fireproof coverings, that are resistant to hail and U.V. degradation, 5) research on designs for specific crops in specific areas, and 6) sensitivity analysis for each crop and location looking at alternate designs.

More importantly, a better understanding of plant requirements is desperately needed. Controlling the environment is only possible if you know the plants' requirements. Different species as well as varieties of the same species may require different day and night temperatures, as well as unique nutritional and plant culture requirements. Controlled environment agriculture is only an advantage if it can be regulated for the plants to be grown.

The biggest challenge in the future will be educating the public, particularly in those areas that affect everyday living. If we can educate the public, many of the existing and potential problems will be self-resolving. Most people have very limited knowledge of the nutritional value of fresh vegetables and fruits as compared to the same product that has been stored.

Obviously, research and development are lacking in many areas in the U.S. The areas being currently researched are mostly related to energy savings. This is an important area of research which must continue. However, we must not forget other areas of equal importance. Greenhouses are designed to produce high quality and high volume per unit area on a consistant basis. High production, uniformity, shelf life, attractiveness of packaging, taste, and nutrition are just a few other areas that are being improved upon. However, all of the above research will be of no value unless we concentrate on marketing our greenhouse products for what they are truly worth.

The greenhouse vegetable industry is changing, improving, and growing daily. One must be well aware of the latest designs and growing systems that are proven successful. He must be willing and capable of adapting to the changing technology. Above all, he must know where to obtain the proper training and how to obtain the correct information for his crop and his climate.

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Nutrient Solutions and Hydroponics

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NUTRIENT SOLUTIONS AND HYDROPONICS

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HISTORY

It has been known from the very early times of horticulture that plants could be successfully grown without soil in an aqueous culture media. As early as 1699 Woodward grew plants in water. Within the next hundred years the science of horticulture had progressed to the point that De Saussure could grow plants in nutrient solutions of known composition, prepared by dissolving various salts in water. By the middle of the 19th century about the same time that Darwin was revolutionizing our concepts of natural history, Sachs (1860) and Knop (1859) were using simple defined nutrient solutions to grow plants to maturity. But it was not until 1929 that an an article in the American Journal of Botany formally advanced the possibility of the economic production of plants in solution culture. The term "hydroponics" was coined by W. F. Gericke at the University of California Berkeley in 1937 in an article in Science. He used the term hydroponics to refer to the economic production of plants in solution culture to distinguish it from the research use of nutrient solutions. The term hydroponics has an analogy in geoponics, a Greek term for agriculture which was in use before the latinized term agriculture was generally adopted. The direct derivation of the word is from "hydro" for water and "pono" for labor thus it means the labor of water. At this time in the development of hydroponics there was a number of exaggerated claims made by the early enthusiates as to the production potential and necessary conditions for growth in hydroponics. However during the second world war hydroponics was effectively utilized for production of vegetables for the troops in the Pacific which showed the feasibility of using it for crop production. In 1950 the classic reference by Hoagland and Arnon (The Water Culture Method for Growing Plants without Soil) on solution culture was revised to its present form which became one of the standard nutrient solutions for hydroponics. Because of solution cultures long history and many uses in research there have been developed numerous solutions which differ only slightly. Each solution being developed for a specific set of conditions some of which were horticultural and some of which were site specific in order to optimize the growth of a specific plant or a group of selected plants. Probably the most comprehensive review of available solution culture techniques is by Hewitt in 1966 (Sand and Water Culture Methods used in the Study of Plant Nutrition). Although this book is somewhat old there has been relative few new concepts with most of the recent invocations being related to better technical solutions of old problems.

MAJOR DIFFERENCES BETWEEN HYDROPONIC AND SOIL CULTURE

DEFINITIONS

Often the term hydroponics is misused to include the entire cultural procedure for growing plants including the overall greenhouse operation.In this paper I am going to use a more restrictive definition of hydroponics and use it in its pure form as a method of supplying water and nutrients as a dilute aqueous culture media rather than using soil as the source of the nutrients. In operational terms this just means the replacement of soil as a rooting media by a culture solution and the provision of some means of aeration and support for the roots.

ROOT FUNCTION

In order to understand the implication of this replacement of soil as a rooting media we must look at the physiological requirements of the plant root for proper growth and development. The roots of plants in addition to absorbing water and nutrients also provide physical support for the plants. Roots for proper functioning require a suitable environment in relation to soil atmosphere (O_2 , CO_2), temperature, water (quantity and quality), and appropriate soil physical structure. Defining the proper environment is not as easy as it appears on the surface because of the large diversity both in physiology and structure found in plants.

In addition many roots do more than just absorb water and nutrients. I think that it is clear that there would be different environmental considerations for proper and optimal functioning of roots from tomatoes, lettuce, carrots and potatoes. It is evident that root crops use their roots for more than just water and nutrient absorption. They are both storage organs an in some plants the means of vegetative propagation and dispersal. However, even in the root crops, the absorption of water and nutrients is still the principal and also a essential function of the roots and it is this function with which we are concerned with in hydroponics.

WATER SUPPLY

In this paper we will be concerned with the supply of water and nutrients to plants by way of a nutrient solution instead of soil. Probably the first concern must be the quantity and quality of the water supply required for making the nutrient solution. The amount of water required by the plant will depend on a number of factors such as temperature, relative humidity, wind speed and per cent canopy cover. Fortunately for calculating consumptive use of water we can assume that most greenhouses will maintain a relative constant environment so that the major variable in estimating water use is the canopy cover. The rule of thumb is 0.3 gal/day/ft^2 of canopy or about 100 gal/yr/ft^2. In a modest greenhouse 30 X 30 ft this would be 90,000 gal/yr used by the plants just in transpiration if cover is maintained through out the year. This does not take into account water lost to evaporation or used during solution renewal and other uses such as cooling. These losses can be large especially if it is desirable to keep the relative humidity of the greenhouse low.

The quality of the water is determined by many factors of which total salt,pH and toxic ions are of principal concern for hydroponics. For this discussion I will only mention organics as a potential problem as most water supplies are essentially free of them. Naturally occurring organic material such as humic acids which give many natural waters a brown color are not usually a problem for it requires unusually large amounts to cause problems such as lowering the pH and affecting micronutrient supply. In fact humic acids could be potentially of benefit in that they could absorb many materials that become toxic at high concentrations. On the other hand, contamination of water with organics from agricultural or industrial wastes (for example pesticides and herbicides) will vary so much in their effects and degree of toxicity that they can only be treated on a case by case basis.

WATER QUALITY

The factor that most often affects water quality is total salt or as it is more commonly reported in water quality reports, total dissolved solids (TDS). Thus TDS is a good general measurement and a first approximation of water quality. When the TDS of the water increases, the potential for salinity problems increases. The range of TDS found in natural waters is very broad, for example in southern California the three principal water sources are the Owens River at 200 TDS, the Feather River at 400 TDS, and the Colorado River at 800 TDS. All of these waters are usable for agriculture and hydroponics but with an increasing degree of cultural and management difficulty. If we use a 30 X 30 ft greenhouse as an example and our calculated 90,000 gal/yr of water use the amount of salt which would come in with Owens River water would be 150 lb/yr, with Feather River water 300 lb/yr, and with Colorado River water 600 lb/yr.Fortunately none of these waters have particularly an undesirable mix of salt. It is just that within a years time there can be a large build up of salt within the greenhouse system which makes periodic renewal of solutions a necessity if high TDS water is used.

The other measure of dissolved material is Electrical conductivity (EC) usually given as millimhos/cm . This is a measure of the amount of electrical current that the dissolved salts can carry. This measurement provides about the same information as the TDS measurement but is affected to a small degree by the type of salt present. As a first approximation an EC of one equals 500 ppm TDS of sodium chloride. If water quality information is obtained from a water company the salt concentration will often be given in TDS. The only problem with this is if you want to monitor your own water quality, TDS is neither a rapid nor convenient method water quality determination, for water must first be evaporated and the residue weighed to obtain this measurement. On the other hand , there are many inexpensive Ec meters available with which an EC reading can be obtained in seconds using only small volumes of water. Because all salts do not respond the same to the EC measurement there is not an exact agreement between TDS and EC but the correlation is sufficient for both to be useful in monitoring hydroponic solutions.

All salts and materials dissolved in the nutrient solution will affect plants, salinity is the overall result of too much salt being present in the nutrient solution. (Salt in this context means all dissolved ions). However many salts can also have a specific ion toxic effect on plant growth at much lower concentrations than those concentrations that cause salinity effects. The specific effects will be discussed later. Sodium of the common salts present in natural waters is of most concern in relation to salinity problems. In Table 1 plants are listed according to how they are able to tolerate salinity. Salinity affects plants by restricting their ability to absorb and utilize water. Thus any thing that is done culturally to increase water use efficiency will make it possible to use water of lower quality in terms of salinity.

The total salt criteria for judging the water quality of supply water is only one of the screening criteria that should be used in evaluating water quality. Even if the total salts are sufficiency low to be usable from an salinity point of view, there could still be problems with specific ion toxicity. Specific ion toxicity can result from unusually high concentrations of any specific element but the toxic levels are affected by many factors and must be determined individually for each mineral. As a general rule any element can be toxic if present at high enough concentrations. However, certain elements are almost never present in concentrations high enough to be toxic such as calcium, nitrogen, phosphorus, and potassium and perhaps sulfate. Then there are certain elements such as sodium, mangnesium, boron, copper and zinc that are often found at levels that are toxic for hydroponic use. Table 2 provides a number of different criteria that are used to judge the quality of water for drinking, irrigation, and my estimate of limitations for hydroponics. The toxic limits provided here are for common horticultural crops such as tomatoes and lettuce. The problem with presenting a table like this is that there is a tendency to extrapolate these limits for use with other plants and it is known that certain plants are mutually incompatible and can not grow in the same nutrient solution. For example alfalfa and subterranean clover will not grow in the same nutrient solution because of a phosphate problem. In order for the nutrient solution to have sufficient phosphorus for alfalfa to grow the solution will be toxic to subterranean clover. The same incompatibility is true for barley and sunflower in respect to boron. Thus any set of solution limits can at best be good only for a certain group of plants but not all plants.

Also in Table 2 notice that the official limit of irrigation water for some elements is greater than I would suggest would be toxic for hydroponic use. The reason for this is that irrigation water is applied to soil which has a very high buffering capacity to absorb cations such as copper and zinc, and once they are absorbed on the clay or organic matter of the soil they have only limited availability to plants. In pure hydroponic systems there is no buffering capacity nor any thing else to absorb and buffer these high concentrations of trace elements. Thus they are completely available to the plants for absorption and are therefore toxic in hydroponic solutions at levels given as safe for irrigation water. What this tells us is that although some waters are perfectly safe for use under field conditions they may not be safe to use directly for hydroponics.

The other thing to understand about toxic limits in nutrient solutions is that the real limitation is not with the nutrient solution but it is a function of the plants response to the specific minerals in the nutrient solution. In table 3 is a list of plants separated according to their tolerance to boron. The rule of thumb for boron toxicity in nutrient solution is that only boron sensitive plants will be affected by boron concentrations less than 0.5 ppm and only very tolerant plants to boron can stand concentrations greater than 1.0 ppm. Boron happens to be a very mobile element within the plant and therefore has a tendency to follow the transpiration stream and thus concentrates in the edges of the leaves where the plants lose water to transpiration causing a marginal leaf burn. The burn or necrotic area with time will enlarge as the plant continuous to absorb boron along with the water it requires. Therefore young plants and young leaves are much less affected with boron toxicity.

There is another simple measurement that is extremely helpful in evaluating water quality, that is pH. I have found that a pH meter with a glass electrode is the method of pH determination that will provide constant results in the many different conditions found in hydroponics. Although most plants can tolerate a reasonably wide range of pH 9-4 if the nutrient solution is adjusted to make sure all the essential elements are present at acceptable concentrations and that no element is at toxic concentrations. However, if the pH is outside of the range of 5.5 to 7 it may be very difficult to provide all the essential nutrients at appropriate concentrations. I use the pH of the nutrient solution as an indicator of the condition of the nutrient solution in much the same way that a medical doctor will use a persons temperature as a diagnostic tool. Any sudden changer in pH of the nutrient solution usually indicates that the plants are under some form of stress. If the plants absorbs more anions than cations, the solution will become acidic. Most nutrient solutions are designed so that most horticultural crops will absorb an equal amount of anions and cations in order that the pH of the solution will not change. Thus if ammonium is used in place of nitrate in a pH balanced nutrient solution the pH of the nutrient solution will become acidic.

USE OF LOW QUALITY WATER

One of the more common forms of hydroponic culture is the closed system gravel culture in which the nutrient solution is periodically circulated through pea gravel beds to supply water and nutrients to the plants. A short pumping cycle wets the gravel, after which the nutrient solution drains back into a reservoir where it remains until the next nutrient application. Ordinarily the solution is used for a period of one to two weeks, then discarded, and a fresh solution added. Sometimes additional nutrients are added after one week to assure that sufficient nutrients are available to the plants during the second week. This is usually done during a peak harvest period when rapid growth is occurring. Occasionally solutions have been carried longer by adding additional fertilizer each week.

Extended use of hydroponic nutrient solutions is of interest from the stand point of basic hydroponics especially in regards to the quality of the make up water. It is also of interest from the standpoint of economics and for environmental reasons because of a potential pollution hazard to underground water supplies if the solutions are discarded on porous soil surfaces. It is possible to extend the use of nutrient solutions for long periods of time by prudent additions of nutrients and careful monitoring of the solutions and plant growth.

Extended use is possible, but the length of safe use is limited by the quality of the make up water and the impurities in the nutrient salts used. Accumulations of excess amounts of micronutrients as impurities, as well as calcium, magnesium, sodium and chloride or sulfate from the make up water, are the basic limitations to the extended use of nutrient solutions. Ideally the nutrient solution should be prepared from deionized water and technical grade chemicals, but even if expense were not a consideration it would be difficult to avoid the eventual accumulation of salts.

The following guidelines should be helpful to hydroponic growers who wish to extend the use of their nutrient solutions. These guidelines are based upon experiences with tomatoes, so it may not be directly applicable to all plants but the concept will work if the differences in the plants are taken into account. Also the difficulty of hydroponic solution maintenance will vary with water quality, the physical components involved, plant growth conditions and management.

Water quality of the make up water is a basic consideration. High salt water immediately imposes a time limitation on the extended use of any nutrient solution, and in the extreme case very salty water can not be used at all for hydroponics. A complete analysis of the water should be obtained, including as many of the micronutrients and heavy metals as possible. The water analysis can act as a guide to determine which nutrients will need to be added to prepare the nutrient solution. Some nutrients may already be present in the water in sufficient quantity or at quantities greater than those required by the plant. Additionally some minerals may be present in the water which are not required by the plant.These minerals with time will accumulate in the nutrient solution and to some degree in the plants themselves. A certain amount of accumulation in the plant is not bad if their concentration does not exceed the toxic limit of the plant. In fact accumulation in plant tissues can help to remove some of the salts from the nutrient solution with out ill affects. If the minerals are accumulated in the old leaves they may be lost to the system when the old leaves are removed. Only little is known about the upper limit of trace element concentration in the nutrient solution, however the values found in Table 2 will serve as a good guideline. For the macronutrients the objective of extended use will be to maintain the concentrations of the individual nutrients as defined for the nutrient solution in Appendix #1. There are many formulas which have been used successfully in hydroponics. Those mixes which are sold as premixed salts, however, are not practical for extended use, since it is not possible to be selective in the salts to be added to the nutrient solution. Formulas prepared from individual salts can be effectively altered, both in concentration and content, whenever laboratory analysis of the water or the solution EC measurements indicates that it is desirable.

MANAGEMENT FOR EXTENDED USE

Immediately following initial preparation of the nutrient solution it is necessary to determine the electrical conductive (EC) of the solution. All salts should be thoroughly mixed before making this determination. The EC is essentially a measurement of the total salt content of the solution, and the figure obtained (EC) will be used as the reference standard, or base line used to estimate when and the amount of nutrients to add to the solution. The initial EC will be equal to the EC of the make up water plus the EC increase due to the nutrient salts added. The EC of the nutrient salts alone is about 0.8 millimhos/cm.

As the plants extract nutrients from the solution, the total salt content of the solution decreases which reduces the EC. The EC is not a measure of the concentration of individual salts, however studies have shown that there is a good correlation between EC and total salt concentration. The EC of the nutrient solution should be measured every day or so depending upon the size of the plants and their growth rate. As the EC decreases, nutrients should be added to the solution to bring the solution EC back to the base line.The quantity of nutrients to add is most directly related to the volume of the reservoir and also to the number, size and growth rate of the plants.

If the make up water contains appreciable amounts of calcium, sodium, magnesium or other salts there will be an accumulation of these salts in the solution. This is even so for the required nutrients if they are present in amounts in excess of the plants requirements. There are two alternatives for extended use: 1) modify the nutrient formula so that the nutrients present in the make up water will not be added with the nutrients (Appendix #2 provides information on formula modification), or 2) establish an increasing EC standard so as to account for increase of the excess salts added with the nutrient. The former is the most efficient procedure, but requires some chemical calculations in order to keep all nutrients in proper balance. Chemical analysis are also highly desirable to follow the modifications. The latter method (increasing base line) has been utilized experimentally with success, but the increasing standard is only a rough estimate with out analysis, since the additions of salts from the water and plant uptake can only be approximated. The maximum EC which plants will tolerate in hydroponic solution without growth reduction is not well documented, but it does vary with species as it does in soils. Tomatoes have been successfully grown for short period at EC'S of 4 to 4.5 with no apparent adverse effects, but until more is known this concentration should not be exceeded. Other plants are less tolerant of salts than tomatoes (see table 1).

