PROCEEDINGS

THIRD ANNUAL CONFERENCE

THEME: PRACTICAL HYDROPONICS

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FORWARD

The Board of Directors in an attempt to find both a broad subject-title, and yet a subject of compelling interest to each individual hydronponicist, have this year chosen, PRACTICAL HYDROPONICS. But if one thinks, talks, or acts anywhere in the field of soil-less culturing, or even any of the many ancillary disciplines that are closely related to hydroponics, it occurs to me that, in no way of this less than practical.

The scientists, the back-yard or apartment growers, the suppliers, the commercial growers--all are here today and will have something to say to one another about "the state of our art" right now. This is because all of our ultimate goals are the same; to learn to grow the members of the plant kingdom under controlled, measureable conditions that produce these members in a superior way, with superior results.

By continuously attacking th problems of hydroponics from every aspect, these problems must eventually yield. This 'will' to manifest the pioneer spirit, in some special area, like hydroponics, is what holds the intense interest of each Society member, or the other grower-suppliers. Their year-in, year-out loyalty to this field will supply the 'shoulders' for those in the future to stand on.

And this year, too: Special thanks to those who have so freely donated of their time and efforts to put this conference together; Vice-President, Dave Peale; Secretary, Gene Brisbin; Treasurer, Mary Downey; and Program Co-ordinator, Joe O'Brien.

Virgil M. Allison
President

PROCEEDINGS OF THE THIRD ANNUAL CONFERENCE

Theme: Practical Hydroponics

TABLE OF CONTENTS

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Plant Nutrition in Hydroponics

Emanuel Epstein
Department of Land, Air and Water Resources
University of California, Davis
Davis, California 95616

The kinds of hydroponics. - There are three reasons for growing plants without soil: pleasure, commercial production, and scientific teaching and research. The first two applications usually go by the term "hydroponics," while the scientists using this method speak of "solution culture." I shall use both terms, as appropriate, and refer to "soilless culture" as a general term, to cover all methods of growing plants in which they acquire nutrients from solutions rather than soil.

The theme of this year's conference is "Practical Hydroponics," which would seem to stress hydroponics for pleasure and profit, but not scientific investigation. My own topic, however, is Plant Nutrition in Hydroponics, which implies research. I trust that by the time I have finished you will agree with me that plant nutritional research using solution culture is most definitely practical. If it were not for such research there would be no hydroponics. Conversely, if it were not for solution culture techniques, the science of plant nutrition could not have reached anything remotely resembling its present advanced stage. Plant nutritional research and soilless plant culture are inextricably connected; neither can develop without the other. Therefore a consideration of plant nutrition including plant nutritional research should indeed be part of a session on practical hydroponics, as the organizers of this conference realized.

<u>The beginnings of plant nutrition</u>. - In the early part of the nineteenth century two French scientists, Theodore de Saussure and Jean-Babtiste Boussingault, were the first to provide good evidence that plants require for their normal development certain mineral elements that their roots absorb from the soil (Epstein, 1972). But soils are complex and their chemical composition cannot be accurately controlled. It was therefore a great advance in the study of plant nutrition when the German botanist, Julius von Sachs, showed in the mid-1800's that plants could be grown with their roots not in soil but in water with certain salts dissolved in it. That was the beginning of hydroponics, and the beginning as well of a new era in plant nutritional research.

Figure 1 shows the set-up used by Sachs to grow plants in solution culture. After germinating the seed in moist, well-rinsed sawdust he inserted the seedling into a perforated cork, which supported the plant, its roots dangling in the solution. Similar experiments were done at about the same time by W. Knop and afterwards by many more investigators. Set-ups very similar to the one shown in Fig. 1 are still used by hobbyists and for instruction and some research. Being small-scale, they do not lend themselves to commercial production. The only flaw in the simple Sachs set-up is that it provides no means for aerating the solution - a feature that all modern systems of soilless culture provide for.

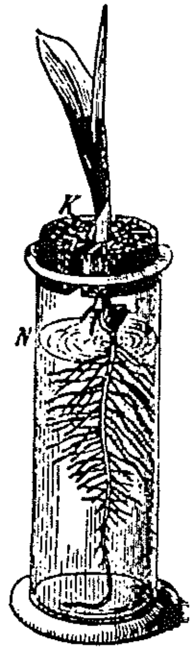

Fig. 1. Solution culture set-up used by Sachs in the middle of the ninteenth century. The roots are immersed in the nutrient solution. From Julius von Sachs, Lectures on the Physiology of Plants, Clarendon Press, Oxford, 1887.

What is it that makes an experiment like this so superior to one in which the roots are in soil? The essential feature is this: the plant nutritionist can make up a nutrient solution in any chemical composition desired, and can then follow changes in its composition with the progress of time. The main reason that its chemical composition will change is the fact that the plant absorbs mineral nutrients from the solution, depleting it. With a soil-grown plant, things are very different. The chemical composition of the soil cannot be accurately controlled, and changes in its chemical composition with time cannot be monitored well.

<u>Essential elements</u>. - The control of the chemical medium to which the roots are exposed in solution culture made possible one of the great success stories of plant nutritional research, very important both for the science of it and for practical hydroponics. That story has to do with the identification of those chemical elements that plant roots have to absorb for the mineral nutrition of the plant. While soil probably contains at least traces of virtually every naturally occurring element in the periodic table of elements, nutrient solutions can be made up to contain certain salts as desired, and elements not wanted can be omitted.

Using this procedure, scientists by the end of the last century had found that plants need at least the following mineral nutrients: nitrogen, phosphorus, sulfur, potassium, calcium, magnesium, and iron. All these mineral nutrients except iron are "macronutrients," that is, nutrients required in fairly large amounts by the plant, while iron is a "micronutrient," required in relatively small amount. In addition it was known that plants acquire carbon from the air, through the process of photosynthesis, and of course the elements of water, hydrogen, and oxygen. Ten elements, then, seven of them mineral nutrients, were known to be essential or indispensable for the growth of plants when the present century began.

It might be thought that this procedure is simple, straightforward, and therefore likely to give definitive information as to what nutrient elements plants require. In principle that is so, but in actuality it is not. I said before that "elements not wanted can be omitted" from nutrient solutions. If, then, element X has been omitted from the nutrient solution but the plant grows well just the same the conclusion would be that element X is not essential for the plant, in other words, is not a nutrient. But that phrase, "elements not wanted can be omitted," is deceptively simple when we are dealing with those elements needed by plants in small amounts only, the micronutrients. Unless sophisticated methods of purification are used, sufficient quantities of such an element may be present as a contaminant in the water used, in the salts furnishing the macronutrients, or may be released from the walls of the vessel or introduced from the air. Even carry-over from the seed may furnish appreciable amounts of micronurients. Therefore a plant may grow well in a solution to which some essential micronutrient X had not been added, leading the investigator to the conclusion that element X is not needed, whereas in reality the plant did in fact need it and obtained it, unbeknownst to the investigator, in the form of an inadvertent contaminant present in the environment of the plant.

At the beginning of the present century, methods for obtaining highly purified water and salts were relatively primitive. It is now clear that the nutrient solutions used at that time did indeed contain appreciable quantities of micronutrients that the investigators did not know about. As purification methods improved dramatically in the early decades of the present century it became possible to exclude elements from the solution cultures that previously had been present as contaminants. As a result, from early in the century till 1954, six more micronutrient elements were discovered. They are manganese, zinc, copper, boron, chlorine, and molybdenum. That brings the total number of mineral nutrients now known to be generally essential for higher green plants to 13. With the addition of the non-minerals carbon, hydrogen, and oxygen, that makes a total of 16 nutrient elements.

Table 1 shows this list of elements, and some indication of th quantities of them that plants need. These quantitative aspects var much among different plants, and among plants in different environ ments, so that the numbers given in that table are approximate only

In this table, the elements are arranged in order of increasin quantities as normally needed by plants. Several features stand out (a) The non-mineral elements, oxygen, carbon, and hydrogen, account fo by far the greatest percentage of plant dry matter. That is becaus cellulose, the main structural material of plants, consists of the three elements. (b) Among the mineral nutrients the differences in t amounts needed is huge; for each atom of molybdenum required there h to be about one million of nitrogen. (c) The actual concentrations some of the micronutrients that need to be present are very low, on order of some parts per million and for molybdenum, only a fractio one part per million.

It is for this latter reason that the discovery of essentiality of most of the micronutrients required the developme highly sophisticated physical and chemical procedures for purgi water, the macronutrient salts, and the containers used of very amounts of impurities. It does not take much contaminatior nutrient solution to supply a plant growing in it with the mol it needs, even if the experimenter is convinced that he did any!

It follows that we cannot be sure that the list of essenti nutrients given in Table 1 is complete. The last element to

... chlorine; its essentiality was discovered in

Table 1[1/]

Concentrations of Nutrient Elements in Plant Materials at

Levels Considered Adequate

Element	Chemical Symbol	Concentration in dry plant matter (parts per million for micronutrients, % for macronutrients)	Relative number of atoms with respect to molybdenum
		ppm	
Molybdenum	Mo	0.1	1
Copper	Cu	6	100
Zinc	Zn	20	300
Manganese	Mn	50	1,000
Iron	Fe	100	2,000
Boron	B	20	2,000
Chlorine	Cl	100	3,000
		%	
Sulfur	S	0.1	30,000
Phosphorus	P	0.2	60,000
Magnesium	Mg	0.2	80,000
Calcium	Ca	0.5	125,000
Potassium	K	1.0	250,000
Nitrogen	N	1.5	1,000,000
Oxygen	O	45	30,000,000
Carbon	C	45	40,000,000
Hydrogen	H	6	60,000,000

[1/] Modified after Epstein (1972).

setting up highly purified solution cultures have been greatly improved, but they have not been applied systematically to discover additional plant micronutrients. If such attempts were made, using the latest techniques, it is possible that elements not now recognized as essential would join the list of plant micronutrients. Recent advances in our knowledge of the mineral nutrition of animals makes that likely.