The success of the extended use of nutrient solutions is in practice dependent upon avoiding salt accumulation or excess of specific salts in the system in toxic quantities. Zinc and copper are two elements which seem to accumulate frequently (probably from metals in the plumbing system). It has been found that accumulations of these two metals can occur in such great quantities on the roots of tomato plants and that there is interference in uptake of nutrients with resulting deficiency in the leaves. Other trace elements have also been found at potentially toxic concentrations in the roots. Thus phytotoxicity and salinity are the principal problems which occur under long term extended use and will result in some definite limits to this practice. However the real solution to these problems is the use of high quality water for hydroponics.

HYDROPONIC SYSTEMS

PURE HYDROPONICS

Pure hydroponic systems (solution culture) may be either an open type system or a closed type system. In a closed system there is no drainage and every thing added to the system, remains in the system. However in general use there is usually some modification in that the solution is periodically renewed. Although I have grown tomatoes for a full year, where nutrient solution was added for all make up water with out any renewal of the solution. There are a number of reasons for periodically renewing the solution 1) the supply water contains minerals that the plant can not use which therefore build up and cause a salinity problem with time. 2) The nutrient solution is not matched to the plant and certain nutrients build up with time and cause a salinity problem. 3) With time it is also possible for microorganisms to build up and become a potential hazard. All hydroponics systems require that the roots be constantly aerated. In closed pot systems this is usually done with a air pump, in a small system this can be done by an aquarium air pump equipped with plastic tubing. Do not use air stones for many of then are treated with copper to reduce algae growth which can be toxic to plants in a hydroponic system. Containers for hydroponic systems can be made from a variety of materials but glass plastic and stainless steel are common in small systems. In larger systems wood or concrete lined with polyethylene film are common materials. The open type system is commonly set up as a flow system in which the nutrient solution is added at one end of a trough or tank system an drained off at the other end. If the nutrient solution is recycled it can be treated as a variation of the closed system. In a flowing system it is not always necessary to bubble air into the system for aeration because the flowing nutrient solution provides aeration as it flows though the troughs in which the the plants are growing. If the troughs are deep and the flow is slow, aeration may be a problem.

NUTRIENT FILM TECHNIQUE

Large flowing systems composed of shallow troughs are generally referred to as the Nutrient film technique (NFT). In this system the troughs are constructed with a slight fall (3 inches per 100 Feet) to allow the solution to drain back to the sump tank from which it is repumped to the head of the trough. The depth of nutrient solution is maintained by the slope so that the solution barley covers the root system, this provides for adequate aeration at all times. The troughs for NFT can be constructed of many materials as long as all the material in direct contact with the water is nonphytotoxic. Materials commonly used are polyethylene tubing, PVC pipe, fiberglass, and plastic or asphalt lined wood or concrete.

AGGREGATE SYSTEMS

The most common variant of pure hydroponics is some form of aggregate culture. In aggregate culture gravel, sand or some other inert particulate is used to support the plant and hydroponic nutrient solution is added frequently to supply the essential mineral nutrients. The advantage of aggregate culture is that the roots can support the plant at least during the seedling stage and root aeration does not have to be supplied separately. However management and equipment requirements of aggregate systems are different from pure solution culture and are even different between aggregates because of their different water and nutrient holding capacities.

GRAVEL CULTURE

Pea gravel has been one of the most popular rooting media for aggregate systems. It is universally available but make sure that the gravel used is not phytotoxic and also it should not be porous so that salt and pathogens can not enter into the gravel and be carried over between crops. A gravel system retains much less water and nutrients than a soil system, therefore it is necessary to add nutrient solution frequently. The aggregate system is usually designed to recirculate the nutrient solution from a supply tank through a pump operated by a time clock which supplies the plant bed with nutrient solution four to six times a day depending upon the season. Gravel beds are drained through perforated pipes in the base of the bed. They are often fed through these same pipes or from the surface by way of a drip irrigation system. A disadvantage of the gravel system is that roots will eventually grow into the drain pipe. This will impeded drainage causing loss of root volume and loss of production and/or plants if it is not routinely cleaned. Gravel troughs are generally about two feet wide, two thirds of a foot deep and filled with one fourth inch pea gravel. In gravel culture it is important to make sure that the beds are not contaminated with soil because of potential pathogen problems present in soils, thus the gravel should be washed before it is placed in the beds and the bed protected from soil contamination during entire growing season. The nutrient solution supply tank should be large enough to provide about 5 gal of nutrient solution for each plant (based on plants the size of tomatoes). Because plant roots require aeration the beds should not be filled with water for periods longer than 20 minutes otherwise there could be root damage. It is also advisable not to fill the bed to the point where the surface of the gravel is wet for this will cause a surface crust of algae to form.

SAND CULTURE

Sand culture in concept is not much different from gravel culture. The main difference is the greater water and nutrient holding capacity of the sand. Because of this sand does not need the frequent irrigations that gravel does. This allows sand culture to be managed more like a soil system. In sand culture the full floor of the greenhouse is often covered with sand to a depth of one foot. The sand is laid over a liner of plastic or some other material to separate it from the soil beneath. The floor is graded so that it will drain well, a grade of 4 inches per 100 feet with drain lines every 30 inches connected to a common drain is a popular design. The sand used should be a well washed concrete sand.

ARTIFICIAL SOIL AND OTHER MEDIA

There are many other media in use that are basically used and managed as aggregates in a hydroponic system.These are artificial soils such as Peat-lite (peat and vermiculite) mixtures of sphagnum, rock wool and various organic materials such as sawdust, straw and bark. These materials are used because of their good aeration and good water and nutrient holding capacity. They are watered with a hydroponic nutrient solution to supply the required nutrients to provide a low risk cultural procedure for plant production. However this is done with the sacrifice of loss of control and responsiveness of a true hydroponic system.

NUTRIENT REQUIREMENTS

Plant physiologists generally accept 16 elements as being essential for normal growth and development of plants. That is, only 16 elements have been shown to meet the strict requirements of essentiality as set forth by Arnon and Stout. Three of these elements are normally obtained from the atmosphere or water (carbon, hydrogen and oxygen). The other 13 elements referred to as the mineral nutrients are generally obtained directly from the soil and therefore must be supplied by the hydroponic nutrient solution. These mineral nutrients are divided into the macronutrients and the micronutrients, based on the amount of each nutrient required by the plant. In addition to these 16 elements, sodium has been shown to be essential for halophytes and cobalt is required for the symbiotic fixation of nitrogen by legumes.

Potassium, Calcium, Magnesium Phosphorus, Nitrogen, Sulfur	Macronutrients
Iron, Clorine, Boron, Manganese Zinc, Copper, Molybdenum	Micronutrients

The animal physiologists recognizes about 25 elements as being essential for animals these are Arsenic, Cobalt, Chromium, Fluorine, Iodine, Nickel, Selenium, Silcon, Tin, and Vanadium in addition to those required by plants except that boron is required by plants and not by animals.

NUTRIENT PREPARATIONS

The preparation of a hydroponic nutrient solution is relatively easy if the water and salts are pure. However, if pure water and salts are not available the actual composition of these materials will have to be considered and in some cases adjustments made. The preparation of nutrient solutions should be done under conditions of extreme cleanliness. When plants are grown in hydroponic culture, in contrast to soil, there is relative little buffering capacity or resistance to change in the system and very small amounts of phytotoxic materials will result in plant growth reduction. The hydroponic solution given in Appendix #1 was developed for tomatoes, but has been found adequate to satisfy the nutrient requirements of many types of plants. Slight modifications of this solution may prove better depending upon the plant species being grown and the type of growth desired. That is, whether top growth, root growth, fruit or some other aspect of growth or yield is being encouraged. For example, if corn and certain other grass type plants are to be grown in this nutrient solution, the amount of added iron should be increased 2 to 4 times. However the most common modification is that of the overall concentration of the nutrient solution. For young plants and germinating seeds the half strength solution is too strong. I find that one tenth strength is a good concentration for germinating seeds. And a one fifth strength solution is sufficient for seedling growth. When growing native plants it is not unusual to find that they grow best on a one tenth or one fifth strength nutrient solution. The formula presented in Appendix #1 is a minor modification of half strength Hoaglands solution. Concentrated stock solutions are prepared so that routine nutrient additions can be done by simple dilutions without the need to weigh and dissolve numerous salts each time. The stock solutions can be stored successfully, preferably in a cool dark place. It will be necessary to prepare the two concentrates (#1 and #2) in separate containers in order to avoid a precipitate of calcium and phosphate. Fiberglass, plastic or stainless steel containers are recommended. These containers should be opaque to light because these solutions provide an excellent media for the growth of green algae in the presence of light. Once the concentrated nutrient stocks are prepared, most of the tedious work is done and it is then possible to concentrate on how best to use these hydroponic solutions for growing plants.

TABLE 1 Relative Tolerance to Salinity

Tolerant	Semitolerant	Sensitive
EC=12	EC=10	EC=4
Garden Beet	Tomato	Radish
Kale	Broccoli	Celery
Asparagus	Cabbage	Green Beans
Spinach	Bell Pepper	
	Cauliflower	
	Lettuce	
	Sweet Corn	
	Potatoes (White)	
	Carrot	
	Onion	
	Peas	
	Squash	
	Cucumber	
EC=10	EC=4	EC=3

TABLE 2 Water quality limits for irrigation water and drinking water (mg/l)

ELEMENT	For water used continuously on all soils	For short term on fine textured soils only	Drinking water	Solution culture
Aluminum	1.0	20.0	---	---
Arsenic	1.0	10.	0.01	---
Beryllium	0.5	1.0	---	---
Boron	0.75	2.0	---	---
Cadmium	0.005	0.05	0.01	0.09
Chromium	5.0	20.0	0.0005	1.09
Cobalt	0.2	10.0	---	0.38
Copper	0.2	5.0	1.0	0.47
Fluorine	---	---	0.7	---
Iron	---	---	0.3	---
Lead	5.0	20.0	0.05	---
Lithium	5.0	5.0	---	---
Manganese	2.0	20.0	0.05	---
Molybdium	0.005	0.05	---	---
Nickel	0.5	2.0	---	0.55
Selenium	0.05	0.05	0.01	---
Vanadium	10.0	10.0	---	0.41
Zinc	5.0	10.0	5.0	2.06

TABLE 3 Relative Tolerance to Boron

Tolerant	Semitolerant	Sensitive
Tamarix	Sunflower	Pecan
Asparagus	Potato	Black Walnut
Date Palm	Acala Cotton	Navy Bean
Sugar Beet	Pima Cotton	Plum
Mangel	Tomato	Pear
Garden Beet	Sweetpea	Apple
Alfalfa	Radish	Grape
Gladiolus	Field Pea	Kadota Fig
Broadbean	Rose	Persimmon
Onion	Olive	Cherry
Turnip	Barley	Peach
Cabbage	Wheat	Apricot
Lettuce	Corn	Blackberry
Carrot	Zinnia	Orange
	Pumpkin	Avocado
	Bell Pepper	Grapefruit
	Sweet Potato	Lemon

Within each group the first named are the most tolerant

Appendix #1

Preparation of Stock Concentrats For Nutrient Solution (for 200:1 dilutio)

Stock Concentrate #1

	Amt./L	Amt/5gal
Potassium Nitrate (KNO_3)	50.55 g	33.8 oz
Mono-Potassium Phosphate (KH_2PO_4)	27.22 g	18.2 oz
Magnesium Sulfate ($MgSO_4:7H_2O$)	49.30 g	32.9 oz
Micronutrient Concentrate	100 ml	64 fl.oz

Fill with water and mix thoroughly to dissolve all salts

Micronutrient Concentrate

	g/l	oz/5gal
Boric Acid (H_3BO_3)	2.850	1.90
Manganese Sulfate (MnSO :H O)	1.538	1.03
Zinc Sulfate ($ZnSo_4:7H_2O$)	0.219	0.15
Copper Sulfate ($CuSO_4:5H_2O$)	0.078	0.05
Molybdic Acid (85%) ($MoO_3:2H_2O$)	0.020	0.01

Fill with warm water to disslove all salts

Stock Concentrare #2

	g/l	oz/5gal
Calcium Nitrate * ($Ca(NO_3)_2:4H_2O$)	118.0	78.8
Sequestrene 330 Fe	5.0	3.3

Mix the iron chelate thoroughly in a small amount of water befor adding to the calcium nitrate concentrate

* If agricultural Calcium Nitrate (Norsk Hydro) is used with a formula of $5Ca(NO_3)_2\ NH_4NO_3:10H_2O$) add only 88.8 gm/l or 59.3oz/5gal.

Approximate concentration of nutrients in final solution

	NO_3-N	PO_4-P	K	Ca	Mg	SO_4-S	Fe	B	Mn	Zn	Cu	Mo
ppm	103	30	140	83	24	32	2.5	0.25	0.25	0.025	0.01	0.005
meq/l	7.5	1	3.5	4	2	2						

Appendix #2

SUGGESTED COMPOUNDS FOR FORMULA MODIFICATION

	Amount required to replace one equ in 5/gal of conc.
Potassium phosphate (KH_2PO_4)	P = 1.13 lb K = 1.13 lb
Di-ammonium phosphate ($(NH_4)_2HPO_4$)	P = 1.10 lb
Phosphoric acid (52%) (H_3PO_4)	p = 1.13 lb (0.312 Liters)
Phosphoric acid (85%) (H_3PO_4)	p = 0.96 lb (0.257 Liters)
Calcium nitrate (Commerical) ($5Ca(NO_3)_2:NH_4NO_3:10H_2O$)	N = 0.74 lb Ca = 0.74 lb
Calcium nitrate (Regent grade) ($Ca(NO_3)_2:4H_2O$)	N = 0.98 lb Ca = 0.98 lb
Ammonium nitrate (NH_4NO_3)	N = 0.33 lb
Potassium nitrate (KNO_3)	N = 0.84 lb K = 0.84 lb
Nitric acid (HNO_3)	N = 0.75 lb (0.24 Liters)
Urea ($CO(NH_2)_2$)	N = 0.25 lb

Substitution should be made on an equivalent basis only. For example,if the tap water contains sufficient calcium the calcium nitrate could be lift out of the forumla, but an equivalent amount of nitrogen must be supplied from another sourse. If ammonium nitrate is the choice, multiply 0.33 lb by 4 equivalents required to obtain the amount of ammonium nitrate tobe used for each 5 gallons of stock concentrate in place of the calcium nitrate. Partical subsititution is also possible if the water only supplies part of the requirement.

Greenhouse and Patio Growing Ideas

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GREENHOUSE AND PATIO GROWING IDEAS

JIM MCCASKILL of
HYDROHARVEST SYSTEMS

I find a constant problem with the word "HYDROPONICS"---Most everyone gives me the definition of Hydroponics as "Growing Plants without Soil". Is that what your concept of the word is??? Well, really that is only a part of it---and **only the smallest part as I see it.**

The real definition of Hydroponics is:

THE SYSTEM OF GROWING PLANTS WITHOUT SOIL, **AND UTILIZING A FULLY-FORMULATED PLANT FOOD CONTAINING AT LEAST TWELVE OF THE INORGANIC BASIC CHEMICAL ELEMENTS,** WHICH REMAIN SOLUBLE AND AVAILABLE FOR OPTIMUM PLANT DEVELOPMENT. THE SYSTEM DOES REQUIRE PROTECTION OF THE PLANT ROOTS BY SOME FORM OF COVERING TO PREVENT DAMAGE TO OR DESTRUCTION OF THE ROOTS FROM LIGHT, AND TO KEEP THEM IN A HIGH HUMIDITY ENVIRONMENT.

Well, at least that is my definition. And the real key is the use of the 12 soluble available elements for plants to grow--6 Macro Nutrients and 6 Micro Nutrients.

To determine which is the most important, let me ask you a question. WHAT IN THIS UNIVERSE OF OURS IS THE MOST VITAL FACTOR OF LIFE?? WHAT--IF IT IS MISSING, WOULD DESOLATE OUR PLANET. Now, some will call out "Sun", and "Water", and "Heat" & "Air". These are important, but there is something very. very small--very, very vital.

Consider for a minute--CHLOROPHYL. In the process of photosynthesis CHLOROPHYL brings the Sun's energy into the construction of BASIC SUGAR. Every facit of life for plants,

$$6CO_2 + 6H_2O --- C_6H_{12}O_6 + 6O_2.$$

NO OTHER NATURAL PROCESS BUILDS BASIC SUGAR, ON WHICH ALL LIFE ON THIS EARTH IS TOTALLY DEPENDENT.

Chlorophyl is a very complex molecule. It has Carbon, Nitrogen, Hydrogen, Oxygen, and ONE OTHER ELEMENT. IT IS THE INORGANIC MINERAL ELEMENT---MAGNESIUM. Of all the 12 elements needed for plant growth--and life--MAGNESIUM is at the top of the list. What makes the GREEN of all plants is CHLOROPHYL. What makes the CHLOROPHYL is Magnesium, *yet you can't buy Magnesium in* *a Nursery Store..*

I have had a standing offer for the past 10 years to my students. I will give a crisp, new $50 bill to any student bringing me a package of plant food from a Nursery Store containing MAGNESIUM. Now the most available form is Epson Salts. And you go to the DRUG STORE for it---not the Nursery Store. Not a single Nursery can stay in business WITHOUT the green of Chlorophyl--yet, no one in the Nursery Industry will stock Magnesium Sulfate (Epson Salts) on the shelf. The price is too low, and they can't make any money on it.

Let's take a side trip and look at another problem thrown at gardners---this time by the Fertilizer Industry--WATCH:

$$Ca(NO_3)_2 + MgSO_4 -- Mg(NO_3)_2 + Ca(SO_4).$$

Soluble CALCIUM---GONE! Soluble SULFATE---GONE! The white flocculation and precipitation is $Ca(SO_4)$---97% insoluble, and NEVER AGAIN AVAILABLE for plants, except in the most infinite of quantites. DRYWALL GYPSUM is what we have in the bottom of the tank!!

You can give yourself troubles, even with the best of Hydroponic nutrient formulas. Do any of you take your 10-12-16 ounces of Plant Food for 50 gallons of solution, and dump it in 2 or 3 gallons of warm water to get it dissolved? And then, you pour the concentrate into the total 50 gallons. Oh, you do??---how much white precipitate do you have in the bottom of your tank?? That is the Calcium Sulfate, now insoluble, for your plants in the bottom. BY MIXING THE NUTRIENT IN A SMALL AMOUNT OF WATER, YOU LET THE PARTS PER MILLION OF CALCIUM AND SULFATE GET TOO HIGH---SAY, 2-3,000 PPM. WELL, ANY TIME THE CALCIUM AND SULFATE IS MORE THAN ABOUT 400 PPM, YOU START THE FLOCCULATION PROCESS, AND YOU LOSE VIRTUALLY EVERY PART OF CALCIUM AND SULFATE IN YOUR FORMULA.

HEY, DON'T DESTROY YOUR PLANTS WITH A MECHANICAL GOOF-UP LIKE THIS. PUT THE LARGE QUANTITY OF NUTRIENT DIRECTLY INTO THE LARGER QUANTITY OF WATER---IT WILL DISSOLVE IN A FEW MINUTES.

Now---the 2nd most important Nutrient---NITROGEN. It is most amazing because it will enter plants as a Positive Cation of NH_4^+, and as a Negative Anion of NO_3^-. BUT---78% of the Earth's Atmosphere is FREE ELEMENTAL NITROGEN---and it has ZERO effect on plants and animals. Every breath you take is 78% Nitrogen, and only 21% Oxygen.

AND NITROGEN IS ALWAYS CHANGING---

In the soil, their are many separate species of micro-organisms converting each step along the way. NH_4^+ to NH_3^+ to NH_2^+ then to NH^+, and over to NO^-, up to NO_2^-, and then to NO_3^-.

Now the NH_4^+ competes with the Ca^{++}, the Mg^{++}, the K^+, the Fe^{++}, B^{++}, Mn^{+++}, Cu^{++}, Zn^{++} & the Mo^{+++}. They all want to go into the plant as Cations.

But the NO_3^- competes only with the SO_3^- and the PO_4^- to go into the plant. They go in the plant as Anions.

THEN THE STRANGEST THING HAPPENS---Once the NO_3^- gets into the plant, it starts reversing this above process, going to NO_2^-, NO^-, over to NH^+, NH_2^+, NH_3^+ and NH_4^+, to then be metabolized into the plant structure---leaf, stem flower or fruit.

That first NH_4^+ which went into the plant direct--usually goes direct to the leaf. Look in the Nursery Store. Virtually every Nitrogen carrying Plant Food on the shelf is Ammonia--NH_4^+. The warmth of the spring and summer--WOW--TURNS PLANTS MIGHTY GREEN WHEN FEED NH_4^+. BUT, IT'S A "QUICK FIX"--IT DOESN'T LAST LONG. But the NO_3^- metabolizing back thru the process I just described, gives the plants better, long lasting green.

In Hydroponic writings, nearly every writer says to use 25% NH_4^+ and 75% NO_3^- in your formulation. I HAVE NEVER USED NH_4^+ IN ANY COMPOUNDED FORMULA. And, two years ago, Dr J. Benton Jones, from University of Georgia wrote an article recommending the NON-USE of NH_4^+ for Hydroponic Formulation. Dr. Jones was a speaker here at the Society Conference 3 years ago, in 1982.

So Far, I've been dealing with information which applies to both Greenhouse and Patio Growing. Before I go on, I will mention that NH_4^+ in a greenhouse should only be used on hot summer days--and only enough for it to be picked up by the plants during that one day's sunlight. High NH_4^+ on cloudy days will give you trouble. Do not use NH_4^+ in the winter in a greenhouse as it will give your plants a long spindly stem, with extra long space between the leaf nodes.

Okay, now let's look at some factors needing special attentior for different handling in the Greenhouse from the Outside Patic Growing.

I. Plant Root Cover.

I don't call it soil, because most greenhouse growers us Artificial Root Cover Mix---Peat Moss, Vermiculite, Perlite, an Sand most generally. Wholesale growers of Patio & House Plant use the same type of Mix, but many PATIO GROWERS will put i quite a bit of soil in the grow-boxes and pots on the Patio.

Of vital concern for all is--

Sterilization of the Root Covering
Oxygenization of the Roots
Water Movement & Retention for the plants

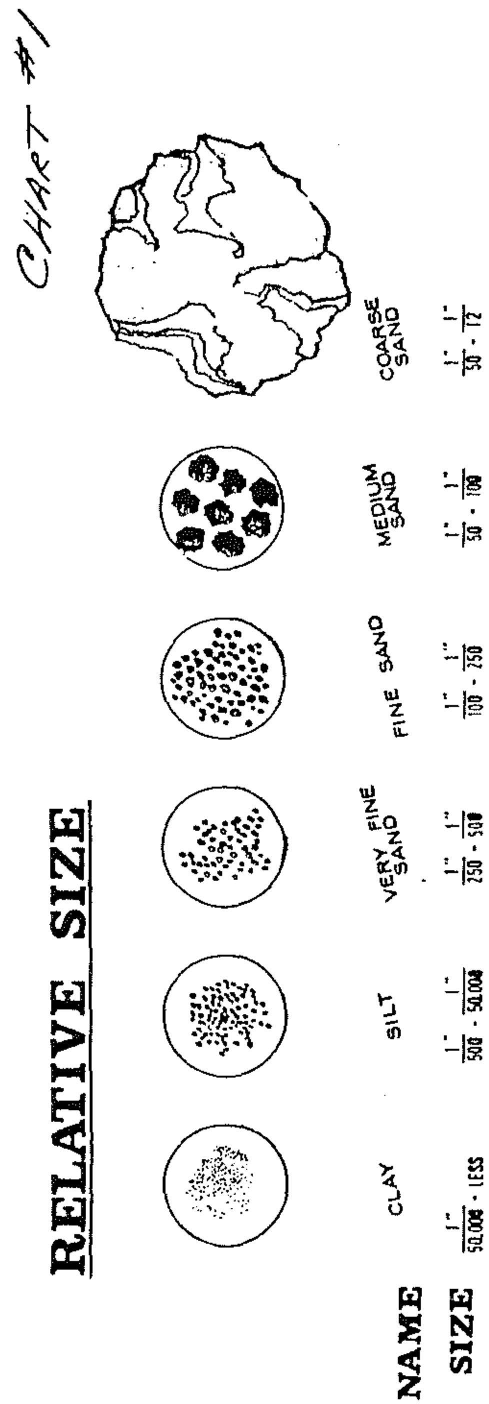
Oh,Oh!! Did you ever wonder how our forefathers, coming acros the country, 100-150 years ago, selected the place to Homestea and build a Cabin and settle down?---THEY DID IT BY TH HANDFUL!!!

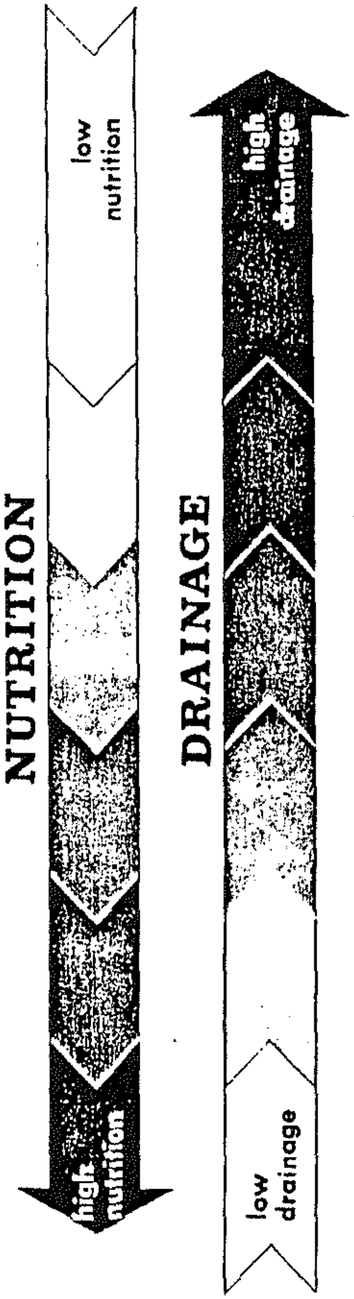
At a likely spot they dug into the ground a few inches. The taking a HANDFUL of soil, THEY SQUEEZED IT. Then slowly ope their clenched fist, they watch to see what happened. AND HEF WAS THE ANSWER AS TO STAYING OR MOVING ON!!

If the soil spilled out between their fingers, with N cohesion, they were in SAND--NO GOOD. Crops dry out to fast. I it stuck together in a solid clump--TOTAL cohesion, they were i clay--NO GOOD. Clay can hold the water away from the crops, ar there is no aeration to the roots so the plants wilt and die.

If the soil broke into small clods with some cohesion ther was some sand, some silt and some clay. Then they smelled i for organic decay. And when it was real dark brown, or eve black, THEY STAYED--THIS WAS IT, THE HOMESTEAD.

Today, we're more sophisticated. We can put together change the root media in the Greenhouse and Patio growing fr the things I mentioned earlier. I MOST CERTAINLY CANN RECOMMMEND THE USE OF SOIL IN THE GREENHOUSE MIX. You introdu too many possibilities of infection from improperly sterili





WHERE IS THE CALCIUM & MAGNESIUM???

can set off even a few spores of micro-organism into a killing infection. STERILIZATION, with temperatures of 165 Degrees for 20 minutes is a must to clear any Soil of its micro-organisms.

I was called by th owner of a small greenhouse some time ago. He was in trouble and didn't understand why. I found that he had used some Potting Mix off the shelf of the Nursery store for germinating his seed. He then transplanted his seedlings into his greenhouse beds--leaving the potting mix on the roots. HE GREW THE ONLY GREENHOUSE BEDS I HAVE EVER SEEN WITH THOUSANDS OF SYMPHYLANS---SMALL WHITE 12 LEGGED GRUBS, WHICH DODGED THRU THE GRAVEL LIKE CRAZY. They ate the roots like you cannot believe. He had sterilized the gravel before putting it in the beds, but the potting mix was not---and he paid for it.

II. Oxygenization or Aeration

Going on---the Root Cover Media must provide AERATION. Taking a lesson from some of the Hydroponic systems and equipment I've seen, I have my own way of Aeration. But first, the ideas from others.

1.BILL SKAIFE, from his Anything Groes Systems--now called "Truck Farms" has a fascinating idea. He puts the rooting media into a stocking. Then he puts the stocking down into a 3 inch pipe, which develops as a Humidity Chamber, with 100% Relative Humidity. But it allows the roots to metemorphisize two kinds of roots--Water and Nutrient seeking ones, and Oxygen seeking ones. Even with some of the roots continuously in water for weeks, the others always provide Oxygen when needed at night, and things grow excellently, with no rot in the roots.

2.GROSFILLEX Self-Watering Planters are also interesting. The base holding the roots and root cover media above the bottom reservoir is slotted. This allows Oxygen to get to the roots, even with the wick constantly drawing water up into the media. There is also an overflow so that the reservoir cannot be overfilled. There are over 10 million of them in France, where they are made, and all their literature is printed in SEVEN languages as they are sold all over the world. Go to the LAZY GARDNER booth here at the show to see this system.

3.MCCASKILL HUMIDITY TUBE--now that is a good name. Relying on the ideas from these two above, I find that ANY POT OR GROW BED IN A GREEN HOUSE OR ON A PATIO, can benefit from better aeration. Here is how you do it. Take a small plastic tube or pipe, about 1/4 or 1/2 inch in INSIDE diameter. With a small size drill-bit, drill lots of holes thru it, 1/4 inch apart, putting them on all sides by rotating the tubing as you drill. Now, take a large metal rod--the same OUTSIDE diameter, and poke holes--3 or 4 will do--thru the root media--clear to the bottom of the pot or bed. Now insert the tubing into this hole and leave it.

BEHOLD, YOU HAVE A SMALL HUMIDITY CHAMBER FROM THE OUTSIDE AIR TO THE BOTTOM OF THE BED, AND AIR CAN GET IN THE MEDIA THRU THE HOLES. The roots then metamorphisize Oxygen seeking roots by these holes, and you never again have your roots rot from overwatering, and no Oxygen for the Respirative period of the plant's metabolizing complex molecules at night.

III Water Movement & Retention

It is necessary to correlate the type of watering system you are using, both in the Greenhouse and on the Patio, with the size of the particles of the rooting media, and the characteristics of the media. We have had lots of discussion from others about using Gravel--with Flooding; Sand--with Drip; Peat-Lite--with wicking; and some other mixing & matching.

Flooding and Drip water systems are letting Gravity and the weight of the water be predominant. Some mechanism--usually a pump--must provide the water above the rooting media. Wicking relys on closeness of the particles of the root media to have Capillary Action do the work. Enclosed Chart #1 gives the soil particle sizes and their drainage abilities. Peat Moss, Vermiculite, and Perlite aid in water retention for the plants when they are present. These additives do help hold water in the root media.

Flooding & Gravel belong only in the Greenhouse. Drip & Wick belong on the Patio, and many Greenhouses use them.

Now here is a MAJOR point of difference between Greenhouse & Patio growing---HUMIDITY---WOOPS!!!--There is no such term as HUMIDITY. What's the right term?? YES, it is RELATIVE HUMIDITY.

WATER CARRYING CAPACITY OF AIR IS DIFFERENT AT EVERY TEMPERATURE OF THE AIR. In studying Relative Humidity in high school or college, the instructor nearly always uses the example of a graph--starting at the low temperatures and moving up, showing the gradual increase of water carrying capacity--with an arc turning upward. (Where as a Straight Line would have resulted if the relationship had been constant.)

But in a Greenhouse, the most vital part of understanding of Relative Humidity is **COMING DOWN THE TEMPERATURE SCALE.**--and the resulting higher and higher Relative Humidity as the air cools, until you reach 100% Relative Humidity--and then pass the point (better called the Dew-Point) which results in moisture being deposited on the sides of the Greenhouse.

THE REALLY VITAL POINT AT THIS TIME IS THE HARBORING OF EVIL AS THE ATMOSPHERE IN THE GREENHOUSE STAYS AT 100% RELATIVE HUMIDITY. NOW, LOOK CLOSELY---The winter afternoon sun has brought the temperature up to 85 degrees with about 60% Relative Humidity--GREAT GROWING CONDITIONS. NOW THE SUN GOES DOWN, and at 4:30 its gone. Temperatures drop from 85 to 80 and to 75, then 70 and down to 65 degrees.

At 85 degrees with 60% Relative Humidity we have about 7.8 Grains of water in each Cubic Foot of Air. Now, at 68 degrees temperature, we Reach 100% Relative Humidity---where the Wet and Dry bulbs of the Psychrometer read the same. THE SAME 7.8 GRAINS OF WATER IS STILL IN EACH CUBIC FOOT OF AIR, IS IT NOT??? NOTHING HAS TAKEN THE WATER OUT, HAS IT???

FOR THE REST OF THIS NIGHT, AND EVERY OTHER NIGHT OF THE YEAR, THE PLANTS ARE OPEN TO **INFECTIOUS DOOM.** Every fungus needs 100% Relative Humidity for Fruitation or Sporation to occur:

BOTRITIS--100% Relative Humidity and Low Temperatures

POWDERY MILDEW--100% R.H. & High Temperatures

FUSARIUM, PHYTHIUM, VERTICILLIUM, RHYZOCHTONIA---THEY ALL NEED 100% RELATIVE HUMIDITY.