Animals including humans rely for most of their mineral nutrient needs on plants, directly by eating plants, or indirectly by eating animals which in turn ate plants. We should therefore consider the mineral requirements of animals. Specifically, we should ask whether the list of essential or nutrient mineral elements is the same for plants and animals. The answer is no. One plant micronutrient, boron, is not known to be needed by animals. On the other hand, animals require a number of minerals that have not been shown to be essential for plants. With one exception, these additional elements are all micronutrients, or, as the animal nutritionists say, "trace elements." Sodium is a mineral element required by animals in fairly large amounts. The micronutrients or trace elements that have been found essential for animals but not for plants are iodine, cobalt, selenium, chromium, nickel, vanadium, silicon, arsenic, and fluorine. With the exception of iodine and cobalt, these micronutrients have been found to be essential in research conducted during the last three decades (Mertz, 1981). This is the very period during which plant nutritional research on essential elements has not been active. The success of the animal nutritionists in discovering new trace elements was due to the application of the latest techniques for eliminating trace element contaminants from the animals' diets and maintenance of super-clean environments.

There are, then, ten mineral elements that animals require but that are not known to be needed by plants. In addition, there is a quantitative difference in respect to chlorine. It is a nutrient for both plants and animals, but for plants the requirement is small, making chlorine a micronutrient for them, while for animals chlorine is needed in fairly large amounts. Table 2 is a summary of the mineral elements known to be nutrients for plants and animals. Chlorine is listed twice, as a micronutrient for plants and a macronutrient for animals.

Consideration of this table leads to an interesting question for plant nutritionists and operators of hydroponic installations. The question has to do with the discrepancy in the mineral requirements of plants and animals. Sodium is needed by animals and humans but not, so far as we know, by crop plants. Chlorine is needed by animals and humans in much greater quantities than plants require. And finally, the animals need nine micronutrients that are not known to be nutrients for plants.

This discrepancy seldom poses a problem when crops are grown in soil. Soils contain all these elements, and plants normally absorb them even if they do not require them for their own growth. The animal consumer of the plant therefore obtains these elements. But hydroponic solutions are made up to supply only the mineral elements that we know to be needed by the crops. We therefore face the question whether hydroponically grown plants contain the animal and human trace elements which hydroponics operators do not deliberately include in their formulations.

The answer is that even hydroponically grown plants will contain trace elements needed by animals. The nutrient salts used for

Table 2

Mineral Nutrients of Plants and Animals

	Macronutrients	Micronutrients
Plants and animals	Nitrogen Phosphorus Sulfur Potassium Calcium Magnesium	Chlorine* Iron Manganese Zinc Copper Molybdenum
Plants		Boron
Animals	Sodium Chlorine*	Iodine Cobalt Selenium Chromium Nickel Vanadium Silicon Arsenic Fluorine

*See text.

hydroponics are not the extremely pure salts of the chemical laboratory but technical or fertilizer grade, so that they contain appreciable amounts of many elements as contaminants. The water of hydroponic installations is not the ultra-pure water used in research but tap water, which also supplies miscellaneous elements including some of these micronutrients. In most hydroponics installations the roots are not immersed in the nutrient solution, as in Sachs' experiment (Fig. 1) and in scientific set-ups ever since, but instead grow in sand or gravel or sawmill waste - all materials which will supply assorted micronutrients to the plants. Finally, few if any people are vegetarians living exclusively on hydroponic produce. For all these reasons there needs to be little concern that crops grown hydroponically will lack micronutrients required by man and beast, and that diets will be deficient in these elements.

Deficiencies. - Turning now to possible mineral deficiencies not in animals and humans but in the crops themselves we must focus on those mineral elements that we know to be required by the plants. Any crops, whether grown in soil or soilless culture, may suffer from some mineral nutritional deficiency if a particular nutrient is present in the soil or in the nutrient solution at too low a concentration, or in a chemical form that makes it poorly available for absorption by the roots.

The risk of such mineral deficiency disorders occurring is greater in conventional agriculture, with plants in soil, than in hydroponic culture. Many soils are deficient in this or that nutrient element. Furthermore, the chemistry of many soils is such as to make certain elements poorly available to plants. For example, a high pH, common in many Western soils, tends to cause iron to be precipitated in forms from which plant roots cannot easily absorb it. That condition tends to cause iron deficiency or chlorosis in plants. In many well leached, acid soils, on the other hand, such as we have in the East and especially the South, phosphorus gets tied up by the solid material of the soil in ways that render it relatively unavailable to crops. These and still other soil factors making for mineral deficiencies in crops are not always easy to correct; often, they are very difficult indeed to cope with.

In hydroponic culture the operator is in control of the nutrient supply and of the pH. As a result, nutrient deficiencies are not as common as in soil culture, and more easily and more quickly corrected when they do occur.

With the complications due to soil eliminated, why should nutrient deficiencies ever show up in hydroponics? The causes are basically the same as those that are responsible for deficiencies in soil culture: the concentration of the nutrient may be too low, or it may be precipitated as a solid that makes it unavailable to the roots.

The concentrations that are too low can result from inadequate additions of the nutrient in the first place, from inadequate replenishment as the plants grow, and from too slow a flow of the nutrient solution or too infrequent pumping of it through the system. Any one of those factors can result in the roots being exposed to such low concentrations of a given nutrient that they cannot absorb it fast enough to supply the growing plants adequately.

The other condition that can cause deficiencies is precipitation of the nutrients as a solid. That can happen with iron and phosphorus, for example, if the pH of the nutrient solution is permitted to get too high.

What all this means is that the hydroponic grower needs to monitor nutrient concentrations and pH rather carefully and consistently. Soils are somewhat self-adjusting systems, slow to change. But hydroponic solutions can get out of kilter very quickly unless the grower is on top of the situation at all times.

Despite all precautions, deficiencies of nutrients will occasionally occur. The most obvious way in which they manifest themselves is by the development of more or less characteristic symptoms. They are useful because if identified early, the deficiency can be promptly attended to by a suitable addition of that nutrient. At the same time, deficiency symptoms need to be interpreted carefully. A given deficiency, say zinc deficiency, may cause certain symptoms in one crop but quite different ones in another. On the other hand, deficiency symptoms of some elements, for example iron and nitrogen, may look so much alike as to make it difficult to decide which element is deficient. Also, there may be simultaneous deficiencies of two or more nutrients, causing the plant to suffer a setback but without giving the grower any clear clue as to the cause of the plant's distress.

These precautions should be kept in mind when reading and using the following descriptions of mineral nutrient deficiency symptoms modified from Epstein (1972).

Nitrogen. Excepting only drought, no other deficiency is as dramatic in its effects as is nitrogen deficiency. General chlorosis or yellowing and an etiolated or "leggy" habit are the most characteristic symptoms. Growth is retarded and slow, and the plants have an unthrifty, spindly appearance. Fruit is often exceptionally well colored. The more mature parts of the plant are first affected because nitrogen is translocated from older to young, actively growing regions.

Sulfur. Sulfur deficiency symptoms resemble those of nitrogen deficiency. Plants are chlorotic, spindly, and grow poorly.

Phosphorus. Dark green or blue-green foliage is one of the first symptoms of phosphorus deficiency in many species. Often red, purple, or brown pigments develop in the leaves, especially along the veins. Growth is reduced and under conditions of severe deficiency the plants become stunted.

Potassium. Potassium deficiency in many species causes leaves to be dark green or blue-green, as in phosphorus deficiency. Necrotic (dead or dying) spots often develop on the leaves. There may also be marginal necrosis or leaf scorch. Growth is subnormal and under severe conditions buds may die ("dieback").

Calcium. Symptoms of calcium deficiency appear earliest and most severely in young, growing regions and young leaves. Calcium requirements seem to be high in such tissues, and calcium contained in older, mature tissues tends to become immobilized there and is not appreciably moved out to the young, actively growing regions. Growing points are damaged or die ("dieback"); in flowers and developing fruit the symptoms are known as "blossom-end rot." The growth of roots is severely affected. The damaged roots become prone to infection by bacteria and fungi.

Magnesium. Unlike calcium, magnesium is readily mobilized from mature to young, actively growing regions of the plant. As a result it is in mature leaves that deficiency symptoms first make their appearance. Marginal chlorosis is common, often accompanied by development of a variety of pigments. Chlorosis may also begin in patches or blotches which later merge and spread to the leaf margins and tips. The variety of symptoms in different species is so great that a generalized description of magnesium deficiency symptoms is even more difficult than it is for those of other deficiencies.

Iron. A general chlorosis of young leaves is the most telling symptom of iron deficiency. At first the veins may remain green, but in most species in which the deficiency has been observed the veins also become chlorotic eventually.

Manganese. The symptoms of manganese deficiency vary greatly from one crop to the next. Leaves often show an interveinal chlorosis, the veins making a green pattern on a yellow background, much as in early stages of iron deficiency. There may be necrotic spots or streaks on leaves. Leaves of some species become malformed. In severe cases, plants are badly stunted.