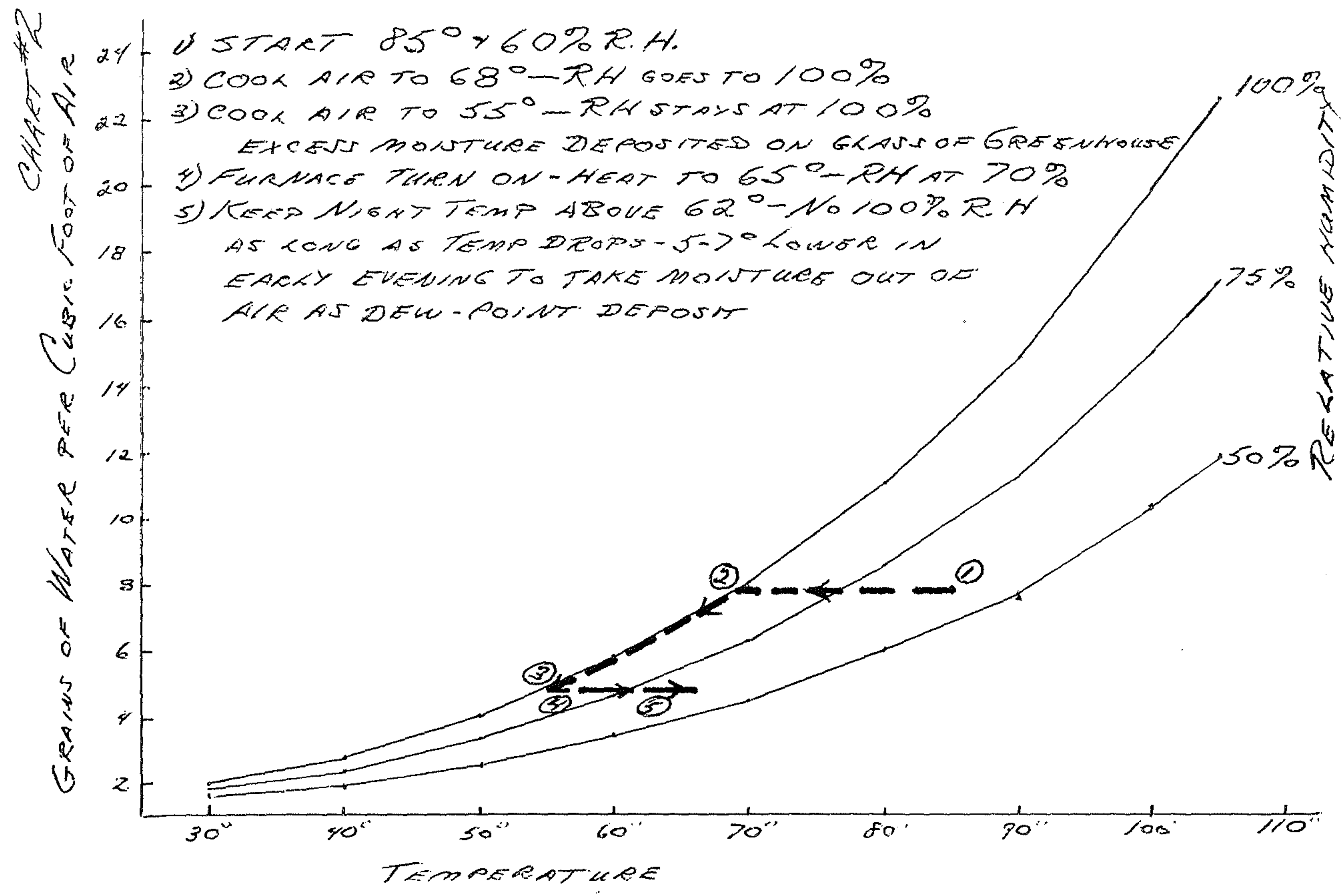


CHART #2
GRAINS OF WATER PER CUBIC FOOT OF AIR
1) START 85° & 60% R.H.
2) COOL AIR TO 68°—RH GOES TO 100%
3) COOL AIR TO 55°—RH STAYS AT 100%
EXCESS MOISTURE DEPOSITED ON GLASS OF GREENHOUSE
4) FURNACE TURN ON-HEAT TO 65°-RH AT 70%
5) KEEP NIGHT TEMP ABOVE 62°-No 100% R.H
AS LONG AS TEMP DROPS-5-7° LOWER IN
EARLY EVENING TO TAKE MOISTURE OUT OF
AIR AS DEW-POINT DEPOSIT
24
22
20
18
16
14
12
10
8
6
4
2
100%
75%
50%
RELATIVE HUMIDITY
1
2
3
4
5
30°
40°
50°
60°
70°
80°
90°
100°
110°
TEMPERATURE

In the Greenhouse you have to set up a system to REDUCE this Relative Humidity BELOW 100%--down to 80-85%--to shut off the sporation of Infectious Fungus. In Chart #2, I have shown the idea of bringing the early night-time temperature down to about 55 degrees--to take out an extra grain or two of moisture from the air in the Greenhouse. The idea is, just once each night---at the beginning---to let the temperature come down; then for the rest of the night, keep it up to 62-65 degrees so as to not interfere with the metabolism of the complex molecules the plant builds during the Respiratory Phase of growth, when it is using Oxygen.

I'm still trying to find the standard type of Humidistats and Thermostats which I can combine in some way to do this. So far, no success--but I'm sure that the Computer System which Terry Walton explained to us last year could handle it. My short experience with computers tells me that this small extra item could be programmed into the computer very easily.

The only other way is to have the Greenhouse system include an outside vent--which will bring cold outside air directly THRU the furnace to be heated. It would be drier air, and after heating, mix thru-out the Greenhouse to bring the Water Content below the 100% Relative Humidity where Fungus grows rampant.

Outside on the Patio, it's a different story (except in rainy, damp weather). Naturally, in the daytime, Spray Misting of the growing area could be needed to RAISE the Relative Humidity to an Optimum of 50-60%. Better Photosynthesis occurs with the Stomata Cells open for more CO_2---and more basic sugar making. I highly recommend for Patio Growing, that you have open dishes of water available for Evaporation of water into the air.

Well, let's move on---

The Russians have a Secret Weapon which is saving them Millions of Rubles yearly in their Health Care Costs. IT'S MANUFACTURED RIGHT HERE IN THE UNITED STATES. U. S. BIG BUSINESS doesn't want it known--General Electric, Westinghouse, and Sylvania have done everything they can to Poo-Poo the products---even cutting prices severely to attempt to drive this competition out of business.

There is a small Company--getting bigger--which manufactures a Flourescent Light Bulb which tests out at 91% of the Equivalent of the Light Spectrum of the Sun. Dura-Test Corporation builds a light with 16-35% more of the Reds, Greens, Blues and Violets than any other Artificial Light on the market.

AND THE RUSSIANS LOVE IT!!!

IN SIBERIA, EVERY CITIZEN SPENDS 20-45 MINUTES EVERY DAY, during the long dark winter-time, in a LIGHTED CUBICAL. The lights are from the U.S.A. Within the first TWO winters' use of these lights--

-Underground Miners Lost Time from Illness dropped nearly 50%.

-Women's Menstral Period improved from once every 5-6 months to every 30 days as in the Temperate Latitudinal Zone.

-Child Illness from their previously poor immunity systems dropped nearyly one-third.

-Nearly 30% of the doctors were moved to other parts of Russia---they just weren't needed here because of the improved health of the people.

CHART #3

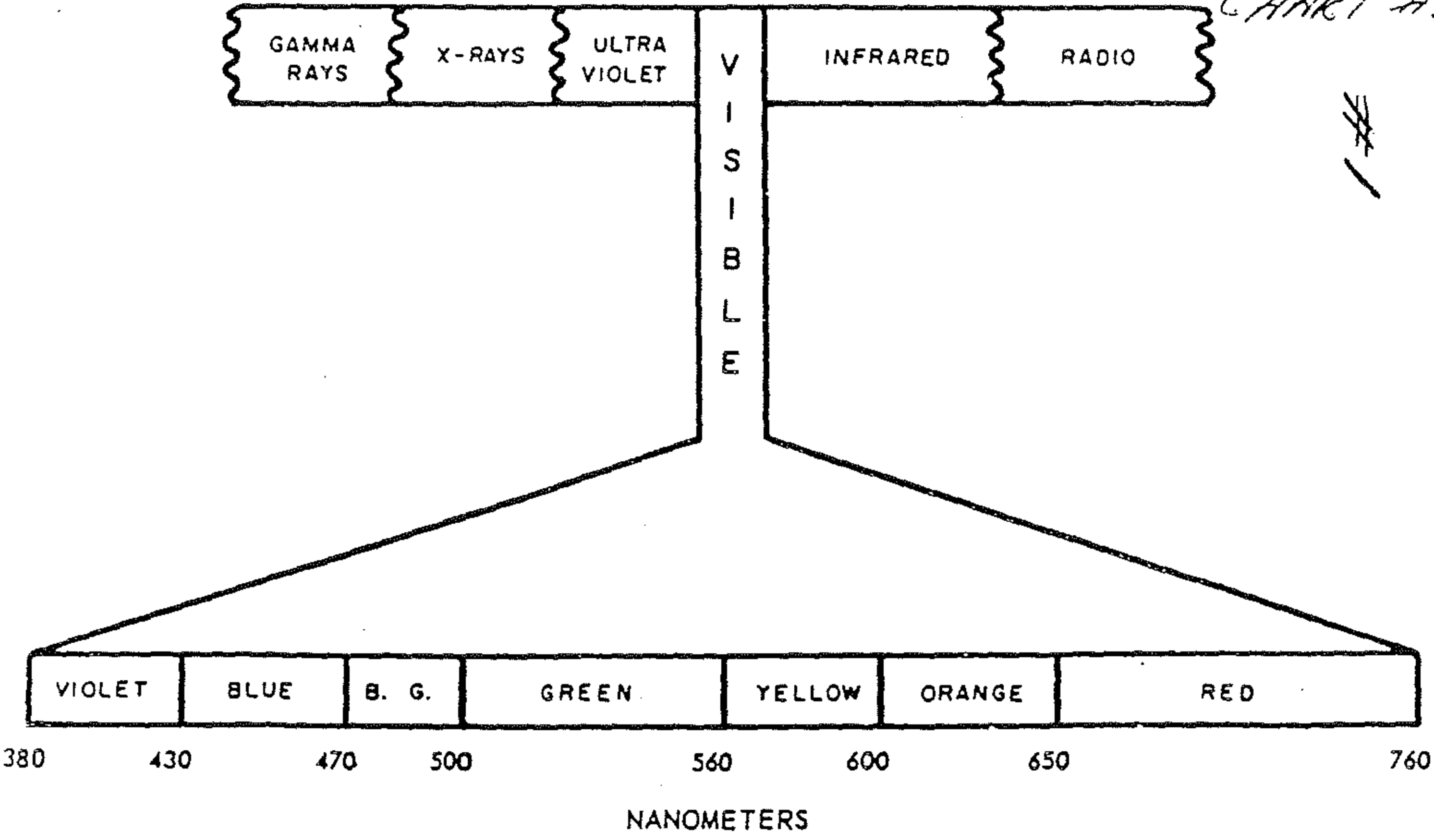
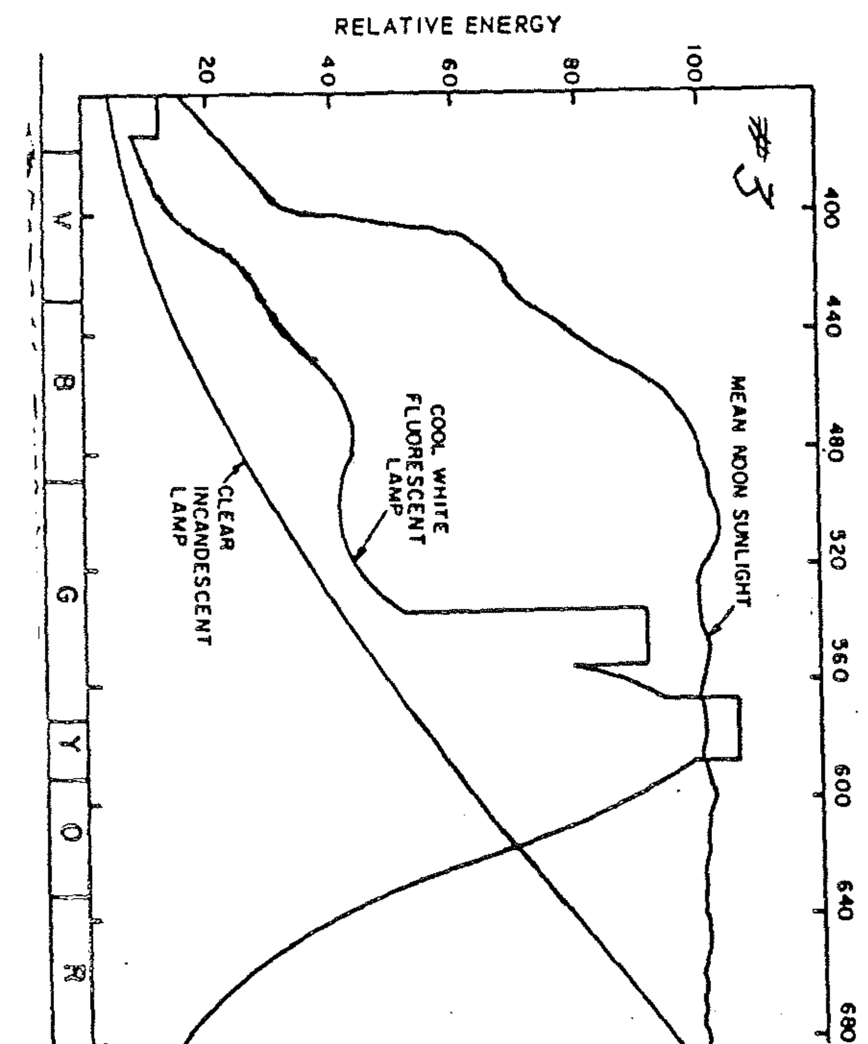


Figure 1. Wavelengths of visible and invisible radiations of the electromagnetic spectrum.



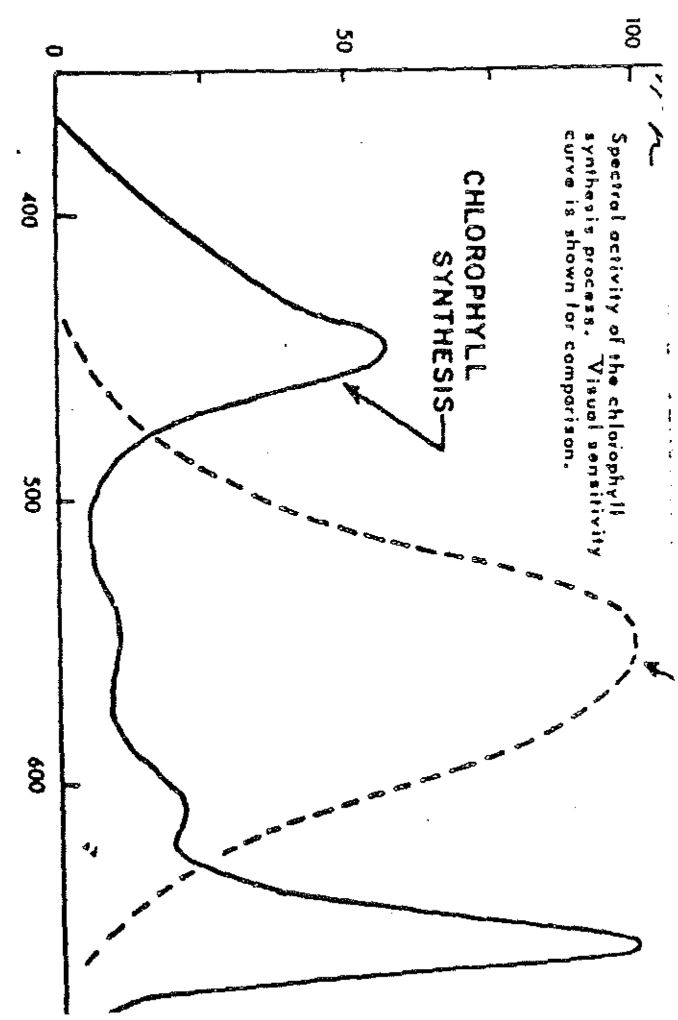
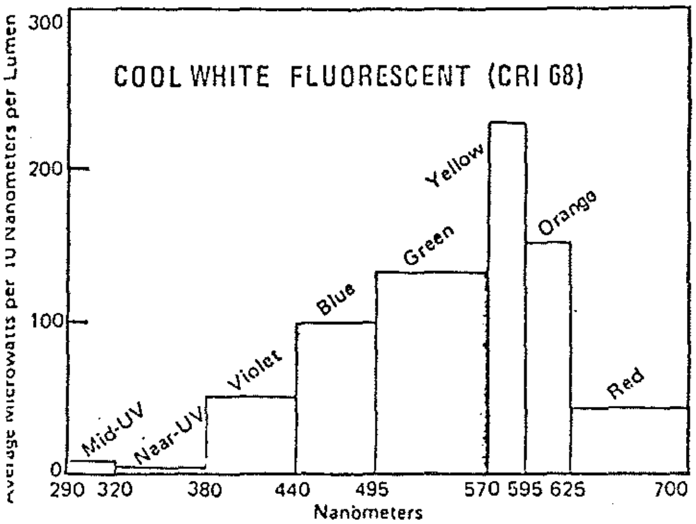
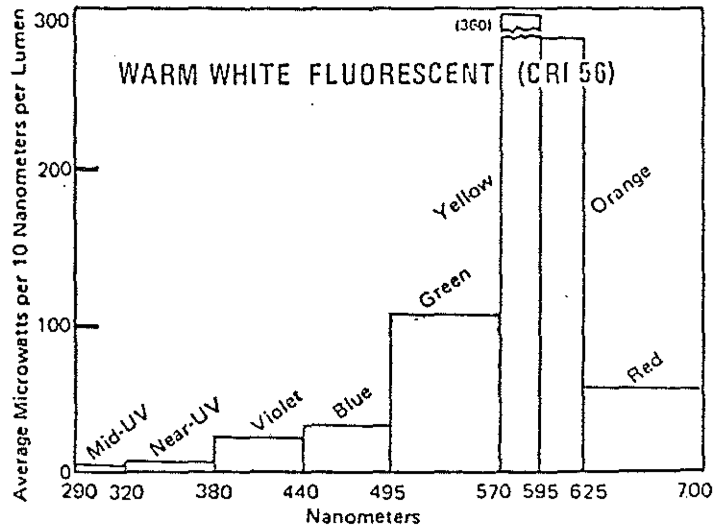
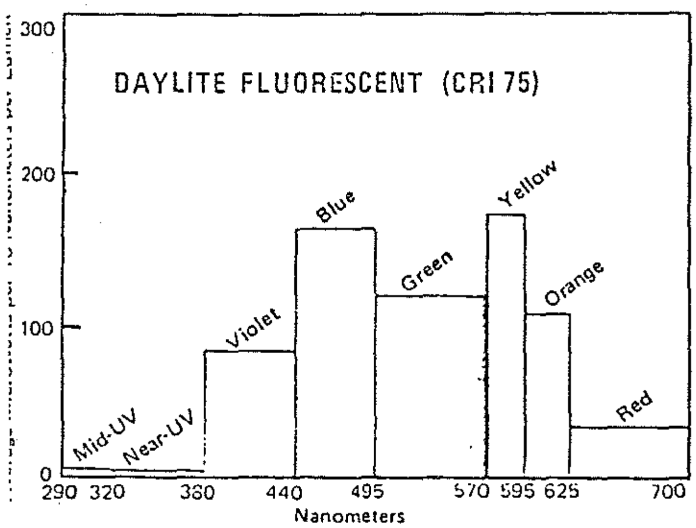


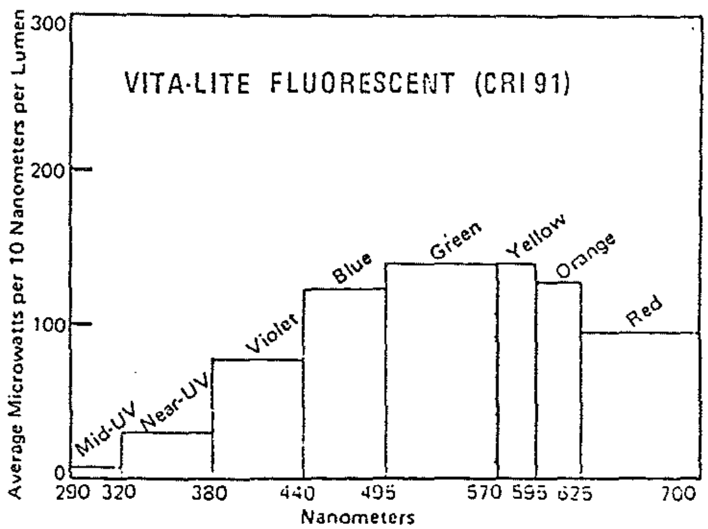
CHART #4

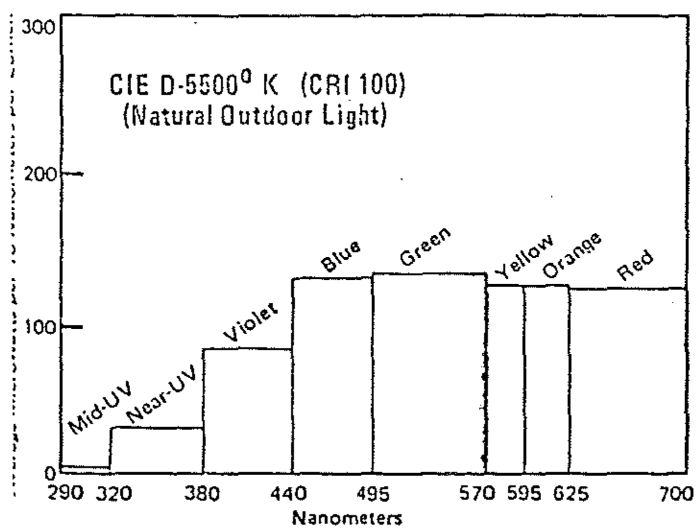
For The First Time, Man-Made Light That Simulates Nature's Visible and Ultraviolet Spectrum...Vita-Lite!











These are spectral energy distribution charts. They show the average amount of light generated in each color band by the light source being measured. These are the "color ingredients" of each type of light.

The chart at left (C.I.E. D-5500° K) is specified by the International Commission on Illumination as representative of natural outdoor light. Its Color Rendering Index (CRI) is 100.

The other charts represent the three most common fluorescent lamps and Vita-Lite. Their Color Rendering Indexes are shown on the charts.

Compare them all. Only Vita-Lite matches the visible and ultraviolet spectrum of natural outdoor light. And like natural light, it is the "whitest" light, promoting maximum see-ability of form and color.

VITA-LITE THE UNPOLLUTED LIGHT.

Note: For maximum effectiveness, use Vita-Lite in open-type or "egg crate" fixtures or with ultraviolet-transmitting diffusers. Duro-Test makes no claims for Vita-Lite fluorescent lamps other than those made in its printed literature.

My wife and I use Vita-Lite Flourescent lamps in our living room. We have a 4-foot fixture over our main reading chairs. And for over 10 years, we have gone without colds and flu--with only 1 or 2 small attacks.

Four years ago, my wife wanted to rearrange the living room furniture for a change. So we did---but I didn't move the lights. We just used floor lamps with incandescent bulbs in them. That's when we began to have trouble.

In about six months I suddenly realized something was wrong--so I moved the furniture back, (while my wife was out of town). And within about 30 days, no more colds or illness. Now, I must mention that Dura-Test Corporation issues disclaimers on every one of their products as to THEY'RE NOT BEING SOLD FOR HEALTH VALUES---BUT I KNOW THE VALUE OF THE SUNLIGHT TO HUMAN LIVING--AND SO DO THE RUSSIANS!! A COLOR RENDERING INDEX (CRI) OF 91% IS PRETTY CLOSE TO 100%.

WHY AM I TELLING YOU THIS???

EVER SINCE THE WORLD BEGAN, PLANTS, ANIMALS AND HUMANS HAVE BEEN OUT IN THE OPEN--UNDER FULL-SPECTRUM SUNLIGHT.

Only in recent 100 years or so--since Edison invented the light bulb in 1879--has the Human Race moved INSIDE under Artificial Light. And you are trying to grow plants under these same Artificial Lights.

The chart #3 I've included, shows the Early Incandescent Bulbs---with the horendous excessive Red and Far Reds emitted from them. and very little else. (See diagram #3 of Chart #3). Plants grown exclusively under incandescent bulbs become very long and spindly, and don't flower very well. Then put a Plant under Black Light (which is predominately Violets and Blues) and the growth is very short and stumpy. PLANTS NEED BOTH ENDS OF THE LIGHT SPECTRUM, AND NOT MUCH IN THE MIDDLE.

General Electic, Westinghouse, and Sylvania build bulbs to ENHANCE objects and materials so that business can sell more. ENHANCEMENT, NOT HEALTH AND WELL BEING IS THEIR BY-WORD. The Sensitivity of the Human Eye picks up predominately Greens, Yellows, and Orange. All the light bulbs from these Companies direct their emphasis on Enhancement of these colors--GREEN, YELLOW, AND ORANGE.

BUT PLANTS NEED VIOLETS, BLUES, REDS, AND FAR REDS. See Diagram #2 of Chart #3, and you will see what the Plant Growth and Chlorophyl Synthesis curves are. Plants DON'T use the Greens, Yellows, and Orange part of the light spectrum.

The logistics of moving Artificial Lights and their fixtures, makes it difficult and costly to supplement normal Greenhouse light with Artificial Light. Up and down, up and down--the fixtures cannot be left in place as they cast too much shadow, and interfere with the normal sunlight which you put the Greenhouse in operation for in the first place.

Patio and Living Room growing can be aided greatly with a full-spectrum flourescent light like the Vita-Lite, with a CRI of 91% of natural sunlight.

There is one more factor of growing which is one of my MAJOR concerns. MAKE CERTAIN THAT YOU HAVE ALL TWELVE (12) ELEMENTS AVAILABLE IN YOUR NUTRIENT SOLUTION. *Learn how to build your Nutrient to your own ideas.*

You don't have to worry about converting Grams to Ounces, or Liters to Gallons. You don't have to know what a Normal Solution is. You don't have to know Atomic Weights or Atomic Numbers. THERE IS A SIMPLE "RULE OF CONVERSION" SO THAT YOU CAN KNOW EXACTLY WHAT PARTS PER MILLION YOU HAVE IN YOUR NUTRIENT SOLUTION.

All packages of plant food show the Percentages of Nutrient on them. These THREE numbers, usually shown on the front, are the N, P, K percentages. Nunmbers like 12-8-20 means Nitrogen 12% - Phosphates 8% - Potassium 20%. There is a SPECIAL FACTORING for the P-Phosphorus and the K-Potassium which I will explain in just a minute. But for N-Nitrogen at 12%--Here is the "Rule of Conversion":

"Divide the Elemental Percentage of Nutrient by 4; move the Decimal point one place to the RIGHT; the resultant is the PARTS PER MILLION when 1 GRAM OF THAT SUBSTANCE IS PUT IN 1 GALLON OF WATER."

SO, "N"=12 - Divide by 4 = 3.0 - Move the Decimal one to the Right = 30. WHEN I PUT ONE GRAM OF THE NUTRIENT INTO ONE GALLON OF WATER, I HAVE 30 PARTS PER MILLION OF NITROGEN IN MY SOLUTION. OH--But you say you want 150 PPM Nitrogen. That's easy--use 5 GRAMS. 30 x 5 = 150

Also, be aware:

1 Ounce in 28.4 Gallons = SAME PPM
3.5 Ounces in 100 Gallons = SAME PPM

The Manufacturers recommendations might be "One Rounded Tablespoon" or "One Heaping Teaspoon" or "One Handful" in a quantity of water---BUT YOU WILL NEVER KNOW EXACTLY WHAT HE IS RECOMMENDING, UNLESS YOU HAVE THE QUANTITIES OF EACH COMPOUND HE HAS USED, AND THE ATOMIC WEIGHTS. I guarantee you it will take a good chemist 20-30 minutes to give you the PPM, while this "Rule of Conversion" will do it in 30 seconds--and you won't even need a pencil and paper.

Now the Fertilizer Industry is cheating the American Public--and has for nearly 80 years. The 2nd number is P-Phosphorus. BUT IT IS NOT ELEMENTAL P, it is the Compounded form--P_2O_5. The Atomic weight of Phosphorus is 31, and Oxygen is 16. 31x2 + 16x5 = 142. P-64/142 = 0.44. AND 0.44x8 = 3.5%. The Elemental P is NOT 8%--it is 3.5% The other 56% of the 8% is Oxygen. And by the way, the compound form P_2O_5 is an unstable form which quickly converts to stable PO_4^-, but the Fertilizer Industry could care less.

Now apply the "Rule of Conversion" to the Elemental P---3.5/4 = .88: move the Decimal one to the Right = 8.8 PPM (Call it 9.0). And for each gram of this 12-8-20 Nutrient in ONE Gallon of water we have 9 PPM of Elemental Phosporus. And using 5 Grams--as we are for the 150 PPM of Nitrogen, we have 45 PPM of Phosphorus.

The Fertilizer Industry did it to the Public again, as to the 3rd number--K-Potassium. Here they use K_2O--which is 83% K and 17% O. So instead of 20% K, it is 20% K_2O and only 16% Elemental Potassium. Okay---"Rule of Conversion" applied is 16/4 = 4.0; move the Decimal One to the Right gives 40 PPM from each GRAM in each GALLON; and 5x40 = 200 PPM.

Then using 5 grams of the whole Nutrient 12-8-20 in ONE GALLON

PARTS PER MILLION ANALYSIS of NUTRIENT

CHACON MULTI--PURPOSE PLANT FOOD

Label Reads 15-15-15 + 7% S + .25% Fe

Directions call for 1/2 Teaspoon/Gallon

(by Weight - 1/2 Teaspoon = 2 Grams)

Calculation:

		Decimal		
N = 15% /4	=	3.75 Rt One	= 37.5 x 2 Gms	= 75 PPM
P = 15% x0.44/4	=	1.65 Rt One	= 16.5 x 2 Gms	= 33 PPM
K = 15% x0.83/4	=	3.00 Rt One	= 30.0 x 2 Gms	= 60 PPM
S = 7% /4	=	1.75 Rt One	= 17.5 x 2 Gms	= 35 PPM
Fe = 0.25%/4	=	0.063Rt One	= .63 x 2 Gms	= 1.26 PPM

PLEASE NOTE - NO CALCIUM & NO MAGNESIUM

CONTINENTAL NUTRICULTURE FORMULA

Label Reads 8-8-24 + 5% Ca + 2% Mg + 3% S

Directions call for 1.6 Lbs (25.6 Oz) for 100 Gallons

Rule of Conversion allows for 3.5 Oz/100 Gallons

(25.6 / 3.5 = 7.3 Multiplier)

CALCULATION:

		Decimal		
N = 8% /4	=	2.0 Rt One	= 20.0 x 7.3	= 146 PPM
P = 8% x0.44/4	=	0.88 Rt One	= 8.8 x 7.3	= 64 PPM
K = 24% x0.83/4	=	5.0 Rt One	= 50.0 x 7.3	= 365 PPM
Ca = 5% /4	=	1.25 Rt One	= 12.5 x 7.3	= 91 PPM
Mg = 2% /4	=	0.50 Rt One	= 5.0 x 7.3	= 36.5 PPM
S = 3% /4	=	0.75 Rt One	= 7.5 x 7.3	= 55 PPM

CHEM-GRO HYDROPONIC NUTRIENT

Label Reads 10-8-22 + 5% Ca + 1% Mg + 3% S

Directions call for ONE Teaspoon per Gallon

(by Weight - ONE Teaspoon = 6 Grams)

CALCULATION:

		Decimal		
N = 10% /4	=	2.50 Rt One	= 25.0 x 6 Gms	= 150 PPM
P = 8%% x0.44/4	=	0.88 Rt One	= 8.8 x 6 Gms	= 53 PPM
K = 22% x0.83/4	=	4.57 Rt One	= 45.7 x 6 Gms	= 274 PPM
Ca = 5% /4	=	1.25 Rt One	= 12.5 x 6 Gms	= 45 PPM
Mg = 1% /4	=	0.25 Rt One	= 2.5 x 6 Gms	= 15 PPM
S = 3% /4	=	0.75 Rt One	= 7.5 x 6 Gms	= 45 PPM

of water, we have a total of:

N-Nitrogen = 150 PPM
P-Phosphorus = 45 PPM
K-Potassium = 200 PPM

--And you have an exact known answer of the Nutrient Solution. We Haven't used a pencil and paper---and without all my explanation---we have done it in about ONE MINUTE.

I'm including Chart #5 which has three of the Packages of Plant Nutrient--two of which are Top Quality Hydroponic Plant Nutrients--developed to Parts Per Million with my "Rule of Conversion". I have developed them on the basis of the Manufacturers' recommended amounts.

I realize that most plant food packages don't claim the Elemental Percentages of Magnesium, Calcium, and Sulfur. Of course Epson Salts sold in the DRUG STORE is not sold as a plant food, so you need to know the Elemental Mg percentage:

Calcium Nitrate	N=15.5	Ca=21
Magnesium Sulfate (Epson Salts)	Mg=10.0	S =13
Potassium Nitrate	K=37	N =13.7
Potassium Sulfate	K=41.5	S =17

Don't forget, you buy Epson Salts in the Drug Store. And by the way, One of the homework assignments I always give the first night of my classes is to buy some Epson Salts and take a hot Epson Salts bath. I'm assigning each one of you to do the same when you get home. Pretty kooky for a plant class, you say?? But what helps Plants also helps the Human Existence.

Just in case you are intersted in knowing how the "Rule of Conversion" works, invite me back again as a speaker, and I'll tell you the simplicity of it. It's ligitimate.

ENJOY ENJOY ENJOY !!!!

MAR 22 1985

SUPPLEMENT GUIDES FOR BEGINNERS

BASIC PREMISE OF ALL GROWING---TO OPTIMIZE CONDITIONS BEARING ON THE PLANT BEING GROWN SO AS TO UTILIZE **BOTH INTERNAL SYSTEMS** WITHIN THE PLANT TO THEIR FULLEST CAPABILITY:

1. TRANSPIRATION. Movement of the water and nutrient into the plant and up to the leaves for Photosynthesis utilizing the CO_2 from the air to manufacture bsic sugar.
2. RESPIRATION. Movement of new sugar, after the sun goes down, back to the roots for metabolizing of complex molecules by use of OXYGEN.

My definition of Hydroponics includes *"Protection of the Roots by a covering to prevent damage of destruction by LIGHT, and to keep them in a high humidity environment".* LET'S LOOK AT THE VARIOUS TYPES OF ROOT COVERING, AND COMBINE THAT WITH WATERING SYSTEMS AND NEEDED EQUIPMENT FOR GOOD PLANT GROWTH.

ROOT COVER	WATERING	NEEDED EQUIPMENT
1. GRAVEL "Hi-Gro Lite" Pea Gravel	FLOOD-GRAVITY	PUMP for Pressure TANK for recovery Enclosed/recycle
2. SAND	DRIP--GRAVITY Non-Recovery of overflow	PUMP for Pressure Drain Lines to Remove Excess Viaflo Tape Dble-Wall Tubing
3. REDWOOD SHAVINGS Bag Culture "Pillow Pak"	DRIP--GRAVITY Top Spray	PUMP for Pressure Spot Spitter-Fan Spray Spaghetti Line/Emitter Viaflo Tape Dble-Wall Tubing
4. NURSERY MIX Peat Moss, Perlite, Vermiculite Mix	DRIP--GRAVITY	PUMP for Pressure Spaghetti Line/Emitter Viaflo Tape Dble-Wall Tubing
5. WICKING	CAPILLARY UP-FLOW Reservoir Below	SMALL SIZE ROOTING PARTICLES FOR WATER MOVEMENT UPWARD NO PUMP EQUIPMENT
6. N.F.T. (Nutrient Film Technique) -No Root Media-	FLOWING WATER IN COVERED BED "Pass-Thru Tube" No Blockage of Water Flow by Roots	PUMP for Pressure ROOTING BEDS must be enclosed for Humidity Chamber

IN USING DRIP IRRIGATION YOU MUST BE AWARE THAT THE AMOUNT OF WATER APPLIED MUST EXCEED THE AMOUNT LOST BY BOTH EVAPORATON FROM THE SURFACE, AND TRANSPIRATION BY THE PLANTS. THIS WILL PREVENT SALT BUILD-UP IN THE MEDIA WHICH CAN DAMAGE THE PLANTS. THE OVER-FLOW SHOULD ALWAYS HAVE SOME SMALL AMOUNT OF DISCHARGE.