Zinc. "Little leaf" and "rosette" are the classical symptoms of zinc deficiency in the tomato and some other crops. Both result from failure of tissues to grow normally. Failure of leaves to expand causes little leaf, and failure of stems to elongate causes leaves to be so closely telescoped as to give rise to the rosette symptom. In some species leaves become chlorotic, but in others leaves may be dark green or blue-green. Leaves may become twisted and necrotic. Flowering and fruiting are much reduced under conditions of severe zinc deficiency, and the entire plant may be stunted and misshapen.

Copper. Symptoms vary greatly depending on the species. Leaves may be chlorotic or deep blue-green with margins rolled up. Young shoots often die back, whereupon new shoots emerge from multiple buds further back, making for a bushy appearance. Flowering and fruiting are curtailed; annual plants may fail to develop and may die in the seedling stage.

Chlorine. Unlike all the other nutrients, whether needed in small amounts or large, chlorine is never deficient in agricultural crops. The reason for that is that the atmosphere contains salt, mainly sodium chloride, from the oceans. Storms over the sea whip salt spray into the air, and this "cyclic salt" circles the globe and eventually is brought down by rain. Soil and water therefore contain chlorine - enough to supply plants. As a result, chlorine deficiency symptoms have only been observed in solution culture set-ups purified to a high degree, and in only a few crops. In the tomato, the symptoms of chlorine deficiency are, at first, a blue-green and shiny appearance of young leaves. In the heat of the day the tips of the young leaves wilt and dangle down, though they may recover at night or on cool, cloudy days. As the deficiency progresses a characteristic "bronzing" shows up on the leaves, followed by chlorosis and necrosis. Under severe deficiency conditions plants are spindly and stunted. Wilting, discoloration (bronzing), and necrosis are also observed in other crops. However, as already mentioned, chlorine deficiency is not likely to be encountered in crop production.

Boron. Growing tips often are damaged by boron deficiency and may be killed. Tissues of plants with this deficiency appear hard, dry, and brittle. Leaves may become distorted and stems rough and cracked,

<u>Plant nutrition in soils and hydroponics</u>. - The management of the mineral nutrition of crops differs a good deal depending on whether the plants are grown in soil or hydroponically. Some of these differences have been mentioned above; there are still others. The question I want to raise in this final section of my presentation is this: apart from practical aspects of management, are there in these two systems really basic differences in the processes that the plant performs in acquiring and using mineral nutrients? At the level of the fundamental physiology of the plant, does its mineral nutrition in hydroponics differ from that in soil?

As a first approximation, the answer to that question is no. What does a good soil contribute to the nutrition of the plant? It contributes water and mineral nutrients to the roots. And water and mineral nutrients are what a hydroponics system contributes to the roots. In these fundamentals, there is no difference between the two systems. In that respect, both a good, well managed field or greenhouse with soil beds and a competently run hydroponics set-up will provide excellent conditions for the mineral nutrition of the crops.

But beyond that first approximation there are indeed some differences between the two systems worth considering. They are not necessarily in the nature of advantages or disadvantages. I shall discuss what to me seem the most important differences in plant nutrition between the two types of crop culture.

1. Roots in soil absorb nutrients mainly from the water in the soil, the soil solution. That solution is usually dilute; the concentrations of nutrients in it are most conveniently expressed in parts per million. As the roots withdraw nutrients from this

solution nutrients are released into it from the solid phase of the soil, especially clay materials, so that the plant has a continual supply of the nutrients. But at any one time, nutrient concentrations in the soil solution tend to be low. Roots often proliferate widely through the volume of soil that is available to them, and have to pump the nutrients into their cells from the dilute solution that they encounter. All this takes metabolic energy.

Hydroponic solutions are more concentrated than soil solutions and are circulated past the roots. The roots do not have to extend themselves so widely as in soil, and do not have to extract mineral nutrients from a very dilute solution. This means that the plants need to expend less energy to acquire nutrients than do soil-grown plants. That energy can go instead into the growth of more plant material and yield.

2. The solid matter of soils, especially clayey ones, represents a dense material that the roots have to push through as they grow in the soil. In so doing they expend metabolic energy, just as any gardner does who pushes a shovel through the soil. The energy expended by the plant in this physical work of tunneling through the soil is not available for the growth of the top including the tomatoes or cucumbers or whatever the plant produces.

All the metabolic energy the plant has comes from the process photosynthesis carried on in the leaves with the energy sunlight. That energy is stored in the form of starch and sugar. A soil-grown plant must expend a portion of that stored energy growing an extensive root system, for pumping nutrients into root cells from a dilute solution, and for physically driving root tips through dense soil material. Metabolic energy used in these activities is not available for the production of commercially valuable yield. Plants in hydroponic systems do not have to expend energy for these operations, leaving more available for production. In that sense, hydroponics is more efficient than soil culture.

3. Soil-grown roots are often - some say almost universally - associated with fungi. The roots and the fungal microorganism form a symbiotic system. That combined system of roots and fungi is called mycorrhizae, or fungus-roots. It is more efficient in absorbing nutrients present at low concentrations, especially phosphate, than roots unaided by such fungi.

   Hydroponically grown roots seldom if ever are mycorrhizal. Thus they lack this means of making for efficient absorption of scarce nutrients. But in a well managed hydroponics system nutrients are not scarce, making the collaboration of fungi unnecessary. In terms of the expenditure of metabolic energy the hydroponic, non-mycorrhizal plant has an advantage, because supporting the fungus requires energy.

4. Soil-grown plants acquire at least part of their nitrogen from nitrogen-fixing microorganisms. They are either free living in the soil or, like the fungi discussed above, associated symbiotically with the roots of plants, especially legumes. These microorganisms have the unique ability of fixing the nitrogen gas of the atmosphere in forms that plants can use.

Hydroponic plants lack this biological mechanism of getting nitrogen from the air transformed into forms available for absorption. All their nitrogen has to come out of the nutrient solution made up by the grower to contain nitrogen salts that plants can take up - nitrate or ammonium, or both.

There are, then, some significant differences in the mineral nutrition of soil-grown and hydroponic plants. Energy-wise, the advantage seems to lie with hydroponics. But remember that "there is no such thing as a free lunch." The plants may require less energy for their mineral nutrition in hydroponics, but the system as a whole does not require less. The difference in the energy budget is made up by industrial means: building and maintaining the installation itself, making and transporting and supplying all the nutrients, pumping them through the system - all that takes energy. In ordinary agriculture, Mother Nature - the soil and the sun - supply much of the materials and the energy that in hydroponics are supplied through industrial means. That is why in hydroponics, more of the photosynthetically generated metabolic energy of the plant itself may be channeled into the production of yield.

<u>Summing up</u>. - Hydroponics, like conventional soil culture, is a means for supplying crops with water and mineral nutrients. While the known list of plant nutrients is not necessarily complete, hydroponic installations are likely to furnish all the plants' mineral requirements, either because they are deliberately included in the nutrient solution or because they are present as impurities in the water and salts used, and in any solid material provided to support the roots.

Micronutrients required by man and beast but not by plants are not deliberately added to hydroponic salt mixes but the impurities referred to above are likely to supply appreciable quantities of these elements, also.

Like soil-grown crops, hydroponically raised plants can suffer from deficiencies and excesses of mineral elements. Changes in these conditions can occur much more rapidly in hydroponics than in soil culture, soils being self-adjusting systems that are slow to change. On the other hand, correction of such conditions is accomplished more easily and quickly in hydroponics.

While fundamentally soil culture and hydroponics perform the same function for crops - the supply of water and mineral nutrients - some differences exist in the mineral nutrition of plants grown under these conditions. Because soil solutions are dilute, roots have to proliferate farther and pump nutrients into their cells more energetically than is the case in the more concentrated hydroponic nutrient solutions. The need of roots to push through the solid mass of the soil is elminated in hydroponics. These differences represent a saving of metabolic energy by the hydroponic plant - energy that may instead be diverted to the production of usable produce. Hydroponically grown plants do not have the advantage of soil-grown ones that comes from association with microorganisms "collaborating" with the plants in their mineral nutrition. But neither do hydroponic plants use any of their metabolic energy to support such microorganisms. The savings of metabolic energy in the mineral nutrition of hydroponically grown plants are made possible by the expenditure of the industrial energy needed for the construction of the hydroponic installations, for the manufacture and transport of fertilizer salts, and for the pumping of nutrient solutions.

Acknowledgment

I thank J. D. Norlyn for comments.

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HYDROPONIC TECHNIQUES, METHODS AND PRINCIPLES: RESEARCH NEEDS IN HYDROPONICS

J. Benton Jones, Jr.[1]

INTRODUCTION

It is hard to realize at times that hydroponics, that is the growing of plants in a nutrient solution, has been practised for many thousands of years. It is only recently that hydroponics has been commericallized as a possible technique for the economic production of plants. Hydroponics has proven to be a valuable system for studies on the nutrient element nutrition of plants, with many of the techniques devised in the mid and late 1800s for such studies still in use today. It has only been the commerical application of these techniques of nutrient solution culture that have been found difficult to manage. There are some who believe that hydroponics will eventually become a major technique for plant production, particularly in those situations where soil resources are limited and for the high cash crops, such as winter vegetables grown in some type of enclosure. Today, one can point to the hydroponic systems in operation in the Middle East, northern Africa, western Europe, England and in some parts of the United States as indicators of the interest in growing plants hydroponically.

If interest were to be measured by the number of books written about hydroponics in recent years, then one would assume that hydroponics is indeed a major system of wide acceptance and use. Certianly, the establishment of the HYDROPONIC SOCIETY OF AMERICA could be memtioned as another sign of intense interest. In deed the interest in hydroponics is here, the question to be asked and possibly answered in this paper, is whether this interest is justified in terms of potential and real commerical value for hydroponic growing. If one were to obtain all his informtion from the current books on the subject, one would obtain a very glowing evaluation about hydroponics. Most, if not all the books on the subject, write little about the problems inherent in the technique, or offer little to the reader about what one might do to minimize the potential hazards associated with some of the hydroponic systems. For example, if I were to limit only my evaluation of hydroponc growing based on the experience that Georgia growers have had in the last 10 to 15 years, then I would say that hydroponic growing is a failure since the vast majority, and in fact all hydroponic growers in Georgia have failed with their hydroponic businesses.

It is easy to condemn a system of growing as has been done in the State of Georgia for hydroponics where potential growers are given considerable warning and advice not to attempt hydroponics. Although hydroponics is not a system of growing for everyone or for every growing circumstance, there are applications and places where its use can be highly profitable, and in some instances, the only way to grow plants.

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1. Professor, Department of Horticulture, University of Georgia, Athens, Georgia 30602

It may be well to stop and define some terms so that we all understand what is going to be discussed. Like most technical systems, the jargon used to describe hydroponic systems is loosely applied. Dr. John Larsen of the Texas Agricultural Extension Service offers this classification of soilless culture terms:

SOILLESS CULTURE

Hydroponics or Water Culture	Media Culture		
	Organic	Inorganic	Mixtures
1. NFT (Nutrient Film Technique)	1. Peat moss	1. Gravel	1. Peat-vermiculite
2. Aeroponics (misting roots)	2. Pine bark	2. Hadite	2. Pine bark-vermiculi
	3. Rice hulls	3. Lava Rock	3. etc.
3.Continually aerated nutrient solution	4. etc.	4. Vermiculite	
		5. etc.	

In this classification system, hydroponics becomes one form of soilless growing athough all growing systems are essentially "hydroponic" in nature since plants can only obtain their required nutrient elements from solution, whether this nutrient element containing solution exists as a mist, in a culture solution vessel, in a peat-lite mix or even in soil. Therefore, using Dr. Larsen's system of classification, hydroponics would be restricted to those systems which essentially do not use a root supporting system.

Inorder to put some order into this presentation, I would like to follow Dr. Larsen's classification scheme and discuss the various types of soilless growing systems based on the nature of the root supporting media. The two broad catagories will be "Hydroponics or Water Culture" and "Media Culture."

CULTURE MEDIA GROWING

1. Organic and Mixtures

One does not normally relate growing of plants in some organic substance, such as sphagnum peatmoss or pine bark either alone or in mixtures with vermiculite or perlite, as hydroponics. But, in deed it is. These substances provide little in the way of the essential nutrient elements which must therefore be added in some form. Such mixes are widely used for the production of bedding plants, and the pot culture of flowering and woody ornamentals. More recently, the long-term production of winter vegetables in the greenhouse is being done in bags containing an organic mix with water and nutrient elements being dripped into the bag on a carefully controlled schedule.

The composition of most organic soilless mixes is essentially modifications of that proposed by researchers at Cornell University and the University of California, and are frequently referred to as "peat-lite mixes" and the "U.C. mixes," respectively. Formulae for these mixes and others are given in Table 1. Fertilizer supplementation will vary depending on use for the mix. For long-term use, additional nutrient element supplementation may be required and recommendations are usually based on the crop and system design with the recommended fertilizer being added to the irrigation water.

Table 1. INGREDIENTS TO MAKE ONE CUBIC YARD OF SOILLESS MIX

	Type of Mix					
Ingredient	Cornell Peat-Lite*	U.C. Mix #D*	U.C. Mix #E*	Canada Mix Seedling*	NJ Tomato Greenhouse	Georgia Greenhouse Tomato
Sphagnum peatmoss	11 bu.	16.5 bu.	22 bu.	12 bu.	9 bu.	--
Milled pinebark	--	--	--	--	--	9 bu.
Vermiculite	11 bu.	--	--	10 bu	9 bu.	9 bu.
Perlite	--	--	--	--	4 bu	--
Sand	--	5.5 bu.	--	--	--	--
Limestone	5 lbs.	9 lbs.	7.5 lbs.	4 lbs.	8 lbs.	10 lbs.
Superphosphate (0-20-0)	2 lbs.	2 lbs.	1 lb.	1 lb.	2 lbs.	--
5-10-5 fertilizer	6 lbs.	--	--	--	--	--
10-10-10 fertilizer	--	--	--	2lbs.	--	10 lbs.
Potassium nitrate	--	--	0.3 lb.	0.5 lb.	--	--
Calcium nitrate	--	--	--	--	1 lb.	--
Magnesium sulfate	--	--	--	--	--	3 lbs.
Calcium sulfate	--	--	--	--	--	5 lbs.
Borax	10 gms.	--	--	1 gm.	10 gms.	--
Chelated Iron	25 gms.	--	--	--	35 gms.	--

* These mixes are mainly for short-term growth, while the other mixes are for long-term greenhouse tomato.

A sub-irrigation system using pine bark as the culture medium has been successfully used for the production of winter tomatoes and cucumbers, as well as other vegetables in both greenhouse and outdoor culture. Seven inches of pine bark is placed over an inch of gravel in a water tight box-like container. An inch and a half of water is maintained in the bottom of the box. The essential elements are added to the pine bark and supplemental additions made from over head when needed. The system is self-sustaining, requiring little attention by the grower. A design of the box container and automatic watering system is shown in Figure 1.

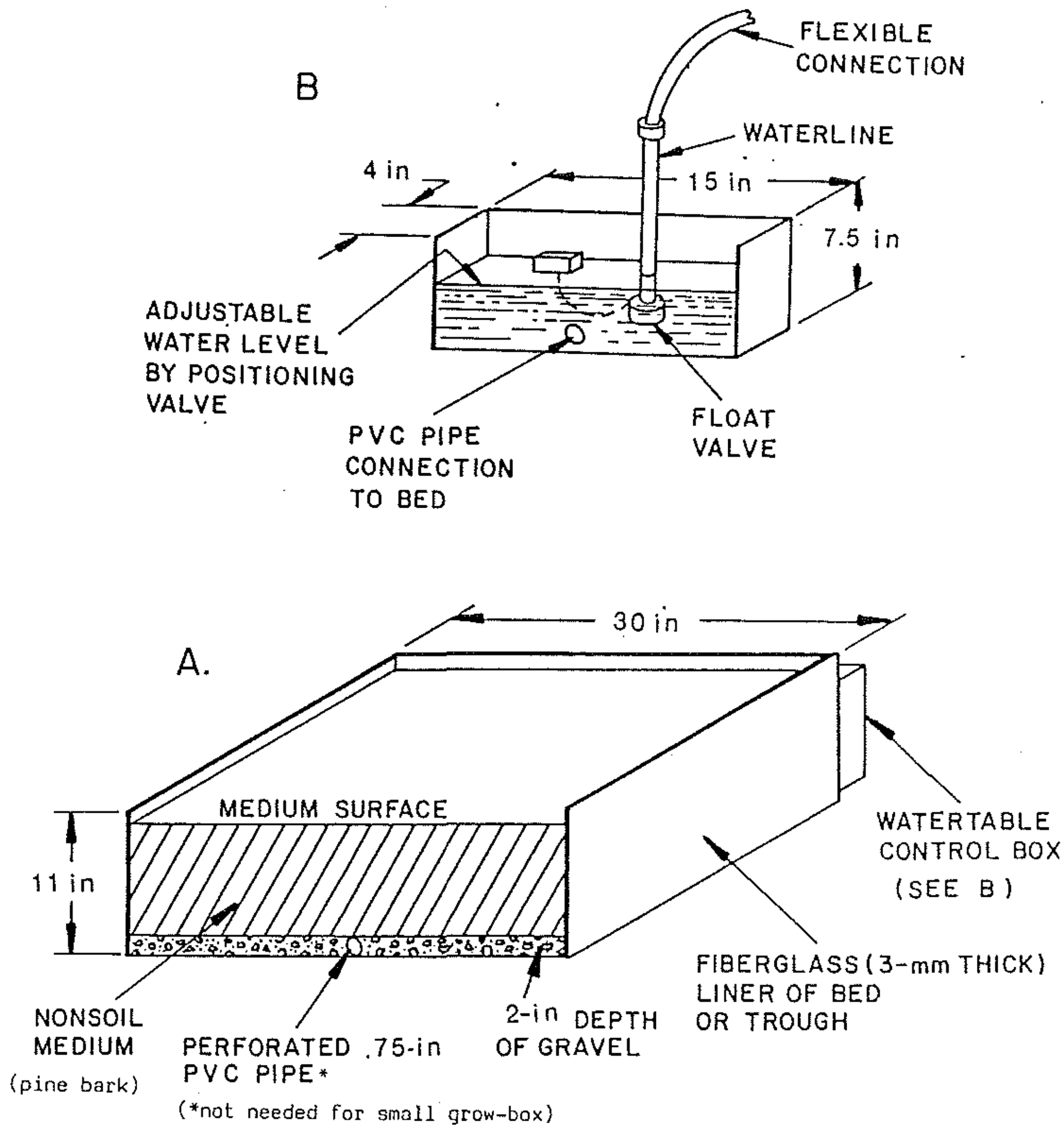


Figure 1

TYPICAL DESIGN FOR A PINE BARK GROW-BOX

(This design was used successfully in a greenhouse tomato system. Size in width and length is not as important as depth. Watering system shown here is automatic but it may be done by hand)

Soilless systems of growing employing some organic substrate as the rooting medium are in wide use and will continue to be so. Bag and container growing, as well as more sophisticated systems such as Skaife's Pipe Dream, will continue to be explored and developed. For these systems additional research is needed to determine ideal container size, and what, effect media characteristics and size distribution, and nutrient element composition and balance will have on plant growth and development. Their acceptance and wide use today are primarily being determined by cost and ease of management. However, this may change as sphagnum peatmoss and pine bark, the most frequently used soilless mix substrates, become less available and more costly.