POINTS OF CONCERN FOR SELECTION OF POSITON FOR A GARDEN:

1. SUNLIGHT 2. AIR MOVEMENT 3. TEMPERATURE 4. PLANT DENSITY 5. CROP MIXING

I. LIGHT

Understand Plants as to SHADE TOLERANT or INTOLERANT. Some plants must have full sun, others partial, and others can grow well without direct sunlight.

A. If the vegetable or fruit product you want is the *"FRUIT OF THE FLOWER"* you must have FULL SUNLIGHT. Any shading will reduce the yield of the plant. Best examples are Tomatoes, Cucumbers, Squash, Corn, Melons, etc.

B. If the product is the leaf only, some shading is acceptable. However, there should be some 2-3 hours of sunlight on the plants.

C. Artificial Lights, if used as the main source, or a supplement source, must have the flourescent bulb source of the light WITHIN 12-15 INCHES of the growing tips. The whole light rigging of the fixture and source bulb should be moved out of the way of the natural sunlight. There are the new Hi-Intensity bulbs for INTERIOR growing, and special equipment for their suspension---I'm not really involved here with them.

II AIR MOVEMENT

A. New CO_2 must move across the leaf surface to go into the Stomata Cells for Sugar Manufacturing by Photosynthesis in the leaf.

B. Cools the leaf surface for better growing of the plant.

C. Prevents Humidity Build-Up and Cold Spots in the growing area.

III TEMPERATURE

Most plants go into "HOLD" or Dormancy of growth if the temperature is below 50 Degrees. With plants dealing with the "FRUIT OF THE FLOWER" the temperature should be kept higher. Lowest for Tomatoes is 62-65 degrees; Cucumbers, 68-70 degrees; Melons, Squash & Peppers, about 65 degrees.

When the temperature goes too low in the night, then the whole plant has to warm up--using some of the early morning "SUN" hours. This of course reduces the total daytime sun-hours for plant growth and Photosynthesis.

IV PLANT DENSITY

In Commercial greenhouses, plant density is very important. The "Interior" plants away from the sidewalls must get there sunlight from the top only. However, in small yard or patio growing, your density is limited only by the size of your beds. Be sure your radishes and carrots are 1-2 inches apart. Keep the lettuce at 6-8 inches. You need enough space for each vegetable to grow properly. As for Vine type--tomatoes, melons, cucumbers--you can use arbors or trellisesor support strings, fanning them out away from the bed--BUT ALWAYS ON THE NORTH SIDE OF THE BED. The roots are all you need the bed for--the stems and vines can grow away from the bed.

V CROP MIXING

I HAVE INCLUDED A CHART WHICH ONE OF MY CLASS MEMBERS GAVE ME SOME YEARS AGO. HERE ARE LISTED THE FRIEND AND ENEMIES OF VARIOUS GARDEN PLANTS. Mix all you want to, but be aware of these few Enemies that some plants have.

COMPANION PLANTING---

Because plants grow so quietly, you would think that their world is all Peace and Bliss. NOT SO---Among plants, there are definite Friends and Enemies. Some plants protect each other from Insect Infestations. Others provide shade for their friends. Others, again, just like each other and grow better if they are neighbors.

In Hydroponics, if you are going to ask two or more plants to happily share the same planter-bed, you should make sure that they are compatible. Here is a list---keep the friends together and move the enemies to a different grow-bed.

PLANT	FRIENDS		ENEMIES	
Anise	Coriander		-	
Asparagus	Parsley Tomato	Basil	-	
Sweet Basil	Aspargus		Rue	
Bush Beans	Beets Cabbage Carrots Cauliflower	Cucumber Potato Summer Savoy Strawberry	Rue Fennel Garlic	Onion Shallot
Pole Beans	Carrots Cauliflower Sweet Corn Cucumber	Savoy Radish	Beets Fennel Garlic Kohlrabi	Onion Shallot
Beets	Bush Bean Cabbage Chives Onion	Kohlrabi Lettuce Shallots	Pole Bean	
Borage	Strawberry		-	
Broccoli	Cabbage	Tomato	-	
Brussel Sprouts	Tomato		-	
Cabbage	Bush Bean Beets Broccoli Camomile Celery	Dill Lettuce Potato Sage Mint	Strawberry Tomato Pole Bean	
Camomile	Cabbage		-	
Caraway			Fennel	
Carrots	Bush Beans Pole Beans Chives Leek Lettuce Onion	Peas Potato Radish Rosemary Sage Tomato	Dill	
Califlower	Bush Bean Pole Bean	Tomato	-	
Celeriac	Cauliflower Tomato Bush Bean	Leek Cabbage	-	
Celery	Cabbage Cauliflower Bush Bean	Leek Tomato	-	
Chervil	Radish		-	

PLANT	FRIENDS	ENEMIES
Chives	Beets, Carrots	Peas, Beans
Coriander	Anise	Fennel
Sweet Corn	Pole Bean, Peas, Potato, Pumpkin, Bush Bean, Cucumber, Squash	—
Cucumber	Bush Bean, Sunflower, Peas, Pole Bean, Radish	Sage, Potato, Aromatic Herbs
Dill	Cabbage	Carrots, Tomato
Fennel		B Beans, P Beans, Kohlrabi, Caraway, Coriander, Tomato
Garlic	Beets, Onions	Bush Bean, Pole Bean, Peas
Grape	Hyssop	—
Hyssop	Grape	Radish
Kale	Tomato	—
Kohlrabi	Beets, Onion	Tomato, Pole Bean, Fennel
Leek	Carrots, Celeriac, Celery, Onion	—
Lettuce	Beets, Cabbage, Carrots, Onions, Radish, Strawberry, Cucumber	—
Onions	Beets, Carrots, Garlic, Kohlrabi, Lettuce, Strawberry, Tomato, Savory	Bush Beans, Pole Beans, Peas
Parsley	Asparagus, Tomato	—
Peas	Sweet Corn, Carrots, Cucumber, Potato, Radish, Turnips, Beans	Garlic, Onion, Shallot
Pumpkin	Sweet Corn	Potato
Radish	Pole Bean, Carrots, Chervil, Letuce, Peas, Cucumber, Nasturtium	Hyssop
Rosemary	Sage	—
Rue		Sweet Basil
Sage	Cabbage, Rosemary	Cucumber
Summer Savory	Bush Bean	—
Shallot	Beets	Bush Bean, Pole Bean, Peas
Spinach	Strawberry	—
Squash	Nasturtium, Corn	—

PLANT	FRIENDS		ENEMIES
Strawberry	Bush Bean Borage Lettuce	Onion Spinach	Cabage
Sunflower	Cucumber		Potato
Tomato	Asparagus Kale Onion Parsley Stinging Nettle	Chives Marigold Nasturtium Carrots	Dill Fennel Kohlrabi Cabbage
Turnip	Peas		—

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HYDROPONICS, HYDRONUTRITION, & HEALTH

BY PEARL YAMANE AND GROVE HAYNES

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HYDROPONICS, HYDRONUTRITION, & HEALTH

The National Cancer Institute recently embarked upon a program, which they estimate will save 20,000 lives a year through improved diet.(1) The diet is a result of years of research by the National Research Council and includes the following recommendation:

EAT: More high fiber foods such as fruits and vegetables

: more whole grains

: more "cruciferous" vegetables (named for their cross shaped flowers) such as cabbage, brocolli, and brussels sprouts

: more vegetables rich in beta carotene like leafy greens and deep yellow vegetables such as carrots, pumpkin, acorn squash

Note that most of the food recommended on the National Cancer Institute's diet list can be produced in a hydroponic garden. We are going to show that not only can they be produced in larger yields hydroponically, but they can be more nutritious than field crops grown with the same fertilization.

HIGH YIELDS VS. NUTRITION

The effectiveness of hydroponics in producing large yields has been well documented, but the important question of the nutritional value of food produced must be examined if hydroponics is to play an important role in food production.

The purpose of this paper is to examine the nutritional value of hydroponically grown produce as compared to field grown produce using the same fertilization. We will look at the protein content as well as the mineral content of two important food crops: Wheat and soybeans.

We would like to begin with several conclusions drawn by agronomists from their research in plant nutrition at Purdue University, 1982:

> "Concentrations of minerals in hydroponically grown soybeans are higher than for field grown beans due to the high availability of the mineral elements to the plant from the nutrient solution." (2)

Agronomists from Kansas State University drew similar conclusions from their study regarding protein content of hydroponically grown wheat.

> "Plants grown under controlled conditions with hydroponics did not suffer temperature, drought, or pest-induced stresses. Yield was significantly increased by the beneficial effect of phosphorous on both tillering and seed set. Despite that, grain protein concentration increased with increased phosphorous supply." (3)

Notice that **despite** the increase in yield, the wheat grain concentration of protein increased also. Why did the researchers use the term "despite"? The reason is this: In past research the increase in yield of a field crop is usually accompanied by a decrease in protein concentration of that crop. Conversely when researchers have been able to raise the protein concentration of a field of wheat, the yield suffers. "Wheat producers are reluctant, because of economic considerations, to fertilize for higher protein concentrations, particularly if yields are not increased. Breeders are handicapped by the inverse relationships between wheat grain yield and protein concentration."(3)

Modern laboratory techniques are making it possible to measure the nutritional value of plant tissue in precise ways. By using atomic absorption spectrophotometry the uptake by plants of trace elements can be measured in quantities less than one part per billion. This method provides a means of accurately assessing the effectiveness of various agricultural techniques in producing nutritious food.

HIGH YIELD AND NUTRITION

Hydroponics has been shown by recent research to be more effective in producing not only bigger yields, but of also imbueing crops with more minerals and protein than the same crops grown in fields with the same fertilization.

What significance has this as far as the future of the science of hydroponics? It has two major impacts. First, its importance to the immediate health needs of the public. Secondly, it has implication for long range planning to provide nutritious food for emergency needs in the face of several environmental threats to field crops, such as weather, pestilence, and pollution.

TRACE ELEMENTS DEFICIENCIES AND DISEASES

Recent developements in nutrition research have revealed the importance of trace elements in the human diet. We have long known that certain diseases were caused by deficiencies of traces of elements such as iodine and iron. Several other elements that had previously been considered as "minor" are now correlated with common diseases -- zinc, chromium, magnesium and, even the once thought to be toxic element, selenium are now seen to play an important role in human health.

Any of the essential elements can be toxic in high doses, and for this reason it is safer to get them in vegetable form than as synthesized supplements. When consumed in a vegetable they are not only buffered but, they are also accompanied by enzymes that chelate them and help in their digestion and assimilation by the human recipient.

Another health aspect of growing food hydroponically is the avoidance of toxic metals such as lead, cadmium, and mercury.(4) These heavy metals are toxic in even small doses and are prevalent in many soils where field crops are grown. In addition to heavy metals, we will later bring out evidence to show that pesticide residues linger in the soil much longer than we thought.

Recently the universities and agri research organizations are beginning to take an interest in hydroponics as a research tool in learning more about plant nutrition. Using hydroponic techniques it is possible to precisely control the nutritional environment of the plant, and thus assess its effect on the nutritional value of plants. This research has important implications for home growers as well as large commercial growers. How can small growers use the new knowledge in making their own crops more nutritious?

SEA WATER FOR TRACE ELEMENTS

Most pre-packaged nutrient mixes have only the nutrients that are necessary for plant growth and omit trace elements which are nevertheless important to the consumer of the produce. For this reason it may be necessary to add those elements that are often absent such as selenium, chromium, zinc, silicon, and vanadium, etc. What the health-conscious grower needs is a simple means of fortifying the nutrient mix until such complete mixes become available. A simple way of doing this is to use sea water or sea solids.

In our own experience we have found that a small amount of sea water (15cc to a gallon of water) not only serves to correct minor trace element deficiencies in our tomatoe plants, but also exposes the plants to many elements that are essential to us but are not included in the ordinary nutrient mixes.
James Taylor has done work in this area and says:

"Comparing the required essential elements of man to those of plants, I found 13 additional elements required by man which are not required by plants. Please note they are all present in sea water." (5)

Taylor notes that "In fact hydroponic vegetables have been grown successfully in as much as 20% sea water and 80% fresh water while producing highly nutritious crops." Taylor's emphasis is on nutrition and he recommends a weak mixture of sea water and fresh water. "Consistent usage (of sea water) will deliver plenty of trace elements to your vegetable crops. Besides, the object is quality not quantity."(5)

Recent research shows that it is not necessary to sacrifice quantity for quality when you grow hydroponically, but we feel Taylor is putting the emphasis where it should be.

HYDROPONICS AND WORLD HUNGER

The higher yields and superior nutritional value of hydroponic crops make them ideal as emergency food sources. In those arid and desert-like areas where soil is depleted or where urban conditions provide little food growing capacity, the high protein and mineral qualities of hydroponic produce would be advantageous. We must adapt hydroponic methods to the materials and energy resources indigenous to the third world.

Appropriate technology must be used where there is undependable electric power, little water, or adverse weather conditions. If these conditions are taken into consideration hydroponics could save many lives where the population is decimated by arid soil, drought, or isolation from agricultural centers.

AGRIBUSINESSES AND EMPHASIS ON YIELD

In many over cultivated areas of the U.S., the soil no longer yields a crop of high nutritious value. As we have seen, a large or voluptuous crop does not necessarily mean a nutritious crop, because of the inverse relationship between yield and nutrition in field crops.

Attempts to refertilize are usually directed toward increasing yield, and not nutritional content of field crops. Economic incentive to increase nutritive value is weak or even negative if there is danger of reducing yield when fertilizing for nutrition in field crops. No such negative incentive exists for hydroponic crops because high nutrition as well as high yield may be obtained simultaneously.

HYDRONUTRITION

Hydronutrition is a term we coined to describe the process of controlling the nutrient uptake of food crops in order to insure that the plants thus produced will be of the most nutritious order. In other words, if we want particular nutrients in our diet we must be sure that crops are exposed to the proper nutrients and in right proportions while growing. The hydro prefix denotes water as the vehicle for the nutrients, because nutrients must be in a soluble form before they can pass through the plant tissue. This is true for plants grown in soil as well as soilless culture. "Large organic compounds making up soil humus are not absorbed by the plant, but must first undergo decomposition into the basic inorganic elements (ionic form)." ([6])

NUTRIENT UPTAKE BY PLANTS AND HUMANS

We see many similarities in plant nutrient biology and human nutrient physiology:

First, the similarity of nutrient needs: Elements known to be essential to humans are more numerous than those known to be essential to plants, but they encompass all of the same 16 elements that plants need plus several more.([7])

Secondly, the process of nutrient absorption by plants and humans is similar. The events that occur at the interface between nutrient solution and the root epidermis is similar to the events that take place where the human nutrients pass through the villi or short hair-like projections in the small intestine. The main difference is that the food molecules are reduced to ionic form by bacterial action, whereas in hydroponics the ions are released by disolving the molecules in water. The same electrostatic laws operate however, that may cause bonding and make some elements unavailable to the enzymatic system of the human. In humans, toxic metals such as lead, cadmium, and mercury disturb basic physiological processes because of their powerful force in such bonding. It is, for this reason, important to prevent these toxic metals from entering our food chain. And a good place to stop them is at the roots of the plants that we eat.

ESSENTIAL OR TOXIC ELEMENTS?

Those elements essential to humans over and above the 16 essential to plants may accidently be taken up by plants if they are exposed to them . "Plants are not particularly selective in the uptake of elements. They have a tendency to absorb a variety of non-essential (to them) elements if they are present in an available form." (7) This cuts both ways for us. If we do not take charge of the environment to which the plant is exposed, the plant may take up elements toxic to us when ingested. On the other hand, the same plants grown in a controlled environment can be made to provide our bodies with elements which are nutritious and rarely found in that same plant when soil grown.

TRACE ELEMENTS AND DISEASES

"Two elements iodine and cobalt, which are not essential for plants, are vital to the bio-economy of higher animals. While plants can thrive in areas that are deficient in iodine and cobalt, animals grazing on these plants are likely to develop deficiency diseases." (7)

Other elements often not administered to plants but nevertheless necessary for human health are listed by Dr. Walter Ebeling, such as sodium, vanadium, silicon, cobalt, and selenium. (8)

In comparing Tuli's list of 16 essential elements for plants to Ebeling's list of essential elements for animals, we find some which need to be examined carefully to ascertain their role in human health. They are: Chromiun, selenium, iodine, vanadium, silicon, and cobalt. These essential-to-human elements are often left out of plant fertilizers. There are several nutrients essential to plants and humans which are commonly deficient among various human populations. Iron, zinc, potassium, calcium, magnesium, have each in turn, been correlated with deficiency diseases by their absence in the human diet.

We can look at some of the human diseases correlated with deficiencies of various elements and see that the soil, upon which the sufferers of these diseases rely for food, is often deficient in these same elements.

SELENIUM AND KESHAN'S DISEASE

Deficiency of selenium and cardiomyopathy was linked as far back as 1935 when the incident of this affliction, termed Keshan's disease, was found to predominate in areas where soil was deficient in selenium. Supplements of selenium in diets of those effected were given. "The results confirm that oral selenium is effective in preventing Keshan's disease." (9) This truly impressive and definitive study clearly shows that selenium is essential for man, and populations living in low selenium areas or on diets low in selenium are at risk of cardiomyopathy. Selenium can be toxic in large doses, and the poisoning of the wildlife refuge at Kesterson Reserve should remind us of this.