2. Inorganic Media

The more commonly practiced systems of hydroponic growing have been in the gravel and sand beds with the nutrient solution being periodically pumped from a storage tank into the growing bed. The nutrient solution is then allowed to return to the storage tank to be recirculated later according to a predetermined schedule, frequently referred to as the "feeding cycle." A typical system of this type is shown in Figure 2. Other substances have been used in place of gravel or sand as given in Dr. Larsen's classification system shown earlier in this paper.

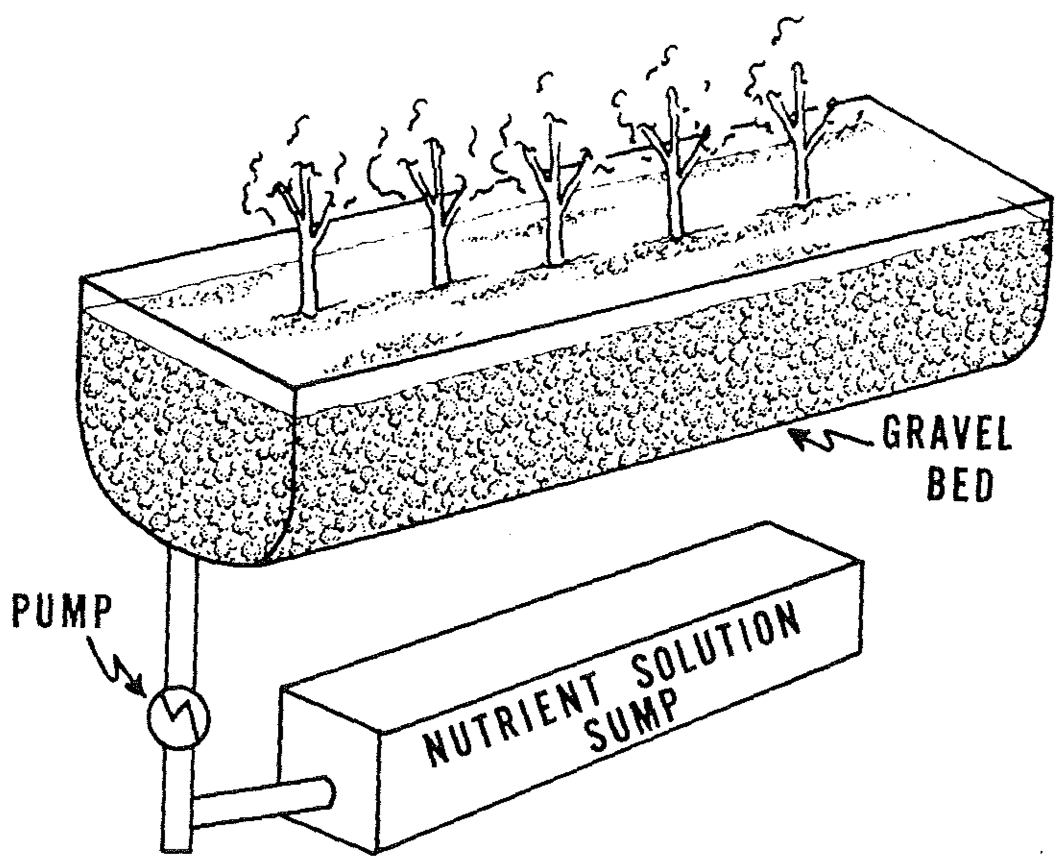


Figure 2. A TYPICAL DESIGN FOR THE GRAVEL-SUMP HYDROPONIC SYSTEM

These inorganic media systems suffer from several serious problems, frequently related to their size and the need for a large nutrient solution storage tank and intricate system of piping and nutrient solution flow. Nutrient solution management becomes difficult and costly at times when sizeable quantities of nutrient solution must be replenished. The common procedure is to dump the spent solution and reconstitute, meaning the loss of sizeable quantities of water and unused nutrients. Unused nutrient elements will be left behind in the gravel growing bed as either precipitates, adsorbed or even absorbed on or in the inorganic support media. These accumulating deposits may begin to significantly alter the composition of replenished nutrient solution and thereby adversely affect plant growth.

Probably one of the most troubling aspects of these systems is disease control. Once an organism enters the system, it is almost impossible to eradicate without completely dismantling the entire system and carefully sterilizing. It has been my personal observation that initial crops in inorganic media systems can be quite good, but succeeding crops are progressively poorer. This seems to be due to a number of factors, such as the accumulation of nutrient elements, remaining residues from previous crops and the steady increase in organisms in the rooting media, all contributing to the steady decline of following crop performance. In some instances it is difficult to specifically identify the exact cause for declining production frequently associated with most inorganic media hydroponic systems.

I believe that it is safe to say that any hydroponic system employing an inorganic media is doomed to failure, or maybe better said, characterized by declining production and disappointing performance, unless the system can be thoroughly cleaned between crops.

HYDROPONICS OR WATER CULTURE

1. Culture Systems

Referring the Dr. Larsen's classification system once more, he gives three examples of hydroponics or water culture growing, NFT - Nutrient Film Technique, Aeroponics and Continually Aerated Nutrient Solution. The last system is widely used by plant physiologists as a technique for growing plants were exacting control of the growing media is required. Most of the essential plant nutrient elements have been established using similar techniques. This system is shown in Figure 3. The plant is suspended in an aerated nutrient solution whose composition can be altered at most any time. However, this hydroponic technique is not suited for large commerical systems.

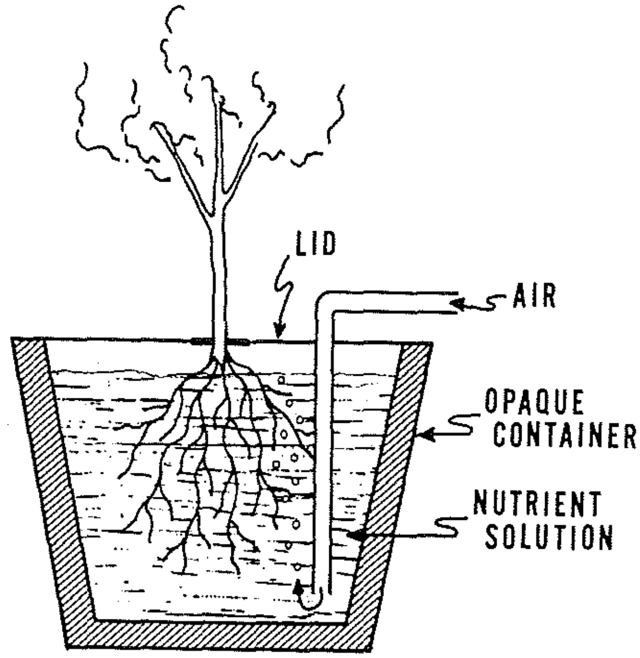
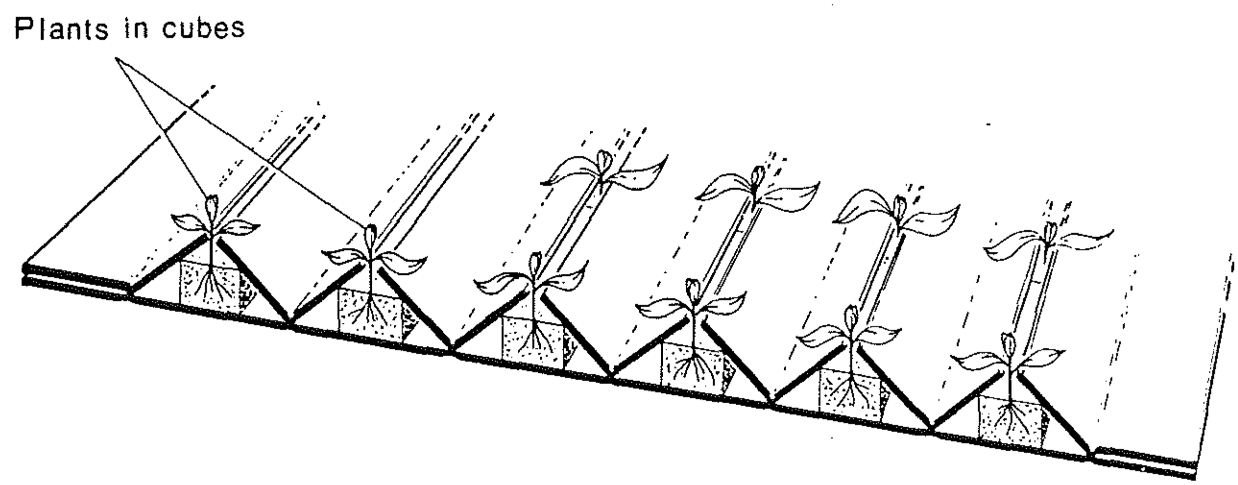


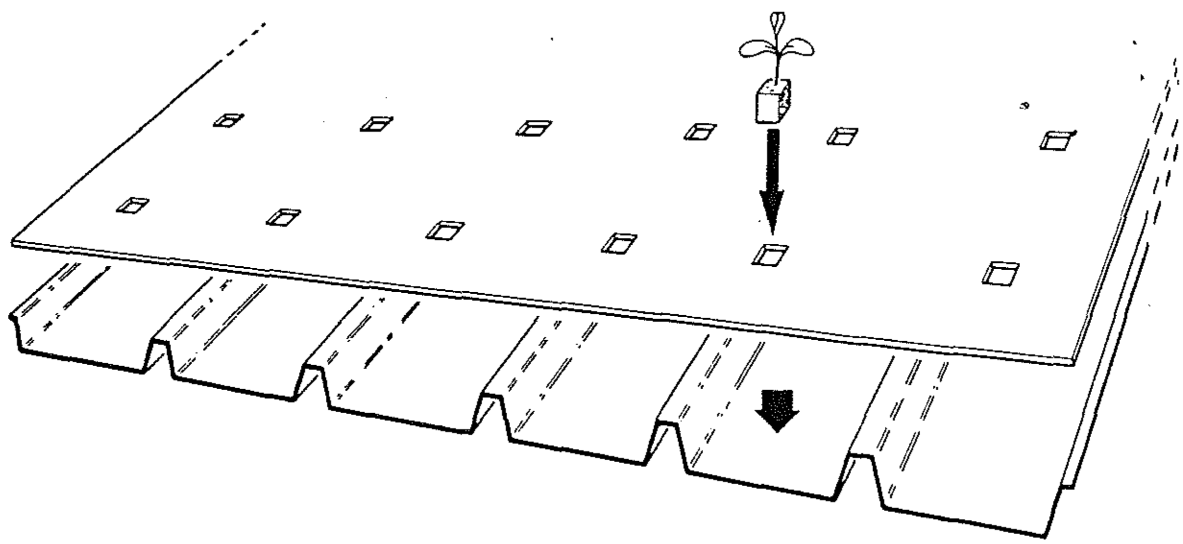
Figure 3. AERATED WATER CULTURE SOLUTION HYDROPONIC SYSTEM

There has been a modification of this technique by having the nutrient solution flowing and the essential nutrient elements added with each pass of the solution through the rooting containers. Those who have proposed this system feel that plant growth is better and the results obtained more typical than if the nutrient solution is allowed to remain in place. Such a system also allows the researcher to monitor the kinetics of nutrient element uptake. Much has been discovered about plant nutrient element nutrition through the use of this technique. A more indepth discussion of the nutrient solution management will be given later which is related to this system. The application of a flowing nutrient element solution has been commerically adopted by Allen Cooper, a system he named, "NFT."

NFT, Nutrient Film Technique, has attracted much attention in recent years, with a number of commercial systems available to growers. The plant roots are suspended in a flowing path of nutrient element solution as shown in Figure 4.



Flexible multi-channel that can be rolled



Rigid multi-channel

Figure 4. TWO ILLUSTRATIONS OF THE NUTRIENT FILM TECHNIQUE SYSTEM FOR HYDROPONIC GROWING (From: "The ABC of NFT" by Dr. Allen Copper, page 32)

Although this system of growing hydroponically offers some unique advantages over media culture systems, it too is not without its problems. Careful metering and control of the nutrient solution are essential. Normally, the required nutrient elements are injected into the moving stream of the nutrient solution as it makes its circuit. If the path of plants in the growing trough is long, those plants near the end of the stream will "see" a different nutrient solution composition than those at the head. The first to be depleted is the oxygen supply. NFT can also be subject to disease control problems. Although NFT does do away with the problems associated with inorganic media substrate systems, nutrient solution storage, metering of the nutrient elements, and intricate piping and pumping devices are required which makes the system quite expensive and tricky to operate. Therefore, the future of NFT as a significant system for hydroponic growing is in some doubt.

Aeroponics may be the only hydroponic system with a future. It has a number of unique advantages, such as the precise control of the nutrient solution, while inadequate aeration is not a problem. The piping and nutrient solution storage system can be quite simple. One-way passage of the nutrient solution is also possible without the waste of water and nutrient elements. Water volume is low, making it a valuable technique where water supplies are minimal. Several commerically designed systems will probably be on the market in the near future. In an aeroponic system, the roots are suspended in a container which is continuously bathed in a mist of nutrient solution. The mist of nutrient solution may be produced by several means, either by nozzles or laser holed pipes (See Figure 5).

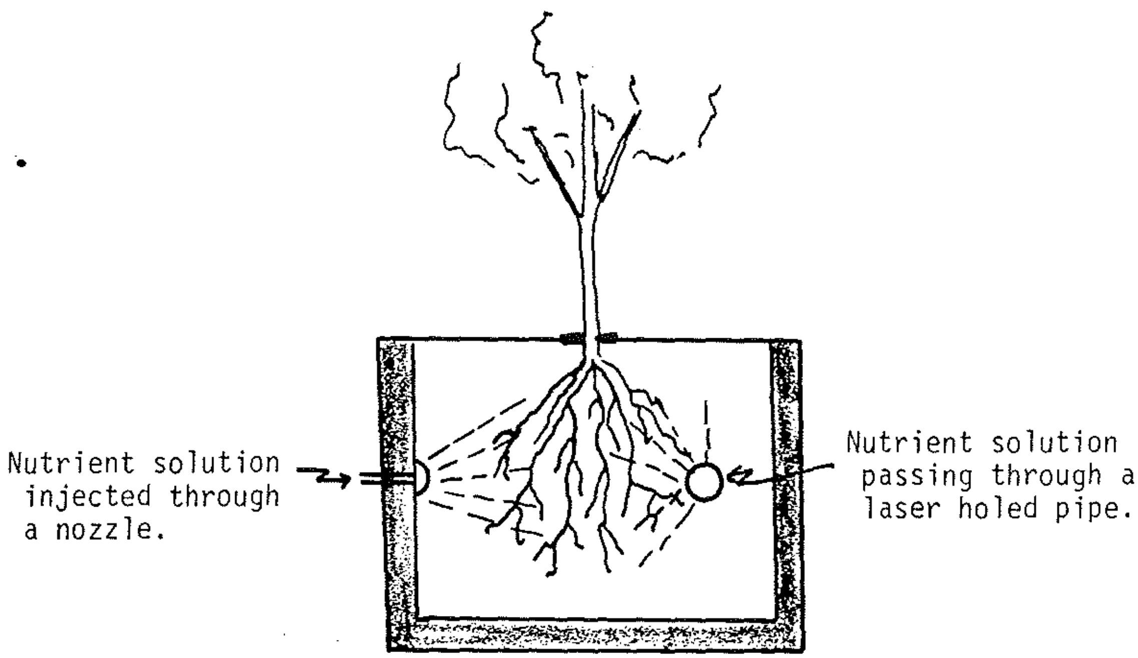


Figure 5. AEROPONICS SYSTEM WITH NUTRIENT SOLUTION INTRODUCTION BY MEANS OF NOZZLES OR LASER HOLED PIPE.

Up to this point we have discussed most of the common growing systems that have been adapted for commerical plant production. All of them will "work", but some work better than others. It is obvious that from personal experience and hearing from others, that the organic substrate system and aeroponics are the only two soilless systems that have a significant future commercial application. All of the others have major limitations and problems, as well as being expensive to establish and operate.

The "ideal" hydroponic system would be one with no moving parts and that would supply all the essential nutrient elements in their proper concentration and ratio to each other. Such a system is possible and may make its appearance in the commerical market in the near future.

2. Nutrient Solution Management

Probably no other aspect of hydroponic growing is as improperly managed as that required to ensure that the nutrient solution is correctly constituted and maintained during its use. Most books on hydroponics do not provide the detail needed to adequately advise growers. There are many ways and formula given in books which have been extracted from various sources. What is missing are the details as to why certian elemental combinations are placed in the formula and how the constituted nutrient solution is to be used, and for what crops and cropping conditions.

It is interesting to note that most nutrient solution formula are based on what Arnon and Hoagland proposed in the 1940s. They have defined the optimum nutrient solution as the "minimum concentration which gave maximum yield and beyond which there was no further improvement." There have been numerous modifications made, mostly changes in the concentration and source for certian elements. Most hydroponic growers fail to realize that the composition of the nutrient solution is specifically related to its use, the ratio of volume of nutrient solution per plant and the schedule for replishment. Arnon and Hoagland's nutrient solution formula was based on its use for the culture of tomatoes in which 4 gallons of nutrient solution per plant and weekly replenish were the conditions for its use. Any significant change in either of these conditions will affect the expected response. A common modification is to increase the number of plants, thereby reducing the volume/plant ratio and then to extend the replishment cycle. The result of these practices should be obvious - possible nutrient element stress, poor plant growth and reduced yield.

Much has been discussed and written about the affect of the pH of the nutrient solution on plant growth. It is difficult to specify the best pH range unless something is known about the elemental composition of the nutrient solution. The main factor influencing pH response is the ratio of ammonium- to nitrate-ions in the nutrient solution. If nitrate is the major nitrogen source, then the best pH range is 5.0 to 6.0, but if the ammonium-ion is, then the optimum pH is 7.0 to 8.0. However, in a flowing nutrient solution system, such as NFT, then the optimum pH for the nutrient solution based on either nitrogen source is from 5.0 to 6.0. The danger from an increasing pH in the nutrient solution comes from its affect on the loss of iron (Fe) by precipitation with phosphorus (P), a real danger if an inorganic rooting substrate is used.