Golden emphasizes that we should not assume that because an element is required in a small quantity it can be ignored and states:

> "Iodine is required by the body in a daily amount which is about one hundredth of the requirement for iron. It would seem therefore that the argument, often advanced, that trace elements are required in such small amounts that diets must supply sufficient is, by analogy with iodine, fallacious." (9)

He further connects disease and deficient soil when he refers to the history of goitre or thyroid disease, "-- the occurance of goitre in man was geographically associated with a low iodine content of food and water."(9)

Other diseases with a similar depleted soil etiology listed by Golden are:

Iron ----- Anemia
Zinc ----- Acrodermatitis enteropathica
Calcium -- Osteoporosis
Chromium - Hyperglycemia & aortic plaques

Dr. Walter Ebeling, professor of entomology emeritus UCLA Dept of Biology, points out that the incidence of bone diseases is related to soil in Atlanta, Georgia. "X-rays showed a consistent correlation between calcium and phosphate deficiencies in the soil of their home areas, and rachitic conditions leading toward deformities (in 3 to 5 year olds)." (8)

Other diseases that Dr. Ebeling lists as soil-element depletion connected are:

Mangesium ---- tetany, a disease of diary cattle
Selenium ---- cancer
Chromium ---- diabetis
Iron --------- anemia
Zinc --------- retarded growth
manganese ---- bone deformity
iodine ------- goitre

Recent research reinforced the connections between deficiency of selenium and incidence of cancer, low chromium and diabetis. The field of health and micronutrients is being more clearly brought into focus by new information regarding the importance of fresh fruits and vegetables in the diet.(1)

HYDRONUTRITION - HOW IS IT ACCOMPLISHED?

Now that we have looked at the hazards of relying on chance to supply essential micronutrients in our diet, we will tackle the difficult question of how to gain control over the nutrients that go into our food supply. Because of the impossibility of precisely controlling uptake of soil grown plants (17), and because the hydroponic method is, in its basic concept, a controlled nutrient environment for plants, let us look more closely at the details of how to accomplish this goal through hydroponics, or more specifically, hydronutrition.

In order to precisely control the nutrient environment of the hydroponic plant, we must begin with pure H20 or at least know what is in the water we use. A complete water analysis can be easily obtained from your local water dept. This should be the first step in gaining control of your plants' nutrient environment. If the water contains elements which are inconsistent with your health in quantities large enough to be toxic, using it for your garden is contra-indicated.

It has been demonstrated in the past that hydroponic methods produce more yield per square foot of growing area than field crops.(6) Only recently has research revealed that the nutritious content of vegetables grown hydroponically is also superior to that grown in fields. There are a number of reasons for this but they may all be summed up this way: Theoretically hydroponics should minimize the amount of stress that plants undergo throughout their development. This is accomplished by controlling the nutrient environment through knowledge of plant needs and supplying the proper nutrient at the proper time in the proper proportions. Although this is a difficult task it is possible when growing in a solution of fully dissolved nutrients and pure H20.

TOXIC METALS IN SOIL

The difficulty of achieving such control in field grown crops are many. If we compare hydroponics to crops grown in soil in a controlled environment and try to have all conditions of the two methods equal, we still find hydroponics superior for one basic reason. The nutritional content of soil is not as manipulable as is the nutritional content added to H20. We can more precisely control the nutritional environment of the plant grown hydroponically by increasing or decreasing the strength of the nutrient solution at will. In soil where we add nutrients it is often to the detriment of the soil grown plant because of the possible danger of toxic accumulations.

Toxic accumulations of elements can be averted in hydroponic situations by diluting the growing solution or rebalancing it.

Imbalances can be determined by ion selective electrodes or titration. In order to balance a hydroponic solution one must know what the particular plant needs at each stage of its growth in order to produce the desired effect. At this point we are going to digress somewhat from the usual desired effect which is higher yields, and focus on nutritional content because it is more relevant to our subject of HYDRONUTRITION. We earlier pointed out the importance of certain vegetables for health as recommended by the National Research Council.

ACCUMULATOR VEGETABLES

The reason these vegetables are important to our health is mainly because they are accumulators of essential elements. They are little storehouses of those difficult to get elements such as chromium, zinc, selenium, and vanadium, as well as the more common elements, calcium, iron, copper, sulfur, etc. There is a certain amount of specialization among plants for accumulating specific elements. The leafy vegetables which accumulate a lot of iron also accumulate chromium (Cr) for instance, and often there is a specific location in the plant where the accumulation occurs. "Fleshy roots of beets and turnips have lower Cr concentrations than the leaves."(10) This is a good example of the specificity of plant tissue toward certain elements because Cr is known to be difficult to translocate from the roots of most plants. "There is very little translocation of any Cr from any Cr source from the roots to the tops of any species". And "it appears that saturation of the Cr uptake process would not take place at any Cr concentration that could be maintained in a soil solution."(10) Here we have an example of the specificity of an element for a certain plant part. Cr favors roots but its specificity was overruled by beets and turnips which translocated it to their tops when it was in the company of iron concentrations. This one example of the translocation of Cr involves three principles which make this process complicated.

1. The specificity of plant parts to accumulate any elements.

2. The specificity of elements toward accumulating in certain parts of the plant.

3. The specificity of certain elements toward each other. In this case iron aided in the translocation of Cr from root to tops of beets and turnips. Also, sometimes elements interfere with each other's uptake by plants.

In order to control the accumulation of desired trace elements in plants we must understand these three principles and how they interact with each other. Elements often interfere with each other in translocation as well as in uptake, and some aid each other in these processes. This is a factor of their relationship to each other in an electromotive way. Excessive levels of any one element can have an adverse effect on the uptake of other elements. This is effected by the valence of each ion as well as the PH balance of the solution.

The complexity of understanding the interrelationships involved between these three principles and controlling them is difficult enough even in a hydroponic situation where we are starting with a known quantity, H20. When we are starting with an already complex and for the most part unknown substance such as soil, the task of understanding these interactions and controlling them becomes infeasible. At best we can only "guess-timate" what nutrient value will result from our agricultural efforts. Often heavy metals such as cadmium and lead are already present in the soil and not only interfere with uptake of desired elements, but become part of the plant tissue which will later be ingested by the unwary consumer.(4,12,13)

PESTICIDE RESIDUES

In addition to heavy metals in soil, there are also pesticide residues which are taken up by new crops. Increasing evidence suggests that pesticide residues are not as biodegradable as we thought.

> "Contrary to the general belief that bond residues become an integral part of the polymolecular structure of the organic matter without a recognizable relationship to the original pesticide, our data demonstrate that a considerable proportion of such residues in humic materials was comprised of the parent molecule and its monodealkylated analogue."(14)

It becomes increasingly clear that the nutritional value of our soil grown vegetables is threatened by:

1. Depletion of nutrients in soil
2. Complexion of essential elements with heavy toxic metals such as lead and cadmium.
3. Pesticide residues even where pesticide applications have ceased.

The first two threats can be eliminated by growing hydroponically and the third can be ameliorated if the growing media is replaced, if and when, it comes into contact with pesticides.

NUTRIENT CONTROL IN HYDROPONICS

How far can we go in controlling the nutrient content of vegetables? We have seen that some plants are accumulators of trace elements. It is important that the plants we chose to eat are not only accumulators, but they must also accumulate elements in the specific part of the plant that we eat. We have given an example of why Cr is so difficult to get into our food because it tends to locate in root structures and is not mobile except in a few cases where the strong specificity of the plant for accumulating in the upper leaves can move it.(11) Unfortunately when this occurs in beets and turnips, we lose most of the Cr unless we eat the tops as well as the roots. Other vegetables sources of Cr:

Green pepper -------	19	mcg/3	1/2	oz.
parsnips -----------	13	"	"	"
spinach ------------	10	"	"	"
carrots ------------	9	"	"	"
navy beans ---------	8	"	"	"
lettuce ------------	7	"	"	"
green beans --------	4	"	"	"
cabbage ------------	4	"	"	"

RDA Cr - 50 to 200 mcg/day

Lettuce and spinach are trace element accumulators in their leaves, but are not specific for any particular elements. They will in fact just as efficiently accumulate lead and mercury as they do the essential elements, if we expose them to the toxic heavy metals.

In cases where plants are weak in uptake of certain elements it is possible to supplement them by elevating that particular nutrient in an accumulator which will be eaten with them. Legumes are low in the sulfur containing amino acids and should be eaten with a grain which has been fortified with sulfur.

> "Since sulfur amino acids are the most limiting in legume proteins, it is likely that application of sulfur fertilizers might elevate the level in grains, thus increasing their availability for protein synthesis."(15)

Corn might be a likely hydroponic crop for sulfur fortification. Other vegetable sources of sulfur:

brussels sprouts
garlic
cabbage

Selenium is an element essential to human health for which the RDA is 50-200 mcg per day. It is accumulated by the cruciferae class of vegetables such as broccoli, cauliflower, and brussels sprouts. "These absorb about eight times more selenium than the cereals."(8)

Selenium is now being studied as to its role in the prevention of cancer. "A comparison of lung cancer rates of various countries found that they were lower in those that had higher amounts of selenium in the tobacco."(1)

The significance of cruciferae and leafy greens in our diets was mentioned earlier in context with recommendations by the National Research Council. It appears that the elements gained from eating the "flowers" of the cruciferae are instrumental in activating enzymes which human cells use to detoxify alien substances, converting them to a form that can be excreted harmlessly. (16)

Also recommended were yellow vegetables such as carrots, pumpkin, squash, and fruits because of their high content of retinoids which researchers think are anti-carcinogenic.(1)

The soybean, an important food crop worldwide, was studied extensively to determine its capacity for accumulating trace elements, both in the field and hydroponically. The research was done by the Dept. of Agronomy in conjunction with the Dept. of Foods and Nutrition at Perdue University in 1983. This definitive study clearly stated that hydroponics was a superior way to endow soybeans with more concentrations of essential elements. The researchers attributed this fact to "the high availability of the mineral elements" to hydroponically grown plants.(2) By using gamma ray spectroscopy, after plant parts were dried in a vacuum oven, they were assayed for radioactivity to determine with precision the amount and location of trace element accumulations for iron, zinc, and chromium. Researchers concluded the following:

1. Iron is relative immobile once it has arrived via the xylem to living tissues, therefore leaves accumulate more iron than stems and seeds.

2. Seeds do accumulate some Fe--legume seeds more so than cereals.

3. Cereals and grains contain more Zn and Cr than do legume seeds.

4. Zinc is greater in stems and leaves of soybean plants than in roots.

5. Chromium usually remains in roots.

6. They also found that an important factor effecting distribution of elements is the time of their application relative to the growth cycle of the plant.

As in all things, it seems that timing is important and this leads to our next topic, the impact of hydroponics on protein content of crops.

THE DILUTION EFFECT

Protein content was the subject of research by the Dept. of Agronomy, Kansas State University in 1982. Again they found that hydroponics excelled over field crops by endowing plants with more protein and yield than fields grown with the same fertilization. In this study phosphorous was manipulated and its effects studied. Field crops gained in yield but lost protein content when phosphorous was increased. This protein loss was attributed by researchers to what they call the dilution effect. They pointed out that this had also occured with increased potassium fertilization. (3)

The dilution effect was also noted by P.B. Tinker at a London Royal Society discussion in 1981.(17) The dilution effect has occurred with increase of nitrogen fertilization in soil grown crops, and can be a problem in hydroponically grown crops if the proper control of nutrients is not employed. This brings us back again to the question of timing.

When should increased fertlization occur in order to maximize protein content as well as yield? This question is being asked more recently since the importance of nutrition has taken its place along side yield as a goal for agriculture. The question has little significance for field agriculture because of the difficulty of manipulating nutrients in that setting.(17)

TIMING IN NUTRIENT CONTROL

The question of when to increase and when to decrease nutrient concentration for maximum yield and nutrition are of vital importance to hydroponists. We must look at several parameters of plant physiology to answer this question.

1. How are nutrients taken up by the plants?
   Passive--(with the electro chemical gradient)
   active--(against the electro chemical gradient)

2. How is this uptake effected by:

   A. Weather and temperature (seasons)

   B. Stage of growth of the plant: Seedling, foliage, and flowering or fruiting.

Here are some statements on this subject by various hydroponists concerning weather and fertilizer application.

1. Resh: "When the weather is cloudy for more than 1 or 2 days it may be necessary to cut the recommended fertilizer application by half, and if the cloudy weather lasts more than 5 days, skip the odd fertilizer application completely. (6)

2. Taylor: "During periods of cool weather, we should use stronger concentrations to make up for the slower flow rate." (5)

3. Tinker: "The distinction between active and passive uptake is often confused by the strong physico-chemical **adsorption** of ions. This **adsorption** of metal on cell wall material is independent of temperature, rapid, and depends on the concentration of the ion solution." (17)

COMPLICATIONS

The uptake of nutrients by plants is in general surrounded by controversy because of the extreme complexity of events which occur at the root structure. Not only are there complex electromagnetic interactions between elements, but there are complicated reactions between elements and root cells, exudates and root conditions such as fungal hyphae of vesicular-arbuscular mycorrhiza. It is important to distinguish between the process of absorption and the process of **adsorption** where the ions are held to the surface of the roots by electrochemical attraction. In some cases **adsorption** is very high and elements are bound to root cell walls but that does not mean that the elements are available to take part in enzyme action.

Adsorption binding to root cell walls is caused by resistance that some plants have to high levels of some elements in solution. In general, however, the uptake of micronutrients Cu, Zn, Mn, Fe is linear up to a 100 micro-mole concentrations, and in the case of copper, uptake is actually enhanced by mycorrhiza.(17)

Once taken up, copper functions with several essential enzymes within the plant. One of which is a copper metalloprotein called plastocyanin which is involved in photosynthesis. Researchers are discovering more each day about the essential function of the trace elements for plants as well as for humans. For this reason the factors that inhibit and facilitate uptake of micronutrients are getting more attention.

THE HYDRONUTRITIONIST

It is at this interface between plant and human nutrition that we hydronutritionists are focused. The similarity between the two systems often tempt us to hypothesize cause and effect relationships, where in actuality only correlations exist.

We have seen many studies which show correlations between pathology in both humans and plants and deficiencies of trace elements. In very few cases is the mechanism which causes the pathology understood. It is the approach of the hydronutritionist to seek a bridge between human physiology and plant biology in order to better understand them both. We can never hope to achieve optimum health until we see ourselves a part of the process of nutrient flow from the environment to plants to animals. The laws which govern the interaction of elements remain constant throughout all these stages. But at each stage there evolves greater complexities because of extraneous forces. And we have reached the highest stage when even the psycho-glandular processes of the human being must be considered as part of the whole play of interactions of one element with another. The hydronutritionist must look at this whole, but at the same time try to tease out the seperate variables and trace them back to their origin in the environment of the ingested plant.

We find much support for the hypothesis that: Ill health begins with the environment of the plants that we ingest.(18) We have tried to show that although those plants may appear healthy, we can no longer be sure that their tissue is consistent with our needs unless we have controlled their nutrient uptake and determined, by assay, their content. This is a difficult, but not impossible, task if we bring to bear the full weight of our formidable new technologies.

It becomes apparent that we must begin to give more emphasis to methods of insuring a reliable and nutritious food production. Our hypothesis is that hydroponics can do this, and so it is with the new and exciting science of hydroponics where new discoveries are being made rapidly, and soon there will be no need for growers to fly by the seat of their pants so to speak. In the midst of such diverse opinions and variety of approaches arises several important facts which we have found to be well researched and which auger well for the future of hydroponics. To us the most important of all is research which shows the potential for producing more nutritious food for a malnourished world without losing yield, and to us that is the bottom line.

Grove Haynes　　　　Pearl Yamane

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We wrote this in answer to the request to describe the concept of GRUAT for the 6th Annual Conference of the Hydroponic Society of America. GRUAT is short for GRUATTAWH, GR Urban Agri Tech to Avert World Hunger. GRUATTAWH is our cable address and its purpose is to link us with areas of the world where agriculture is sparse or not adequate to feed the inhabitants. It is supported by profit from Grovering Hydroponics. We offer free to any nonprofit organization, who is feeding the hungry, our services as consultants and our free books in order to help them devise appropriate technology for that purpose. We make available information free on any devices or inventions which would be instrumental in embellishing the yield and nutritional content of their crops. When we realized that the patent process interfers with the free exchange of this vital information, we dropped our own.

We are not committed to any particular products or equipment. In this way we hope to remain objective observers of the clients' needs and growing conditions. We try to examine, without bias, the whole gamut of choices available. We first research out the growing condition the client faces and then choose the appropriate technology for these conditions. It is often necessary to cross breed equipment and create new hybrid systems composed of technology borrowed from outdoor drip irrigation, as well as green-house equipment, etc. We choose whatever does the job most efficiently considering the economics of the situation and the materials indigenous to the area where the crops are to be grown. For instance, harsh growing conditions such as those that exist in the Phillipines where there is difficulty in growing because of the typhoons, monsoons, and high humidity, call for unusual designs. Here we must protect crops with a structure which will keep out fierce insects, withstand 140 MPH winds, and yet allow for ventilation of the hot, moist air. Power sources are unreliable and expensive, making the conventional methods of cooling and ventilation unfeasable.

This is an example which taxes all of the resources of GRUAT. But there are places where conditions are much worse, and the people suffer even more because of those conditions. We see hydroponics as one of the tools to help those unlucky ones.

If we can unfetter the powerful force of this new science, YOU, who have experienced its bounty, know what it can do.