It might be well to discuss the relationship between sources of nitrogen in the nutrient solution. There is increasing evidence that the ammonium-ion can be detrimental to plant growth, the effect varying with stage of plant development and crop. Since ammonium nitrate (NH_4NO_3) is frequently used as a source of N in some nutrient solution formula, the ammonium-ion may represent at least half of the total N found in the nutrient solution. For some crops and during the fruiting stages of growth for others, such nutrient solutions may result in disappointing plant growth and development which can terminate in a significant reduction in yield.

Since the evidence is not specific regarding the possible detrimental effect of the ammonium-ion on plant growth, it is difficult to advise growers as to the best procedure to follow. However, it would seem wise that whenever possible, the ammonium-ion be excluded from the nutrient solution, or kept less than 20% of the total nitrogen content to provide some degree of pH control.

It has been shown that the pH of the nutrient solution is determined considerably by the ratio of ammonium- to nitrate-ions in solution (see Figure 6).

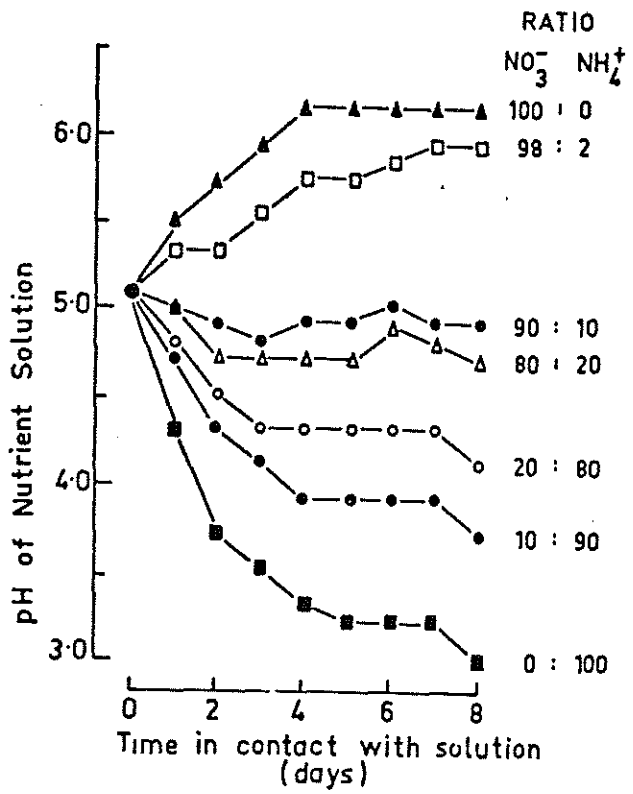


Figure 6. Effect of the ratio of nitrate to ammonium nitrogen on the rate and direction of pH changes in nutrient solutions in contact with the roots of <u>Triticum aestivium</u> plants.

(From: Trelease, S.F. and Trealease, H.M., Am. J. Bot. 22: 520-542. 1935)

As shown in Figure 6, the pH rises with time when the nutrient solution contains less than 10% of its nitrogen source as the ammonium-ion, and falls if the ammonium-ion is greater than 20% of the total nitrogen in solution. A common recommendation calls for the ammonium-ion not to exceed 25% of the total nitrogen in the initial nutrient solution which should have the effect of minimizing the ammonium/nitrate ratio influence on pH, while keeping the nutrient solution pH within the desirable range during the period of its use.

An interesting observation has been made regarding the utilization of ammonium- and nitrate-N when present in the same nutrient element solution. As the total nitrogen content of the nutrient solution increases, there seems to be an increasing preference for the nitrate form of nitrogen over ammonium (see Figure 7).

This seems to indicate that the ratio of ammonium- to nitrate-ions could be narrowed as the total nitrogen content of the nutrient solution increases without significantly affecting plant growth due to ammonium toxicity.

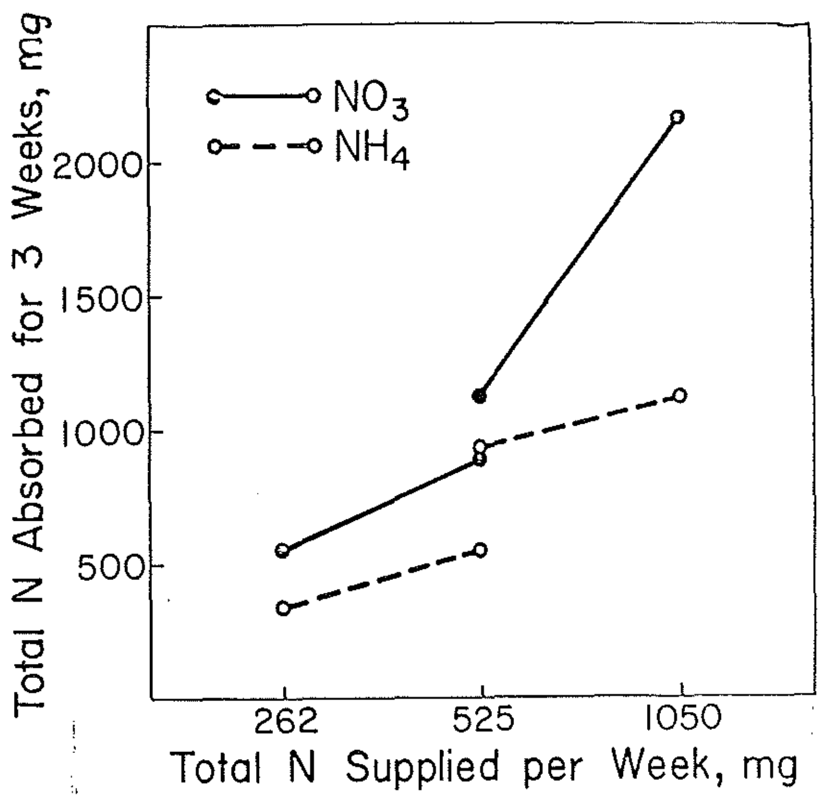


Figure 7. TOTAL NITROGEN ABSORBED BY GREENBEAN PLANTS GROWN HYDROPONICALLY AS EITHER NITRATE OR AMMONIUM AT THREE TOTAL NITROGEN LEVELS.

Although it is well known that the temperature of the rooting medium can affect plant growth, few mention the possible effects of low nutrient solution temperature on plant growth. I have seen plants wilt in the greenhouse when on a warm day, cold nutrient solution is circulated through the growing beds. As a rule of thumb, the nutrient solution temperature should be approximately that of the ambient air temperature. The effect of low medium temperature is to reduce the uptake of water and nutrient elements. On the other hand, there is no gain by heating the growing bed or nutrient solution above the ambient air temperature. In experiments conducted in Georgia with greenhouse tomato as a winter vegetable crop, yields were not increased by heating an organic media (pine bark) bed, nor did bed heating serve as a substitute for air temperature modification. For example, increasing the growing bed temperature 10 degrees above the normal bed temperature and reducing the day/night time air temperatures by 5 degrees, resulted in delayed fruiting with no effect on yield. However, growing bed heating does become beneficial when its temperature drops below the optimum air temperature for that crop.

As was mentioned earlier, few who apply the hydroponic technique fully realize the significance of the ratio between the volume of nutrient solution and number of plants, as this ratio is very important for proper nutrient solution management. In most circulating hydroponic systems, the plant essentially "sees" a different nutrient solution during the period of its use as was shown earlier, the pH changing, and the concentration and ratio among and between the elements also changing. Since concentration and ratio are factors which affect nutrient element uptake by plant roots, the initial composition of the nutrient solution may not be what is best for optimum plant growth. Therefore, unexpected deficiencies, and reduced growth and yield may occur. Such deficiencies can be corrected by either increasing the concentration of the elements in the nutrient solution or increasing the frequency of the replishment cycle. For flowing systems, one way to accomplish the same effect is to increase the flow rate. Examples of the effect of flow rate and concentration of an element in the nutrient solution is shown in Figure 8.

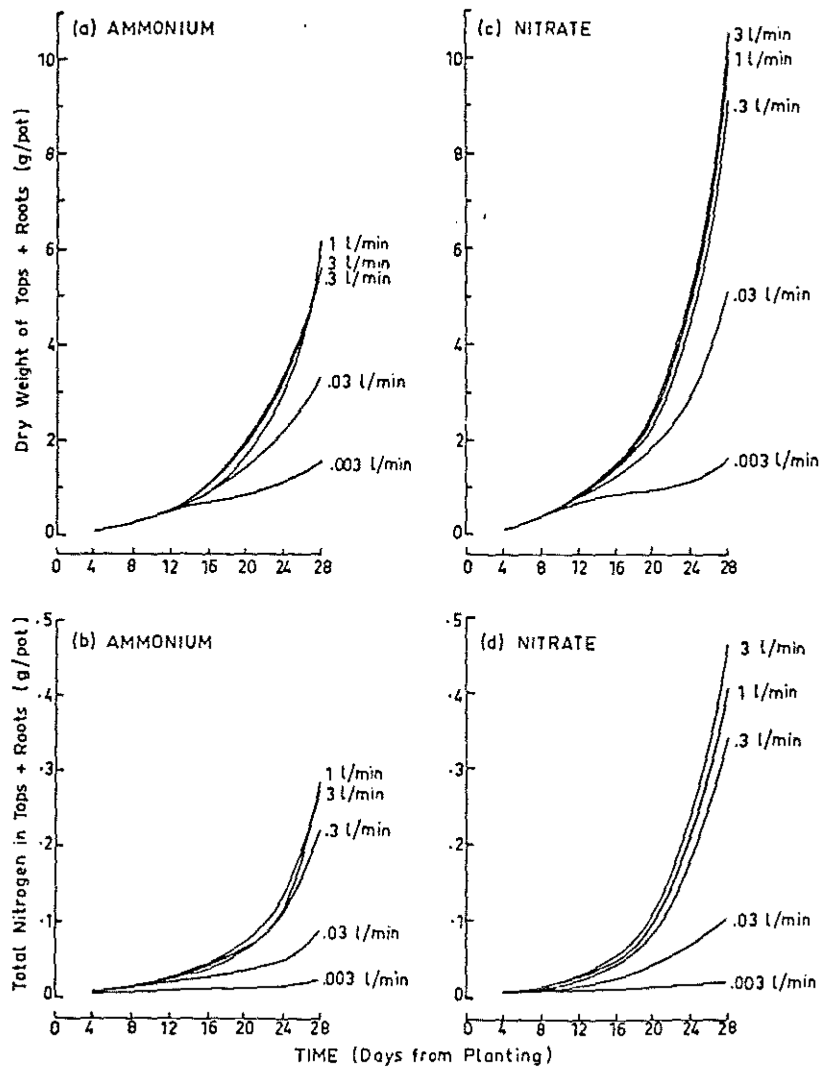


Figure 8. FITTED CURVES SHOWING TIME COURSE OF INCREASE IN THE DRY WEIGHT AND TOTAL NITROGEN CONTENT OF WHEAT PLANTS SUPPLIED WITH A NUTRIENT SOLUTION CONTAINING APPROX. 5uM AMMONIUM OR NITRATE NITROGEN AT FLOW RATES OF .003, .03, .3, 1 AND 3 LITERS PER POT PER MINUTE. (From: Edwards, D. G. and Asher, C.J., Plant & Soil 41: 161-175. 1974).

Another way of expressing this effect is to note that in a flowing nutrient solution, equal growth was obtained for a nutrient solution containing 39 ppm K flowing at 1.2 ml per minute compared to a 5 ppm K nutrient solution flowing at 8 ml per minute. Therefore, it becomes necessary to devise a specific nutrient solution formula and schedule of use based on the volume/plant ratio, flow rate and replenishment schedule. In addition, formula, use and replenishment schedules must also be fixed based on plant stage of development.

An "ideal" nutrient solution management system may be characterized as one in which the plant is growing in an infinite volume of nutrient solution in which its composition never changes. From a practical standpoint, this system may be difficult to devise and operate for hydroponic systems in current use. However, such a criteria fits best with aeroponics. Another tack would be to so constitute the nutrient solution so there would be no changes occurring with use and the solution sufficiently buffered to resist a change in pH. Such a system is not beyond possibility and could be so devised as to make it one with few moving parts (an important criteria for energy conservation and stoppages), a system mentioned earlier in this paper. Another way would be to meter into the moving stream of circulating water the elements required by the plant at such concentrations that the return flow is essentially pure water.

Another way of managing the nutrient solution would be to determine the "minimum" concentration of element required to obtain maximum growth in a self-feeding hydroponic system. The objective would be to balance the flow of water and essential nutrient elements in such a way that there is no change in the composition of the nutrient solution surrounding the roots. Such a system would work best with an inorganic substance (such as perlite) as the rooting medium. There have been several studies published that have shown that such a system can work well. What is needed is a careful study of how best to constitute the nutrient solution so that the balance and concentration of elements in the nutrient solution around the roots will not be changed by the uptake of both water and elements by the plant.

Few hydroponic growers are fully aware of the use and value of periodic analyses of the nutrient solution. The nutrient solution should be checked before use and during its use. Unfortunately, such analyses require the use of an analytical laboratory which is both time consuming and costly. There are analysis kits available that can be used by the grower to check most of the elements in the nutrient solution. The best kit is made by HACH Chemical Company. It is worth the investment in money and time to learn how to use such kits. By monitoring the nutrient solution during its use, the grower can see what is happening to the composition of the nutrient solution and hopefully avoid deficiencies and other problems associated with each of the required essential plant nutrients. It is common practice by some growers to monitor the pH of the nutrient solution during its use or to determine its conductivity. But more is needed as there is no substitute for a track of the elemental content of the nutrient solution during its period of use. Unfortunately, there is little in the literature on how to interpret such analysis results and how best to adjust the make-up of the nutrient solution to avoid nutrient element stress due to changes in the composition of the nutrient solution. Here the grower may have to develop his own procedures based on experience, trial and error.

SUMMARY

The future of hydroponics will depend to a considerable extent on the development of new techniques for its implimentaion. Most of the current systems are too expensive to construct and operate as well as being difficult to manage. Hydroponic growing will be primarily used in those areas where soil growing is difficult, if not impossible. It is doubtful that hydroponics will become a common system of growing unless techniques can be devised to reduce the initial cost and operating expenses. However, soilless culture using some organic mix as the rooting media will be in wide use for some time to come. Solution culture, currently being practised as gravel or sand culture and more recently by NFT, will probably decline in use. It seems to me that aeroponics will become the system of the future.

Considerable research is needed to establish better critieria for nutrient solution management than is currently being recommended and used. It will be interesting to see if significant changes in the composition of the nutrient solution will come as researchers begin to look for ways of balancing the nutrient elements in the solution to maximize elemental utilization and to reduce inter-element effects. More specific systems of nutrient solution management are needed than are currently being recommended and used. More than just a modification of current techniques is needed. Most hydroponic systems will "work" if properly designed and managed, but with the greater demand for higher productivity and greater economic returns, more than just a working system is needed. Most of the hydroponic techniques devised up to now do not perform in such a manner that makes them capable of meeting these new demands.

CIQRO
Centro de Investigaciones de Quintana Roo, A.C.
Puerto Morelos
Quintana Roo
Tel. (992) 3.75.90

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February 6th., 1982.

SOME EXPERIENCES WITH HYDROPONICS IN THE MEXICAN CARIBBEAN.

Abstract.

Introduction.-

Quintana Roo is the youngest state in Mexico. It was created in 1974 as a result of the touristic investments in the area. Before that, it was a territory with very few inhabitants. By now it has a population of 250,000 people and it is growing very fast. It is located on the Yucatan Peninsula, eastern part of Mexico by the Caribbean Sea and it has an area of 5,083 sq.Km. The climate is humid tropical, AW in the Köppen clasification with a mean temperature of 25°C. and a rainfall of 1300 mm/year distributed mainly between June and October.

The orography of this region is flat, there are no rivers nor superficial currents, but there is water in the subsoil. The soil types are mainly "lithosols" and "rendzines". The vegetation is evergreen seasonal forest. The agricultural activity is completly undeveloped and it occupies only a 1.5 % of the total state area. Mainly there is corn cultivation under slash and burn cultivation, so this is why almost all the food is imported from other parts of the Republic, even from as far away as Mexico City, with the consecuence of high prices and bad quality.

In June of 1979 the "Centro de Investigaciones de Quintana Roo, A.C." was created as a Civil Association, sponsored by the Mexican Government

The main purpose of this Center is to contribute to the development of the state. During 1981 a project to produce vegetable crops by means of hydroponics was begun in Puerto Morelos, the see of CIQRO, which is a small town located 36 Kms. south of Cancún.

Objetives.-

To develop the basic technology for vegetable crop production by means of hydroponics in this area through the installation of a simulator of a commercial field and to do research based on the observations of this field. This document is concerned with the first observations of this installation.

Installations.-

We used an area of 3000 sq. mts. from a 10 acres experimental modul where the jungle was cleared. This area has a layer of crushed limestone to avoid weeds. The water supply comes from a 13 mts. de well which has 7 mts. of water. Forty beds of 15 x 0.80 x 0.20 mts about 12 sq. mts. each, were constructed using wood from the same jungle.

Growing Medium.-

The beds mentioned before have a layer of 5 cms. of gravel and 15 c of beach sand. This sand has a high content of Calcium Carbonate, in the first trials we had good results.

Nutrient Solution.-

It is based on the commercial fertilizer 17-17-17 that disolved at rate of 11.8 gr. per 10 liters of water to make a concentration of:

N	200	ppm
P	86	ppm
K	166	ppm

The microelements are supplied in a stock solution which give a concentration when dilluted of:

Cu	0.05 ppm
Mn	0.2 ppm
Zn	0.1 ppm
Mo	0.005 ppm
B	0.5 ppm
Fe	5 ppm

Seeders.-

A subirrigation system for the seedbeds has been installed using gravel and containers of 200c.c. with sand.

Irrigation System.-

It consists on a trickle irrigation system, using microtube of 1mm. diameter inserted in 1/2 inch polyethylene hose. This 1/2 inch hose is also inserted in the main line of 1.5 inch. The system includes a proportioner that works at a rate 1:128 for the nutrient solution. This devise injects the solution in the flow of water pumped from the well.

Results.-

The 40 beds were designed for 4 crops: 10 for cucumbers, 10 for cantaloupes, 10 for tomatoes an 10 for green beans. As of today, we have finished harvesting 3 beds of cucumbers with the following results:

Crop:	Cucumber
Nº of plants:	250
Variety:	Geminy
Date Seeding:	September 14th.
Total Kgs.:	750 Kgs.
Fruits/plant:	10
Average fruit weight:	300 grs.