Grove Haynes　　　　Pearl Yamane

Common Insects and Diseases of Greenhouse Vegetables

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Annual Meeting
Concord, California

COMMON INSECTS AND DISEASES OF GREENHOUSE VEGETABLES

by

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"Hydroponic vegetable crops grow faster than field crops because of the nearly perfect environment, they are protected from soil diseases....and insects". This quote is from an article on hydroculture published in Arizona Highways magazine. A more accurate statement would probably say that insects and diseases can grow faster in greenhouses than outdoors because of the nearly perfect environment of warm temperatures and high humidities."

After more than seven years working with greenhouse crops, I would like to go over some of the problems I have seen and discuss possible controls. Diseases first, then insects.

SLIDES

FUNGAL DISEASES

Damping Off (Pythium) - Common on many crops.

Symptoms--rapid wilt of seedlings, "pinched" appearance of seedling at soil line.

Cultural Control - Grow seedlings with adequate warmth, light and water in sterilized media.

Chemical Control - Captan. Experimental use of Ridomil (1/8 ounce a.i. per 100 gallons nutrient solution) has been shown to be effective in NFT systems. (Note: Benlate may intensify pythium problem.)

Greymold ***(Botrytis cinerea)*** - Can effect stem, petiole and fruit of tomato and cucumbers. Infection often occurs at wound sites on plant and on dead tissue. Crowding of plants, excessive humidity (95%) contribute to disease formation and excessive growth caused by over fertilization of nitrogen.

Cultural Control - sporulation completely inhibited below 80% RH, remove spore sources.

Chemical Control - Benlate, Botran on tomatoes.

Powdery Mildew ***(Erysiphe cichoracearum)*** **white color and** ***(Sphaerotheca fuliginia)*** **brown color** - Causes powdery growth on upper surface of cucumber leaves. Tiny black fruiting bodies may develop in older areas of infection. Young leaves are resistant to infection and leaves 16-23 days-old are most susceptible. Fruit is generally not infected directly, but damaged leaves lower yield and quality. Optimum temperatures for mildew spore germination--79^{o}F. Once established, high humidity is not required for continued infection, unlike many other diseases.

Cultural Control - Avoid over crowding, over shading, excessive fertilizer. Since spores actually killed by free water, spray plants with water in morning to prevent germination.

Chemical Control - Nothing California registered. Karathane, Benlate, Funginex and Bayleton have been used experimentally.

Sclerotinia Rot - White Mold ***(Sclerotinia sclerotiorum)*** - This fungal disease attacks the stem and fruit of greenhouse cucumbers, tomatoes and lettuce. Infected parts often covered with white mass and later black sclerotia may form. Disease often starting on dried blossoms resulting in a rot of the blossom-end of the fruit.

Cultural Control - Avoid unnecessary plant crowding, overly vigorous soft growth and excessive humidity.

Chemical Control - Benlate on greenhouse tomatoes.

BACTERAL DISEASE

Angular Leaf Spot (*Pseudomonas lachrymans*) - Distinctly angular, water soaked, brown spots. Shape formed by leaf veins delimiting growth. In humid conditions, may cover entire leaf. Bacteria spread mostly by splashing water and develops rapidly at temperatures between 75-81°F. Pathogen is generally seed-borne originally and persists on infected crop residue.

Cultural Control - Use clean seed, prevent free water from standing on leaves.

Chemical Control - No California registered chemicals. Fixed Copper sprays have been used experimentally.

VIRUS

Cucumber Mosaic Virus - Signs of infection often difficult to define. Leaf symptoms show pattern of alternate dark and light green areas, with shortened internodes. Fruits can also be affected. The typical cucumber mosaic virus is reportedly rarely transmitted if at all with the seed. It is chiefly spread by insects from nearby field crops and weeds.

Cultural Control - Screening of ventilators to exclude aphids and aphid pest control will ordinally prevent disease infection.

COMMON INSECTS AND MITES

Greenhouse Whitefly (*Traileurodes vaporariorum*) - Powdery white insects found on undersurface of leaves where they suck plant sap. The cycle from egg to adult emergence takes approximately four weeks, and the adult white fly can live about three weeks. Heavy infestations also produce significant honeydew which encourages sooty mold fungus on leaves and fruit. A parasitic wasp-- *Encarsia formosa* is available for whitefly control in greenhouses. Optimum temperatures for effective control are around 70-90°F. Many common pesticides are not compatible with *Encarsia* use.

Chemical Control - Registered products include--Malathion, Dibrome and Thiodan (Tomatoes only.)

Leafminer (*Liriomyza* sp.) - Adults are small-black flies with yellow markings. Eggs are laid between layers of leaf. Larvae mine leaf, gradually increasing in size.

Chemical Control - Malathion and Dibrome.

Two-Spotted Spider Mite (*Tetranychus urticae*) - Tiny eight-legged pests that feed on plant sap, usually on the lower leaf surface. Feeding damage characterized by speckling. During heavy infestations, webbing is produced and foliage may dry. Egg-to-adult cycle--10 days. Predatory mites such as *Phytoseiulus persimilis* are commercially available for greenhouse release. Optimum temperature for predator reproduction is 79°F. Temperatures of 86°F. and above reduce effectiveness of *P. persimilis* as mite predators.

Chemical Control - Malathion, Dibrome. Kelthane has been used experimentally.

Straw Mite (*Tyroglyphus*) - This pest is new to California greenhouse vegetables. The mite is creamy-white and smaller than the two-spotted mite. It feeds on leaves while still in shoot tips. The first signs of infestation are small holes in unfolding leaves, later expanding into larger irregular holes. Plants grown in manure, straw and redwood bark are susceptible.

Chemical Control - Dibrome. (Canada also recommends Thiodan.)

SOME CALIFORNIA REGISTERED PESTICIDES FOR SOME GREENHOUSE VEGETABLES
MARCH 1985

This list does not constitute a recommendation. Always refer to the label for specifics of use.

CHEMICAL/FORMULATION	CROP(S)	PESTS	MANUFACTURER
Malathion 57% E.L. Cythion 57% E.L.	Cucumber Endive Lettuce Radishes Tomatoes Watercress	Aphids, armyworms, cabbage looper, cutworm, caterpillars, Drosophila, earwigs, garden fleahoppers, mealybugs, spider mites, thrips, whiteflies, serpentine leafminers	Hopkins American Cyanimid
Dibrom 8 Miscible (Naled)	Tomatoes Cucumber (vapor treatment only)	Tomato fruitworm, hornworm, leafminer, flea beetle, mites, aphid, leafroller, mealybug, whiteflies	FMC Oxychem Ortho
Thiodan 50 W.P. Thiodan 3 E.C. Thiodan 2 C.O. E.C. Thiodan--Pyrenone C.O. E.C. Thiosulfan 2 E.C. (Endosulfan)	Tomato	Various beetles, aphids, cabbage looper, stinkbug tomato fruitworm, tomato russet mite, yellow-striped armyworm, hornworm, whiteflies	FMC Oxychem
Phosdrin 4 E.C. Phosdrin 10.3 W.S.	Lettuce	Aphids, corn earworm, cutworms, Dipterous leafminer, cabbage looper, grasshoppers, mites, lygus bug, saltmarsh caterpillars, false chinch bugs, thrips	Shell
Bacillus Thuringiensis 3.2 W.P.	Cabbage Cucumber Lettuce Tomato	Cabbage looper, hornworms, tomato fruitworm, armyworms	Various
Benlate 50% W.P.	Tomato	Graymold *(Botrytis)*, Leaf mold *(Cladosporium)*, White mold *(Sclerotinia)*, *Cercospora* leaf spot, *Phoma* leaf spot	DuPont

CHEMICAL/FORMULATION	CROP(S)	PESTS	MANUFACTURER
Dithane M22 80% W.P.	Tomato	*Cladosporium* gray mold, early blight, late blight, Septoria leaf spot, gray leaf spot (*Stemphylium*), *Anthracnose*	Rohm and Hass
Botran 6 Dust Botran 6 Kolodust 25 Dust Botran 6 Sulphur 25 Dust	Tomato Leaf Lettuce	*Botrytis* stem canker *Botrytis* rot	FMC
Captan 5 Dust Captan 10 Dust Captan 50 W.P. Captan 80 W.P.	**Various:** Seedlings and transplants	Preplant soil treatment for damping-off and root rot fungi	FMC Stauffer
Dichlorvos (DDVP)	Cucumber Lettuce (aphids)	Aphids, thrips	Summit Chemical Company

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From: Ogawa, U.C. Davis, Plant Path.

Table 1. Common fungal, bacterial and virus diseases of cucumbers

	Relative Economic Importance on:[a]			
Disease (Causal Agent)	Foliage	Blossom and/or Fruit	Stem	Root
Fungal Diseases				
Gray mold (Botrytis cinerea)	++	+++	+++	-
Downy mildew (Pseudoperonospora cubensis)	++	-	-	-
Powdery mildew (Erysiphe cichoracearum and Sphaerotheca fuliginea)	+++	-	-	-
Pythium diseases	-	+	++	++
White mold (Sclerotinia sclerotiorum)	+	++	+	+
Rhizopus stolonifer	-	+	-	-
Bacterial Disease				
Soft Rot (Erwinia carotovora)	+	+	-	-
Viral Disease				
Cucumber Mosaic (Cucumber Mosaic Virus)	++	+	+	-

[a]Importance: +++ Common; ++ occasional; + seldom; and - never or no information available.

From: Ogawa, U.C. Davis, Plant Path.

Table 2. Interactions of the Pathogen, Host, and Environment Produce Disease

Pathogen	Inoculum Source	Infection of Host: Healthy Tissue	Infection of Host: Injured Tissue	Environmental Parameters: Temperature for growth (°C): Optimum	Minimum	Maximum	Free Moisture Requirement
Fungi:							
Botrytis cinerea	Decaying tissues and debris	+	+++	20	0	35	Yes
Pseudoperouospora cubensis	Host	++	-	20	5	>38	Yes
Erysiphe cichoracearum & *Sphaerotheca fuliginea*	Host	++	-	27-28	10	32	No
Pythium spp.	Soil	++	+	25-34	5-10	40-46	Yes
Sclerotinia sclerotiorum	Sclerotia	+	+++	20-25	5	30	Yes
Rhizopus stolonifer	Soil	-	+++	17-27	5	35	Yes
Bacterium:							
Erwinia carotovora	Soil	-	+++	23-32	2	35-37	Yes
Virus:							
Cucumber Mosaic Virus	Perennial Hosts; Transmitted by Aphids	+++	-	Infection occurs at temperatures favorable to plant growth		Thermal Inactivation 70	No

Table 3. Possible disease management programs for crops in general[a]

Pathogen or Cause	Host	Environment
1. Quarantine	1. Clean seed or stock	1. Pathogen-free area
2. Barriers	2. Resistant rootstock	2. Field cultivation
3. Eradication	3. Resistant cultivar	3. Irrigation
a. diseased plants or parts	4. Planting	4. Nutrition & pH
b. vectors	5. Pruning	5. Climate
4. Chemical	6. Crop thinning	a. geographical area
a. protectant	7. Harvesting	b. temperature
b. eradicant	8. Postharvest handling	c. sunlight
5. Therapy	9. Processing procedure	d. humidity
a. heat	10. Rotation and/or fallow	6. Cover crop or sod
b. chemical	11. Induced host resistance	7. Bio-environment
c. aging	a. genetic engineering	a. vectors
6. Biological	b. chemical	b. animals
		c. weeds
		d. mycorrhizal fungi

[a]Developed as a teaching device for the Department of Plant Pathology, University of California, Davis, CA 95616

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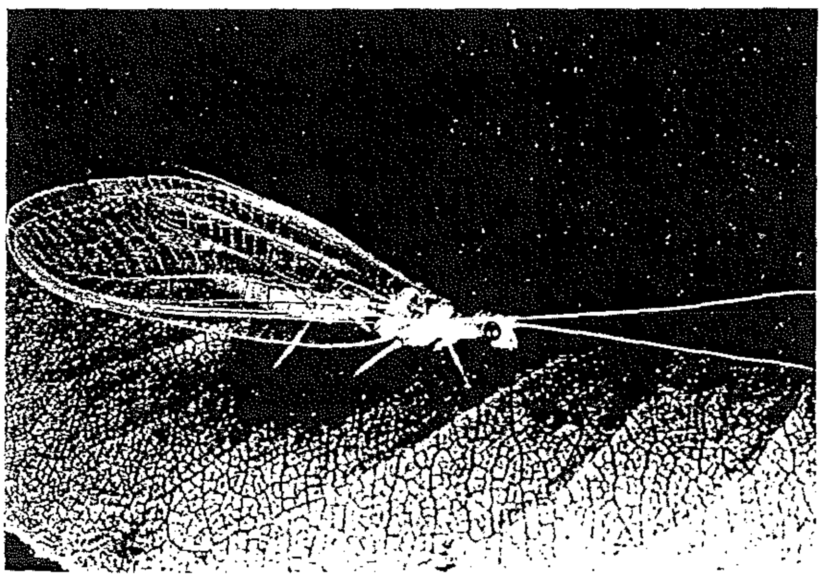
From: Ogawa, U.C. Davis, Plant Path.

Some Commercial Sources of
BIOLOGICAL CONTROL AGENTS
in California

— Predators

— Parasites

Right: Praying mantis: actual size 35mm.
Below left: Green lacewing: actual size 12mm.
Below right: Parasitic wasp laying egg in aphid: actual size 3mm.



Biological control is the use of parasites, predators, and disease-causing organisms to help keep insect pests in check. Naturally occurring agents are continually at work in the environment. In some cases man has intervened in this process by releasing additional numbers of these agents in an attempt to improve the biological control of pests. However, limitations do exist with this type of program. For example, some biological control agents, such as the praying mantis, are general feeders, and are just as likely to capture and consume a beneficial insect as a crop-destroying pest. Others, such as the convergent lady beetle, cannot be expected to remain confined to the locale where they are released. Despite the limitations of some biological control agents, positive results have been obtained and interest in them continues. The purpose of this leaflet is to provide information on some commercial sources of parasites and predators available in California.

Cooperative Extension **University of California**
Division of Agriculture and Natural Resources

7115

Agents

- AA = Predatory midge—*Aphidoletes aphidmyza*
- DM = Predatory mites—*Phytoseiulus persimilis, Metaseiulus occidentalis, Amblyseius californicus, A. hibiscii*
- FN = Parasitic nematodes
- GL = Green Lacewing—*Chrysopa carnea*
- HD = Decollate Snail—*Ruminia decollata*
- LB = Ladybugs (lady beetle)—*Hippodamia convergens*
- MH = Black scale parasite—*Metaphycus helvolus*
- MP = Mealybug destroyer—*Cryptolaemus montrouzieri*
- MR = Fly parasite—*Muscidifurax zaraptor*
- NG = Navel orangeworm parasite—*Goniozus legneri*
- NV = Fly parasite—*Nasonia vitripennis*
- PM = Chinese praying mantis—Egg cases—*Tenodera aridifolia sinensis*
- PV = Fly parasite—*Pachycrepoideus vindemiae*
- RS = Red scale parasite—*Aphytis melinus*
- SE = Fly parasite—*Spalangia endius*
- SP = Fly parasite—*Sphegigaster sp.*
- TP = Tomato pinworm parasite—*Apanteles scutellaris*
- TW = Parasitic wasp—*Trichogramma spp.*
- TZ = Fly parasite—*Tachinaephagus zealandicus*
- WP = Whitefly parasite—*Encarsia formosa*

Below: Lady beetle devouring aphid: actual size 7mm.

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The photographer is Jack Kelly Clark.

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Agents	Sources
HD, MP, RS	Associates Insectary P.O. Box 969 Santa Paula, CA 93060 (805) 933-1301
MR, SE, SP	Beneficial Biosystems 1603-F 63rd Street Emeryville, CA 94608 (415) 655-3928
GL, SE, TW	Beneficial Insects, Ltd. P.O. Box 154 Banta, CA 95304 (209) 835-6158
MR, SE	Beneficial Insectary 245 Oak Run Road Oak Run, CA 96069 (916) 472-3715
DM	Biotactics 7765 Lakeside Drive Riverside, CA 92509 (714) 685-7681 (call after 6 p.m.)
FN	BR Supply Company c/o 815 W. Center Visalia, CA 93291 (209) 732-3422
HD, LB, MH, MP, NV, RS, SE, TW	Foothill Agricultural Research, Inc. 510 W. Chase Drive Corona, CA 91720 (714) 371-0120
DM, GL, HD, LB, MP, RS, TW, WP	Integrated Pest Management 305 Agostino Road San Gabriel, CA 91776 (818) 287-1101
AA, WP	J.C. Wagoner Insectaries Route 2, Box 2410-d Davis, CA 95616
DM, GL, LB, MH, MP, NV, PM, PV, RS, SE, TW, WP	Natural Pest Control 9397 Premier Way Sacramento, CA 95826 (916) 362-2660
FN	The Nematode Farm, Inc. 335 Birch St. Palo Alto, CA 94306 (415) 494-8630
HD (for release in 8 southern California counties only)	Pacific Agricultural Laboratories, Inc. 839 E. Mission Rd. Fallbrook, CA 92028 (619) 728-4695
AA, DM, FN, GL, HD, LB, MH, MP, MR, PM, PV, RS, SE, TW, WP	Peaceful Valley Farm Supply 11173 Peaceful Valley Road Nevada City, CA 95959 (916) 265-3339
DM, HD, GL, LB, MH, MP, MR, NG, RS, SE, TW, TZ, WP	Rincon Vitova Insectaries, Inc. P.O. Box 95 Oak View, CA 93022 (805) 643-5407
MR, SE, SP, TW, TZ	Spalding Laboratories 760 Printz Road Arroyo Grande, CA 93420 (805) 489-5946
LB, PM	Many nurseries and discount stores.